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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 751

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER April 22, 1919

EXPERIMENTS ON THE DIGESTIBILITY OF WHEAT BRAN IN A DIET WITHOUT WHEAT FLOUR.[1]

By ARTHUR D. HOLMES, *Specialist in Charge of Digestion Experiments, Office of Home Economics.*

CONTENTS.

REVIEW OF PREVIOUS INVESTIGATIONS.

Wheat in some form constitutes a very large proportion of the average dietary. The larger part of the wheat used for human food is consumed in the form of bread, which ordinarily is prepared from one of three common types of wheat flour—white flour (commercially known in this country as standard patent), entire or whole-wheat flour, and graham flour. The importance of wheat in the American dietary is readily appreciated when it is noted that in normal times the annual per capita consumption is approximately 5 bushels;[2] it has been estimated[3] that excluding wheat breakfast foods, macaroni, spaghetti, and similar foods, and referring only to the three common flours, patent, entire, and graham, they supply 20 per cent of the protein, and 26 per cent of the carbohydrate of the average dietary. In times of stress even greater reliance is placed on bread, and it is a matter of repeated observation that those of relatively small incomes tend to make bread a predominating portion of the diet. With the outbreak of the war, and the prospect of a diminished supply of some food materials, the question of a more complete milling of wheat

[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.
[2] U. S. Dept. Agr. Bur. Crop Estimates Rept., 3 (1917), No. 10, p. 99.
[3] U. S. Dept. Agr. Office Expt. Stas. Circ. 110 (1911), p. 26.

and the effect of a modification in milling upon the nutritive value of the resulting flours assumed unusual importance to those concerned with the feeding of large numbers of people.

In the modern milling processes the germ, together with a large portion of the outer layers of the wheat kernel, is removed. The removal of the germ, which contains practically all of the wheat fat or oil, lowers the energy value somewhat but improves the keeping quality of the flour. Chemical analysis shows that the outer layers of the wheat kernel, also removed in the preparation of patent flour, contain protein, carbohydrate, and mineral matter, constituents which are necessary for the proper nutrition of the body. Very recently it has been demonstrated by McCollum and coworkers[1] that the wheat germ contains Fat-soluble A, and this and the outer layers of the wheat kernel some Water-soluble B,[2] both of which are essential in the dietary to prevent nutritional diseases. These substances are present, it is true, in limited amounts, insufficient for the needs of the body during its entire lifetime and yet in amounts not wholly negligible. With these facts in mind the question very naturally arises whether it is not desirable to include the entire kernel in wheat flour rather than to utilize only the interior portions of the kernel. In order to arrive at an intelligent solution of this question it appears necessary to consider the large number of factors influenced by a modification of milling conditions. Of special interest to the student of nutrition is the effect on the digestibility of wheat flour of including a part or the whole of the wheat germ and the outer layers of the wheat kernel in the flour.

Since wheat flours contain very little fat, interest has been centered on the digestibility of the protein and carbohydrate supplied by the different types of wheat flours; and in general the digestibility of wheat protein has received the most attention.

The earlier work of the Department of Agriculture included a large number of studies of the digestibility of wheat flours, prepared from both spring and winter wheats, and from wheat grown in different localities. In the tests referred to below, the wheat was milled so as to produce from the same lot of wheat, white (patent) flour representing 72 per cent of the wheat kernel, entire or whole-wheat flour representing 85 per cent of the wheat kernel, and graham flour representing 100 per cent of the wheat kernel.

Woods and Merrill[3] conducted 13 digestion experiments with white-flour bread in which the protein was 86.4 per cent and the carbohydrate 98.3 per cent digested, five experiments with entire-

[1] Jour. Biol. Chem., 25 (1916), No. 1, pp. 105–131, figs. 19; 28 (1916), No. 2, pp. 211–229, figs. 17.

[2] Jour. Biol. Chem., 24 (1916), No. 4, p. 493.

[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 85 (1900), pp. 32, 33.

wheat bread in which the protein was 86.7 per cent and the carbohydrate 97.2 per cent digested, and six experiments with graham bread in which the protein was 77 per cent and the carbohydrate 92.4 per cent digested. In a later publication the same authors report[1] that the digestibility of white flour is 93.8 per cent for protein and 98.9 per cent for carbohydrate, that the digestibility of entire wheat flour is 80.8 per cent for protein and 96 per cent for carbohydrate, and that the digestibility of graham flour is 81.3 per cent for protein and 91.1 per cent for carbohydrate.

Snyder[2] in studies of the digestibility of wheat flours reports that the digestibility of white flour is 85.3 per cent for protein and 97.5 per cent for carbohydrate, that the digestibility of entire wheat flour is 80.4 per cent for protein and 94.1 per cent for carbohydrate, and that the digestibility of graham flour is 77.6 per cent for protein and 88.4 per cent for carbohydrate. In experiments made to determine the digestibility of hard spring and soft winter wheats, Snyder found that the digestibility of hard spring wheat[3] flours is 88.3 per cent for protein and 97.7 per cent for carbohydrate for white flour, 86.2 per cent for protein and 96.2 per cent for carbohydrate for entire wheat flour, and 82.8 per cent for protein and 91.5 per cent for carbohydrate for graham flour; he also found that the digestibility of flours prepared from soft winter Michigan wheat[4] was 92.8 per cent for protein and 98 per cent for carbohydrate for white flour, 85.7 per cent for protein and 92.9 per cent for carbohydrate for entire wheat flour, and 79.4 per cent for protein and 89.3 per cent for carbohydrate for graham flour.

In other studies to determine the digestibility of flours prepared from wheat grown in different localities Snyder[5] found that the digestibility of protein supplied by Oregon wheat flours was 84.9 per cent for protein and 98.2 per cent for carbohydrate for white flour, 71.1 per cent for protein and 94.1 per cent for carbohydrate for entire wheat flour, and 63 per cent for protein and 91.2 per cent for carbohydrate for graham flour, and that the digestibility of Oklahoma wheat flours was 90.9 per cent for protein and 97.7 per cent for carbohydrate for white flour, 79.6 per cent for protein and 90.5 per cent for carbohydrate for entire wheat flour, and 77.3 per cent for protein and 87.9 per cent for carbohydrate for graham flour.

Since in these tests made by the United States Department of Agriculture the diet was comparable, and, as far as possible, uni-

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), p. 32.
[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 101 (1901), p. 33.
[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 126 (1903), p. 29.
[4] U. S. Dept. Agr., Office Expt. Stas. Bul. 126 (1903), p. 45.
[5] U. S. Dept. Agr., Office Expt. Stas Bul. 156 (1905), p. 36.

form experimental conditions were maintained, it is perhaps fair to consider all of these digestion experiments as a group. The digestibility of white flour obtained by averaging the 31 tests noted above is 88.1 per cent for protein and 95.7 per cent for carbohydrate; the digestibility of entire wheat flour obtained by averaging the 23 tests is 81.9 per cent for protein and 94 per cent for carbohydrate; and the digestibility of graham flour obtained by averaging the 24 tests noted is 76.9 per cent for protein and 90.6 per cent for carbohydrate.

Considering these tests as a whole, it appears that the protein and carbohydrate are more completely assimilated from white flour than from entire wheat or graham flours, the last being the least assimilated; or in other words, the increasing of the amount of bran included in a flour is accompanied by a corresponding decrease in its digestibility.

A number of investigations have been conducted in European countries to determine the effect on digestibility of including more or less bran in the flours prepared from wheat and other cereals.

Among the earlier studies of the nutritive value of wheat is a study by Rubner,[1] who determined the digestibility of the protein present in three flours milled so as to contain 30 per cent, 70 per cent, and 100 per cent of the wheat kernel. He found that the protein of the 30 per cent flour was 79.3 per cent digested, the protein of the 70 per cent flour was 75.4 per cent digested, and the protein of the 100 per cent flour 69.5 per cent digested. Blyth[2] conducted a series of experiments to determine the digestibility of wheat meal (flour prepared from the entire wheat kernel) when eaten without the addition of other food materials. In one experiment of 29 days divided into three periods, during the first period of 8 days 81 per cent of the protein supplied by the 16 ounces of wheat meal eaten daily was digested, during the second period of 14 days 82 per cent of the protein of 20 ounces of meal was digested, and during the third period of 7 days 84 per cent of the protein of 28 ounces of meal was digested. In a second experiment of 7 days' duration in which the diet consisted of whole meal and distilled water, the subject digested 90 per cent of the protein supplied by the meal eaten, which varied from 16 to 22 ounces daily.

Pugliese[3] conducted studies to determine the effect of milling on the digestibility of wheat flour. He reports that the digestibility of the protein of flour containing 85 per cent of the wheat kernel is 10 per cent less than the digestibility of the protein of flour containing 75 per cent of the wheat kernel.

[1] Ztschr. Biol. 19 (1883), pp. 45–100.
[2] Proc. Roy. Soc. [London], 45 (1888–89), No. 279, pp. 549–553.
[3] Rev. Gén. Sci., 26 (1915), No. 21, pp. 612–617.

It is sometimes contended that test periods of three or four days' duration are too short to give reliable data regarding the digestibility of foods. Newman and Robinson,[1] who question the accuracy of results of digestion experiments of only three days' duration, studied the relative digestibility of white flour and whole meal (flour prepared from whole wheat kernel) breads of which 700 to 800 grams were eaten with 600 cubic centimeters of milk and 30 grams of butter fat daily for a period of two weeks. As a result of four experiments in which, with one exception, the protein of white flour was more completely digested, they found that on the average the protein of white flour was 89.3 per cent digested while the protein of whole meal was 85.9 per cent digested. They also report that the digestibility of the protein of a wheat meal (92 per cent of the kernel) was 76.7 per cent as compared with a digestibility of 80.4 per cent for the protein of another wheat meal (88 per cent of the wheat kernel).

Experiments conducted by Hindhede[2] to determine the relative digestibility of coarsely ground wheat as compared with ordinary white flour are not open to this criticism, since they were of seven months' duration. He found that the protein of coarsely ground wheat (bread) eaten with margarine was 75 per cent digested while the protein of ordinary wheat flour eaten in a similar diet was 85 per cent digested. In both instances the total carbohydrate was found to be practically completely digested.

Additional evidence regarding the effect on digestibility of including bran in flour is available in the reports of several investigators. Inasmuch as the experimental conditions employed in the tests of the digestibility of wheat flours made by the European investigators were not uniform, it is perhaps not possible to make as direct comparisons as in the case of the American studies. In general, considering the results of these investigations as a whole, it is apparent that the protein of flours containing a relatively small proportion of bran is more completely digested than the protein present in flours which contain a large proportion of bran.

In order to secure additional evidence regarding the effect on digestibility of including bran in flour Snyder[3] conducted two series of three digestion experiments each comparing digestibility of the protein of straight-grade flour and the digestibility of the protein of the same flour to which he added 14 per cent of finely ground bran (the amount of bran which he assumed to be normally present in graham flour). His results were as follows: The digestibility of bread from the flour with the bran was for protein 85.9 per cent

[1] Jour. Hyg. [Cambridge], 12 (1912), No. 2, pp. 132, 134.

[2] Skand. Arch. Physiol., 33 (1916), pp. 263–290; abst. in Chem. Abs., 12 (1918), No. 1, p. 54.

[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 156 (1903–1905), p. 42.

(83.2 per cent, 84.4 per cent, and 90 per cent) and for carbohydrates 93.4 per cent (93 per cent, 92.8 per cent, and 94.3 per cent) and the digestibility of bread from the same flour without the bran was for protein 90.9 per cent (90.2 per cent, 91.9 per cent, and 90.6 per cent), and for carbohydrates 97.7 per cent (96.7 per cent, 98.2 per cent, and 98.1 per cent). As noted by Snyder, "Subject No. 3 digested practically the same proportion of the protein from the flour with the bran as from that without it," and considering these data alone one could conclude that the digestibility of bran protein was 90 per cent. If, on the other hand, the figures reported for subject No. 2 for the digestibility of protein of flour with bran, 84.4 per cent, and without bran, 91.9 per cent, are considered alone, the calculated digestibility of bran protein would be approximately 39 per cent. In general, however, the average values obtained in these tests for the digestibility of the mixture of white and bran flours, 85.9 per cent for the protein and 93.4 per cent for the carbohydrate, as compared with the digestibility of white flour alone, 90.9 per cent for protein and 97.7 per cent for carbohydrate, are in agreement with those obtained in the earlier studies of the digestibility of white and graham flours and indicate that the addition of bran, even if finely ground, to flour lowers the digestibility of the flour.

It is very generally believed that the difference in the digestibility of the protein and carbohydrate contained in graham flour and white flour is due to relative insolubility of bran cellulose in the human intestinal juices. That there is experimental evidence to substantiate such a theory is indicated by results of digestion experiments in which the crude fiber present in the foods and feces was studied.

Prausnitz[1] reports that the crude fiber of wheat bread is 53 per cent (52.6 per cent and 53.4 per cent) digested. This value, 53 per cent, is somewhat lower than the figures obtained by other investigators for the digestibility of the crude fiber of fruits and vegetables. In 30 digestion experiments conducted by Jaffa[2] to determine the digestibility of common fruits and nuts he found that on an average the crude fiber was 78.54 per cent digested. Constantinidi[3] states that the crude fiber of potatoes is 79 per cent digested. As the result of two experiments Weiske[4] concludes that the crude fiber of a diet of celery, cabbage, and carrots is 55 per cent (63 per cent and 47 per cent) digested. Bryant and Milner[5] report that the crude fiber of green corn is 60 per cent digested, that of potatoes 74 per cent, that of cabbage 77 per cent, that of beets 88 per cent, and that of apple

[1] Ztschr. Biol., 30 (1894), p. 350.
[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 132 (1901–2), p. 69.
[3] Ztschr. Biol., 23 (1887), p. 452.
[4] Ztschr. Biol., 6 (1870), pp. 456–466.
[5] Amer. Jour. Physiol., 10 (1903), No. 2, p. 97.

sauce 95 per cent digested. As a rule cellulose of fruits and vegetables seems to interfere with their digestion to a limited extent only.

In grains, on the other hand, the cellulose forms the hard dry envelope and is much more impervious to the action of the digestive juices. With this fact in mind Finkler[1] attempted to devise a process for milling wheat which would render the bran more digestible and which would liberate the protein inclosed within the cellulose walls. He recommends the milling of wheat in a solution of sodium chlorid or a solution of sodium chlorid containing lime. He states that artificial digestion experiments show the protein of the "finalmehl" obtained by this process is as completely digested as the protein of white flour.

While a consideration of the results of the numerous digestion experiments made with different types of wheat flours leads to the conclusion that wheat bran is not as well assimilated as the interior portion of the wheat kernel, a review of the literature has failed to reveal any data on the digestibility of wheat bran when eaten in a diet which did not contain any portion of the remainder of the wheat kernel. It would seem that definite data regarding the digestibility of wheat bran when eaten in a diet containing no wheat flour are of material value in connection with the consideration of the effect of different percentages of milling of wheat upon the digestibility of the protein and carbohydrate contained in the resulting flours, and it was for the purpose of securing such data that the experiments here reported were undertaken.

METHODS OF PROCEDURE.

The methods employed in this investigation, especially the way the bran was prepared for eating, were essentially the same as those followed in experiments to determine the digestibility of nonsaccharine grain sorghums and millets.

In the investigations previously reported in which the digestibility of bran has been considered, the bran was referred to as "fine bran" or "very fine bran," but in the majority of instances no definite data are given regarding the coarseness or fineness of the bran used, and, accordingly, it is impossible to make a direct comparison of the results of the different studies.

In the study here reported the size of the bran particles received special attention, both fine and coarse bran being included in the tests, in order to determine the effect of this factor upon laxative properties. An ordinary commercial wheat bran secured in the open market was ground until relatively fine in the experimental mills of the Bureau of Chemistry. On bolting, all the ground bran passed

[1] Jour. Roy. Inst. Pub. Health, 19 (1911), No. 4, pp. 193–199, pls. 2.

through the 20-mesh sieve, 68 per cent remained on the 40-mesh sieve, 20 per cent remained on the 70-mesh sieve, 4 per cent remained on the 90-mesh sieve, 2 per cent remained on the 109-mesh sieve, and the remainder, 6 per cent, passed through the 109-mesh sieve. Two series of experiments were conducted, one with the ground bran described above and referred to in this paper as "fine wheat bran" and one series with unground bran in the form of "flakes" which were a part of the lot from which the fine wheat bran was prepared. The test periods were of 3-days' or 9-meals' duration. The urine was not collected and no attempt was made to maintain a nitrogen equilibrium, or uniform body weights. The feces were separated in the usual way by means of pulverized charcoal taken in gelatin capsules with the first meal of the test period and the first meal following the period. The foods and feces were analyzed by the usual chemical methods.

SUBJECTS.

Five different subjects assisted in this investigation and with the exception of one subject (P. K.) all took part in the two series of tests which were made. These subjects, students in medical or dental schools whose ages varies from about 20 to over 40 years, were so chosen as to be fairly typical of the average person of this period of life. While all were young men of normal appetites and to all appearances of good health, they were of quite different temperaments. Subject A. J. H., a strong, vigorous young man who had served one or two enlistments in the U. S. Army and who had seen service in the Philippines, possessed a particularly hearty appetite. Subject P. K., on the other hand, a man of over 40 years of age, took little more than necessary exercise, was studiously inclined, had a tendency toward constipation, and would be very properly classed as of sedentary habits. The other three subjects, while not representing such direct contrasts, were, nevertheless, not in the least alike as regards food habits, and kinds and amounts of exercise taken, although they were of about the same size and age.

All the subjects were instructed to submit a report of their physical condition during the test periods. They were also instructed to observe special care in reserving any uneaten portion of the diet and in the separation and collection of the feces resulting from the experimental diet.

EXPERIMENTAL DIET.

Since information regarding the digestibility of the protein supplied by wheat bran was especially desired, the diet was so chosen that the accessory foods should contain a minimum of protein and at the same time should not be totally different from an ordinary simple mixed diet possessing some variety. The experimental diet consisted of a bran bread as the principal food, with enough accessory foods to make the diet tolerable and reasonably palatable, namely, boiled and mashed Irish potatoes (in limited quantities), fruit, butter, sugar, and tea or coffee.

The bran bread was prepared daily. A sufficient quantity of potatoes to supply all the subjects for the entire test period was boiled, mashed, and uniformly mixed at the beginning of the period. The fruit (oranges), butter, and sugar were purchased in the open market. The bran bread was made by the following recipe, which as will be noted contains some ginger and molasses. These materials were added primarily to make the bran more palatable and to mask its nature somewhat.

BRAN BREAD.

15 cups bran.
3¾ teaspoons soda.
1⅞ cups molasses.
3¾ teaspoons salt.
5 teaspoons ginger.
1 scant cup lard.
1⅞ quarts hot water.

The lard was added to the hot water and the mixture added to the other ingredients, after which the whole was uniformly mixed. The bread was baked about 1½ hours. Since the bran contained no glutinous material to serve as a binder, the bread did not rise well and tended to crumble.

The digestibility of the protein and carbohydrate of the bran alone has been estimated by making allowance for the undigested protein and carbohydrate resulting from the accessory foods. In estimating the digestibility of bran alone by the method which has been outlined in full in earlier publications[1] it has been assumed, as a result of averaging the results of earlier experimental data, that the digestibility of the accessory foods is as follows: The protein of potatoes, 83 per cent[2]; of butter, 97 per cent[2]; and of fruit, 85 per cent[2]; while the digestibility of carbohydrate in potatoes, fruit, and sugar, is 95 per cent,[2] 90 per cent,[2] and 98 per cent,[2] respectively.

The details of the digestion experiments are recorded in the following tables, which include the kind, amount, and total weight of different foods eaten by each subject, the weight of the various constituents of the foods, the weight of the feces, the amount of food utilized, the coefficients of digestibility of the entire ration, and the estimated digestibility of the bread alone.

EXPERIMENTS WITH FINE WHEAT BRAN.

While the seven experiments which were made with fine bran were not all carried on at the same time, the subjects and experimental

[1] U. S. Dept. Agr. Buls. 470 (1916), p. 7; 525 (1917), p. 4.
[2] Connecticut Storrs Sta. Rpt. 1899, p. 104.

conditions were the same for the two groups, experiments Nos. 417, 418, and 420 and experiments Nos. 460, 461, 462, and 463. The following table reports the results of these experiments:

Data of digestion experiments with fine wheat bran in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 417, subject D.G.G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread made of fine bran	1,714.0	796.3	93.2	138.2	596.5	89.8
Potato	568.0	428.8	14.2	0.6	118.7	5.7
Fruit	852.0	770.9	2.1	2.7	74.7	1.6
Butter	524.0	57.7	5.2	445.4		15.7
Sugar	134.0				134.0	
Total food consumed	3,792.0	2,053.7	114.7	586.9	923.9	112.8
Feces	438.0		79.3	37.0	267.6	54.1
Amount utilized			35.4	549.9	656.3	58.7
Digestibility of entire ration (per cent).			30.9	93.7	71.0	52.0
Estimated digestibility of bran alone (per cent)			18.0		38.4	
Experiment No. 418, subject A.J.H.:						
Bread made of fine bran	1,495.0	694.6	81.3	120.5	520.3	78.3
Potato	588.0	443.9	14.7	.6	122.9	5.9
Fruit	771.0	697.6	1.9	2.4	67.6	1.5
Butter	482.0	53.0	4.8	409.7		14.5
Sugar	142.0				142.0	
Total food consumed	3,478.0	1,889.1	102.7	533.2	852.8	100.2
Feces	471.0		85.0	196.3	127.0	62.7
Amount utilized			17.7	336.9	725.8	37.5
Digestibility of entire ration (per cent).			17.2	63.2	85.1	37.4
Estimated digestibility of bran alone (per cent)			(1)		69.2	
Experiment No. 419, subject R.L.S.:						
Bread made of fine bran	1,372.0	637.4	74.6	110.6	477.5	71.9
Potato	497.0	375.2	12.4	.5	103.9	5.0
Fruit	807.0	730.2	2.0	2.5	70.8	1.5
Butter	282.0	31.0	2.8	239.7		8.5
Sugar	78.0				78.0	
Total food consumed	3,036.0	1,773.8	91.8	353.3	730.2	86.9
Feces	440.0		90.2	47.0	246.0	56.8
Amount utilized			1.6	306.3	484.2	30.1
Digestibility of entire ration (per cent).			1.7	86.7	66.3	34.6
Estimated digestibility of bran alone (per cent)			(1)		28.8	
Experiment No. 420, subject O.E.S.:						
Bread made of fine bran	1,399.0	650.0	76.1	112.8	486.8	73.3
Potato	520.0	392.6	13.0	.5	108.7	5.2
Fruit	876.0	792.6	2.2	2.7	76.8	1.7
Butter	280.0	30.8	2.8	238.0		8.4
Sugar	196.0				196.0	
Total food consumed	3,271.0	1,866.0	94.1	354.0	868.3	88.6
Feces	410.0		81.2	52.3	224.8	51.7
Amount utilized			12.9	301.7	643.5	36.9
Digestibility of entire ration (per cent).			13.7	85.2	74.1	41.6
Estimated digestibility of bran alone (per cent)			(1)		37.6	

[1] Negative results, the fecal protein exceeding that in bran eaten.

Data of digestion experiments with fine wheat bran in a simple mixed diet—Con.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 460, subject D.G.G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread made of fine bran	1,483.0	670.2	84.4	142.5	521.6	64.3
Potato	394.0	297.5	9.9	.4	82.3	3.9
Apple	738.0	624.3	3.0	3.7	104.8	2.2
Orange	281.0	244.2	2.2	0.6	32.6	1.4
Butter	258.0	28.4	2.6	219.3	....	7.7
Sugar	108.0	....	....	....	108.0	....
Total food consumed	3,262.0	1,864.6	102.1	366.5	849.3	79.5
Feces	195.0	....	39.0	16.3	117.1	22.6
Amount utilized	....	....	63.1	350.2	732.2	56.9
Digestibility of entire ration (per cent)	....	....	61.8	95.6	86.2	71.6
Estimated digestibility of bran alone (per cent)	....	....	56.8	....	71.0	....
Experiment No. 461, subject A.J.H.:						
Bread made of fine bran	997.0	450.5	56.7	95.8	350.7	43.3
Potato	503.0	379.8	12.6	.5	105.1	5.0
Apple	420.0	355.3	1.7	2.1	59.6	1.3
Orange	575.0	499.7	4.6	1.1	66.7	2.9
Butter	390.0	42.9	3.9	331.5	....	11.7
Sugar	49.0	....	....	....	49.0	....
Total food consumed	2,934.0	1,728.2	79.5	431.0	631.1	64.2
Feces	169.0	....	37.6	18.6	91.8	21.0
Amount utilized	....	....	41.9	412.4	539.3	43.2
Digestibility of entire ration (per cent)	....	....	52.7	95.7	85.5	67.3
Estimated digestibility of bran alone (per cent)	....	....	43.2	....	67.5	....
Experiment No. 462, subject P.K.:						
Bread made of fine bran	1,505.0	680.1	85.7	144.6	529.3	65.3
Potato	518.0	391.1	12.9	.5	108.3	5.2
Apple	759.0	642.1	3.0	3.8	107.8	2.3
Orange	332.0	288.5	2.6	0.7	38.5	1.7
Butter	238.0	26.2	2.4	202.3	....	7.1
Sugar	33.0	....	....	....	33.0	....
Total food consumed	3,385.0	2,028.0	106.6	351.9	816.9	81.6
Feces	237.0	....	46.0	23.2	138.0	29.8
Amount utilized	....	....	60.6	328.7	678.9	51.8
Digestibility of entire ration (per cent)	....	....	56.8	93.4	83.1	63.5
Estimated digestibility of bran alone (per cent)	....	....	50.1	....	65.3	....
Experiment No. 463, subject R.L.S.:						
Bread made of fine bran	1,255.0	567.1	71.4	120.6	441.4	54.5
Potato	396.0	299.0	9.9	.4	82.7	4.0
Apple	657.0	555.8	2.6	3.3	93.3	2.0
Orange	166.0	144.3	1.3	.3	19.3	.8
Butter	133.0	14.6	1.3	113.1	....	4.0
Sugar	44.0	....	....	....	44.0	....
Total food consumed	2,651.0	1,580.8	86.5	237.7	680.7	65.3
Feces	154.0	....	33.9	12.8	88.3	19.0
Amount utilized	....	....	52.6	224.9	592.4	46.3
Digestibility of entire ration (per cent)	....	....	60.8	94.6	87.0	70.9
Estimated digestibility of bran alone (per cent)	....	....	55.7	....	74.7	....
Average food consumed per subject per day	1,075.4	616.0	32.4	133.9	264.7	28.3

Summary of digestion experiments with fine wheat bran in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of protein of bran alone.	Estimated digestibility of carbohydrate of bran alone.
		Protein.	Fat.	Carbohydrate.	Ash.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
417	D. G. G.	30.9	93.7	71.0	52.0	18.0	38.4
418	A. J. H.	17.2	63.2	85.1	37.4	[1]	69.2
419	R. L. S.	1.7	86.7	66.3	34.6	[1]	28.8
420	O. E. S.	13.7	85.2	74.1	41.6	[1]	37.6
460	D. G. G.	61.8	95.6	86.2	71.6	56.8	71.0
461	A. J. H.	52.7	95.7	85.5	67.3	43.2	67.5
462	P. K.	56.8	93.4	83.1	63.5	50.1	65.3
463	R. L. S.	60.8	94.6	87.0	70.9	55.7	74.7
Average		37.0	88.5	79.8	54.9	44.7	56.6

[a] Negative value, fecal protein exceeding that of bran eaten. Not included in average.

The subjects ate on an average 32 grams of protein, 134 grams of fat, and 265 grams of carbohydrate daily, which taken together furnished in round numbers 2,400 calories. The diet was somewhat low in energy for active young men and decidedly low in protein. With the diet followed, a low protein consumption is almost unavoidable, for it was hardly possible to eat more of the bran bread than was consumed (approximately 420 grams daily), and in order that the bran might supply the major portion of the protein intake it was not desirable to increase the amount of potato taken with the bread.

The average coefficients of digestibility of the diet as a whole were found to be for protein 37 per cent, for fat 88.5 per cent, and for carbohydrate 79.8 per cent. Excluding experiments Nos. 417, 418, 419, and 420, in which the digestibility of protein was very low, the average coefficient of digestibility for protein becomes 58 per cent. Excluding experiment No. 417 and leaving out the negative values it becomes 51.4 per cent for the protein of bran alone.

As regards the laxative properties of the diet, records kept by the subjects show a variation from "condition entirely normal" to "bowels very loose." In three of the experiments, Nos. 418, 419, and 420, the amount of bran protein excreted in the feces exceeded that supplied by the bran eaten. In these cases, and also in experiment No. 417, where the digestibility was very low as compared with other tests, it might be assumed that an increase of peristalsis has effected a greatly decreased absorption, or that for some cause there has been an increase in the elimination of metabolic nitrogen through the intestines.

The figure 44.7 per cent reported for the digestibility of bran protein results from averaging the figures obtained in five tests, while the figure 56.6 per cent reported for bran carbohydrate results from averaging eight experiments. The figure 44.7 per cent agrees closely with that obtained by Pannwitz,[1] who found that the protein of finely ground bran was 43.7 per cent digested. However, the value 51.4 per cent obtained by including only three tests is considerably higher than his figure. The figure 56.6 per cent for the digestibility of bran carbohydrate is materially lower than that of the carbohydrate of cereal flours or meals or the carbohydrate of the average mixed diet, a fact in accord with data reported by other observers.

The figure 88.5 per cent obtained for the digestibility of the total fat of the diet is of interest. Except for the very little in the bran and in the potato and fruit the fat consumed consisted wholly of lard used in the preparation of the bread and butter eaten with the bread and potato. The digestibility of lard[2] had been found to be 97 per cent. In similar experiments[2] the digestibility of butter was found to be 97 per cent, and when it was included in a diet of meat loaf (containing hard palates of cattle), potato, crackers, sugar, and tea or coffee, the butter[3] was 95 per cent digested. In other experiments in which the diet consisted of bread, potato, fruit, butter (which supplied practically all the fat of the diet), sugar, and tea or coffee, the butter[4] was over 95 per cent digested. In more recent experiments in which butter[5] was eaten in conjunction with dasheen, milk, fruit, and tea or coffee, butter was over 96 per cent digested. It perhaps may be possible that the bran stimulated peristaltic action to such an extent that the fats, lard, and butter did not remain in the alimentary tract long enough to become as completely absorbed as they otherwise would.

EXPERIMENTS WITH UNGROUND WHEAT BRAN.

Seven experiments were made to determine the digestibility of the protein supplied by unground bran (flakes). The experiments were made in two groups, the first comprising experiments Nos. 409, 411, and 412 during the period March 13 to 16, inclusive, and the second experiments Nos. 436, 437, 438, and 439 during the period May 8 to 11, inclusive. With one exception the same subjects assisted in both groups of experiments, and uniform experimental conditions

[1] Nährwerth des Soldatenbrotes, Inaug Diss., Berlin, 1898, p. 123.
[2] U. S. Dept. Agr. Bul. 310 (1915), p. 21.
[3] U. S. Dept. Agr., Jour. Agr. Research, 6 (1916), No. 17, p. 647.
[4] U. S. Dept. Agr. Bul. 525 (1917), p. 8.
[5] U. S. Dept. Agr. Bul. 612 (1917), p. 8.

were maintained for all the experiments. The data resulting from these tests are summarized in the tables which follow:

Data of digestion experiments with coarse wheat bran in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 409, subject to D.G.G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread made with unground bran	1,260.0	660.4	55.1	105.2	373.3	66.0
Potato	546.0	412.2	13.7	.5	114.1	5.5
Fruit	784.0	707.8	2.0	2.5	70.2	1.5
Butter	199.0	21.9	2.0	169.1		6.0
Sugar	142.0				142.0	
Total food consumed	2,931.0	1,802.3	72.8	277.3	699.6	79.0
Feces	236.0		50.4	17.8	140.3	27.5
Amount utilized			22.4	259.5	559.3	51.5
Digestibility of entire ration (per cent)			30.8	93.6	79.9	65.2
Estimated digestibility of bran alone (per cent)			13.4		45.4	
Experiment No. 410, subject A.J.H.:						
Bread made with unground bran	1,107.0	580.2	48.4	92.4	328.0	58.0
Potato	509 0	384.3	12.7	.5	106.4	5.1
Fruit	688.0	621.1	1.7	2.2	61.7	1.3
Butter	233.0	25.6	2.3	198.1		7.0
Sugar	77.0				77.0	
Total food consumed	2,614.0	1,611.2	65.1	293.2	573.1	71.4
Feces	256.0		66.2	32.9	121.6	35.3
Amount utilized				260.3	451.5	36.1
Digestibility of entire ration (per cent)				88.8	78.8	50.6
Estimated digestibility of bran alone (per cent)			(1)		45.8	
Experiment No. 411, subject R.L.S.:						
Bread made with unground bran	1,335.0	699.7	58.3	111.5	395.6	69.9
Potato	361.0	272.6	9.0	.4	75.4	3.6
Fruit	817.0	737.6	2.0	2.6	73.2	1.6
Butter	149.0	16.4	1.5	126.6		4.5
Sugar	208.0				208.0	
Total food consumed	2,870.0	1,726.3	70.8	241.1	752.2	79.6
Feces	226.0		63.0	17.4	114.5	31.1
Amount utilized			7.8	223.7	637.7	48.5
Digestibility of entire ration (per cent)			11.0	92.8	84.8	60.9
Estimated digestibility of bran alone (per cent)			(1)		59.4	
Experiment No. 412, subject O.E.S.:						
Bread made with unground bran	1,119.0	586.5	48.9	93.4	331.6	58.6
Potato	507.0	382.8	12.7	.5	105.9	5.1
Fruit	586.0	529.0	1.5	1.9	52.5	1.1
Butter	66.0	7.3	0.6	56.1		2.0
Sugar	297.0				297.0	
Total food consumed	2,575.0	1,505.6	63.7	151.9	787.0	66.8
Feces	167.0		33.9	10.3	97.8	25.0
Amount utilized			29.8	141.6	689.2	41.8
Digestibility of entire ration (per cent)			46.8	93.2	87.6	62.6
Estimated digestibility of bran alone (per cent)			35.6		60.3	

[1] Negative results, fecal protein exceeding that in bran eaten.

Data of digestion experiments with coarse wheat bran in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 436, subject D.G.G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread made with unground bran	1,454.0	696.5	69.9	147.1	462.8	77.7
Potato	438.0	330.7	11.0	.4	91.5	4.4
Fruit	700.0	607.6	2.1	2.8	85.4	2.1
Butter	418.0	46.0	4.2	355.3		12.5
Sugar	164.0				164.0	
Total food consumed	3,174.0	1,680.8	87.2	505.6	803.7	96.7
Feces	297.0		63.3	26.6	170.1	37.0
Amount utilized			23.9	479.0	633.6	59.7
Digestibility of entire ration (per cent)			27.4	94.7	78.8	61.7
Estimated digestibility of bran alone (per cent)			16.7		41.5	
Experiment No. 437, subject A.J.H.:						
Bread made with unground bran	1,055.0	505.4	50.7	106.8	335.8	56.3
Potato	466.0	351.8	11.6	.5	97.4	4.7
Fruit	630.0	546.8	1.9	2.5	76.9	1.9
Butter	387.0	42.6	3.9	328.9		11.6
Sugar	103.0				103.0	
Total food consumed	2,641.0	1,446.6	68.1	438.7	613.1	74.5
Feces	140.0		30.4	18.8	69.4	21.4
Amount utilized			37.7	419.9	543.7	53.1
Digestibility of entire ration (per cent)			55.4	95.7	88.7	71.3
Estimated digestibility of bran alone (per cent)			49.7		72.1	
Experiment No. 438, subject R.L.S.:						
Bread made with unground bran	1,129.0	540.8	54.3	114.2	359.4	60.3
Potato	420.0	317.1	10.5	.4	87.8	4.2
Fruit	684.0	593.7	2.1	2.7	83.4	2.1
Butter	99.0	10.9	1.0	84.1		3.0
Sugar	88.0				88.0	
Total food consumed	2,420.0	1,462.5	67.9	201.4	618.6	69.6
Feces	183.0		39.5	17.4	100.3	25.8
Amount utilized			28.4	184.0	518.3	43.8
Digestibility of entire ration (per cent)			41.8	91.4	83.8	62.9
Estimated digestibility of bran alone (per cent)			31.1		58.4	
Experiment No. 439, subject O.E.S.:						
Bread made with unground bran	1,009.0	483.3	48.5	102.1	321.2	53.9
Potato	439.0	331.4	11.0	.4	91.8	4.4
Fruit	675.0	585.9	2.0	2.7	82.4	2.0
Butter	285.0	31.4	2.8	242.2		8.6
Sugar	208.0				208.0	
Total food consumed	2,616.0	1,432.0	64.3	347.4	703.4	68.9
Feces	173.0		40.3	19.0	89.6	24.1
Amount utilized			24.0	328.4	613.8	44.8
Digestibility of entire ration (per cent)			37.3	94.5	87.3	65.0
Estimated digestibility of bran alone (per cent)			21.6		60.7	
Average food consumed per subject per day	915.6	526.5	23.6	103.0	237.0	25.5

Summary of digestion experiments with wheat bran in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of protein of bran alone.	Estimated digestibility of carbohydrate of bran alone.
		Protein.	Fat.	Carbohydrate.	Ash.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
409	D. G. G.	30.8	93.6	79.9	65.2	13.4	45.4
410	A. J. H.	(1)	88.8	78.8	50.6	(2)	45.8
411	R. L. S.	11.0	92.8	84.8	60.9	(2)	59.4
412	O. E. S.	46.8	93.2	87.6	62.6	35.6	60.3
436	D. G. G.	27.4	94.7	78.8	61.7	16.7	41.5
437	A. J. H.	55.4	95.7	88.7	71.3	49.7	72.1
438	R. L. S.	41.8	91.4	83.8	62.9	31.1	58.4
439	O. E. S.	37.3	94.5	87.3	65.0	21.6	60.7
Average		35.8	93.1	82.8	62.5	28.0	55.5

[1] Negative result, fecal protein exceeding that of diet.
[2] Negative result, fecal protein exceeding that of bran eaten. Not included in average.

On an average the food consumed by the subjects furnished 24 grams of protein, 103 grams of fat, and 237 grams of carbohydrate daily, with an average energy value of approximately 1,970 calories. Although the subjects ate, in round numbers, 400 grams of the bran bread daily, the total amount of protein supplied per day was small. However, it was desirable that bran should furnish the major portion of the protein, and so, as was the case in the experiments with finely ground bran, no attempt was made to increase the protein intake by increasing the amount of potato consumed with the coarse bran bread.

The coefficients of digestibility of the diet as a whole were 35.8 per cent for protein, 93.1 per cent for fat, and 82.8 per cent for carbohydrate. These values are, of course, lower than those which have been reported for an average mixed diet,[1] namely, 92 per cent for protein, 95 per cent for fat, and 97 per cent for carbohydrate.

It is of interest to compare the coefficients of digestibility of the fat of the diet, 93.1 per cent (practically all obtained from lard used in preparing the bread and butter eaten with the bread and potato), with the coefficient of digestibility, 97 per cent, found for both lard and butter in experiments previously reported.[2]

In experiment No. 410 a negative value was obtained for the digestibility of protein, the amount excreted in the feces exceeding the amount supplied by the diet. In experiments Nos. 409, 411, and 436 the coefficients of digestibility were decidedly lower than in the remaining tests. Excluding these low values the coefficient of digestibility of protein becomes 45.3 per cent. The average digestibility of the carbohydrate of the coarse bran, 55.5 per cent, closely approximates the value 56.6 per cent obtained in the tests with finely ground bran.

[1] Connecticut Storrs Sta. Rpt. 1901, p. 245.
[2] U. S. Dept. Agr. Bul. 310 (1915), pl. 21.

In computing the digestibility of bran protein negative results were obtained in experiments Nos. 410 and 411; that is, the fecal protein was greater than that supplied by the bran. In three of the remaining tests (experiments Nos. 409, 436, and 439) the values were decidedly lower than in the remaining tests. Omitting these low values the average coefficients of digestibility for bran becomes 38.8 per cent instead of 28 per cent.

The reports made by the subjects regarding their physical condition vary from "normal except for occasional slight pains in the stomach after eating" to "extreme laxative effect."

No definite relation was apparent between such observations and the coefficients of digestibility. It is also interesting to note that the subjects were all of the opinion that no differences with respect to laxative effect were noted in the tests with finely ground and with coarse bran.

GENERAL DISCUSSION.

The results of numerous studies conducted both in this country and abroad to determine the digestibility of wheat flours containing little, if any, bran as compared with the digestibility of flours containing all the bran normally present in the grain show that the protein and carbohydrate of flours from which the bran has been largely removed is more completely utilized by the human body than the protein and carbohydrate of flours prepared from the whole grain.

So far as can be learned, no studies have been made to determine the digestibility of wheat bran when eaten as a constituent of a diet which did not include the flour prepared from the remainder of the kernel. With the purpose of securing more data on the digestibility of wheat bran included in a diet from which all forms of wheat flour were excluded, two series of experiments were made, one with fine bran and one with coarse bran, the subjects and experimental conditions being alike for both series.

An average of 465 grams of fine bran bread, equivalent to 155 grams bran, and of 395 grams of coarse bran bread, equivalent to 132 grams bran, was eaten per man per day. The results of tests with fine bran indicate that the protein supplied by the bran was 44.7 per cent and the bran carbohydrate was 56.6 per cent digested, while the results of the tests with coarse bran indicate a digestibility of 28 per cent for the bran protein and 55.5 per cent for the bran carbohydrate. The result for the digestibility of fine bran protein is in agreement with the results of Pannwitz,[1] who found that the protein of fine rye bran was 43.68 per cent digested.

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[1] Nährwerth des Soldatenbrotes, Inaug. Diss., Berlin, 1898, p. 100.

The digestibility of the protein of white flour obtained by averaging the results of the 31 tests reported in the United States Department of Agriculture investigations noted on page 4 is found to be 88.1 per cent. The digestibility of the protein of graham flour (representing the whole kernel) obtained by averaging the results of the 24 tests reported in the same investigations by the United States Department of Agriculture is found to be 76.9 per cent. If it is assumed that white flour contains 15.1 per cent[1] of protein which is 88.1 per cent digested and that fine bran contains 15.4 per cent[1] of protein which is 44.6 per cent digested, then by calculation the digestibility of the total protein supplied by a graham flour consisting of 72 per cent of white flour and the remainder of fine bran would be 75.8 per cent. It is an interesting coincidence that the value 75.8 per cent calculated for the digestibility of graham flour should agree so closely with the value 76.9 per cent obtained by averaging the results of the determination of the digestibility of protein of graham flour found in the 26 digestion experiments noted above.

The coefficients of digestibility of the diet as a whole (37 per cent for protein, 88.5 per cent for fat, and 79.8 per cent for carbohydrate, in the series in which fine bran was eaten, and 35.8 per cent for protein, 93.1 per cent for fat, and 82.8 per cent for carbohydrate, in the series in which coarse bran was eaten), are lower than the coefficients of digestibility, 92 per cent for protein, 95 per cent for fat, and 97 per cent for carbohydrate, reported[2] for the ordinary mixed diet. This indicates the way in which the rough, relatively indigestible bran influenced the digestibility of the entire diet. It is also possible that the bran stimulated peristaltic action to such an extent that the food materials were not as completely absorbed as is normally the case when they pass through the alimentary tract without increased peristalsis.

In general the amount of feces voided by the subjects during the tests with bran was larger than normal. This condition was noted by all the subjects regardless as to whether they were of active, athletic, or sedentary habits. Some of the subjects found the bran diets decidedly laxative. Little, if any, difference was noted by the subjects as a whole between the laxative effects of the fine and coarse brans.

It is hoped that the results of the experiments here reported when considered in connection with the available data on the digestibility of wheat will be of value in determining the most economical and physiologically efficient method of utilizing wheat for human food.

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 156 (1905), p. 14.
[2] Connecticut Storrs Sta. Rpt. 1901, p. 245.

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THE UTILIZATION OF IRRIGATED FIELD CROPS FOR HOG PASTURING.

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CONTENTS.

SOME IMPORTANT FACTORS IN SWINE PRODUCTION ON IRRIGATED LANDS.

On nearly every irrigation project in the United States it is possible to produce pork in commercial quantities. Swine growing has proved to be one of the industries through which the irrigation farmer can utilize certain of his field crops advantageously. The importance of this industry in irrigated districts fluctuates widely from year to year in response to various changes in economic conditions. One of the most important economic factors influencing swine production in these regions is the relationship between the prices of feeds and the prices of pork. Frequent changes in this relationship have resulted in great instability in the swine industry on irrigated lands and this has led to much economic loss.

To establish the swine industry in a community requires time and continued effort. Swine growers, to be successful, must acquire skill and have some special equipment; they must develop well-bred herds of suitable breeds, and they must build up and maintain a reputation for producing a continuing supply of pork. In other words, successful swine production requires that the producer adjust his operations so as to be able to remain in the business continuously.

In the past, swine production on irrigated lands has involved too many speculative features. Farmers commonly have gone into the business extensively when prices were high, only to go out of it later when prices were low. Thus, they have incurred losses in both transactions. Besides, they have expended large sums for equipment, which deteriorated rapidly when not in use.

One of the many causes of this uneconomic practice has been a lack of information as to the possibility of utilizing certain field crops produced under irrigation and the values of these crops when measured in terms of pork production. In some instances these values have been overestimated and overstocking has resulted; in others, farmers have underestimated feed values, and have either understocked with hogs or have sold both their hogs and their feed in the mistaken belief that "the market would pay more for the feed than the hogs would." Irrigation farmers have been strongly inclined to rely exclusively on old-established methods of swine production, so that at times of advancing grain prices, swine holdings have been inordinately reduced. Too little attention has been paid to the possibilities of utilizing fully certain field crops which are peculiarly adapted to irrigation farming. Many irrigation farmers have failed to appreciate the range of field crops available to them as feed for hogs, and to understand the swine-producing possibilities of irrigation agriculture through a better use of these crops.

Most of the published data regarding the feeding values of various crops used in swine production have been secured in nonirrigated sections. These data can not always be applied safely in irrigated districts, particularly in reference to crops which are pastured by hogs or "hogged off." One of the most important points in connection with the hog-pasturing method of utilizing these crops is the labor-saving feature—a feature of great importance in the sparsely settled irrigated districts, where labor commonly is expensive and difficult to secure.

Since 1912 the Department of Agriculture has been conducting experiments at its Western Irrigation Agriculture field stations[1] in

[1] These field stations are operated by the Office of Western Irrigation Agriculture of the Bureau of Plant Industry. Since 1914 the Animal Husbandry Division of the Bureau of Animal Industry and the Office of Demonstrations on Reclamation Projects in the Bureau of Plant Industry have cooperated in this work. The State experiment stations of Montana, Nebraska, and Oregon also cooperate in the investigations in those States.

the utilization of irrigated field crops in swine production. Reports of certain features of these investigations have been made from time to time,[1] and the results secured at individual stations have been discussed. In this bulletin an attempt is made to bring together some of the more important information which has been obtained at all

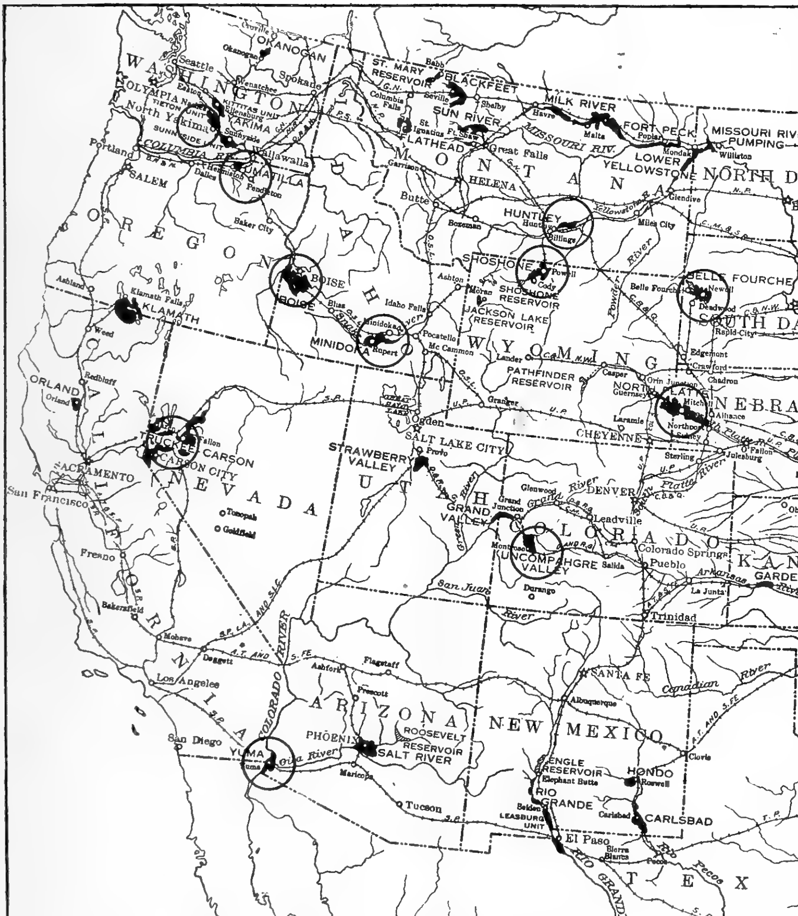

FIG. 1.—Map of the western United States, showing the location of the Government irrigation projects. The projects on which data have been obtained with reference to the utilization of irrigated crops by hog pasturing as discussed in this bulletin are shown by circles.

these stations with reference to the feed efficiency of certain irrigated field crops used as hog pasture and for hogging-off purposes. Some data which have been secured in tests[2] conducted in cooperation with

[1] See the list of publications near the end of this bulletin.

[2] These cooperative tests were supervised by the following field men employed by the Office of Demonstrations on Reclamation Projects: E. F. Rinehart, Charles S. Jones, L. E. Cline, Carl Christopher, Don G. Magruder, H. A. Lindgren, R. P. Bean, and H. A. Ireland.

irrigation farmers are also included. The locations where the information was obtained are shown in figure 1.

Many questions in this connection still need investigation, and experiments for this purpose are now in progress. This bulletin is issued as a contribution to the knowledge of the subject, in the belief that it will be helpful to practical swine growers and to the various agencies engaged in stimulating swine production on irrigated lands.

CHARACTER AND USE OF EXPERIMENTAL DATA.

In this bulletin, no attempt has been made to present the data on a monetary basis. Cash values of crop products and of hogs are changing constantly, so that in any event it is necessary to recalculate a financial statement of the results of a feeding operation to make it fit an individual case. In the present instance, the results have been measured and expressed in terms of pork production. In each test, the quantities of feed consumed and the area of land pastured have been set over against the gains made by the hogs during the period involved.

The tests reported cover a wide diversity of conditions with reference to number and size of animals used, area of land and quantity of supplementary feeds involved, and duration of the feeding period. These conditions are set forth in the tables and text. By consulting these, the reader can study the results of the tests in terms of area of land, quantity of supplementary feeds, total gains and rate of gain, and in many instances carrying capacity per unit area of land. With information on these points it is possible to apply the results reported to a variety of conditions on irrigated lands.

PASTURING ALFALFA.

In alfalfa, the irrigation farmer has an unexcelled forage crop for swine. This crop is grown more extensively than any other forage on the irrigated lands, and it yields abundantly. Its rapid growth, its palatability, and its high feeding value fit the crop admirably for hog pasture. There is, perhaps, no more economical method of growing pigs than to pasture them on alfalfa, if the latter is supplemented with the proper carbonaceous feeds. It is probable that, on the irrigated lands, with their abundance of alfalfa pasture, stocker hogs can be produced more cheaply than in any other swine-producing section of the country. Alfalfa pasture should be regarded as a basis for most of the operations of swine production on irrigated lands.

The results that can be secured with swine on alfalfa pasture depend chiefly upon the character of the animals, the stand and growth of the crop, the method of management, and the character and quantity of the supplementary feeds used. The stand and growth of the alfalfa crop vary so widely from year to year in different fields and in different parts of the country that only an approximation can be made of the productivity of alfalfa fields in irrigated sections. In 1916, the average yield of alfalfa hay on 381,323 acres harvested on all the Government reclamation projects was 3.2 tons per acre, according to reports made by the United States Reclamation Service. This acreage included newly-seeded land as well as land on which good stands of alfalfa had become established. Ordinarily, only established stands are used as pasture for hogs. The yields of the pastured fields, therefore, are somewhat greater than the average for the entire alfalfa acreage. An approximation of the productivity of the alfalfa lands used as hog pasture in the experiments reported in this bulletin is given in Table I, which shows average yields of alfalfa at five Western Irrigation Agriculture field stations.

TABLE I.—*Average yields of alfalfa hay at five Western Irrigation Agriculture field stations.*

Station.	Years.	Yield per acre (tons).	Remarks.
Yuma (Arizona-California)	1916	5.	Estimated yield of field used for hog pasture.
Truckee-Carson (Nevada)	1916	3.	Average yield of 49 plats on good and poor soil.
Scottsbluff (Nebraska)	1913 1916	5.42	4-year average yield of 15 plats with established stands in field K.
Huntley (Montana)	1913 1916	5.79	4-year average yield of 9 plats with established stands in field K.
Belle Fourche (South Dakota)	1913 1916	3.73	4-year average yield of 10 plats with established stands in field A.

It will be noted from Table I that the yields of established stands of alfalfa at the Yuma, Scottsbluff, and Huntley field stations average 5 tons or more per acre, while those at the Truckee-Carson and Belle Fourche stations are somewhat lower than this. These figures are useful only as a general indication of the productivity of the alfalfa fields used as hog pasture at these stations in the experiments reported in this paper.

The principal supplementary feeds are, of course, the cereals. The cereal crops—barley, corn, oats, rye, and wheat—are grown on most irrigation projects, but in varying degrees of importance. In 1916 these crops occupied 26.1 per cent of the cropped acreage on the Government reclamation projects, while alfalfa occupied 44.5 per cent of the cropped acreage the same year. Grain sorghums are grown extensively in the Southwest where they are used both as a principal feed for hogs and as a supplement to alfalfa pasture. Rye is not grown extensively for its grain under irrigation. A general idea of the yields obtained of the four principal cereal crops grown throughout the irrigated regions of the western United States can be had from an examination of the figures showing the average yields of wheat, oats, barley, and corn on 15 leading reclamation projects during the three years, 1913, 1914, and 1915. These figures, which include about 80 per cent of the total cereal acreage on all the Government reclamation projects during the three years mentioned, are presented in Table II.

TABLE II.—*Acreages and average yields of the principal cereal crops on 15 leading reclamation projects*[1] *during 1913, 1914, and 1915.*

Crop.	Average annual acreage.	Average yield per acre (pounds).	Rank in—	
			Acreage.	Yield.
Wheat	65,787	1,200	1	3
Oats	47,688	925	2	4
Barley	36,583	1,267	3	2
Corn	32,948	1,501	4	1

[1] These projects are the Salt River, Yuma, Uncompahgre, Boise, Minidoka (pumping and gravity), Huntley, North Platte, Truckee-Carson, Rio Grande, Klamath, Belle Fourche, Sunnyside, Tieton, and Shoshone. The locations of these projects are shown in figure 1.

Considering the yields obtained with these crops and their comparative suitability as supplements to alfalfa pasture in swine feeding, it appears that corn and barley should be grown more extensively. As long as irrigation farmers grow cereal crops to sell, it is likely that corn and barley will increase but slowly in importance. The necessity of developing live-stock industries in order to secure full utilization of the alfalfa crop and to sustain the productivity of the soil is becoming increasingly evident, however, and this is leading to a better appreciation of those cereal crops which, all things considered, are more suitable for use in feeding operations.

Since 1912 data showing the results obtained from alfalfa pasture and various supplements have been secured. These supplements include corn, barley, wheat, shorts, and milo, each used separately, and a number of mixtures of one or more of these feeds and of some additional feeds. In the following pages data are presented to show the results secured on alfalfa pasture, first, without supplements, and, second, with supplements of various kinds.

PASTURING ALFALFA WITHOUT SUPPLEMENTARY FEED.

It has been generally assumed that maximum returns can not be secured by pasturing alfalfa with swine unless a supplementary feed is used, and the few tests which have been conducted have supported this assumption. The results obtained in three tests at the Scottsbluff Experiment Farm and one on the Tieton Reclamation Project are shown in Table III.

TABLE III.—*Results secured with four lots of pigs on irrigated alfalfa pasture without supplementary feed on the Scottsbluff Experiment Farm and the Tieton Reclamation Project in 1914, 1915, and 1916.*

Pigs.	Location.	Time.	Number of pigs.	Average initial weight.	Area of pasture.	Time of test.	Gain (pounds). Total per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Average carrying capacity per acre.
				Lbs.	*Acres.*	*Days.*				*Lbs.*
Lot 1	Scottsbluff	Summer, 1914	6	59	0.25	90	408	4.53	0.19	1,620
Lot 2	do	Spring, 1915	3	108	.25	60	308	5.10	.43	1,450
Lot 3	do	Summer, 1915	6	33	.25	90	304	3.40	.14	944
Lots 2 and 3	do	All season, 1915			.25	150	612	4.10		
Lot 4	Tieton project	Summer, 1916	60	35	18.00	63			.30	

The pigs in lot 4 had access to 18 acres of alfalfa, much more than they could consume, so that the only significant figure secured with this lot was the average daily gain per pig, which amounted to 0.3 pound during the 60-day period. In lots 1, 2, and 3 the average daily gains were all low, considering the sizes of the pigs; and, as will be seen later, the gains per acre and the carrying capacity were lower than those which are secured when the pasture is supplemented with grain.

While the tests which have been conducted show that the best utilization of alfalfa pasture for hogs can not be secured without the use of some supplementary feed, irrigation farmers still pasture hogs in large numbers on alfalfa without supplements. It is true that hogs can be maintained in this way for some time, and that they frequently continue to make small gains for rather long periods. Continued pasturing without supplements, however, prevents good development, makes a hog pot-bellied and renders him incapable of making the most efficient use of concentrated feed later when he is being finished for market. Much of the disappointment experienced by irrigation farmers in finishing hogs for market is due to unthriftiness in the hogs resulting from inadequate previous feeding. The fact that hogs on alfalfa pasture alone will make some growth and that for some time they may not show any signs of serious nutritional deficiency is likely to be very misleading. The serious effects of such feeding are not always noticeable until the finishing period, when it is too late to remedy any defects which may appear.

The practice of pasturing alfalfa without supplements should be avoided whenever possible. On the other hand, if a farmer finds it impossible for a time to obtain any supplementary feed, this fact should not cause him to go out of the hog business. If no grain feed or other supplement is obtainable for a few weeks, the hogs can be carried on alfalfa pasture alone. Before resorting to this, however, the farmer should make every possible effort to obtain enough grain for a light supplementary ration, or, failing in this, he can often use such a feed as potatoes, as is pointed out later.

PASTURING ALFALFA SUPPLEMENTED WITH CORN.

In practically all the experiments with hogs on alfalfa pasture which are considered in this bulletin, the hogs have received some supplementary feed. The feeds most commonly used by irrigation farmers for this purpose are corn, barley, and, in the Southwest, grain sorghums; but wheat, shorts, and some other supplements have been fed in some instances. Where plenty of corn is available, it is

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FIG. 2.—A lot of fall shotes on alfalfa pasture on the Scottsbluff Experiment Farm in June, 1913. The pasture was divided into two parts, which were grazed alternately. These five shotes grazed one-quarter acre of alfalfa to its carrying capacity for 61 days and gained at the rate of 1,500 pounds per acre during this period. The supplementary grain requirement was 275 pounds per 100 pounds of gain.

used extensively, and the quantities fed vary widely. In most of the experiments here reported the daily ration has been about 2 pounds of corn per 100 pounds of live weight of pigs, or, in other words, a "2 per cent" ration. Data on this subject have been secured at three of the Western Irrigation Agriculture experiment farms and in cooperation with farmers on three reclamation projects. These data are presented below.

Experiments at the Scottsbluff Experiment Farm.—Data obtained at Scottsbluff from 1913 to 1916, inclusive, with 17 lots of pigs have been tabulated. In these experiments fall pigs were used during the spring periods, which usually extended through May and June, and spring pigs were pastured on the same land during the summer periods, from about July 1 to the end of the growing season in September. Each pasture was divided into two parts, which were pastured alternately, one part being grazed while the other was irrigated and the alfalfa on it allowed to produce new growth. The pigs had access most of the time to salt, slack coal, and rock phosphate and were given the care which is usually necessary in successful swine feeding. A lot of 5 hogs on alfalfa pasture in an experiment at Scottsbluff is shown in figure 2. The results secured with these 17 lots of pigs are summarized in Table IV.

TABLE IV.—*Results secured with 17 lots of pigs on irrigated alfalfa pasture supplemented with corn on the Scottsbluff Experiment Farm during the 4-year period from 1913 to 1916.*

Pigs.	Time.	Corn ration.	Number of pigs.	Average initial weight.	Area of pasture.	Time of test.	Gain (pounds).			Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
							Total per acre.	Per acre per day.	Per pig per day.		
		P. ct.		*Lbs.*	*Acres.*	*Days.*				*Lbs.*	*Pounds.*
Lot 1	Summer, 1914	1.10	8	64	0.25	90	1,008	11	0.35	2,568	196
Lot 2	Spring, 1915	1.00	3	108	.25	60	620	10	.45	2,040	215
Lot 3	Summer, 1915	1.00	9	33	.25	90	836	9	.30	1,602	170
Lots 2 and 3	All season, 1915	1.00			.25	150	1,456	9			189
Lot 4	Spring, 1913	2.30	5	109	.25	61	1,524	25	1.25	2,938	275
Lot 5	Summer, 1913	2.30	12	34	.25	76	2,428	32	.67	2,862	209
Lots 4 and 5	All season, 1913	2.30			.25	137	3,952	29			234
Lot 6	Summer, 1914	2.06	10	59	.25	90	1,900	21	.53	3,806	244
Lot 7	do	2.64	11	70	.25	90	2,940	33	.74	4,554	299
Lot 8	Spring, 1915	2.00	5	108	.25	60	1,244	20	1	2,782	276
Lot 9	Summer, 1915	2.00	12	31	.25	90	1,732	19	.40	2,454	200
Lots 8 and 9	All season, 1915	2.00			.25	150	2,976	19			253
Lot 10	Spring, 1915	2.00	5	108	.25	60	1,180	20	1	2,754	274
Lot 11	Summer, 1915	2.00	12	34	.25	90	1,580	18	.38	2,406	226
Lots 10 and 11	All season, 1915	2.00			.25	150	2,760	19			246
Lot 12	Spring, 1916	2.26	6	83	.25	60	1,440	24	1	2,724	235
Lot 13	Summer, 1916	2.00	10	45	.25	82	1,788	22	.55	2,678	224
Lots 12 and 13	All season, 1916				.25	142	3,228	23			228
Lot 14	Spring, 1916	2.26	20	74	1	60	1,147	19	.95	2,054	247
Lot 15	Summer, 1916	2.70	40	30	1	97	1,995	22	.55	2,189	289
Lots 14 and 15	All season, 1916				1	157	3,142	20			274
Lot 16	Spring, 1915	3.00	6	108	.25	60	1,772	30	1.25	3,478	321
Lot 17	Summer, 1915	3.00	15	33	.25	90	2,520	28	.47	3,244	256
Lots 16 and 17	All season, 1915	3.00			.25	150	4,292	28			283

The data shown in Table IV were secured with 189 pigs in 17 lots, of which 7 contained a total of 50 fall-farrowed pigs, and 10 a total of 139 spring-farrowed pigs. The gains per acre of alfalfa ranged from 9 to 33 pounds per day; the average carrying capacity varied from 1,602 to 4,554 pounds per acre, and the grain fed for each 100 pounds of gain ranged from 170 to 321 pounds. These data will be further discussed later.

Experiments at the Huntley Experiment Farm.—The results obtained with pigs on alfalfa pasture at Huntley from 1913 to 1916, inclusive, are summarized in Table V. There were in all 7 lots. Each lot had access to one-quarter of an acre of alfalfa and was fed a 2 per cent supplementary ration of corn. The same general methods were followed as for Scottsbluff, already described.

TABLE V.—*Results secured with seven lots of pigs on irrigated alfalfa pasture supplemented with a 2 per cent ration of corn on the Huntley Experiment Farm during the 4-year period from 1913 to 1916.*

Pigs.	Time.	Number of pigs.	Average initial weight.	Time of test.	Gain (pounds). Total per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
			Pounds.	*Days.*				*Pounds.*	*Pounds.*
Lot 1	Summer, 1913	12	60	30	744	25	0.50	3,452	301
Lot 2	Spring, 1914	4	113	70	1,012	14	.90	2,206	323
Lot 3	Summer, 1914	9	41	69	1,292	19	.52	2,114	223
Lots 2 and 3	All season, 1914			139	2,304	16			278
Lot 4	Spring, 1915	5	158	80	1,256	17	.86	3,784	414
Lot 5	Summer, 1915	8	38	70	1,220	18	.54	1,818	212
Lots 4 and 5	All season, 1915			150	2,476	17			313
Lot 6	Spring, 1916	5	105	75	1,620	22	1.08	2,906	260
Lot 7	Summer, 1916	8	44	70	1,412	20	.63	2,130	197
Lots 6 and 7	All season, 1916			145	3,032	21			228

The 7 lots used at Huntley contained a total of 37 spring-farrowed pigs in 4 lots and 14 fall-farrowed pigs in 3 lots. The gains per acre of alfalfa ranged from 14 to 25 pounds per day; the average carrying capacity varied from 1,818 to 3,784 pounds per acre, and the grain fed per 100 pounds of gain ranged from 197 to 414 pounds.

Experiments at the Belle Fourche Experiment Farm.—The results secured with 10 lots of pigs are available from Belle Fourche. Each lot had access to one-fourth of an acre of alfalfa and received a 2 per cent supplementary ration of corn. Each pasture was divided into two equal parts, which were grazed alternately, as at Scottsbluff and Huntley, and the methods used were essentially the same as those employed at the other two stations. The results are summarized in Table VI.

At Belle Fourche were 6 lots of spring-farrowed pigs, a total of 43, and 4 lots of fall-farrowed pigs, a total of 16, or 59 in the 10 lots. The gains per acre of alfalfa varied from 12 to 19 pounds per day, the average carrying capacity from 1,434 to 2,720 pounds per acre, and the grain fed per 100 pounds of gain from 200 to 292 pounds.

TABLE VI.—*Results secured with 10 lots of pigs on irrigated alfalfa pasture supplemented with a 2 per cent ration of corn on the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

Pigs.	Time.	Number of pigs.	Average initial weight.	Time of test.	Gain (pounds). Total per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
			Pounds.	*Days.*				*Pounds.*	*Pounds.*
Lot 1	Summer, 1914	5	88	121	1,830	15	0.75	2,720	278
Lot 2	Spring, 1915	4	125	61	938	15	.93	2,046	275
Lot 3	Summer, 1915	7	36	71	1,088	15	.53	1,434	203
Lots 2 and 3	All season, 1915			132	2,026	15			236
Lot 4	Spring, 1915	4	119	61	1,064	17	1.06	2,300	254
Lot 5	Summer, 1915	7	38	71	1,044	15	.54	1,452	214
Lots 4 and 5	All season, 1915			132	2,108	16			234
Lot 6	Spring, 1916	4	102	55	688	12	.75	2,038	270
Lot 7	Summer, 1916	9	60	70	1,274	18	.50	2,348	268
Lots 6 and 7	All season, 1916			125	1,962	16			269
Lot 8	Spring, 1916	4	103	55	658	12	.75	2,058	292
Lot 9	Summer, 1916	8	61	70	1,348	19	.60	2,274	238
Lots 8 and 9	All season, 1916			125	2,006	16			256
Lot 10	Fall, 1915	7	48	36	566	16	.60	1,630	200

Tests made in cooperation with farmers.[1]—The results secured in 10 cooperative tests in which pigs were pastured on alfalfa supplemented with corn are presented in Table VII. In these tests no attempt was made to adjust the number of hogs to the area of alfalfa so as to secure the maximum carrying capacity. The general practice was to allow the pigs to graze at will in alfalfa fields which were also used for hay production, so that the data secured show chiefly the daily gains and the grain consumed per hundredweight of gain. In these tests, furthermore, somewhat higher corn rations were used than in the tests at the experiment farms.

The 10 lots considered in Table VII contained a total of 596 pigs. The average initial weight of these 10 lots ranged from 23 to 175 pounds per head; the pasturing periods varied from 19 to 118 days; the corn rations fed ranged from 1.30 to 6.95 per cent, and the character of the alfalfa fields pastured also varied. The conditions which always influence the grain requirement were, therefore, very diverse.

[1] In the tests made in cooperation with farmers and discussed in this bulletin, the weights of the hogs were secured through the use of a special portable weighing outfit illustrated in fig. 3. The use of this simple outfit greatly facilitated the proper conduct of the tests and by giving exact information regarding the gains made by the hogs materially increased the interest of swine growers in the work.

When the grain rations fed the pigs in these cooperative tests are considered, the results obtained, as indicated by the average daily gain and the grain fed per hundredweight of gain, compare not un-

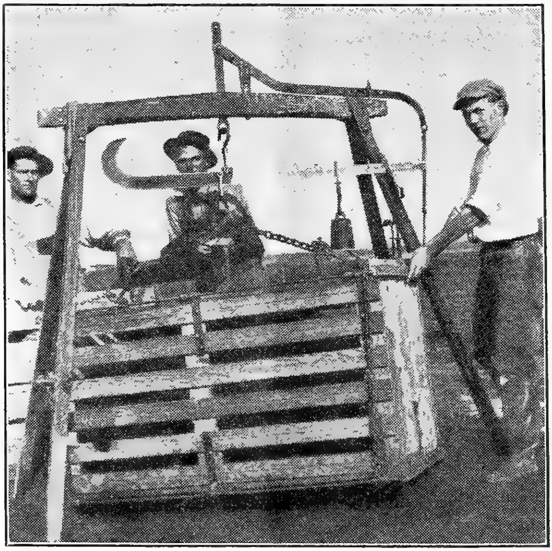

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FIG. 3.—Portable weighing outfit used in the swine-production tests conducted in cooperation with farmers. The crate and the weighing frame are easily taken down and transported from place to place.

favorably with those in the tests made on the experiment farms. It will be noted that increased grain requirement per unit of gain was closely associated with increased size of the grain ration.

TABLE VII.—*Results secured in cooperation with farmers with ten lots of pigs on irrigated alfalfa pasture supplemented with corn on three reclamation projects in 1915 and 1916.*

Pigs.	Project.	Year.	Corn ration.	Number of pigs.	Average initial weight.	Time of test.	Average daily gain per pig.	Grain fed per 100 pounds of gain.
			Per cent.		*Pounds.*	*Days.*	*Pounds.*	*Pounds.*
Lot 1	Uncompahgre	1916	1.30	22	114	33	0.70	228
Lot 2	North Platte	1916	1.86	87	45	31	.40	241
Lot 3	do	1915	2.24	94	23	118	.42	274
Lot 4	do	1915	2.58	64	66	31	.76	263
Lot 5	do	1916	2.62	84	43	31	.48	276
Lot 6	Huntley	1916	3.00	22	66	93	1	332
Lot 7	North Platte	1916	3.31	94	118	68	1.25	415
Lot 8	do	1916	4.87	19	175	27	2.07	478
Lot 9	do	1916	4.90	77	153	36	2.22	414
Lot 10	do	1915	6.95	33	139	19	2.24	494

Summary.—The tests with the 44 lots of pigs on alfalfa pasture supplemented with corn included 895 head. The character of these animals, the quantities of grain fed, the methods of management, and the lengths of the pasturing period varied greatly. In fact, the diversity was such that the results secured probably indicate approximately the limits within which the returns from this method of utilizing irrigated alfalfa will fall. A summary of certain features of the results secured is given in Table VIII.

TABLE VIII.—*Summary of determinations of gains, carrying capacity, and grain requirement made with 44 lots of pigs on irrigated alfalfa pasture supplemented with corn during the 4-year period from 1913 to 1916, inclusive.*

Item of comparison.	Scottsbluff.	Huntley.	Belle Fourche.	Cooperative tests.	Total.
Number of lots	17	7	10	10	44
Number of pigs	189	51	59	596	895
Gains per acre, for the season (15 double lots), double lots gaining between—					
1,456 and 2,000 pounds ... number	1	...	1	...	2
2,001 and 2,500 pounds ... do	...	2	3	...	5
2,501 and 3,000 pounds ... do	3	...	...	...	3
3,001 and 3,500 pounds ... do	2	1	...	...	3
3,501 and 4,000 pounds ... do	1	...	...	...	1
4,001 and 4,292 pounds ... do	1	...	...	...	1
Gains per acre per day (34 lots), lots gaining—					
Less than 10 pounds ... do	1	...	...	...	1
Between 10 and 20 pounds ... do	7	5	10	...	22
Between 21 and 30 pounds ... do	7	2	...	...	9
More than 30 pounds ... do	2	...	...	...	2
Average carrying capacity, pounds per acre (34 lots), lots carrying—					
Less than 2,000 pounds ... number	1	1	3	...	5
Between 2,001 and 3,000 pounds ... do	12	4	7	...	23
More than 3,000 pounds ... do	4	2	...	...	6
Grain consumed per 100 pounds of gain (44 lots), lots consuming—					
Less than 200 pounds ... number	2	1	...	...	3
200 to 250 pounds ... do	8	2	4	2	16
251 to 300 pounds ... do	6	1	6	3	16
301 to 350 pounds ... do	1	2	...	1	4
351 to 400 pounds ... do	...	...	...	...	...
More than 400 pounds ... do	...	1	...	4	5

As shown in Table VIII, 30 lots of pigs were involved in full-season grazing; that is, 15 lots of pigs were used in pasturing alfalfa during the spring period, and the same number of lots were used in the summer period. These are referred to in the table as 15 double lots. The other hogs were pastured for shorter periods. The table shows that the gains per acre for the season ranged from 1,456 to 4,292 pounds. Both these gains were made at Scottsbluff, the lowest with lots 2 and 3, fed a 1 per cent ration of corn, and the highest with lots 16 and 17, fed a 3 per cent ration of corn. Of the 15 double lots, 5 gained from 2,001 to 2,500 pounds per acre, 3 from 2,501 to 3,000 pounds, and 3 from 3,001 to 3,500 pounds per acre. It is reasonable to expect that gains of about 2,500 pounds per acre of alfalfa can be made during the season if the supplementary corn ration is as high as 2 per cent. Variations in the gains will depend on the hogs, the supplementary ration, the crop, and the methods of management.

Of the 34 lots furnishing data on the gains per acre, 22 lots gained from 10 to 20 pounds, and 9 gained from 21 to 30 pounds per acre per day. There was no consistent significant difference between small pigs and large pigs in this connection. In pasturing alfalfa approximately to its carrying capacity, a daily gain of 15 to 20 pounds per acre would be a conservative estimate if the supplementary corn ration were as high as 2 per cent.

Data on carrying capacity are furnished by 34 lots. With 23 of these the average carrying capacity was between 2,001 and 3,000 pounds per acre for the pasture period. Usually the alfalfa pasture will support a somewhat greater live weight of large pigs than of small ones. The carrying capacity is, of course, higher in midsummer than in spring or early autumn, because of the more rapid growth of the crop in warm weather. In the extreme southwestern section of the country, however, a period of slow growth occurs during the hottest part of the summer. An average carrying capacity of 2,500 pounds per acre would be a safe estimate on which to base alfalfa pasturing enterprises if the pasture were supplemented with as much as a 2 per cent ration of corn. The carrying capacity increases rapidly with increased grain allowance.

Of the 44 lots furnishing data on the grain requirement per hundred pounds of gain, 32 required between 200 and 300 pounds. In general, the grain requirement increased with the size of the hogs and the size of the grain ration. With pigs averaging less than 125 pounds at the beginning of a 60-day to 90-day pasturing period, and fed a supplementary corn ration of about 2 per cent, the grain requirement per hundred pounds of gain should not exceed 300 pounds, and with very favorable conditions it should be as low as 250 pounds.

The rate of gain is influenced by the size and character of the hogs, the abundance of the alfalfa, and the size of the corn ration. The average daily gain per pig in the 44 lots on alfalfa pasture supplemented with corn ranged from 0.30 pound to 2.24 pounds, the latter being secured with a lot of thirty-three 139-pound pigs on pasture for only 19 days and fed a corn ration of 6.95 per cent. Of the 44 lots, 11 made average daily gains ranging from 0.30 to 0.50 pound per pig; 16, from 0.51 to 0.75 pound; 9, from 0.76 to 1 pound, and in the remaining 8 lots the average daily gain per pig ranged from 1.01 to 2.24 pounds. These figures, covering the diversity of conditions in the 44 tests, are of value, as they will apply in a general way to mixed lots of pigs, of which many are pastured by irrigation farmers. With such lots the daily gain per pig on alfalfa pasture supplemented with corn can be expected to average from 0.50 to 1 pound, small pigs and light rations producing the lower gains and large pigs and heavier rations producing the higher gains. Of the 44 lots, 16 had average initial weights of less than 50 pounds per pig. The average daily gains of these 16 lots ranged from 0.30 to 0.67 pound. There were 11 lots having average initial weights between 51 and 100 pounds. The average daily gains of these 11 lots ranged from 0.35 to 1 pound per pig, all but one, which received a 1 per cent corn ration, averaging more than 0.50 pound per pig. The 15 lots with average initial weights between 101 and 150 pounds made average daily gains between 0.45 pound (a lot receiving a 1 per cent ration of corn) and 2.24 pounds. Of these 15 lots, 13 averaged 0.75 pound or more gain per day per pig.

PASTURING ALFALFA SUPPLEMENTED WITH BARLEY.

In many irrigated districts barley is extensively used to supplement alfalfa pasture for hogs. In certain districts having short growing seasons corn production is somewhat hazardous, particularly in the absence of satisfactory corn varieties. In such places barley is commonly the leading grain feed for hogs. Table IX shows the results obtained with 15 lots of pigs on alfalfa pasture supplemented with barley. In practically all these tests rolled barley was used, and about a 2 per cent ration was fed. In general, the same methods of pasturing were used as those described for the tests in which corn was the grain supplement.

As shown in Table IX, there were 6 instances in which alfalfa was pastured for approximately a full season, the length of the pasture period ranging from 125 to 190 days. The gains per acre in these instances ranged from 1,912 to 2,788 pounds, both this minimum and this maximum being gained at the Truckee-Carson Experiment Farm with a 2 per cent ration of barley. These results show the effect of differences in the character of the alfalfa pasture and in the pigs used.

Data on carrying capacity are furnished by 14 lots. The average carrying capacity in these 14 lots ranged from 1,075 to 3,114 pounds per acre. One of the two instances in which the lower carrying capacity was obtained was at the Truckee-Carson Experiment Farm in the fall of the year 1916, and the other was in the summer of 1917 at the Yuma Experiment Farm where, as previously stated, alfalfa has a period of slow growth in the hottest part of the summer. In 8 of the 14 instances considered in Table IX, the carrying capacity was above 2,000 pounds per acre. A gain of 2,500 pounds per acre can reasonably be expected from good alfalfa pasture supplemented with as much as a 2 per cent ration of barley; but, as in the case of corn, the gains will vary widely with differences in the hogs, the pasture, and the methods of management.

Eliminating lot 13, which was pastured for only 14 days, the grain requirement of the lots considered in Table IX ranged from 214 to 334 pounds per 100 pounds of gain. One half the lots consumed 300 pounds or less for each 100 pounds of gain, and the grain consumption of the other half ranged from 313 to 334 pounds per 100 pounds of gain. The rate of gain varied from 0.33 pound per pig per day in lot 3, consisting of 12 pigs weighing 33 pounds each, fed a 2 per cent ration of barley, to 1.21 pounds per pig per day in lot 15, consisting of 64 pigs weighing 89 pounds each, fed a barley ration of 3.68 per cent and having access to a large field of alfalfa.

TABLE IX.—*Results secured with 15 lots of pigs on irrigated alfalfa pasture supplemented with barley on five reclamation projects in 1914, 1915, and 1916.*

Pigs.	Location.	Time.	Barley ration.	Number of pigs.	Average initial weight.	Area of pasture.	Time of test.	Gain (pounds).			Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
								Total per acre.	Per acre per day.	Per pig per day.		
			P. ct.		*Lbs.*	*Acres.*	*Days.*				*Lbs.*	*Lbs.*
Lot 1	Scottsbluff	Summer, 1914	1.93	10	56	0.25	90	1,740	19	0.48	3,114	243
Lot 2	do	Spring, 1915	2.00	5	108	.25	60	1,180	20	1	2,758	272
Lot 3	do	Summer, 1915	2.00	12	33	.25	90	1,592	18	.33	2,388	214
Lots 2 and 3	do	All season, 1915.	2.00			.25	150	2,772	18			243
Lot 4	do	Spring, 1916	2.52	19	77	1	60	963	16	.84	1,937	300
Lot 5	do	Summer, 1916	2.50	40	30	1	97	1,738	18	.45	2,060	280
Lots 4 and 5	do	All season, 1916.	2.51			1	157	2,701	18			292
Lot 6	Umatilla	Spring, 1914	2.00	4	84	.25	135	1,768	13	.81	2,196	327
Lot 7	do	Summer, 1914	2.00	4	90	.25	55	524	10	.61	1,682	334
Lots 6 and 7	do	All season, 1914.	2.00			.25	190	2,292	12			329
Lot 8	Truckee-Carson.	All season, 1915	2.00	10	39	.25	125	1,912	15	.37	2,516	313
Lot 9	do	Spring, 1916	2.00	17	37	.50	84	1,336	16	.47	1,926	230
Lot 10	do	Summer, 1916	2.00	10	87	.50	32	484	15	.70	1,986	250
Lot 11	do	Fall, 1916	2.00	6	85	.50	14	110	8	.67	1,075	260
Lots 9, 10, and 11.	do	All season, 1916.	2.00			.50	130	1,930	15			236
Lot 12	do	Spring and summer, 1916.	2.00	10	26	.25	138	2,552	18	.46	2,324	246
Lot 13	do	Fall, 1916	2.00	6	94	.25	14	236	17	.69	2,382	140
Lots 12 and 13.	do	All season, 1916.	2.00			.25	152	2,788	18			237
Lot 14	Yuma	Summer, 1917	2.00	12	38	.75	98	878	9	.56	1,075	324
Lot 15	North Platte project.	Summer, 1915	3.68	64	89	Excess.	32			1.21		329

PASTURING ALFALFA SUPPLEMENTED WITH MILO.

Data are available from 3 tests in which a 2 per cent ration of cracked milo was used to supplement alfalfa pasture at the Yuma Experiment Farm. The same general methods of pasturing were practiced as in the pasturing experiments at the other experiment farms, as discussed above. The results secured are summarized in Table X.

TABLE X.—*Results secured with three lots of pigs on irrigated alfalfa pasture supplemented with a 2 per cent ration of cracked milo on the Yuma Experiment Farm in 1916 and 1917.*

Pigs.	Time.	Number of pigs.	Average initial weight.	Area of pasture.	Time of test.	Gain (pounds). Total per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
			Pounds.	*Acres.*	*Days.*				*Pounds.*	*Pounds.*
Lot 1	Spring, 1916	6	59	0.25	56	1,060	19	0.72	1,896	222
Lot 2	Summer, 1916	6	71	.25	126	2,376	19	.80	2,892	243
Lots 1 and 2	All season, 1916			.25	182	3,436	19			237
Lot 3	Spring, 1917	16	58	.75	120	1,868	15	.77	2,168	240

The results obtained with cracked milo as a pasture supplement at Yuma compare very favorably with those secured with corn and barley in similar tests conducted at the other experiment farms.

PASTURING ALFALFA SUPPLEMENTED WITH WHEAT AND SHORTS.

Generally speaking, the use of wheat as a hog feed has not been extensively adopted by irrigation farmers. In some districts, however, wheat has been produced more extensively than barley or corn, and in these districts the crop has been fed to hogs rather commonly. Feeding unmarketable or low-grade wheat to hogs also has been rather widely practiced in some districts, and some use has been made of shorts for the same purpose. The results secured in three tests in which wheat was used as a supplement to alfalfa pasture and in two tests in which shorts were used are summarized in Table XI. Lots 1, 2, and 4 were on the Tieton Reclamation Project, lot 3 on the Uncompahgre Reclamation Project, and lot 5 on the Belle Fourche Experiment Farm. The wheat used was cracked or ground in each instance. The gain per acre of alfalfa pasture was determined in only one case; so this item is omitted from the table.

TABLE XI.—*Results secured with five lots of pigs on irrigated alfalfa pasture supplemented in three instances with wheat and in two instances with shorts on three reclamation projects.*

Pigs.	Supplement.	Grain ration.	Number of pigs.	Average initial weight.	Time of test.	Gain per pig per day.	Grain fed per 100 pounds of gain.
		Per cent.		*Pounds.*	*Days.*	*Pounds.*	*Pounds.*
Lot 1	Wheat	1.00	7	40	49	0.82	99
Lot 2	do	6.40	12	114	24	2.58	319
Lot 3	do	2.00	11	118	30	1.10	256
Lot 4	Shorts	3.30	5	66	62	.96	331
Lot 5	do	2.00	7	48	36	.53	203

With the exception of lot 1, in which the grain requirement per 100 pounds of gain was very low, the results secured with wheat and shorts as supplements to alfalfa pasture were about the same as those secured with corn and barley.

The above figures are valuable merely as a general indication of the gains which can be expected, and, except lot 1, the probable grain requirements per 100 pounds of gain with hogs having access to alfalfa pasture supplemented with the two feeds mentioned. The use of wheat as a hog feed is not looked upon with favor, particularly under war conditions, because of the need of this grain as human food.

PASTURING ALFALFA SUPPLEMENTED WITH POTATOES.

Potatoes are not ordinarily important as a supplement to alfalfa pasture, but occasionally conditions favor their use for this purpose. On those irrigation projects where potatoes are grown commercially it is sometimes impossible to market the crop through the ordinary channels because of ample production in districts nearer to the large consuming centers. At such time large quantities of potatoes produced under irrigation are wasted. This condition prevailed in a few districts in the spring of 1918. At that time efforts were made by the field men of the Office of Demonstrations on Reclamation Projects to promote the use of potatoes in swine feeding.

One feeding enterprise conducted in cooperation with a farmer on the Truckee-Carson Reclamation Project in May and June, 1918, furnishes an example of how potatoes may be used advantageously under the conditions just described. The farmer who owned the pigs was unable to secure any grain to supplement alfalfa pasture, but he was able to buy 13 tons of potatoes at a very low price. The 28 pigs which were pasturing on alfalfa without supplementary feed were weighed 10 days before the potato feeding began, again on that day, and finally 35 days later, when all the potatoes were consumed and the hogs were sold. The potatoes were fed raw and without limit during the 35-day period. The results are shown in Table XII.

These results are considered satisfactory in view of the fact that the pigs were not in a very thrifty condition at the beginning of the potato-feeding period, having been on alfalfa pasture without supplements. From this test it appears that 6 to 8 pounds of raw potatoes are equal to 1 pound of grain in feeding value as a supplement to alfalfa pasture. It is probable that a higher feeding value of potatoes would be indicated by hogs which had been better fed previously. The quality of the pigs and their market value per pound increased materially as a result of the potato feeding, and a fair return was realized from the potatoes, which otherwise would have been wasted. This test suggests one method whereby hogs may be used advantageously under certain conditions in utilizing potatoes and also whereby the value of alfalfa pasture for hogs may be increased in the absence of the ordinary grain supplements.

TABLE XII.—*Results obtained with one lot of pigs on irrigated alfalfa pasture supplemented with a potato ration on the Truckee-Carson Reclamation Project in 1918.*

Items of comparison.	Alfalfa pasture alone.	Alfalfa pasture and potatoes.
Number of pigs	28	28
Time of test ... days	10	35
Average initial weight per pig ... pounds	137	140
Total gain ... do	77	1,058
Average daily gain per pig ... do	0.24	1.08
Potatoes fed ... do		26,000
Potatoes fed per 100 pounds of gain ... do		2,457

PASTURING ALFALFA SUPPLEMENTED WITH MIXED CONCENTRATES.

It is not an uncommon practice among swine growers on the irrigated lands to feed hogs mixtures of two or more grains or of one grain and some other feed. In this way use is made of swine in utilizing materials which are not readily marketable or which otherwise would be wasted. Table XIII contains data from 13 lots of pigs to which mixed concentrates were fed as supplements to alfalfa pasture. All these lots had an excess of pasture except Nos. 10 and 11, which grazed 1 acre, and Nos. 12 and 13, which had access to 0.4 of an acre of pasture. Lots 1 to 8, inclusive, were on farms on the North Platte Project; lots 9, 10, and 11, on the Uncompahgre Project; and lots 12 and 13, on the Truckee-Carson Experiment Farm.

TABLE XIII.—*Results secured with 13 lots of pigs on irrigated alfalfa pasture supplemented with mixed concentrates on three reclamation projects.*

Pigs.	Supplementary feed.[1]	Ration.	Number of pigs.	Average initial weight.	Time of test.	Gain per pig per day.	Ration fed per 100 pounds of gain.
		Per cent.		*Pounds.*	*Days.*	*Pounds.*	*Pounds.*
Lot 1	Corn 2, shorts 1	3.96	40	34	35	0.72	270
Lot 2	Corn 2, barley 1	2.69	39	58	56	.68	303
Lot 3	Corn 3, spelt 1	2.87	134	47	41	.51	320
Lot 4	Corn 3, wheat 1	4	165	38	41	.62	320
Lot 5	do	6.13	170	50	29	.91	439
Lot 6	Corn 10, wheat 1	4.40	76	45	52	1.08	301
Lot 7	Corn 2, barley 1	1.98	36	48	86	.60	251
Lot 8	Corn 1, oats 2, shorts 2, skim milk 2.	3.30	6	18	137	.94	270
Lot 9	Corn 1, wheat 4½	4.60	31	116	43	1.73	415
Lot 10	Barley 24, tankage 1	3.70	41	86	42	1.43	307
Lot 11	Barley 25, wheat 25, tankage 1.	4	41	146	21	1.47	440
Lots 10 and 11					63		350
Lot 12	Barley 3, tankage 1	2	8	67	84	.48	344
Lot 13	Barley 5, tankage 1	3	8	108	21	.77	440
Lots 12 and 13					105		376

[1] The figures following the names of the supplementary feeds indicate the proportions of these feeds in the various mixtures.

The results summarized in Table XIII show the same general facts with reference to supplements for alfalfa pasture as those brought out where the different grain supplements were used separately, as shown in previous tables. The grain consumed per 100 pounds of gain increases with the size of the hogs as well as with the size of the grain ration. The character of the hogs and the pasture is, of course, very important also. It is of interest to note that lots 10 and 11, consisting of 41 pigs fed barley and tankage for 42 days, followed by barley, wheat, and tankage for 21 days, made a gain during the 63-day period of 3,711 pounds on 1 acre of pasture on the Uncompahgre project. These pigs were well bred, had good care, and the alfalfa pasture was in excellent condition. In addition to the alfalfa pasture, the pigs were fed 350 pounds of grain for each 100 pounds of gain. Contrasted with these results are those secured with lots 12 and 13 at the Truckee-Carson Experiment Farm on an inferior stand of alfalfa. In this instance, the gain per acre in 105 days was only 1,144 pounds, and the grain requirement 376 pounds for each 100 pounds of gain.

COMPARISONS OF VARIOUS SUPPLEMENTARY FEEDS FOR ALFALFA PASTURE.

The preceding tables and discussions have been concerned chiefly with showing something of the results which have been secured with various supplementary feeds for alfalfa pasture, without attempting to make comparisons of the values of these supplements. Many of the data which have been obtained in these feeding enterprises are such that direct comparisons can not be made from them. There are, however, a few instances which furnish bases for comparisons, and these will now be considered.

Corn and barley.—Perhaps the most extensive information at present available regarding the comparative value of grain supplements for alfalfa pasture under irrigation is that secured at the Scottsbluff Experiment Farm in 1914, 1915, and 1916 with corn and barley. The results of the comparative tests made during these three years are summarized in Table XIV.

It will be seen from Table XIV that in four of the five comparisons, somewhat less barley than corn was required for 100 pounds of gain. In the exceptional case, a higher ration of barley than of corn was fed, and the alfalfa pasture used by the barley-fed lot was seriously damaged by a sand storm during the pasture season. It is believed that these two factors account for the comparatively unfavorable showing made by the barley in this instance. From these results and from observations in other pasturing enterprises, it is believed that the choice between corn and barley can safely depend on the prices per pound of the two grains, where one or the other is to be purchased, and on the exigencies of labor and other cultural requirements, where one or the other is to be grown for use as a supplement to alfalfa pasture.

TABLE XIV.—*Summary of results secured in comparative tests with corn and barley as supplements to irrigated alfalfa pasture on the Scottsbluff Experiment Farm in 1914, 1915, and 1916.*

Time and grain used.	Grain ration.	Number of pigs.	Average initial weight.	Area of pasture.	Time of test.	Gain (pounds).		Grain fed per 100 pounds of gain.
						Total per acre.	Per pig per day.	
Summer, 1914:	*Per cent.*		*Pounds.*	*Acres.*	*Days.*			*Pounds.*
Corn	2.06	10	59	0.25	90	1,900	0.53	244
Barley	1.93	10	56	.25	90	1,740	.48	243
Spring, 1915:								
Corn	2	5	108	.25	60	1,244	1	276
Barley	2	5	108	.25	60	1,180	1	272
Summer, 1915:								
Corn	2	12	31	.25	90	1,732	.40	200
Barley	2	12	33	.25	90	1,592	.33	214
Spring, 1916:								
Corn	2.26	20	74	1	60	1,147	.95	247
Barley	2.52	19	77	1	60	963	.84	300
Summer, 1916:								
Corn	2.70	40	30	1	97	1,995	.55	289
Barley	2.50	40	30	1	97	1,738	.45	280

Miscellaneous grains.—There have now been considered 80 lots of hogs pastured on alfalfa supplemented with some kind of grain. Of these 80 lots 44 received corn, 15 received barley, 3 milo, 3 wheat, 2 shorts, and 13 were fed mixed grain rations, each of which contained either corn or barley. The predominance of corn and barley as supplements to alfalfa pastures on irrigated land is thus reflected in the data which have been presented. Other grain feeds are important in certain sections (as, for example, the grain sorghums in the Southwest) and in individual instances in all sections. The data under consideration do not afford comparisons of grains other than corn and barley similar to those made of those two grains in Table XIV. The results secured with milo, as shown in Table X, and with wheat and shorts, as shown in Table XI, furnish no basis for a presumption that these feeds are inferior to corn or barley as supplements to alfalfa pasture. It should be stated, however, that for economic reasons the use of wheat for this purpose is not generally looked upon with favor. The three grains which appear to be best suited for use as alfalfa-pasture supplements in irrigated sections are corn, barley, and the grain sorghums; and, pound for pound, they probably do not differ materially in value for such use. At any rate, it seems certain that any slight differences in feeding value are of decidedly less importance than differences in adaptation to local climatic, economic, and cultural conditions.

ALFALFA PASTURE FOR SOWS AND PIGS.

At the Scottsbluff Experiment Farm in 1914 and 1915, tests were made of alfalfa pasture for sows and their litters. Each lot contained two sows and their litters of spring pigs. Each lot had access to a quarter of an acre of alfalfa divided into two parts, which were pastured alternately for 60 days. The pasture period began on May 4 in 1914 and on April 27 in 1915. One of the lots used in 1914 is illustrated in figure 4. In addition to the pasture the sows and pigs were fed a 2 per cent ration of grain, the pigs being fed grain by themselves. The results are summarized in Table XV.

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Fig. 4.—Two sows and their litters of spring pigs on alfalfa pasture at the Scottsbluff Experiment Farm late in May, 1914. If good alfalfa pasture is supplemented with as much as a 2 per cent ration of corn or barley, an acre will support 6 to 8 sows and 50 to 70 suckling pigs for 60 days. During this time the pigs should gain 25 to 30 pounds each and at the close of the period be ready to go on to alfalfa pasture by themselves.

Table XV.—*Results secured with sows and pigs on irrigated alfalfa pasture supplemented with a 2 per cent ration of grain at the Scottsbluff Experiment Farm in 1914 and 1915.*

Sows and pigs.	Grain fed.	Number of—		Average initial weight (pounds).		Gain (pounds).					Average carrying capacity per acre.	Grain fed per 100 pounds of gain.
						Sows.	Pigs.		Sows and pigs.			
		Sows.	Pigs.	Sows.	Pigs.		Total.	Per pig per day.	Per acre.	Per acre per day.		
											Pounds.	*Pounds.*
Lot 1	Corn	2	14	351	12	−99	472	0.56	1,492	25	1,052	315
Lot 2	...do	2	15	436	15	−93	491	.54	1,592	26	1,155	276
Lot 3	...do	2	15	234	8	−38	423	.47	1,540	26	779	228
Lot 4	Barley	2	17	351	3	−28	446	.44	1,672	28	969	235

On the basis of the results of these tests, an acre of good alfalfa pasture supplemented with a 2 per cent ration of barley or corn would carry 8 sows and from about 50 to 70 suckling spring pigs for a period of 60 days. During this period the pigs should gain an average of 25 to 30 pounds each and be ready at the close of the period to be placed by themselves on alfalfa pasture for the remainder of the summer. Whether results of this character can be obtained will depend on the character of the pigs, the stand and growth of the alfalfa, and the efficiency with which the enterprise is conducted.

EFFECT OF PASTURING ON THE ALFALFA STAND.

It frequently becomes important for a farmer to know something of the effect which hog pasturing has on the stand of alfalfa. Knowledge on this question is useful when plans are being made for pasturing enterprises. At such times it is necessary to select the area to be used and to determine how much land is to be set aside for pasturing.

The intensiveness with which irrigated alfalfa is pastured by hogs ranges from almost negligibly light grazing, in which a small number of hogs are allowed the free run of a large field of alfalfa used primarily for hay production, to the full utilization of the crop by hogs; and beyond this, to extreme overgrazing, in which the grazed area comes to be little more than a dry lot. The very light grazing method may be followed in a field year after year without serious detriment to the stand of alfalfa, but each of the other methods produces marked effects on the stand of the crop. In fields which are grazed approximately to capacity throughout the growing season, the stand is frequently reduced materially in a single year. As the alfalfa plants disappear, weeds, especially grasses, come in, so that the carrying capacity gradually declines. It is seldom profitable to pasture a field to full capacity more than two seasons, and preferably not more than one, as only under unusually favorable conditions will a sufficient alfalfa stand be maintained for a longer time. Overgrazing causes rapid deterioration of the alfalfa stand and soon results in almost complete displacement of the alfalfa plants by weeds or in total lack of plant growth. In fields which are grazed approximately to capacity, the stand of alfalfa can be conserved by practicing sound pasturing methods. The alternate-pasturing method is important in this connection, as it makes it possible to keep the hogs on one pasture while the other is being irrigated, thus preventing the puddling of the soil, which otherwise would occur on all but very light soils. It also allows the plants in each division of the pasture, periods of time at intervals throughout the season in which to recover somewhat from the effects of trampling.

In most cases, the effects of grazing are sufficiently marked to require attention in connection with crop rotation. It is usually desirable to pasture the alfalfa for only one year, or at most two years, before the crop is to be plowed up. In this way efficient utilization of the pasture may be secured, and at the same time the pasturing will be helpful in eradicating the alfalfa in many fields in which the eradication of the crop is a serious problem in crop rotation.

PASTURING SWEET CLOVER.

On the irrigated lands, sweet clover is grown chiefly in fields where alfalfa fails to do well because of seepage or alkali. The species most commonly grown is white sweet clover (*Melilotus alba*). The crop is used chiefly for pasture, to a slight extent for hay, and sometimes it is grown in irrigated districts for its seed, which usually can be marketed in other districts where seed production is more difficult. The crop is not to be regarded as a rival of alfalfa on ordinary irrigated lands, but its ability to grow on certain soils where conditions are unfavorable for alfalfa has resulted in its use on limited areas in irrigated districts.

Two tests of white sweet clover as hog pasture have been made at the Truckee-Carson Experiment Farm. In 1916 a field of 1.25 acres was pastured for a short period (18 days) by 18 pigs, weighing 33 pounds each, which, in addition to the sweet clover, had a 2 per cent supplementary ration of barley. In 1917 nine pigs with an average initial weight of 59 pounds were pastured on a 0.5-acre field for 105 days. For the first 84 days the pigs had a 2 per cent ration of 3 parts barley and 1 part tankage, and during the remaining 21 days a 3 per cent ration of 5 parts barley and 1 part tankage. The results are shown in Table XVI.

TABLE XVI.—*Results secured with pigs on irrigated sweet-clover pasture at the Truckee-Carson Experiment Farm in 1916 and 1917.*

Supplementary feed.	Ration.	Number of pigs.	Average initial weight.	Time of test.	Gain (pounds). Per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Average carrying capacity per acre.	Ration fed per 100 pounds of gain.
	Per ct.		*Pounds.*	*Days.*				*Pounds.*	*Pounds.*
Barley	2	18	33	18	46	2.5	0.18	420	390
Barley 3, tankage 1	2	9	59	84	754	9	.50	1,431	308
Barley 5, tankage 1	3	9	100	21	238	11	.63	1,927	500

In 1916, when the sweet clover was supplemented with barley, the pigs made very poor gains, although there was an abundance of clover and the pigs ate it readily. Because of the poor gains made, the test was discontinued at the end of an 18-day period, when the pigs were transferred to alfalfa pasture. In 1917, when tankage was added to barley in the supplementary ration, the results were somewhat better for the first 84 days, but, during the last 21 days the gains were unduly expensive, 500 pounds of supplementary feed being required for each 100 pounds of gain. The results obtained in these tests should not be regarded as conclusively unfavorable to sweet clover as hog pasture. Further trials need to be made of the crop for this purpose. Pending the making of such trials, sweet clover is likely to continue to be considered inferior to alfalfa as a forage crop for hogs and to be regarded as valuable chiefly on soils where alfalfa does not do well.

HOGGING OFF CROPS.

In several swine-producing districts of the country there is a growing practice of turning hogs into fields of corn or other crops

FIG. 5.—View of a cornfield on an irrigated farm near the close of the hogging period in late autumn. Hogging has proved to be a satisfactory method of utilizing corn crops on irrigated lands, as it saves the labor of harvesting and feeding the crop, produces gains on the hogs economically, and leaves the manure on the land.

at about the time the crops are mature and allowing the hogs to do the harvesting. This practice is becoming common on irrigated farms in connection with corn, and is followed in a limited way with other crops. Three important points in favor of hogging off mature crops are (1) the saving of labor necessary to harvest and feed the crop products, (2) the prompt application of the manure to the land, and (3) the healthful and sanitary conditions of feeding.

During the past six years some data have been secured from tests of hogging off certain of these irrigated crops. A summary of the results follows.

CORN.

In some of the tests here reported the corn has been hogged off without any supplementary feed being used with the corn. In others, the corn was supplemented in various ways. The hogs usually were turned into the cornfields at about the time the corn was well dented. They remained there for varying lengths of time, depending on the size of the field, the number and size of the hogs, and the quantity of feed available. Usually the period ranged from 20 to 40 days, but sometimes it was 60 days or longer. A view of a field in which hogging was continued into the late autumn is shown in figure 5.

Hogging corn without supplementary feed.—The results secured with 23 lots of hogs which harvested corn without supplementary feed have been tabulated. These tests were made at the Scottsbluff, Huntley, and Belle Fourche Experiment Farms, and in cooperation with farmers on the North Platte and Huntley Reclamation Projects. The results are shown in Table XVII.

TABLE XVII.—*Results secured by hogging corn without supplementary feeds on four reclamation projects during the 5-year period from 1912 to 1916, inclusive.*

Location and lot of hogs.	Year.	Number of pigs.	Average initial weight.	Area of field.	Time of test.	Gain (pounds). Total per acre.	Gain (pounds). Per acre per day.	Gain (pounds). Per pig per day.	Estimated—[1] Yield per acre.	Estimated—[1] Corn consumed per 100 pounds of gain.
Scottsbluff:			*Pounds.*	*Acres.*	*Days.*				*Bushels.*	*Pounds.*
Lot 1	1912	7	117	0.25	16	628	39	1.40	56	499
Lot 2	1913	6	91	.25	28	1,012	36	1.50	83	460
Lot 3	1914	4	63	.25	49	1,048	21	1.31	82	438
Lot 4	1914	3	89	.33	77	810	10	1.17	70	496
Lot 5	1914	3	89	.33	77	1,020	13	1.44	81	444
Lot 6	1915	3	75	.25	19	212	11	.91	26	687
Lot 7	1915	3	80	.33	55	666	12	1.34	....	....
Lot 8	1915	3	68	.33	55	483	9	1	....	....
Lot 9	1916	5	94	.25	23	840	37	1.85	67	446
Huntley:										
Lot 10	1913	4	84	.25	23	768	33	2.06	60	437
Lot 11	1914	4	86	.25	22	896	41	2.56	50	324
Lot 12	1915	4	86	.25	25	864	34	2.16	52	340
Lot 13	1916	4	95	.25	20	672	34	2.10	60	500
Belle Fourche:										
Lot 14	1912	2	85	.25	26	340	13	1.62	29	477
Lot 15	1913	8	51	.25	11	560	51	1.60	34	340
Lot 16	1914	4	107	.25	20	582	29	1.80	35	337
Lot 17	1915	5	81	.25	15	548	36	1.80	40	409
Lot 18	1915	12	62	.50	10	451	45	1.87	34	422
Lot 19	1916	3	104	.25	24	518	21	1.80	59	638
Lot 20	1916	3	100	.25	24	350	14	1.29	45	750
Lot 21	1916	3	112	.25	27	562	21	1.86	50	498
North Platte project:										
Lot 22	1915	38	152	3.60	25	580	23	2.19	57	548
Huntley project:										
Lot 23	1915	67	100	13.40	27	183	7	1.40	14	435

[1] Fractions are omitted from figures showing estimated yields but are included in the calculations of the corn consumed per 100 pounds of gain.

The data shown in Table XVII involved 198 hogs and about 23 acres of corn. It will be observed that most of the fields were small, 21 of the 23 containing less than 1 acre each. In average initial weight, the pigs used ranged from 51 to 152 pounds, but 18 of the 23 lots averaged 80 pounds or more per pig. Seven of the lots averaged 100 pounds or more per pig. The length of the hogging period ranged from 10 to 77 days, about half being between 20 and 30 days. The gains per acre varied widely, of course, because of the variations in the yield of corn and the character of the hogs used. The range in gain per acre was from 183 to 1,048 pounds. The gains per acre per day depend chiefly on the yield of corn and the number of hogs per acre, but they are influenced also by the size and thriftiness of the hogs. The animals all made fairly rapid gains, as would be expected of hogs having free access to cornfields.

The yield estimates for lots 1 to 21, inclusive, were made in one of two ways. In some cases the yield of the hogged plat was assumed to equal the average yield of several other plats in the same field with the same cultural treatment. In the other instances the yield of 100 stalks systematically selected in the quarter-acre or half-acre plat was actually determined, and the average yield per stalk so determined was multiplied by the total number of stalks on the plat. These two methods of estimating probably gave results which were within 10 per cent of the actual yields, but the figures should be regarded merely as approximations. The yield estimates in lots 22 and 23 mere made by the farmers owning the fields.

On the basis of these estimates, the corn consumed per 100 pounds of gain ranged from 324 pounds (5.8 bushels), in lot 11 at the Huntley Experiment Farm, to 750 pounds (13.4 bushels), in lot 20 at the Belle Fourche Experiment Farm. In only 5 out of the 21 cases for which estimates were made did the corn consumed equal or exceed 500 pounds per 100 pounds of gain; and in only four cases was it less than 400 pounds. The average for the 12 lots consuming between 400 and 500 pounds of corn per 100 pounds of gain was about 450 pounds, or 8 bushels. This probably is a fair approximation of what should be expected when hogs weighing 75 to 125 pounds are used to hog off the corn without supplementary feed.

Hogging corn with supplementary feed.—The supplements used in the corn-hogging tests considered here include tankage, alfalfa pasture, rape, and the aftermath in alfalfa and grain fields. Data from 14 lots are available and are summarized in Table XVIII. These lots were distributed as follows:

Lots 1, 2, 3, 4, 7, 8, 9, and 10 at the Scottsbluff Experiment Farm.
Lots 5 and 6 on a small farm on the Tieton Reclamation Project.
Lot 11 on the North Platte Reclamation Project.
Lot 12 on the Huntley Reclamation Project.
Lot 13 on the Huntley Experiment Farm.
Lot 14 on the Boise Reclamation Project.

TABLE XVIII.—*Results secured by hogging corn with supplementary feeds on four reclamation projects for the 4-year period from 1914 to 1917, inclusive.*

Hogs.	Year.	Supplementary feed.	Number of pigs.	Average initial weight.	Area of field.	Time of test.	Grain (pounds).			Estimated—	
							Total per acre.	Per acre per day.	Per pig per day.	Yield per acre.	Corn consumed per 100 pounds of gain.
				Pounds.	*Acres.*	*Days.*				*Bushels.*	*Pounds.*
Lot 1	1914	100 pounds tankage.	3	88	0.33	77	1,377	18	2	87	354
Lot 2	1914	do	3	90	.33	77	1,308	17	1.90	88	377
Lot 3	1915	do	3	74	.33	55	606	11	1.22		
Lot 4	1915	do	3	72	.33	55	822	15	1.66		
Lot 5	1916	500 pounds tankage.	60	91	9.40	44	709	16	2.52		
Lot 6	1917	200 pounds tankage.	50	106	6.96	46	733	16	2.22	56	428
Lot 7	1914	Late alfalfa pasture	3	91	.33	77	1,116	14	1.60	81	406
Lot 8	1914	do	3	89	.33	77	1,117	15	1.66	88	420
Lot 9	1915	do	3	78	.33	55	723	13	1.46		
Lot 10	1915	do	3	69	.33	55	699	13	1.41		
Lot 11	1916	do	133	68	47.50	97	335	3	1.34		
Lot 12	1916	do	151	124	15.20	21	391	19	1.87	27	394
Lot 13	1916	Rape	4	82	.50	38	586	16	2	50	485
Lot 14	1915	Aftermath of alfalfa, peas, and wheat.	28	117	1	30	589	19	.70		

The figures shown in Table XVIII involved 450 hogs and 83.2 acres of corn. Only four of the fields contained more than 1 acre each, so that 10 of the lots were small. The average initial weight of the hogs in the 14 lots ranged from 68 to 124 pounds, only three lots having average initial weights as high as 100 pounds per pig. The length of the hogging period ranged from 21 to 97 days. With 10 of the 14 lots this period ranged from 44 to 77 days. The gains per acre ranged from 335 to 1,377 pounds, depending chiefly on the yield of corn and the character of the hogs used. The average daily gain in all but five cases exceeded 1.5 pounds per pig. On the basis of the estimated yields in the seven cases in which estimates are available, the corn consumed per 100 pounds of gain ranged from 354 pounds (6.3 bushels) in lot 1 to 485 pounds (8.7 bushels) in lot 13. The average for these seven lots is 409 pounds. This is somewhat lower than the corresponding figure (450 pounds) indicated as an approximation for the lots hogging corn without supplements.

There appears to be no doubt that supplements reduce the corn requirement. Just how great this reduction is can not be definitely determined from the figures given in Tables XVII and XVIII, but valuable indications with reference to alfalfa pasture and tankage as supplements may be found by comparing the results secured at the Scottsbluff Experiment Farm with the six duplicate lots of three hogs each which were used in the experiments in 1914 and 1915. This comparison is shown in Table XIX, in which the average results of the trials for two years are presented.

TABLE XIX.—*Results secured by hogging corn with supplementary feeds on the Scottsbluff Experiment Farm in 1914 and 1915.*

Items of comparison.	Supplementary feeds.		
	None.	Alfalfa pasture.	Tankage.
Lots of hogs.....number..	4	4	4
Hogs per acre in each lot.....do....	9	9	9
Length of hogging period.....days..	66	66	66
Average initial weight per hog.....pounds..	82	82	81
Total gain per acre.....do....	744	930	1,029
Average daily gain per hog.....do....	1.25	1.57	1.73
Estimate of corn consumed per 100 pounds of gain.....do....	524	446	405
Tankage consumed per 100 pounds of gain.....do....	....	....	29

It will be seen that the lots which received supplementary feed made more rapid gains and consumed less corn per unit of gain than those which received no supplements. Holden,[1] who first reported the results of this experiment, concluded that with the usual price for tankage, the use of that material as a supplement to hogged-off corn would be better than not to use any supplement, but that where the hogs could have access to alfalfa pasture it was doubtful whether it would pay to feed tankage. In any event the desirability of giving the hogs access to alfalfa pasture is apparent. At the time of year when corn is hogged off in irrigated districts, the growth of alfalfa is relatively slow, so that the small quantity of alfalfa which the hogs eat would otherwise be wasted in most instances.

At the Huntley Experiment Farm, where rape, grown with the corn, has been tested as a supplement to hogged-off corn, no material effect on the rate or amount of gains has been observed. This might not be the case in sections where rape produces a heavy growth. It seems likely that in most irrigated sections access to an alfalfa field during the corn-hogging period will furnish a satisfactory supplementary feed for the hogs, particularly in view of the inexpensiveness of this supplement.

FIELD PEAS.

Field peas have not been widely adopted as a hog feed on irrigated lands generally. The use of the crop for this purpose, however, has been sufficiently successful on individual farms in a large number of districts to indicate the high value of the crop as hog feed. Most of the difficulties encountered in attempts to use field peas in swine feeding have been production difficulties. As will be indicated later, widely varying results have been secured from hogging off peas in different fields in a single locality. These variations reflect the wide differences in the yields obtained by different farmers. The success-

[1] Holden, J. A. Experiment in disposal of irrigated crops through the use of hogs. Dept. Agr. Bul. 488, 25 p., 3 fig. 1917.

ful production of field peas requires a wise selection of a variety from a very large number and careful attention to the cultural requirements of the crop. The crop undoubtedly is adapted to the conditions in most irrigated districts, except, perhaps, those in the Southwest, where high summer temperatures prevail. The present indications are that, as farmers learn to grow the crop successfully, its use as hog feed will be widely adopted.

Data are available from 18 of these tests in which field peas were hogged off. In eight of these tests the peas were grown without additional grain. In six tests the peas were grown with wheat. Peas were mixed with oats in one case and with barley in three cases. In

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FIG. 6.—A field of peas being pastured off by hogs on an irrigated farm. This field contained 4.6 acres, and 97 shotes gained at the rate of 843 pounds per acre in 37 days.

12 of the 18 tests no supplementary feed was given. In the remaining instances the pigs had access to alfalfa from which usually the season's hay crops had been harvested. The time of turning the pigs into the field in these tests ranged from late July to mid-September. The pigs may be turned in as soon as the peas show signs of ripening. The duration of the hogging period will depend on the time required to clean up the crop. This depends on the size of the crop and the age and number of the pigs. In these tests the hogging period ranged from 12 to 68 days. A view of one lot of pigs (lot 15 in Table XX) in a field of peas is shown in figure 6.

The very wide diversity in the results secured was due largely to the variation in the size of the crops hogged off. The tests were all conducted on practical farms in cooperation with their owners on five reclamation projects. The results are presented in Table XX.

TABLE XX.—*Results secured by hogging off field peas when grown alone and with other grain crops on five reclamation projects in 1915, 1916, and 1917.*

Pigs.	Project.	Year.	Other grain.	Supplementary feed.	Number of pigs.	Average initial weight.	Area of field.	Time of test.	Gain (pounds). Total per acre.	Per acre per day.	Per pig per day.
						Pounds.	*Acres.*	*Days.*			
Lot 1	Tieton	1915	None	None	67	45	2.20	32	672	21	0.69
Lot 2	Minidoka	1917	do	do	39	113	3.40	55	949	17	1.50
Lot 3	do	1917	do	do	38	94	3.63	68	808	12	1.13
Lot 4	Boise	1917	do	do	33	80	1.50	17	250	15	.66
Lot 5	do	1916	Wheat	do	138	32	5.20	36	915	25	.96
Lot 6	do	1916	do	do	128	68	9	41	515	13	.90
Lot 7	Truckee-Carson	1916	do	do	34	63	1.25	21	760	36	1.40
Lot 8	Boise	1917	do	do	33	91	1.50	14	286	20	.93
Lot 9	do	1917	Oats	do	26	92		18			1.40
Lot 10	do	1916	Barley	do	20	118	1	43	650	15	.75
Lot 11	Tieton	1916	do	do	60	54	3.10	40	716	18	.92
Lot 12	do	1917	do	do	48	63	4.40	37	371	10	.92
Lot 13	Huntley	1915	None	Alfalfa pasture.	66	63	1.90	12	479	40	1.02
Lot 14	Boise	1915	do	do	28	75	1	25	425	17	.61
Lot 15	Minidoka	1915	do	do	97	71	4.60	37	843	23	1.08
Lot 16	Boise	1916	do	do.[1]	33	69	2	31	277	9	.54
Lot 17	do	1915	Wheat	do	28	91	1	25	746	30	1.06
Lot 18	do	1916	do	do	33	86	1	17	447	26	.80

[1] Plus 350 pounds of barley and 600 pounds of milk.

Table XX shows the results of 18 tests involving a total of 949 pigs and a total area of about 50 acres. The number of pigs per lot ranged from 20 to 138, and the fields ranged in size from 1 acre to 9 acres. The gains per acre varied from 250 to 949 pounds. The average gain per acre of the 17 lots for which this was determined was a little less than 600 pounds. Of the eight tests in which the gains per acre were less than 600 pounds, six were on the Boise project; but some of the best gains were made on the same project. These facts indicate the wide variation to be expected in any given locality, depending upon the size of the pea crop in each field. The average daily gain per pig ranged from 0.54 pounds to 1.50 pounds. These gains naturally depend upon the abundance of the feed and the character of the pigs used. While the gains per acre of peas are not strictly comparable with those secured by hogging corn, because of differences in the location of the tests, it is of interest to observe that the ranges in gains per acre of the two crops were not widely different. The range with corn without supplementary feeds was from 183 to 1,048 pounds per acre, while that with peas was from 250 to 949 pounds per acre.

The conditions under which these tests were conducted made it impossible to determine the values of supplementary feeds and the advantages of growing some small grain with the peas. There is nothing in these data to show whether or not a grain mixture or a supplementary feed is advantageous. This is a question which should be thoroughly investigated under irrigation. It was impracticable in the tests reported above to determine the quantity of peas or of peas and other grains required to produce a pound of gain. There is need for experimentation in this connection also.

Speaking generally, it appears that where field peas do well under irrigation their use as a crop to be hogged off should be much more extensive than it is at present. The crop is particularly valuable at times when the commoner grain feeds are high priced, and its utilization by swine growers on irrigated lands offers many excellent opportunities.

HORSE BEANS.

Horse beans have not been tried extensively by irrigation farmers in this country, but in one or two sections, particularly in the Snake River valley of Idaho, the crop has become of some importance. In 1915 plantings of horse beans were made at the Scottsbluff, Huntley, and Belle Fourche Field Stations, with seed produced at Gooding, Idaho. The results were unsatisfactory, as shown by the following report made by the superintendent of the Huntley Field Station on the behavior of the crop at that point, where the results were typical of those secured at Scottsbluff and Belle Fourche:

> A test of horse beans was made in 1916 on a one-eighth acre plat in field A–I. Seeding was done in the latter part of April. The seed was planted closely in rows 20 inches apart. A good stand was secured and the crop made a very good growth up to the time of blooming, which was about August 1. It was attacked at this time by a disease which practically stopped the growth of the plants. In many instances the plants were killed. On a few of the plants a small amount of seed formed. This seed was badly shrunken, as were also the foliage and stems. Only a few of the plants remained alive at the end of the season, and the amount of seed was so small and the quality so poor that the crop was not harvested.

Welch reports[1] as follows regarding horse beans on irrigated lands in Idaho:

> Horse beans (*Vicia faba*), or Broad Windsor beans, are extensively grown in some parts of irrigated Idaho. They are grown almost exclusively for "hogging-off" purposes. During the season of 1915 a crop was grown on the station farm for the purpose of finding its relative value when compared with field peas used in the same way. The horse beans were sown a little too late to secure maximum growth. They are considered somewhat inferior to field peas when used for pork production.

A few farmers in Idaho have reported very satisfactory results from hogging off horse beans. Others have attempted to use the crop for this purpose but without success. It appears that the plants are specially susceptible to the attacks of certain fungous diseases, as was indicated in the test at Huntley. In view of the knowledge at pres-

[1] Welch, J. S. Experiments with legume crops under irrigation. Idaho Exp. Sta. Bul. 94, 14 p., 4 fig. 1917.

ent available, the crop is to be regarded as in the experimental stage, and attempts to grow it for hogging-off purposes should be made conservatively.

GRAIN SORGHUMS.

Although certain of the grain sorghums are hogged off in the irrigated sections of the Southwest, there are but few experimental data regarding the practice. The high value of one of the grain sorghums (milo) as a supplement to alfalfa pasture for hogs already has been pointed out, but only fragmentary evidence is available regarding the practice of hogging off the crop.

In 1916 at the Yuma Field Station, 12 hogs with an average initial weight of 170 pounds were pastured on a half-acre field of milo for 21 days, at the same time having access to a small patch of alfalfa pasture. The hogs gained at the rate of 0.90 pound per day each, or 25 pounds per acre per day. The total gain per acre of milo for the period was 518 pounds. The milo yield was estimated as 1,874 pounds per acre, so that the estimated grain requirement per hundred pounds of gain was 342 pounds. In 1917 another lot of 12 pigs, weighing 113 pounds each, was pastured on an 0.83-acre field of milo for 14 days. They had access to alfalfa pasture, but made little use of it. They gained 25 pounds per acre per day, or 1.76 pounds per hog per day, and the total gain per acre of milo was 355 pounds. The superintendent of the Yuma Field Station reports that much of the grain was trampled into the soft soil and lost. It is generally believed that much of the feeding value of sorghum grain is lost when the grain is fed without grinding. These two tests furnished no evidence on this point. There is need for further experimentation in connection with hogging off grain-sorghum crops, as a number of important problems regarding the practice remain to be solved.

PUBLICATIONS ON SWINE PRODUCTION.

A list of publications issued by the Department of Agriculture containing useful information and suggestions of interest to swine producers on irrigated lands in the western United States is given below. Those of which the price is not stated can be obtained without charge upon application to the Secretary of Agriculture; the others may be obtained by remitting the price specified to the Superintendent of Documents, Government Printing Office, Washington, D. C. As this paper discusses only one phase of swine production on irrigated lands, it is suggested that the reader consult one or more of the publications mentioned below and also publications of the State experiment stations for information regarding other features of the industry.

Farmers' Bulletins.

No. 438. Hog Houses.
724. The Feeding of Grain Sorghums to Live Stock.
765. Breeds of Swine.
780. Castration of Young Pigs.
834. Hog Cholera: Prevention and Treatment.
873. Utilization of Farm Wastes in Feeding Live Stock.
874. Swine Management.
906. The Self-Feeder for Hogs.
913. Killing Hogs and Curing Pork.

Department Bulletin.

No. 488. Experiments in the Disposal of Irrigated Crops through the Use of Hogs.

Miscellaneous Circulars.

Bureau of Plant Industry Circular 116, part B. The Work of the Scottsbluff Experiment Farm in 1912. Price, 5 cents.

Western Irrigation Agriculture unnumbered circular (B. P. I. Document 1081). The Work of the Scottsbluff Reclamation Project Experiment Farm in 1913. Price, 5 cents.

Western Irrigation Agriculture Circular No. 6. The Work of the Scottsbluff Reclamation Project Experiment Farm in 1914. Price, 5 cents.

Western Irrigation Agriculture Circular 11. The Work of the Scottsbluff Reclamation Project Experiment Farm in 1915. Price, 5 cents.

Western Irrigation Agriculture Circular 18. The Work of the Scottsbluff Reclamation Project Experiment Farm in 1916. Price, 5 cents.

Western Irrigation Agriculture unnumbered circular (B. P. I. Document 1084). The Work of the Huntley Reclamation Project Experiment Farm in 1913. Price, 5 cents.

Western Irrigation Agriculture Circular 2. The Work of the Huntley Reclamation Project Experiment Farm in 1914. Price, 5 cents.

Western Irrigation Agriculture Circular 8. The Work of the Huntley Reclamation Project Experiment Farm in 1915. Price, 5 cents.

Western Irrigation Agriculture Circular 15. The Work of the Huntley Reclamation Project Experiment Farm in 1916. Price, 5 cents.

Western Irrigation Agriculture unnumbered circular (B. P. I. Document 1088). The Work of the Belle Fourche Reclamation Project Experiment Farm in 1913. Price, 5 cents.

Western Irrigation Agriculture Circular 4. The Work of the Belle Fourche Reclamation Project Experiment Farm in 1914. Price, 5 cents.

Western Irrigation Agriculture Circular 9. The Work of the Belle Fourche Reclamation Project Experiment Farm in 1915. Price, 5 cents.

Western Irrigation Agriculture Circular 14. The Work of the Belle Fourche Reclamation Project Experiment Farm in 1916. Price, 5 cents.

Western Irrigation Agriculture Circular 20. The Work of the Yuma Reclamation Project Experiment Farm in 1916. Price, 5 cents.

Western Irrigation Agriculture Circular 1. The Work of the Umatilla Reclamation Project Experiment Farm in 1914. Price, 5 cents.

Western Irrigation Agriculture Circular 13. The Work of the Truckee-Carson Reclamation Project Experiment Farm in 1915. Price, 5 cents.

Western Irrigation Agriculture Circular 19. The Work of the Truckee-Carson Reclamation Project Experiment Farm in 1916. Price, 5 cents.

Demonstrations on Reclamation Projects Circular 1. Establishing the Swine Industry on the North Platte Reclamation Project.

Circulars of the Office of the Secretary.

No. 80. Disposal of City Garbage by Feeding to Hogs. Price, 5 cents.
83. Swine-Judging Suggestions for Pig-Club Members. Price, 5 cents.
102. Movable Hog Houses. Price, 5 cents.

Yearbook Separate.

No. 690. Agriculture on Government Reclamation Projects. Price, 5 cents.

SUMMARY.

The irrigated lands of the western United States offer excellent opportunities for the production of pork in commercial quantities, and swine feeding has proved to be a satisfactory method of utilizing certain field crops, but the swine industry in irrigated districts in the past has experienced extremes of expansion and depression.

One of the causes of this instability is a lack of knowledge as to the possibilities of using certain irrigated field crops and as to the value of these crops when measured in terms of pork production. If full advantage is taken of the wide range of feeds available to swine growers on irrigated lands, pork production can be carried on more widely and with more assurance of success than has been the case heretofore.

Most of the published information regarding the values of field crops used in swine production is based on conditions in nonirrigated sections and can not always be applied satisfactorily under irrigated conditions. This is true particularly of those field crops which are pastured by hogs or hogged off.

Since 1912 the Department of Agriculture has been conducting experiments and making observations regarding the utilization of irrigated field crops by hog pasturing. This bulletin discusses the results of pasturing tests involving 149 lots of hogs containing a total of 3,795 animals. In these tests 89 lots containing 2,138 swine were pastured on alfalfa. The other lots were used on sweet clover, corn, field peas, and milo.

Pasturing alfalfa with hogs has been shown to be a very satisfactory method of utilizing that crop and one of the cheapest ways to produce pork. To obtain satisfactory results the alfalfa pasture must be supplemented with some carbonaceous feed. When supplemented with a 2 per cent ration of corn, barley, milo, wheat, or shorts, an acre of good alfalfa pasture can be expected to produce about 2,500 pounds of gain in live weight in a season. Gains as high as 4,292 pounds per acre were obtained in one of the tests reported here, a test in which the hogs received a 3 per cent supplementary ration of corn. The gains per acre of alfalfa depend on the size of the crop, the character of the hogs used, the method of management, and the quantity and quality of supplementary feed given. To pasture alfalfa without supplementary feed is not to be recommended.

Hogs on alfalfa pasture supplemented with about a 2 per cent ration of corn, barley, wheat, shorts, or milo will consume from 250 to 300 pounds of grain per 100 pounds of gain. In general, the grain requirement increases with the increased size of hogs and with increased grain rations. The feeding values of corn, barley, shorts, and milo as supplements to alfalfa pasture differ from one another so little that the choice among these supplements should depend on prices, cultural adaptability, and general economic conditions. When the grain supplement is to be produced by the swine grower, preference usually should be given to corn, barley, and the grain sorghums, depending on the adaptability of each of these crops to local conditions in each instance.

An acre of good alfalfa pasture supplemented with as much as a 2 per cent ration of grain has an average hog-carrying capacity of about 2,500 pounds of live weight for the growing season. Carrying capacity increases rapidly with increased grain allowance, and it varies somewhat during the growing season with the rate of crop growth.

An acre of good alfalfa pasture, if supplemented with a 2 per cent ration of corn or barley, will support 6 to 8 sows and 50 to 70 suckling spring pigs for a period of about 60 days in early summer, during which time the pigs should gain 25 to 30 pounds each. At the close of this period the pigs should be ready to go into alfalfa pasture by themselves for the remainder of the growing season.

The few tests so far conducted indicate that white sweet clover is not to be regarded as a rival of alfalfa as hog pasture. The crop is valuable to irrigation farmers chiefly for use on soils which are too wet or too salty for alfalfa.

The practice of hogging off corn and field peas is a desirable one for swine growers on irrigated lands, in that it saves labor, produces satisfactory gains on the hogs, and adds manure to the soil.

The gains made in the tests of hogging corn reported in this bulletin ranged from 183 to 1,048 pounds per acre of corn when no supplementary feed was given and from 335 to 1,377 pounds per acre where the corn was supplemented. It is estimated that in these tests an average of about 450 pounds of corn was required to produce 100 pounds of gain when no supplement was used, as compared with an average of 409 pounds when the corn was supplemented with tankage, late alfalfa pasture, or rape. Alfalfa pasture is to be preferred as a supplement to corn in hogging off enterprises on irrigated lands because of its cheapness and reliability.

The tests reported show that field peas have a high value as an irrigated crop to be hogged off. The gains in live weight per acre of peas in 17 tests ranged from 250 to 949 pounds, averaging in the neighborhood of 600 pounds. These results compare not unfavorably with those obtained by hogging corn, when the costs of production of these crops are considered. It is to be remembered, however, that in some districts where corn grows well, field peas do not do as well as in cooler localities less favorable to corn. Field peas are particularly valuable as a crop for hogging off when the commoner grain feeds are high priced and the swine grower is seeking a substitute for them.

Horse beans are used satisfactorily in a few irrigated districts, but the crop is to be regarded as in the experimental stage for irrigation farmers generally. This crop appears to be especially susceptible to the attacks of certain fungous diseases.

While grain sorghum, particularly milo, is used to some extent in the Southwest for hogging off purposes, its chief value in swine production probably lies in its usefulness as a supplement to alfalfa pasture and as a finishing feed. When used in either of these ways the grain is cracked or ground, and its feeding value is believed to be higher than when the grain is fed whole, as in hogging.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 753

Contribution from the Forest Service.
HENRY S. GRAVES, Forester.

Washington, D. C. ▼ March 10, 1919

THE USE OF WOOD FOR FUEL.

Compiled by the Office of Forest Investigations.

CONTENTS.

INTRODUCTION.

Wood has always been of considerable importance as fuel in this country, and the present emergency has greatly increased its comparative value for this purpose. Wood is now being cut for fuel in places where for many years it had practically gone out of use. On farms where coal had become the ordinary fuel and was brought in from great distances while wood suitable for fuel went to waste in the neighborhood, wood is now coming into its own again. It is being more used in churches, schools, and homes, and even in factories. The use of wood for fuel saves transportation, it utilizes wood that would otherwise go to waste, and it releases coal for ships and railroads and munitions plants. Heretofore wood has supplied between 10 and 15 per cent of the total amount of fuel used in the United States. The wide distribution of wood fuel supplies, and the fact that they are so located as to save transportation should, under present conditions, lead to a considerable increase in the proportion of wood in our fuel consumption.

The purpose of this bulletin [1] is to aid in the conservation of the Nation's coal supply and in the full and proper use of our wood

[1] As is readily apparent, the material used in this bulletin is largely compiled from many sources. Credit has been given as far as it has seemed practical, but in many instances the data are so adapted and changed that a specific reference would be misleading. Information has been obtained from State wood-fuel and Forest Service publications mainly, but miscellaneous data and tables have been drawn from everywhere. This general statement is made in order to acknowledge help from sources not specifically mentioned.

resources to prevent the recurrence of such a fuel shortage as occurred during the winter of 1917–18, by indicating the best and most economical methods of cutting, distributing, and using wood for fuel. Uneconomical methods of handling the wood increase the cost and waste the product, careless methods of cutting the trees may endanger the future supply, and the reckless use of shade or ornamental trees for fuel is an unjustifiable extravagance.

In the utilization of the forests of the country, including farm woodlands, a great deal of wood material is produced which can not find a use other than as fuel wood. While some of it is used for acid wood, charcoal, etc., most of it is left for fuel or wasted.

Since many of the trees in our forests are fit only for fuel, they will not be cut unless there is a demand for fuel wood. Improvement cuttings, which take the small, diseased, or defective trees, can not be profitably made in many cases unless there is such a demand. Thinnings can frequently be made to pay for themselves if the material is used for fuel. Sometimes products of thinnings can be used for other purposes than fuel, but more often they can not. As proper thinnings and improvement cuttings are a great stimulus to increased production and at the same time improve the quality of the timber, a fuel wood demand opens up a great opportunity for forest improvement and, if widespread and continued, will produce a vast total effect for the better in the character and quality of our forest resources.

Wood waste occurs at every stage of the manufacture of wood products, from the lumber operations through the milling process and in the special processes necessary to shape the article into its final form. A wide use of wood fuel affords a market for this waste, which would otherwise be lost.

Preparing wood for fuel involves slightly more labor than is required to produce coal. It is, however, usually widely scattered labor which is used in wood cutting and hauling, and no increased demand on labor is really made. On most farms there is plenty of time during the winter for both men and teams to work at getting out wood.

WOOD INSTEAD OF COAL FOR FUEL.

USE OF WOOD SHOULD BE LARGELY INCREASED IN RURAL DISTRICTS.

Who can with the least hardship restrict his consumption of coal? Certain classes of consumers require concentrated fuel, such as coal or crude oil; others can use other fuels, but at a considerable disadvantage. Most manufacturers are unable to substitute wood for coal to any great extent because of the character of their heating and power plants and because of their location, which involves railroad haul for wood. For similar reasons domestic consumers in the cities can not well use wood to any great extent. Wholesale rail transportation of fuel wood is not desirable because of its bulk as compared with coal of the same heating value. The substitution can best be made in places where team-hauled wood will take the place of rail-hauled coal. Farmers who own woodlands and villagers who can buy wood from near-by farms can reduce their consumption of coal with least inconvenience to themselves and with the greatest benefit to the public interest.

Because of the large proportion of wood normally used in the South and the long hauls involved in the West it is not likely that the use of wood for fuel can be greatly increased in those regions. In New England, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Missouri, and the Lake States it ought to be entirely practicable in many cases to replace coal with wood. In these 17 States is a rural population of about 20,000,000, which is estimated to use annually 18,000,000 tons of coal. If by substituting wood one-quarter less coal could be burned on farms and one-tenth less in villages, the total saving would amount to nearly 3,000,000 tons, or between 65,000 and 70,000 carloads.

For many uses, and particularly for summer-time use, wood is a more convenient and cheaper fuel than coal. Churches, halls, summer cottages, and other buildings where heat is wanted only occasionally, and then on short notice, find wood more satisfactory for this purpose.

PRESENT USE OF WOOD FUEL.

Up to the present time practically no systematic attempt has been made to take a census of the wood fuel cut or on hand each year. Wood seems to be the only form of fuel on which annual statistics of production are not available.

In 1916 and 1917 the Bureau of Crop Estimates in the Department of Agriculture secured estimates of the number of cords used on the farms but not the total amount cut. It is understood that in 1918 the amount sold from the farm annually will be obtained also, thus showing the total cut.

According to figures collected by the Bureau of Crop Estimates (see Table 1) about 83,000,000 cords of wood fuel were used in 1917 on the farms of the United States. Similar estimates made in December, 1916, indicated that about 82,000,000 cords were used. It is likely that the total amount consumed on farms and in villages and cities is upwards of 100,000,000 cords annually. In these estimates, and in all other references to "cord" in this bulletin, unless otherwise stated, a cord is reckoned as 128 stacked cubic feet—i. e., a pile 8 by 4 by 4 feet.

The value of wood advanced more than 24 per cent from December, 1916, to December, 1917. On the basis of 1917 prices reported, the value of firewood used on farms of the United States is about $283,000,000, or $43.13 per farm.

TABLE 1.—*Wood fuel used on farms.*

	Number of farms 1917 (estimated).	Cords per farm.	Number of cords per State.	Value per cord.		Value of wood used on basis of December, 1917, values.	
				December, 1917.	December, 1916.	Value per farm.	Total value.
Maine	60,000	13	780,000	$6.40	$4.50	$83.20	$4,992,000
New Hampshire	27,000	12	324,000	6.40	4.60	76.80	2,074,000
Vermont	33,000	15	495,000	6.00	4.35	90.00	2,970,000
Massachusetts	37,000	10	370,000	6.35	4.70	63.50	2,350,000
Rhode Island	5,000	10	50,000	5.80	4.00	58.00	290,000
Connecticut	27,000	13	351,000	6.00	4.50	78.00	2,106,000
New York	215,000	14	3,010,000	4.60	4.00	64.40	13,846,000
New Jersey	33,000	8	264,000	5.10	4.00	40.80	1,346,000
Pennsylvania	218,000	9	1,962,000	3.50	2.60	31.50	6,867,000
Delaware	11,000	13	143,000	4.20	3.10	54.60	601,000
Maryland	50,000	13	650,000	4.15	3.20	53.95	2,698,000
Virginia	190,000	18	3,420,000	3.20	2.40	57.60	10,944,000
West Virginia	99,000	16	1,584,000	2.90	2.30	46.40	4,594,000
North Carolina	259,000	17	4,403,000	2.75	2.10	46.75	12,108,000
South Carolina	185,000	14	2,590,000	3.00	2.10	42.00	7,770,000
Georgia	300,000	16	4,800,000	2.50	2.00	40.00	12,000,000
Florida	55,000	11	605,000	3.10	2.60	34.10	1,876,000
Ohio	271,000	13	3,523,000	3.60	3.00	46.80	12,683,000
Indiana	215,000	12	2,580,000	3.70	3.30	44.40	9,546,000
Illinois	250,000	9	2,250,000	4.60	3.40	41.40	10,350,000
Michigan	209,000	13	2,717,000	5.25	4.00	68.25	14,264,000
Wisconsin	180,000	13	2,340,000	5.50	4.20	71.50	12,870,000
Minnesota	157,000	11	1,727,000	5.40	4.30	59.40	9,326,000
Iowa	215,000	5	1,075,000	4.70	4.20	23.50	5,052,000
Missouri	275,000	13	3,575,000	3.20	2.60	41.60	11,440,000
North Dakota	90,000	3	270,000	7.50	6.40	22.50	2,025,000
South Dakota	90,000	3	270,000	6.20	6.00	18.60	1,674,000
Nebraska	135,000	3	405,000	4.25	3.90	12.75	1,721,000
Kansas	180,000	6	1,080,000	4.25	3.30	25.50	4,590,000
Kentucky	265,000	18	4,770,000	2.20	1.70	39.60	10,494,000
Tennessee	250,000	19	4,750,000	2.20	1.75	41.80	10,450,000
Alabama	270,000	18	4,860,000	2.00	1.80	36.00	9,720,000
Mississippi	285,000	16	4,560,000	2.30	1.90	36.80	10,488,000
Louisiana	122,000	15	1,830,000	2.50	2.25	37.50	4,575,000
Texas	430,000	9	3,870,000	3.40	2.80	30.60	13,158,000
Oklahoma	210,000	10	2,100,000	3.10	2.75	31.00	6,510,000
Arkansas	225,000	19	4,275,000	2.35	2.00	44.65	10,046,000
Montana	35,000	10	350,000	4.80	4.50	48.00	1,680,000
Wyoming	15,000	10	150,000	4.50	3.80	45.00	675,000
Colorado	55,000	6	330,000	4.50	3.70	27.00	1,485,000
New Mexico	45,000	9	405,000	4.20	4.00	37.80	1,701,000
Arizona	12,000	9	108,000	5.75	5.40	51.75	621,000
Utah	23,000	8	184,000	5.00	4.00	40.00	920,000
Nevada	3,000	11	33,000	7.00	6.00	77.00	231,000
Idaho	36,000	9	324,000	5.00	4.60	45.00	1,620,000
Washington	65,000	11	715,000	5.20	4.50	57.20	3,718,000
Oregon	50,000	12	600,000	4.70	3.90	56.40	2,820,000
California	95,000	10	950,000	7.40	5.80	74.00	7,030,000
United States	6,562,000	12.6	82,777,000	3.42	2.75	43.13	282,915,000

F—36656—A

FIG. 1.—SAWING EMERGENCY WOOD TO RELIEVE COAL SHORTAGE, GREENVILLE, TENN., JANUARY 18, 1918.

F—43247

FIG. 2.—A LOAD OF STOVE WOOD IN NORTHERN MICHIGAN (ONTONAGON COUNTY).

A detailed survey of the use of wood and coal in selected localities in a number of States gave the following comparative data:

TABLE 2.—*Average annual consumption of coal and wood per family on farms in eight States.*[1]

State and county.	Coal, per family.		Wood, per family.	
	Tons.	Value.	Cords.	Value.
Vermont (Lamoille)	0.1	$1.01	14.3	$65.40
New York (Otsego)	2.5	16.00	12.2	54.80
Pennsylvania (Bucks)	4.9	26.90	6.2	19.00
Ohio (Champaign)	5.7	23.70	12.0	32.50
Wisconsin (Jefferson)	3.0	20.70	7.5	38.80
Iowa (Montgomery)	3.9	29.57	4.8	22.40
North Carolina (Gaston)			14.0	43.58
Georgia (Troup)			17.8	51.60
Average	2.5	14.74	11.1	41.01

[1] From Farmers' Bulletin 635, "What the Farm Contributes Directly to the Farmer's Living," by W. C. Funk. See also Department of Agriculture Bulletin 410, "Value to Farm Families of Food, Fuel, and Use of House," by W. C. Funk.

TABLE 3.—*Average annual consumption of wood per person in eight States, showing the per cent of wood bought and the per cent furnished by the farm.*

State and county.	Per person.		Per cent.	
	Cords.	Value.	Bought.	Furnished by farm.
Vermont (Lamoille)	3.0	$13.62	3.0	97.0
New York (Otsego)	3.1	13.70	1.8	98.2
Pennsylvania (Bucks)	1.2	3.65	5.8	94.2
Ohio (Champaign)	2.9	7.93	6.2	93.8
Wisconsin (Jefferson)	1.1	5.34	7.7	92.3
Iowa (Montgomery)	1.7	8.82		100.0
North Carolina (Gaston)	3.1	9.68	3.9	96.1
Georgia (Troup)	3.3	9.56		100.0
Average	2.4	9.04	3.55	96.45

INDUSTRIAL USE OF WOOD FUEL.

The use of wood fuel by factories reached its greatest development in New England during the acute coal shortage of the winter of 1917–18, because this section was practically shut off for a time from all supplies of bituminous coal, which is the factory fuel. Complete information is not available on the quantity of wood used by the factories or how extensive its use was throughout New England, but it is known that a great many factories were forced to use wood to keep in operation. One dealer reported that he had shipped 5,500 cords of wood to the factories in eastern Massachusetts.

Such use of wood will come about only through necessity, as it costs at least three times as much as soft coal. The only reason for using it, therefore, is to keep the factories running. This points to the fact that in wood fuel the country has a reserve or substitute fuel which can be drawn upon in an emergency, not only to supply domestic consumption but to keep the factories running, although it may not be so efficient in the latter case as coal. Instead of waiting for emergency conditions to arrive, it would be well for both domestic and industrial users of fuel to plan on wood reserves in case the main reliance, coal, is not forthcoming.

It has been reported that cotton mills in South Carolina and elsewhere throughout the South are laying in wood to supply the mills in case of shortage, in addition to their usual supplies of wood for the operatives.

It is, of course, not desirable to use railroad transportation for wood fuel to factories unless there is no coal to haul. Then wood may be moved by rail to avoid shutting down. Many factories are so located at points away from large centers that wood can be used without shipping, and as in the aggregate they consume a large amount of fuel, a change to wood would be an appreciable help.

WHAT TO USE FOR WOOD FUEL.

THINNINGS AND IMPROVEMENT CUTTINGS.

The great bulk of the wood-fuel supply in farming regions should come from thinnings and improvement cuttings on farm woodlands. Except under stress of emergency, trees which will produce lumber or other material of higher value than cordwood should not be cut for fuel.

Trees which are better suited for fuel than for any other purpose, and whose removal will be of benefit to the remaining stand, are:

1. Sound standing and down dead trees.
2. Trees diseased or seriously injured by insect attacks, or those extremely liable to such injury, such as chestnut in the region subject to blight, or birch in the gypsy-moth area; badly fire-scarred trees.
3. Crooked trees and large-crowned short-boled trees which will not make good lumber and which are crowding or overtopping others.
4. Trees which have been overtopped by others and their growth stunted.
5. Trees of the less valuable species where they are crowding more valuable ones, as beech, block oak, birch, hard maple, white oak, or white pine.
6. Slow-growing trees which are crowding fast-growing species of equal value.

TREES ON OLD PASTURES.

On many farms former pastures have become overgrown with red cedar, gray birch, aspen, pine, or other trees. The trees came in slowly and through neglect were allowed to steal much of the pasture. If fuel is to be cut somewhere on the farm, such land as this should be drawn upon first of all and redeemed by removing all the trees and restoring the land to grass. Also, uncleared corners of fields or patches of agricultural land within the border of the wood lot may be cut clean, the wood used for fuel, and the land eventually farmed. The expense of clearing is thus largely or entirely met by the value of the fuel produced.

TOPS AND LOPS.

Thousands of cords of wood from the tops and limbs of trees felled in lumbering operations rot annually or furnish fuel for forest fires. Ordinarily this waste can not be avoided, because lumbering is most important in the less thinly populated parts of the country, and long hauls to cordwood markets are too costly. Sometimes, however, farmers overlook near-by woods operations as sources of fuel. The material is already down and can be worked up easily into cordwood. Owners of cut-over land usually are glad to have such material removed.

MILL WASTE.

Mill waste is very widely used as fuel in the neighborhood of sawmills and woodworking plants. Much of this refuse is burned to supply power for the mills themselves, but considerable is used as fuel by individuals and in some regions by other manufacturers. In many instances there are still large amounts of this material going to waste which could be made available for fuel.

SAWDUST BRIQUETS.

There are now at least three firms on the Pacific coast engaged in the manufacture of sawdust briquetting machinery, and at least three plants for the manufacture of this fuel have been established there.

The main market for briquets will probably be for domestic use where the cleanliness and easy kindling qualities of the briquet are a fine asset. For this use the briquet might be able to compete with coal at only $8.50 a ton, the housewife being willing to pay a little more for the same heat value on account of these desirable properties. The almost total absence of ash, the absolute absence of clinker, and the lack of smoke are great advantages of briquets over coal.

In competing with cordwood the briquet has certain advantages, such as requiring less labor in preparing for the fire, containing less moisture and more wood per pound, and obviating the need for kindling wood.

The best chance for the success of the wood or sawdust briquet is in those regions where sawdust is abundant and coal is expensive. The region best fulfilling these conditions in this country is the Pacific coast, and it is a significant fact that the companies now establishing the industry in America are all, as far as the author knows, on the Pacific coast.

CHARCOAL.

In England it is said that the war has caused a revival of the dying charcoal industry. A great deal has been done with this fuel and there is a possibility of a like interest being aroused in this country as fuel conditions become acute. There are doubtless many places in the wooded districts of the East, especially near large cities, where charoal can be made to advantage in the next few years. Charcoal has a larger heating power per cubic foot than wood, a ton yielding about 2,000 horsepower, and it is cheaper to transport on account of its light weight.[1]

Table 4 gives the production of charcoal in the United States in 1909. It is reported that Michigan and Wisconsin now lead in charcoal production.

TABLE 4.—*Charcoal production in 1909.*[1]

State.	Quantity.	Value.
	Bushels.	
Michigan	13,514,106	$868,003
New York	5,147,160	287,103
Pennsylvania	16,357,598	936,357
All other States	3,998,383	260,181
Total	39,017,247	2,351,644

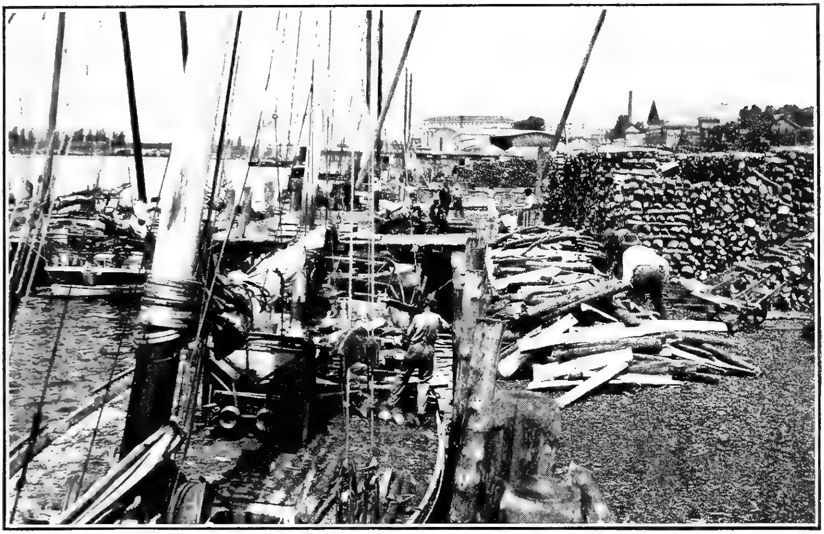
[1] Thirteenth Census, U. S. 1910, vol. 10, p. 622.

SUPPLY OF FUEL WOOD.

With the increased use of wood fuel which is likely to continue for several years, it is important to know how much fuel wood there is in the country and its local distribution and availability. An estimate of the total amount of firewood has never been made. Tentative figures show the following cords per farm in certain selected regions:

Region.	No. of cords per farm.
Northern Vermont	952
Southeastern Pennsylvania	218
Southern Indiana	474
Central Indiana	167
Northern Indiana	344
Northern Wisconsin	317
Southern Minnesota	256
Eastern Iowa	243
Southeastern Nebraska	141
Central North Carolina	1,231
Northeastern South Carolina	1,978
Central Tennessee	192
Northern Alabama	1,660
Northern Louisiana	2,315
Southern Missouri	601
Average	739

[1] "Logging and Lumbering," by C. A. Schenck.



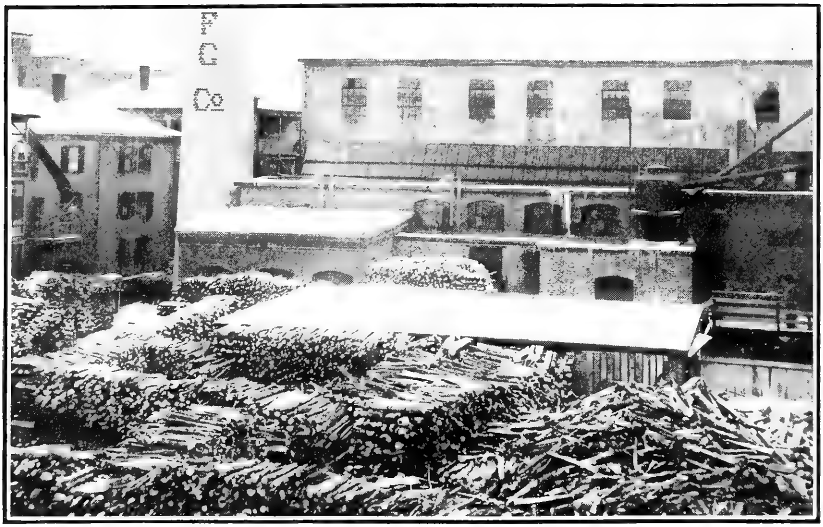
F-37649-A

FIG. 1.—UNLOADING CORDWOOD FOR FUEL FROM SAILBOATS AT WHARVES, WASHINGTON, D. C.

F-37647-A

FIG. 2.—VIEW OF TOP OF STACKS OF CORDWOOD IN ONE YARD AT WASHINGTON, D. C.

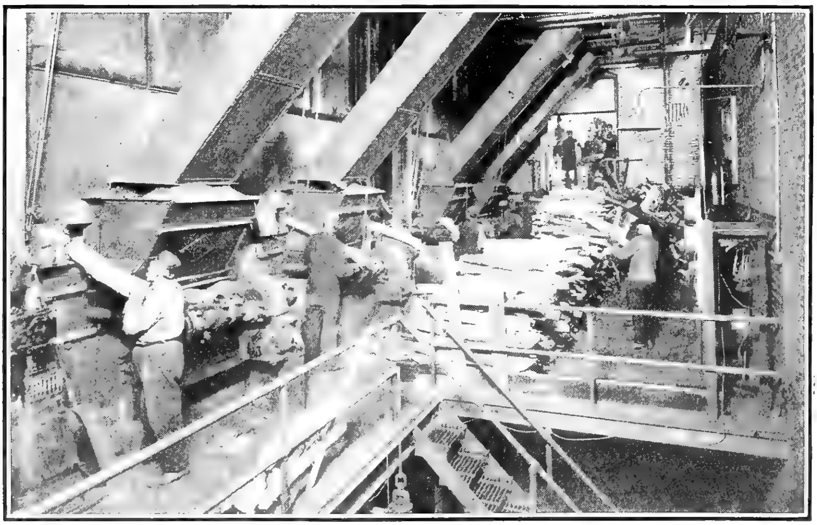
Capacity of yard 5,000 cords.



F-1-RS

FIG. 1.—INDUSTRIAL USE OF WOOD FUEL. STORED WOOD FUEL RESERVE OF A NEW ENGLAND FACTORY.

This supply was obtained in anticipation of a coal shortage. Photo by W. D. Clark, published in American Forestry, June, 1918.



F-2-RS

FIG. 2.—FIRING WITH WOOD FUEL; FURNACES IN A NEW ENGLAND FACTORY EQUIPPED WITH AUTOMATIC STOKERS FOR COAL.

Photo by W. D. Clark, published in American Forestry, June, 1918.

On the farms alone the total area of woodland in the eastern United States is approximately 143,392,000 acres. The first tier of States just west of the Mississippi has a great deal of timber, especially northern Minnesota, southern Missouri, Arkansas, Louisiana, southeastern Oklahoma, and eastern Texas. In the West the wooded areas are for the most part restricted to the mountains. An average of 10 cords per acre, which seems reasonable, would give one and one-half billions of cords for the region east of the Mississippi.

At the average rate of consumption on the farm itself, 12.6 cords per year, 739 cords will last 58 years. On the average this would be ample time to replace the stands and thus continue the supply indefinitely. As a fact, however, the woodland area is in many regions constantly shrinking as a result of land clearing for agricultural use and grazing. Thus unless care is taken of that which remains the future supply of fuel wood will be materially reduced.

The supply of wood fuel in any particular locality depends on more than the total amount of timber. Part of it will be on the land which is suitable for clearing for agriculture, and which will be cleared and improved in the near future. Obviously, the timber on such tracts can all be cut. More will be found on land which should be retained in woodland, and here the question is how much can be cut out safely. As a rule, only a certain percentage can be cut without jeopardizing the forest resources of the future. There is the further question of how much of the wood cut is available for fuel. The trees which are cut may be suitable for lumber, ties, telephone poles, and other higher uses. Therefore, it is essential to know not only the total amount of wood but the amount of fuel wood which can come out without injury to the forest. Only by means of a survey covering these points can a practical and comprehensive plan be developed to coordinate the supply and use of wood fuel within a given region with other forms of fuel which may be available.

PRODUCING AND MARKETING WOOD FUEL.

STUMPAGE.

The first item of cost in producing wood fuel is the price reckoned or paid for stumpage. Stumpage for this purpose ranges in price from nothing to $5 per cord, depending somewhat upon the region, the kind and quality of timber, and the ideas of the owner. In remote districts where land is being cleared the standing cordwood material is sometimes given away. Slash from lumbering operations is also frequently given away for the cutting or is sold at a nominal price.

Timber of better quality than cordwood material may naturally be expected to sell for higher prices than seems justified when compared with reasonable cordwood stumpage prices. Such material should, however, not be so used except in cases of emergency, when other stumpage can not be secured. It is reasonable that higher prices should be paid for stumpage when the area is to be cut clear than when only an improvement cutting is to be made, since the latter method increases the cost of cutting somewhat and besides takes material of the least value, the removal of which is a distinct benefit to the forest. In many cases an owner can well afford to give material from improvement cuttings or thinnings to anyone who will cut it.

Average stumpage prices ordinarily range from 50 cents to $1.50 per cord.

ESTIMATING STANDING CORDWOOD.

While cordwood is generally sold on the basis of measurement after it is cut and corded up, it is frequently desirable, especially in case of buying entire tracts, to estimate the amount of wood while still standing. This can be done by methods similar to those used for saw timber. Table 5[1] shows roughly the number of trees of different diameters required to make a cord.

TABLE 5.—*Number of trees required to yield 1 cord.*

Diameter of tree (breast high, outside bark).	Hardwoods.		Softwoods.
	Northern (beech birch, maple, etc.).	Southern (chestnut, oak, hickory, etc.).	
Inches.			
2		170	
3		90	
4		50	
5	35	25	
6	20	17	
7	15	13	20
8	11	9	13
9	8	7	10
10	6	6	8
11	5	5	7
12	4	4	6
13	3.5	3.4	4.5
14	3.0	3.0	3.7
15	2.5	2.5	3.0
16	2.0	2.2	2.5
17	1.7	2.0	2.1
18	1.5	1.8	1.9
19	1.3	1.5	1.6
20	1.2	1.3	1.5
21	1.0	1.2	1.4
22	.9	1.1	1.2
23	.8	1.0	1.1
24	.7	.9	1.0

The figures given are for trees of average height; allowances should be made in case of unusually short or tall timber.

[1] "Measuring and Marketing Woodlot Products," Farmers' Bulletin 715, by W. R. Mattoon and W. B. Barrows.

FELLING.

On the farms a time when labor can not be used at other work is the best time to cut wood; winter, late fall, and early spring are therefore generally the seasons when most wood fuel is cut. In the South, where the slack season comes at a different time, summer may prove the best season. However, there is no good reason why, if labor is available, fuel wood may not be cut at any time.

In the case of hardwoods which reproduce readily from sprouts the time of cutting is of some importance. The sprouts will start immediately if the timber is cut in the summer or early fall but will not be strong enough to stand the winter, with the result that the reproduction will be winter-killed. On the other hand, if the timber is cut in the winter the sprouts will grow during the spring and summer to such a size and hardihood as to be immune from winter-killing. Winter cutting should therefore be practiced with species which sprout, if reproduction is desired.

Cordwood is generally felled and cut into 4-foot or sled lengths with axes, or in some cases where larger trees are cut, with crosscut saws. Owing to the small size of the material generally cut this is the most economical method of felling the trees. A number of power-driven tree-felling machines have been devised, but none of them have proved practical, and even if they should become so their value would be in felling trees of large size.

The cost of cutting cordwood varies with the prevailing wages of the region and with the kind of timber cut. Woodcutters' wages run from less than $2 to more than $4 per day, or where paid by the cord, as is general in some regions, from about $2 to $3.50 per cord.

The quantity of wood which can be cut per day per man is, of course, the real basis of the cutting cost and depends most on the skill of the workman and on the kind of wood. Inefficient labor will produce but one-half cord of hardwood or 1 cord of softwood per day, whereas good skilled workmen will cut from 1½ to 2 cords of hardwood or from 3 to 4 cords of softwood per day. In one instance men inexperienced in timber work, such as business men from town, cut in hardwoods at the rate of two-thirds of a cord per day for the first day.

These figures include both felling the trees and cutting them up into 4-foot lengths. If material is cut sled length, as is frequently done, more can be cut in a day.

SKIDDING AND HAULING.

In probably the majority of cases the practice is to cut wood into 4-foot lengths and pile it close to where the trees are cut, and to haul it direct from these piles to consumers.

In many cases, however, the trees are merely trimmed or cut into sled lengths and hauled to the consumer to be sawed into stove lengths, or to central points in the woodlot or along a road to be cut up and piled for future hauling. It is possible that extension of this practice may in many instances considerably reduce the cost of producing wood fuel, both by reducing the amount of hand labor required in cutting up the material, in centralizing the work of cutting it up, and in increasing the amount which can be hauled by reducing its weight through seasoning.

Skidding or hauling out to a roadway or central point should not cost over $1 per cord.

SAWING AND SPLITTING.

Stove wood is no longer "bucked up" by hand with a bucksaw, except in isolated cases. Few men can saw more than from 1½ to 2 cords of 4-foot wood into 16-inch lengths in a day, while with power saws of from 6 to 10 horsepower a three-man crew can saw up from 10 to 15 cords per day.

For ordinary use a 24 or 26-inch circular saw, driven by a 6 to 12 horsepower gasoline or kerosene engine, is used. The engine and saw frame are mounted on a truck so as to be readily moved from place to place. Long sticks can be cut up by such a saw as easily as 4-foot pieces, except that in case of larger wood one or more additional men will be required to pass wood to the saw. At the present time complete sawing outfits cost from $200 to $500, depending on the horsepower and the size of the saw. Saw blades cost from $6 to $12, and saw frames from $30 to $40.

Farmers who do not have this equipment and whose requirements will not warrant such an investment may hire such a saw and engine and exchange the necessary labor in its operation within the community, as is frequently done in grain thrashing. Many have gasoline or kerosene engines or tractors, and a small portable saw would therefore be a comparatively minor investment and would pay for itself in working up the average wood lot. It could be used every winter in cutting the yearly supply as well as a surplus which might be marketed. Good opportunities exist for operators of thrasher and silo-filling outfits to do custom sawing during the winter.

For cutting large logs there are on the market several types of power-driven drag-saws, such as are in common use in lumber operations in the Pacific Northwest. These machines, which are generally operated by a 4-horsepower gasoline engine, can be carried from log to log by two men, and cut logs up to 7 feet in diameter. It is claimed that they can cut from 10 to 30 cords of firewood (softwoods) in 10 hours.

F–51620

FIG. 1.—SAWING BLUE GUM (EUCALYPTUS) WOOD WITH GASOLINE ENGINE.

Rate 1½ to 2 cords per hour. Santa Fe Springs, Cal.

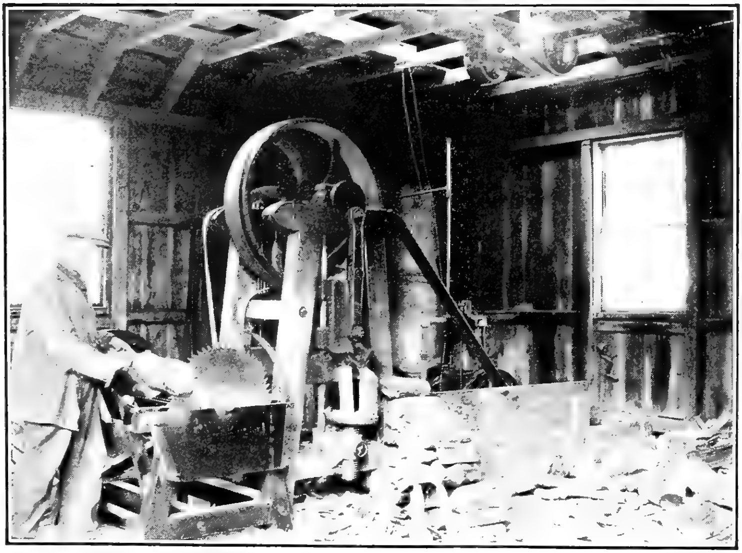
F–36792–A

FIG. 2.—LOAD OF HACKBERRY POLES ON PUBLIC SQUARE FOR SALE AT $2.50 PER LOAD, GALLATIN, TENN.

F-3-RS

FIG. 1.—BUZZ SAW, POWER SPLITTER, AND CONVEYOR, SET UP AT DOVER, MASS.

Photo by W. D. Clark.



F-4-RS

FIG. 2.—TABLE SAW AND SPLITTER OPERATED IN A MASSACHUSETTS FARMER'S WOODSHED.

Photo by W. D. Clark.

These machines weigh from 150 to 200 pounds, and cost from $170 to $200. They are probably not practical for ordinary cordwood operations where the trees are of comparatively small size. The cost of sawing with power saws depends, of course, upon the kind and size of wood sawed and upon the prevailing rate of wages. With three or four-men crews, wages of 30 to 35 cents per hour, and a cut of 16 to 20 cords per day, the average is as follows:

	Cents per cord.
Labor	50
Gasoline	9
Oil	1
Depreciation, interest, etc	10
Total	70

Charges for custom work were from 50 cents to $1 per cord, depending on the number of cuts and the kind of wood, but are now between 75 cents and $1.50.

Splitting is still largely done by hand, often by the consumer in his spare time, so that its cost is not an item to be considered in the price he pays for wood. Although much larger amounts have been split by expert axmen, an average man will seldom split more than four cords of stovewood per day. The amount depends, of course, on the species of wood. Some woods, such as birch, maple, and most conifers, split very easily; others, such as elm, sycamore, gum, and apple, are very hard to split. Most woods split more readily when green or partly dry than when dry. Splitting machines are now coming into more general use around woodyards where considerable quantities of wood are handled. These machines are driven by the same engines which run the cutting-up saws, and sawing and splitting are done at the same time. Two men with such a machine can split the wood as it comes from the saw. By installing an automatic carrier from saw to splitter one man can operate the latter. (See fig. 1.) Splitting by machine should not cost more than 75 cents per cord. By hand it costs around $1 per cord.

SEASONING.

The seasoning of wood for fuel is important, because dry wood has a somewhat greater heating value than green wood, is much more convenient to use, and is very much lighter in weight and therefore can be handled at less cost. In general it seasons more rapidly in the late spring and summer than during the remainder of the year, and most slowly when cut in late winter. The fact that checking is severe in summer does not matter, as this does not injure fuel wood.

The method of stacking depends primarily upon the rapidity with which it is desired to have the wood seasoned. A common practice is to pile the 4-foot lengths in compact piles resting on two bed pieces. This does very well when the wood is to season for six months or longer, but a different procedure must be adopted where more rapid seasoning is desired. The most open form of pile is the so-called "log-cabin" style. A pile which gives almost as good results without occupying nearly as much space has alternate tiers resting on single sticks at each end. There is ample ventilation through the alternate open layers.

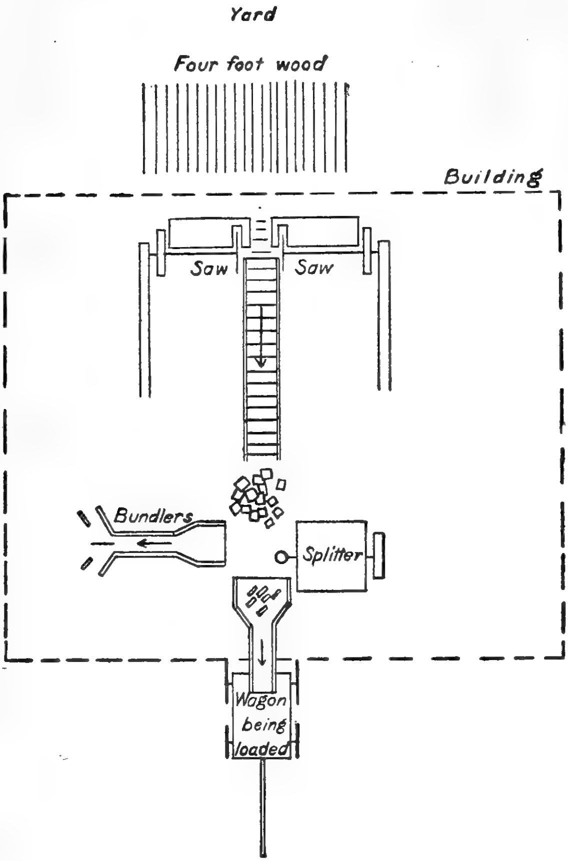


FIG. 1.—Plan of a retail wood dealer's plant for sawing and splitting cordwood.

It is very important for rapid seasoning to place the piles so that the air will circulate readily through them. The ideal place for this purpose is an open field, preferably on a hilltop. The direction toward which the piles face is not very important if there is good air circulation. The best results will be obtained in seasoning if the piles are so constructed as to shed rain as much as possible.

Cordwood of the ordinary species requires a period of from 9 to 12 months to season thoroughly, although the moisture content will be reduced to about 35 per cent in three months' time, depending somewhat on the season of the year. Wood of three months' seasoning has from 85 to 95 per cent as much fuel value as wood of the same species thoroughly seasoned. Even green wood has a heating value of 80 per cent or more of that of dry wood.

TRANSPORTATION.

Ordinarily wood fuel is used within 5 to 10 miles of the locality where it is produced, because its great bulk makes it expensive to ship.

It is commonly hauled from the woods to consumers or to dealers in towns by team or auto trucks. The cost of hauling is determined, of course, by the length of haul and by the amount that can be hauled per trip, which depends upon the condition of the roads and upon the species and dryness of the wood. The lowest cost for a given operation can be attained by letting the wood season thoroughly where it is cut and doing the hauling when the roads are best.

Where much of the haul must be over woods roads or other roads which are normally in poor condition, winter hauling on sleds is favored, since larger loads can be taken in this way. The chief disadvantage in depending on this method is the possibility of deep snow interfering with the hauling. Where the wood can be skidded out and piled beside good roads summer hauling by auto trucks is by far the most economical way to get wood to market.

Costs for hauling wood by team may be put at about 50 to 75 cents per cord per mile. The following tables,[1] which show approximate costs of hauling northern hardwoods, may be taken as fairly typical of the northern and eastern States:

TABLE 6.—*Team capacity per day for hauling various distances.*

Sizes.	Number of cords per day per team.									
	1 mile.	2 miles.	3 miles.	4 miles.	5 miles.	6 miles.	7 miles.	8 miles.	9 miles.	10 miles.
Long wood	7	6	5	3	2	1½	1½	1	1	1
4-foot wood	5	4	3	2½	2	1½	1½	1	1	1
16-inch stove wood	4	3	2½	2	1½	1½	1	1	1	1

TABLE 7.—*Cost of team-hauling per short cord of 16-inch lengths, for different distances and at different wage rates, including charge of 26 cents for handling.*

Distance from town (miles).	Trips per day.	Cords hauled per day.	Approximate cost per cord, with team wage of—		
			$4.50 per day.	$5 per day.	$6 per day.
5 and over	1	3–4	$1.40–$1.75	$1.50–$1.95	$1.75–$2.25
3 to 4	2	6–8	.80– 1.00	.90– 1.10	1.00– 1.25
2 to 3	3	9–12	.65– .75	.65– .80	.75– .90
1 to 2	4	12–16	.55– .65	.55– .65	.65– .75

Although wood fuel can not as a general thing be economically shipped to market, it is in certain instances practicable to do so, especially in districts remote from the coal regions. Since shipment by water is the cheapest method of transportation, towns on navigable rivers and inlets along which are supplies of fuel wood are in the best position to get wood at a reasonable cost. Washington,

[1] "The Price of Fuel Wood," by William K. Prudden, State fuel administrator of Michigan, Mar. 1, 1918.

D. C., uses normally about 17,000 cords of wood fuel annually, most of which is brought up the Potomac by sailboats with an average capacity of 30 cords.

Freight rates on cordwood vary in different sections of the country and on different railroads. At this time, on account of readjustments, it is not possible to give very definite information on freight rates. Recently the rate for distances of about 10 miles has averaged about 50 to 60 cents, and has sometimes reached $1. Around 100 miles the rate has averaged $1.50 per cord, but has in some cases been as low as $1 and in others as high as $2.

CAR CAPACITIES.

The minimum carload measurements on cordwood are as follows:

	Number of cords per car. Dry.	Green.
In box cars 34 feet 4 inches and less in length, inside measurement	12	12
In box cars over 34 feet 4 inches in length and 8 feet and over in height, inside measurement	[1] 17	[1] 16
In box cars over 34 feet 4 inches in length and under 8 feet in height, inside measurement	16	15
On flat or gondola cars 34 feet 4 inches and less in length	12	12
On flat or gondola cars between 36 and 34 feet 4 inches in length	18	16

WEIGHTS.

The following estimates are used for cordwood in shipments by rail when actual weights can not be obtained:

Degree of seasoning.	Pounds per cord.
Dry	3,650
Partly seasoned	4,600
Green	5,200
Mixed	4,600

Approximate weights per cord [2] of a number of the more important fuel wood species are:

	Green. Pounds.	Air dry. Pounds.
Ash, white	4,300	3,800
Beech	5,000	3,900
Birch, yellow	5,100	4,000
Chestnut	4,900	2,700
Cottonwood	4,200	2,500
Elm	4,400	3,100
Hickory	5,700	4,600
Maple, sugar	5,000	3,900
Maple, red	4,700	3,200
Oak, red	5,800	3,900
Oak, white	5,600	4,300
Willow	4,600	2,300

[1] Where the wood is 16 inches or less in length, the capacities for these dimensions for dry and green wood are 16 and 15 cords, respectively.

[2] U. S. Department of Agriculture, Farmers' Bulletin 715, "Measuring and Marketing Woodlot Products."

In loading and unloading from cars or boats one man can handle from 7 to 10 cords of 4-foot wood per day and from 6 to 8 cords of 16-inch wood.

METHODS OF SELLING.

In spite of the fact that fuel wood is not transported any great distance or marketed on an extensive wholesale scale, some organization is needed for its marketing and local distribution. In communities where there are regular wood dealers the problem of bringing the producer and consumer together is simple. Such men have, of course, made a study of the problem and are better qualified than anyone else to perform this service. Unfortunately, however, in a great many communities the amount of cordwood sold has been so small in the past that it has not been worth anyone's while to go into the business of marketing firewood. In such communities the usual practice has been for the woodlot owners to make a house-to-house canvass with their loads. This is usually an expensive way of marketing wood, for the producer spends a large amount of time in finding a customer. A substitute for this canvass is the advertising of wood either in the papers or by posters at public places.

The possibility of selling cordwood through coal or lumber dealers deserves attention in every locality. This would have the advantage of making possible a reduction in cost by using power saws at their yards to cut the wood into stove lengths. A still better plan is for communities to establish and control their own municipal wood yards, at which producers can deliver wood and receive pay for it according to a regular schedule of prices.

MUNICIPAL WOOD YARDS.

Municipal wood yards, war fuel companies, and similar organizations have been tried with fair success. Their field of usefulness will doubtless be greatly increased as their need is more clearly appreciated and their effectiveness becomes more apparent. Some organization is needed to keep alive the wood-fuel idea between seasons and to see that wood is cut, even though it does not seem immediately necessary. Every community should by means of a municipal wood yard or otherwise get in a reserve of wood for the winter, sufficient to insure its members against a fuel famine. One city in New England has made plans to purchase 100,000 cords of wood as a fuel reserve for the city. In one Southern State there are already some 30 municipal wood yards in operation, and plans are being made to have one in practically every community in the State. If this is necessary in the South it is much more urgent in the North, where

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the winters are longer, and snow, especially in northern New England, makes it practically impossible to get out much wood in the depth of winter.

A yard established in 1917 at Durham, N. C., purchased 1,260 cords of wood at an average cost at the yard of $5 a cord. Wood was delivered at an average cost to the consumer of $7. It came from two sources—a sawmill about 14 miles distant from which slabs were shipped by rail, and a farmer's woodland from which cordwood in 8-foot lengths was secured. The slabs were mostly green pine of odd lengths, for which $2 per cord was charged f. o. b. cars. Freight charges amounted to about 75 cents per cord. The coal and wood yard is adjacent to the railroad tracks, and the wood was unloaded from the cars exactly where needed by the sawyers. The wood from the farmers' woodlands near by was green pine and oak, cut in 8-foot lengths and split in halves or quarters. The price was $3.50 per cord piled in the woods. It was hauled from the woods to the roadside by six county teams and there piled in a long rick, from which it was loaded upon motor trucks. Three trucks were used, each making four trips a day and carrying about 1 cord per ton of rated capacity, so that the total daily delivery was about 40 cords. The cost of hauling was about $1 per cord; it would have been less if there had been better loading and unloading facilities. The distance was 2½ to 3 miles. (See fig. 2.)

Cordwood was sold according to the cubic contents of the wagon boxes, most of the wood being sold at the yard. The estimated cost of sawing to stove length was 50 cents per cord on the yard.

MEASURING WOOD FUEL.

CORDS.

A standard cord of firewood is a pile 8 by 4 by 4 feet, which contains 128 cubic feet of stacked wood. It is customary to pile green wood 2 or 3 inches higher than 4 feet to allow for shrinkage and settling as it dries. In measuring piles of wood the average dimensions are taken.

A "running" cord or "face" cord, 8 feet long by 4 feet high and 12, 16, or 24 inches wide, according to the length to which it is cut for use, is frequently called a cord in the market.

Though a cord contains 128 cubic feet the space occupied includes air as well as wood. The actual solid contents of a cord is only about 70 per cent of this amount, or 90 cubic feet for wood of average size. For small sticks, where the average diameter is 4 inches or less, there are less than 80 cubic feet per cord; in the case of larger sticks 10 inches or over in diameter there may be as much as 100 cubic feet per cord. Crooked, rough sticks can not be piled as closely as straight, smooth sticks. Therefore there is less wood in a cord of crooked sticks than in a cord of straight sticks.

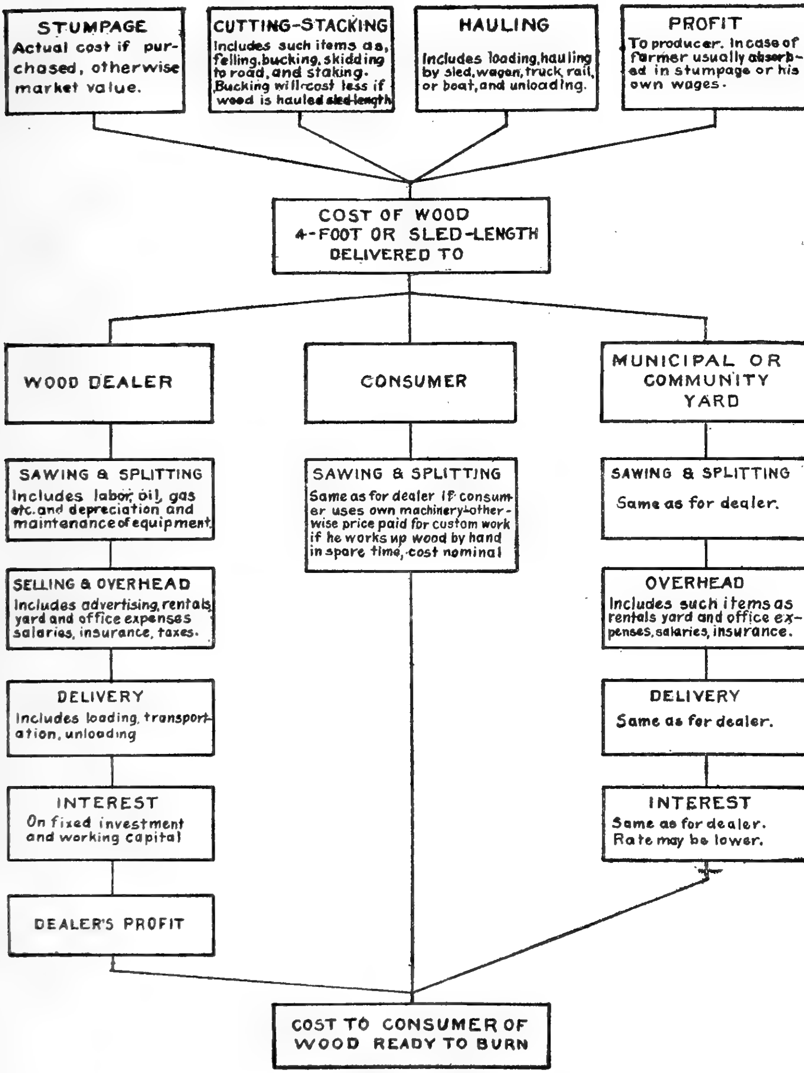

FIG. 2.—The elements of cost of wood fuel.

SELLING WOOD BY WEIGHT.

The great demand for fuel wood and the high prices during the winter of 1917–18 brought out plainly the inadequacy of the cord unit for measuring wood. The purchaser of fuel wood buys it not for its bulk but for its heating value, which depends not upon the volume of wood but upon its weight. A pound of dry wood of one species has about the same number of heat units as a pound of any other species; but a cord, assuming the same solid volume of wood in each case (90 cubic feet), of basswood, for instance, yields but 12,600,000 British thermal units, while a cord of black locust yields 26,500,000 British thermal units. As a matter of fact, we can not assume the same solid volume in two cords of wood; a loosely piled cord of small, round sticks may contain 70 cubic feet or less, while a closely piled cord of large split wood may contain over 100 cubic feet. If it is locust, the first pile will yield 20,700,000 British thermal units; the second, 29,600,000 units. If the first pile is basswood, it will have a heating value of but 9,600,000 British thermal units. The same cord of wood sawed up and repiled will be less than a cord in bulk, though its heating value will not be reduced; thrown loosely into a wagon box, it will fill up considerably more than 128 cubic feet, but will not give off any more heat.

It is now the custom in most places to sell hardwoods and softwoods at slightly different prices because of recognized differences in heating values. Branch wood is frequently sold at a lower price than split body wood, as a result, partly at least, of a hazy recognition of the fact that there is less solid wood in a cord of the former. Chestnut and hickory, however, are frequently mixed together as hardwood, and sold at a given price regardless of whether 90 per cent is chestnut, which would give the cord a low heating value, or hickory, which would give it a high value. In many places even pine, oak, and hickory are indiscriminately thrown together at a uniform price, regardless of the proportion of each, so that one man may for a given amount of money buy twice as much heat as another.

The practice prevalent in some sections of selling wood by the load has afforded excellent opportunities for profiteering without the knowledge of the purchaser. Few people would buy coal by the load instead of by the ton, yet a given load of coal can not vary nearly so much in heat value as a load of wood.

A better way to sell fuel wood would be by weight, which is entirely independent of species, shape, or size of sticks, or of method of piling, and is a very good measure of the fuel value of thoroughly seasoned wood. Green wood, of course, varies considerably in water content and therefore in fuel value per unit weight, and naturally would be sold at a price different from that for dry wood. The extreme difference in heat units per pound between green and dry wood of any species is approximately 70 per cent of the dry value; a pound of green willow, for instance, is worth about one-third as much as the same weight of dry wood. Green wood of most of the hardwoods commonly used for fuel has about half the heating value of dry wood of the same weight.

If weight instead of volume is adopted as the standard measure, it will be necessary to fix certain standards as to time of seasoning of wood offered for sale. This can easily be regulated in the case of larger dealers, wood yards, and probably without serious difficulty even for individual farmers, by use of a licensing system under which a seller shall be required to certify under oath as to the date when his wood was cut.

SELLING PRICES OF WOOD FUEL.

The Federal Government is without authority to fix prices on wood fuel, as the act granting this power for coal and coke does not cover wood. Some States, however, have gone ahead and set price limits on the ground of public necessity in an emergency. While this may be desirable in restricted areas, fixing of a maximum price on wood is scarcely a good general policy, for two reasons:

First, the cost of producing wood fuel depends so much upon local conditions that it would be hard to adjust prices equitably.

Second, price-fixing might tend to limit production to such an extent as to aggravate the crisis by decreasing the amount of wood fuel available during the emergency.

The production of wood will be greatest if prices are left to regulate themselves, possibly with some local supervision. In all cases the producer of wood should be considered entitled to a reasonable profit on the costs of his operation. Some of the "war fuel companies" which were formed during the fuel crisis in the winter of 1917–18 limited their profits to 6 per cent. Municipal yards as a rule sell at cost.

MANUFACTURE OF SAWDUST BRIQUETS.[1]

Practically all of the European machines use some kind of binder mixed with the sawdust, or rely upon the resinous material in the wood to hold the briquet together, but American and Canadian inventors have apparently preferred mechanical binders. One company in Los Angeles is now building machines for the manufacture of briquets of the wire-bound type, and a company in Vancouver is perfecting machines for making the rope-core type. As far as can be ascertained, both of these machines give promise of satisfactory service under conditions of continuous operation. Another Vancouver company is manufacturing machines for the production of briquets composed of sawdust, coal dust, and binder in about the following proportions: Sawdust, 65 per cent; coal dust, 25 per cent; binder (coal-tar pitch, petroleum refuse, or sulphite waste liquor),

[1] "Briquetting of Sawdust on a Commercial Basis," R. Thelen, forest products laboratory, Madison, Wis., in Canada Lumberman and Woodworker, vol. 36, No. 5, pp. 39–40, Mar. 15, 1916.

10 per cent. These briquets are hard and firm and resemble coal briquets in general appearance.

Although the various presses differ greatly in the details of their construction, most of them work on the cylinder-and-plunger principle, the plunger being driven by means of crank and connecting rod or by some toggle-joint system of levers so designed that it is capable of exerting a very great pressure at the end of the stroke. Practically all of them also are automatically fed. In systems in which binders such as pitch are used and in those in which the resins of the wood serve as binders, it is necessary to provide a long cooling trough, sometimes as much as 150 feet in length for the finished briquets. In systems using mechanical binders these cooling troughs are unnecessary.

The cost of manufacturing briquets is not inconsiderable, conservative estimates placing the figures at not less than $3 a ton. The bulk of the fuel prevents its economical shipment over long hauls. This applies both to the finished briquet and to the raw sawdust. It is believed that the ultimate consumer will have to pay at least $6 a ton for the briquets to make the success of their manufacture assured.

MANUFACTURE OF CHARCOAL.[1]

There are two chief methods of producing charcoal, the old kiln method and the modern method of destructive distillation in a closed retort. Most of the commercial charcoal is still made in the kiln, the erection and operation of which costs, for the labor, about 60 cents per ton of charcoal.

Wood loses 75 per cent in weight and 50 per cent in volume in charring. Two cords of hardwood will yield 1 ton of charcoal; 1 bushel of charcoal, the selling unit, weighs about 25 pounds.

For making charcoal the wood should be thoroughly seasoned, free from knots, and of but one species for each kiln charge.

The ground is prepared near water by leveling and hoeing the soil, removing roots and stones, and raising the center of the circle to be occupied by the kiln about 10 inches above its circumference. The usual diameter of the circle is from 15 to 30 feet. The best soil is loamy sand, which secures proper regulation of the draft. The site should be protected from wind.

A "chimney" is erected by placing three or four poles of even height at 1 foot distance from a central pole, and fastening them around the central pole by withes. It is cylindrical if the kiln is lighted from above, and pyramidal if the kiln is lighted from below; and is filled with inflammable substances, such as dried twigs, charcoal, etc.

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[1] Logging and Lumbering or Forest Utilization, pp. 167–168, a textbook for forest schools, by C. A. Schenck, director Biltmore Forest School.

The kiln proper is then constructed in a parabolic form. It consists of two or more tiers of billets placed more or less vertically with the bark turned outward, the big ends downward, the smallest pieces near the chimney and near the circumference, the largest pieces halfway between. These tiers are topped by a cap, consisting of smaller billets placed sloping. If the chimney is cylindrical it extends through the cap; if it is pyramidal it is closed by the cap. In the latter case a lighting channel is left on the ground running radially on the leeward side from the base of the pyramidal chimney to the circumference. This channel, like the chimney, is filled with inflammable material. All irregularities, interstices, and cracks showing on the outside of the kiln are stuffed with small kindling. The kiln is covered by two draft-proof layers so as to exclude the air; first the vegetable layer, one-fourth to three-fourths of a foot thick, made of green branches, weeds, leaf mold, and moss; second, an earth layer, 2 to 6 inches thick, consisting of loam, charcoal dust, etc. If the kiln is lighted from below, a belt about 1 foot high running around the circumference on the ground is left without the earth cover until the fire is well started. The earth layer and the vegetable layer are thoroughly joined by beating with a paddle.

The kiln is lighted early in the morning on a quiet day. The cylindrical chimney is closed on top as soon as the fire is well started in the cap. The lighting channel, in the case of a pyramidal chimney, is similarly closed.

The regulation of the fire and of the draft are the most important functions of the attendant, who guides the fire evenly and gradually from the cap down to the bottom. To check the draft the earth cover is increased. To increase draft, holes of about 1 inch diameter are made through the cover with the paddle reversed. If the wind is strong all holes are closed and the earth cover is increased. Cracks which form in the cover must be closed at once. The kiln may explode if the cover is too heavy and the draft too strong. In dry weather the kiln is continuously sprinkled. The color of smoke escaping through the punctures indicates, by turning blue and transparent, the completion of the charring process above the puncture. The old punctures are then closed and another row of punctures is made about 2 feet below the closed holes.

Refilling is required where dells are forming irregularly, while the kiln gradually shrinks to one-half of its original volume. For refilling, the cover over the dell is quickly removed, all holes having been closed beforehand, and the dell is rapidly filled with new wood.

When the bottom holes show the proper color of smoke, the charring process is completed. All holes are then closed, and the kiln is allowed to cool. The duration of the charring process is from 6 to

28 days, according to size of kiln. The contents vary from 4 to 60 cords.

Beginning at the leeward side the kiln is gradually uncovered. The crust of earth, cut into fragments, is thrown on again. The earth trickling down quenches the fire. After another 12 to 24 hours, preferably at night, the coal is taken out in patches or pockets, slowly and carefully, so as to prevent the flames from breaking out. Water must be at hand to quench incipient fires.

HOW TO USE WOOD FUEL.

Coal has been so generally used lately and furnaces and stoves have become so adapted to its use that it seems impractical to many to burn wood without going to great expense. Such is not usually the case, as simple adjustments will allow wood to be used with coal-burning equipment. The size of the firebox, of course, gives the greatest difficulty, since in many cases it may make it necessary to cut the wood into very small blocks. This trouble, however, is not insurmountable and is not so expensive as it might seem. The matter of adjusting the drafts and arranging the grates is simple.

Following are a number of practical directions which are largely the result of experience in changing from coal to wood fuel.

BURNING WOOD IN STOVES.

A coal-burning stove can be converted into a wood-burning stove by removing the fire brick and substituting lighter bricks at a cost of about $1.25. Most country cook stoves can burn wood with little trouble. If a stove grate is too coarse for wood, a sheet-iron cover over a good part of the surface will make it suitable, or a few fire bricks can be used. Wood grates made in two pieces are sold which can be inserted through the fire door and placed on top of the regular grate.

BURNING WOOD IN FURNACES.[1]

Furnaces are built especially for burning wood in 3 or 4 foot lengths. Short lengths, of course, can readily be burned in an ordinary coal furnace or in a box stove, though this is rather wasteful of fuel. Many furnace manufacturers, however, make a special wood grate for use in their furnaces. One advantage in burning wood is that on moderately cool days the furnace can be run at a lower ebb than when coal is used, consuming only enough fuel to remove the chill. When wood is used in a round pot furnace care should be taken to have each piece lie flat.

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[1]Adapted from a bulletin by E. H. Lockwood, published by P. B. Noyes, director of conservation, U. S. Fuel Administration, Washington, D. C.

USING WOOD ONLY.

There are difficulties in burning wood as a substitute for coal in a steam, hot-water, or warm-air furnace, but it can be done with a fair degree of success, especially in mild weather.

The best form of wood is short blocks, from 8 to 12 inches long, preferably of hardwood, although mixed hard and soft, or even softwood alone, can be used. Medium-sized pieces, such as those found in ordinary cord wood, are suitable, although larger pieces keep the fire better.

The best method of firing is to keep the furnace full of wood packed close with a moderate draft to give the desired amount of heat. As the wood burns more should be added in order to keep the deep bed of burning fuel, which is most economical.

Banking the fire at night requires an extra supply of the largest blocks and special attention to closing the dampers tight. Experience will show the best way, but it can be done with success in most furnaces.

It is not necessary to buy new grates for burning wood, although the ordinary coal grate is not well adapted for wood. A good way is to add a little nut coal to the fire at the start, allowing the layer of coal ashes to remain on the grates. Air required for combustion can pass through the ash layer, which can be shaken lightly without much loss of ashes. The larger the fire box the better the results.

A furnace designed for burning coal may be made into what is known as a "Wilson heater," which is one of the most economical stoves for wood burning, by removing the grate bars and laying fire brick on the floor of the ash pit. A wood fire is then built on the fire brick, and the ash pit door is kept tightly closed and the ventilator in the fuel door open. A wood fire can in this way be made to burn very slowly.

USING A COMBINATION OF WOOD AND COAL.

The simplest way to use wood in a coal furnace, and the most effective in producing heat, is to combine it with coal. The method of firing is to place blocks of wood on the fire to about the level of the fire door, instead of shoveling on coal in the usual way, then add coal on the top, which will fill the crevices between the wood, making a level fuel bed with coal on top. A fuel charge of this kind will produce good heat but will not last as long as a fire pot full of coal, hence more frequent attention is needed.

From 25 to 50 per cent of the coal ordinarily used can be saved by substitution of wood in this way. Any kind or size of wood can be used that will go into the fire pot, and will burn with good efficiency when surrounded with coal.

Any size of coal or coke can be used, but the small sizes fill in best between the chinks in the wood. Buckwheat coal can be burned successfully in this way, and its low price will help to offset the higher price of block wood, making an economical combination.

CAUTION.—When burning the small sizes of coal take care to avoid gas explosions by always leaving a flame burning on some part of the fire; in other words, do not cover the whole fire with fresh fuel at one time.

BURNING WOOD IN FIREPLACES.

Where a fireplace is available wood can be used to good advantage, affording both heat and ventilation. Its value is to supplement a furnace, although it may replace the furnace in fall and spring with decided economy.

It is not generally realized that a wood fire can be kept burning night and day in a fireplace with very little attention and with small consumption of wood. One user reports continuous use of a fireplace in this way for over a month, with dry chestnut wood, where the amount of ashes formed by a month's use was not enough to require removal.

The secret of fireplace management is a plentiful supply of ashes, kept at the level of the andirons. As the blocks burn, an accumulation of glowing charcoal forms in the ashes. This keeps on burning slowly and assists in igniting the fresh blocks on the andirons. A pocket may be formed in the ashes into which the hot charcoal may fall, forming a heat storage. Two or three blocks on the andirons with the hot charcoal in the ashes will form an excellent fire.

To check the fire, ashes are shoveled over one or more of the blocks, covering lightly all the burning wood. This will not put out the fire; it will only check the rate of burning, so that red charcoal will be found when the ashes are removed for addition of fresh fuel.

Fireplace wood is usually cut in longer lengths than stove wood, but the ordinary 16-inch stove length is convenient. Any kind of wood can be used, provided it is dry and seasoned.

A banked fire will keep 10 or 12 hours and will send some heat from the hot bricks all the time. A well-managed fireplace will be found a great addition to the heating system in any residence.

INDUSTRIAL USE OF WOOD FUEL.

Wood is very generally used for fuel by sawmills and woodworking plants. For this purpose it is burned in the form of slabs, 4 feet or so long, or is cut up into "hog" fuel and shoveled or fed automatically into the fire box. In these cases wood fuel is a by-product which would have to be disposed of at some cost if not burned for fuel, so that its use is economical. It is seldom economical to buy firewood for industrial use, except to keep a plant running when other fuel can not be had.

EFFICIENCY OF WOOD FUEL.

THEORETICAL HEATING VALUES OF WOOD.

The heating power or fuel value of a given volume of dry wood is in direct ratio to its specific gravity. By specific gravity is meant the ratio of the weight of a given volume of wood to that of an equal volume of water. Water weighs a little over 62 pounds per cubic foot, and wood, which weighs 31 pounds per cubic foot when perfectly dry, is said to have a specific gravity of 0.50, and so on for other weights.

In theory equal weights of wood substance will give the same amount of heat regardless of the species. In other words, a hundred pounds of absolutely dry cottonwood should furnish as much heat as a hundred pounds of hickory. In reality the varying forms of tissue found in the different species, the addition of resin, gums, tannin, oils, and pigments, as well as water present in varying amounts, cause different woods to have different heating values. The presence of rosin in wood increases the heating power materially, the results of numerous tests showing a difference ranging up to 12 per cent or more.

The composition of absolutely dry wood is approximately as follows: Carbon, 49 per cent; oxygen, 44 per cent; hydrogen, 6 per cent; ash, 1 per cent.

This is fairly constant for all species, except as modified by infiltrations, such as gums, pigments, resins, tannin, etc., so that equal weights of dry nonresinous woods give off practically the same amount of heat in burning. A pound of thoroughly dry wood will furnish under good conditions between 7,000 and 9,000 British thermal units. A pound of good coal will furnish from 12,000 to 14,000 units, making dry wood about 57 per cent as efficient as coal.

When wood containing water is burned part of the heat the wood is capable of yielding is taken up in raising the water to the boiling point and converting it into steam. The steam must then be raised to the temperature of the flue gases. All this heat is lost, and the greater the amount of water present the more heat is carried off. The water in green wood often makes up half of the total weight, especially in sapwood. After such wood is thoroughly air-seasoned there would remain about 20 per cent of water. If the wood is kiln-dried, from 2 to 5 per cent of water remains, and if it is exposed to the air, this percentage is increased by absorption (hygroscopically) from 10 to 15 per cent, depending upon the humidity.

A hundredweight of wood as sold on the market contains about 25 pounds of water, 74 pounds of wood substance, and 1 pound of ash.

These 74 pounds are made up of 37 pounds of carbon, 4.4 pounds of hydrogen, and 32 pounds of oxygen. The oxygen combines with the hydrogen in the proportion of 8 to 1, producing 36 pounds of water and leaving four-tenths of a pound of hydrogen to produce heat. The total amount of water to be evaporated becomes 25 plus 36, or 61 pounds; the amount of wood substance left available for heat production is 37.4 pounds out of the original 100 pounds.

It is evident that the greater the proportion of water the less the amount of available heat. Only about one-half of the weight of wood substances produces heat, while every pound of water combined in the wood requires 1,108 units of heat to evaporate it, from ordinary room temperature (70° F.). Hence under the most favorable circumstances the heating efficiency of a pound of wood containing 25 per cent moisture will be less than that of dry wood not only by the 2,000 units representing the weight of wood replaced by water, but also by one-fourth of 1,108 units, or 277 units, so that its heating value is but 5,723 units instead of 8,000, or 72 per cent of that of a pound of dry wood. On the other hand, if we take the pound of wet wood and dry it out absolutely, so that it weighs three-fourths of a pound, it will have 6,000 heat units, an increase in heating value due to drying of only about 5 per cent.

COMPARATIVE VALUES OF DIFFERENT WOODS.

The comparative values of fuel of various species of American woods are shown in Table 8. These values are necessarily somewhat approximate but afford a good basis for comparison of the different species.

TABLE 8.—*Heat values of cordwood, based on Forest Products Laboratory (Madison, Wis.), weights for oven-dry, air-dry, and green woods and assuming 7,350 B. t. u. available per pound of dry wood with flue gases at 300° F.*

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Alder, red (A. oregona)	14.8	13.0	57	50
Ash, biltmore (F. biltmoreana)	20.7	20.0	80	77
Black (F. nigra)	18.5	16.5	71	64
Blue (F. quadrangulata)	21.3	20.7	82	80
Green (F. lanceolata)	20.6	19.6	79	75
Oregon (F. oregona)	19.7	19.0	76	73
Pumpkin (F. profunda)	19.4	18.2	75	70
White (F. americana)	20.5	19.9	79	77
White (second growth)	23.0	22.4	88	86
Aspen (F. tremuloides)	14.1	12.1	54	47
Largetooth (P. grandidentata)	14.2	12.4	55	48
Basswood (T. americana)	12.6	11.0	48	42
Beech (F. atropunicea)	20.9	19.7	80	76
Birch, paper (B. papyrifera)	18.2	16.7	70	64
Sweet (B. lenta)	23.3	21.9	90	84
Yellow (B. lutea)	20.9	19.4	80	75
Gray (B. populifolia)[1]	17.5	16.1	68	62
Red (B. nigra)[1]	17.5	15.7	68	60

[1] Gray and red birch estimated.

TABLE 8.—*Heat values of cordwood, based on Madison Laboratory weights.*—Con.

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Buckeye, yellow (A. octandra)	12.8	10.1	49	39
Buckthorn (R. purshiana)	20.2	18.6	78	72
Butternut (J. cinerea)	14.3	12.2	55	47
Chinquapin, western (C. chrysophylla)	17.2	13.9	66	53
Cherry, black (P. serotina)	18.5	17.3	71	67
Wild red (P. pennsylvanica)	14.2	13.5	55	52
Chestnut (C. dentata)	15.6	12.9	60	50
Cottonwood (P. trichocarpa)	12.8	10.5	49	40
Cottonwood (P. deltoides)	15.0	12.7	58	49
Cucumber (M. acuminata)	17.8	16.0	68	62
Dogwood, flowering (C. florida)	25.2	23.7	97	91
Western (C. nuttallii)	22.4	21.4	86	82
Elder, pale (S. glauca)	18.4	15.2	71	58
Elm, cork (U. racemosa)	22.6	21.5	87	83
Slippery (U. pubescens)	19.1	17.1	73	66
White (U. americana)	17.7	15.8	68	61
Gum, black (N. silvatica)	18.5	17.4	71	67
Blue (Eu. globulus)	24.1	22.4	93	86
Cotton (N. aquatica)	18.5	16.2	71	62
Red (L. styraciflua)	17.7	16.0	68	62
Hackberry (C. occidentalis)	19.1	17.7	73	68
Haw, pear (C. tomentosa)	24.8	23.1	95	89
Hickory, shellbark (H. laciniosa)	24.8	23.1	95	89
Bitternut (H. minima)	24.2	22.2	93	86
Mockernut (H. alba)	25.4	23.8	98	92
Nutmeg (H. myristicae formis)	22.0	19.9	85	77
Pecan (H. pecan)	24.2	22.5	93	87
Pignut (H. glabra)	25.9	24.7	100	95
Shagbark (H. ovata)	25.4	23.8	98	92
Water (H. aquatica)	24.5	21.6	94	83
Holly (I. opaca)	19.6	17.8	75	68
Hornbeam (O. virginiana)	24.7	23.5	95	90
Laurel, California (U. californica)	20.7	18.8	80	72
Mountain (K. latifolia)	24.9	23.2	96	89
Locust, black (R. pseudacacia)	26.5	25.4	102	98
Honey (G. triacanthos)	24.5	22.5	94	87
Mondrona (A. menziesii)	22.6	20.9	87	80
Magnolia, evergreen (M. foetida)	18.4	15.5	71	60
Maple, Oregon (A. macrophyllum)	17.7	16.3	68	63
Red (A. rubrum)	19.1	17.6	73	68
Silver (A. saccharinum)	17.9	16.4	69	63
Sugar (A. saccharum)	21.8	20.4	84	78
Oak, bur (Q. macrocarpa)	22.6	20.8	87	80
California, black (Q. californica)	20.5	17.7	79	68
Canyon live (Q. chrysolepis)	27.5	25.7	106	99
Chestnut (Q. prinus)	22.4	20.7	86	80
Cow (Q. michauxii)	24.0	22.1	92	85
Laurel (Q. laurifolia)	21.7	19.6	83	75
Pacific post (Q. garryana)	25.3	23.4	97	90
Post (Q. minor)	24.0	22.2	92	85
Red (Q. rubra)	21.7	19.6	83	75
Spanish (Q. digitata)	20.4	18.1	78	70
Spanish (Q. pagodaefolia)	24.0	21.9	92	84
Swamp white (Q. platanoides)	25.1	23.4	97	90
Water (Q. nigra)	21.7	19.7	83	76
Tanbark (Q. densiflora)	21.7	19.4	83	75
White (Q. alba)	23.9	22.4	92	86
Willow (Q. phellos)	21.2	19.3	82	74
Yellow, black (Q. velutina)	22.0	19.7	85	76
Osage, orange (Tox. pomiferum)	30.8	30.1	118	116
Persimmon (D. virginiana)	25.0	24.0	96	92
Rhododendron (R. maximum)	19.5	17.2	75	65
Sassafras (S. sassafras)	17.2	15.7	66	60
Service berry (A. canadensis)	26.1	25.2	100	97
Silverbell (Mohrodendron carolinum)	17.2	15.7	66	60
Sourwood (Oxydendrum arboreum)	19.9	18.2	77	70
Sumac (R. hirta)	17.9	16.9	69	65
Sugarberry (Celtis mississippiensis)	18.5	17.1	71	66
Sycamore (P. occidentalis)	18.5	16.6	71	64
Umbrella (Mag. fraseri)	15.5	13.8	60	53
Walnut, black (J. nigra)	20.8	18.6	80	72
Willow, black (S. nigra)	13.5	10.9	52	42
Western, black (S. lasiandra)	15.5	13.4	60	52
Witch hazel (H. virginiana)	21.8	20.1	84	77
Yellow poplar (L. tulipifera)	15.1	13.9	58	53

TABLE 8.—*Heat values of cordwood, based on Madison Laboratory weights*.—Con.

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Cedar, incense (L. decurrens)	14.5	12.3	56	47
Port orford (C. lawsoniana)	16.3	15.5	63	60
Western red (T. plicata)	12.1	11.7	47	45
White (T. occidentilis)	11.3	10.7	43	41
Cypress, bald (T. distichum)	16.4	14.5	63	56
Yellow (C. nootkatensis)	15.8	15.1	61	58
Douglas fir, Pacific coast (P. taxifolia)	17.7	17.3	68	67
Rocky Mountains	15.6	15.1	60	58
Fir, alpine (A. lasiocarpa)	12.0	11.5	46	44
Amabilis (A. amabilis)	15.1	12.9	58	50
Balsam (A. balsamea)	13.5	11.5	52	46
Lowland white (A. grandis)	15.1	13.3	58	51
Noble (A. nobilis)	14.3	13.7	55	53
Silver, white (A. concolor)	14.3	11.1	55	43
Hemlock, black (T. mertensiana)	17.2	15.7	66	60
Eastern (T. canadensis)	15.0	12.8	58	49
Western (T. heterophylla)	15.0	13.5	58	52
Larch, western (L. occidentalis)	19.3	17.9	74	69
Eastern (L. americana)	19.1	18.1	73	70
Pine, Cuban, slash (P. heterophylla)	22.4	21.6	86	83
Jack (P. divaricata)	15.7	13.4	60	52
Jeffrey (P. jeffreyi)	15.0	12.9	58	50
Loblolly (P. taeda)	19.9	18.1	77	70
Lodgepole (P. contorta)	15.0	13.8	58	53
Longleaf (P. palustris)	22.0	21.1	85	81
Norway (P. resinosa)	17.8	16.8	68	65
Pitch (P. rigida)	18.5	16.4	71	63
Pond (P. serotina)	20.0	18.7	77	72
Shortleaf (P. echinata)	19.9	18.5	77	71
Sugar (P. lambertiana)	14.3	11.7	55	45
Table Mountain (P. pungens)	19.3	17.2	74	66
Western white (P. monticola)	15.7	14.6	60	56
Western yellow (P. ponderosa)	15.0	13.1	58	50
White (P. strobus)	14.2	12.9	55	50
Spruce, Engelmann (P. engelmanni)	11.9	10.5	46	40
Red (P. rubra)	15.0	14.2	58	55
Sitka (P. sitchensis)	13.5	12.7	52	49
White (P. canadensis)	14.1	13.5	54	52
Yew, western (T. brevifolia)	24.4	23.2	94	89
Redwood (S. sempervirens)	14.3	12.9	55	50
Coal, long ton (2,240 pounds)	29.1			
Short ton (2,000 pounds)	26.0			

NOTE.—Values given for resinous woods are low, since resin adds to heating value; for instance, dry longleaf pine with 20 per cent resin has a value of approximately 26,400,000 B. t. u., instead of the 22,000,000 given in the table. The amount of bark in a cord of wood also affects the heating value; for instance, bark of birch, Douglas fir, western yellow pine, and others has a higher value than the wood. Much of the theoretical value of both wood and coal is lost in use. While anthracite and soft coal have about the same theoretical value, only from 70 to 75 per cent of this value is realized with anthracite and from 60 to 65 per cent with bituminous coal. Values decrease as temperature of flue gases increases. To get values for wood only partly seasoned it may be assumed that in most cases it will be about half seasoned in three months, two-thirds seasoned in six months, and entirely air-dry in about a year.

It may be seen from this table that the heating power of a given quantity of green wood is not so very much below that of the same wood after it has been dried. The choice of wood for fuel does not, however, depend entirely upon its calorific power; other factors, such as freedom from smoke, completeness of combustion, and rapidity of burning, play a very important part. Green wood is not only much heavier to handle but it is also harder to ignite and to keep burning, unless mixed with dry wood or with coal, and makes more smoke. For a slow fire green wood or a mixture of green and dry wood is often more satisfactory than dry wood alone, since the latter burns up rapidly and much of its heat escapes up the pipe.

Heating values of different parts of the same tree may vary considerably, because of differences in moisture content, proportion of bark to wood, and other factors. Tests made by the department of forestry of the Michigan Agricultural College gave the following results:

Position.	Moisture.	Dry matter.	British thermal units (per pound).	
			Green wood.	Dried wood.
	Per cent.	*Per cent.*		
Beech, sap, near stump	40.2	59.8	5,534.4	9,253.5
Beech, heart, near stump	25.2	74.7	7,258.0	9,718.5
Beech, sap, near top	44.1	55.9	5,086.6	9,098.5
Beech, limb, 2 inches diameter	36.2	63.8	5,888.4	9,227.1
Maple, sap, near stump	36.1	63.9	5,581.9	8,735.8
Maple, heart, near stump	32.8	67.2	5,870.8	8,735.8
Maple, sap, near top	30.8	69.2	6,099.1	8,813.3
Maple, limb, 2 inches diameter	35.7	64.3	5,817.2	9,045.8

In a number of species the bark has a higher heating value than other parts of the tree. In the Northwest, Douglas fir bark is often a principal source of fuel in firing donkey engines. The bark of shagbark hickory has a high fuel value and burns with intense heat, but with much crackling. In the case of many woods, such as the cedars, the bark has a comparatively low fuel value and leaves a large proportion of ash.

Root wood is little used for fuel, mainly because of the difficulty in getting it and its awkward form. It is interesting to note, however, that the roots of mesquite are capable of producing more heat than the average butt cut, and are commonly dug up for firewood where other wood is very scarce. Very often mesquite roots are so much more developed than the rest of the tree that the name "underground forests" has been applied to stands of the timber in semiarid regions.

The rapidity of burning may be important where quick heating is desired. As a general rule the softwoods burn more readily than the hardwoods, while the lighter hardwoods burn more readily than the heavier ones. The pines, for instance, give a quicker, hotter fire and are consumed in a shorter time than birch, but birch gives a more intense flame than oak. On the other hand, the oaks give a more steady heat. Less than 5 per cent of the wood used as fuel is consumed in the industries, the remainder, or more than 95 per cent, being used for domestic purposes, where such qualities as ease of ignition, rapidity of combustion, freedom from smoke, uniform heating, or quickness of burning, depending on the particular results desired, are more important than calorific value. A few species, such as chestnut, butternut, tamarack, and spruce, are in ill favor for open fires because they throw off sparks.

Another point worth bearing in mind in connection with the burning of wood in place of coal is the difference in the amount of ash produced. A cord of hardwood will make only about 60 pounds of ashes, while a ton of hard coal will make from 200 to 300 pounds.[1]

A pound of wood briquet, irrespective of species, should have about the same heat value as dry wood, probably a little higher, on account of the heat value of the organic binder (if one is used), which may have a greater unit heat value than wood and thus raise the average slightly. If the resins in the wood are used as binders the same result may be expected. In comparing briquets with cordwood or stove wood it must be remembered that the briquet is usually drier and will therefore generate more heat per pound of material than will wood.

In actual use wood fuel does not always show up as favorably in comparison with coal as the above heat values would indicate. This is probably due to the fact that it is not the actual heat-producing power of the fuels that is compared but the efficiency of the apparatus for utilizing the heat. Wood requires about one-third more grate surface and two-thirds more cubical space than coal for generating an equal amount of steam.

In logging engines a ton of good grade bituminous coal is considered equivalent to a cord and a half of air-dry oak or two cords of softwood. Two and a half cords of pine knots (about 125 cubic feet) are thought to furnish about the same amount of steam as 1 ton of southern soft coal. For general calculations for stationary engines 1 ton of coal is considered equivalent to 2 cords of wood, or 1 pound of coal to 2¼ pounds of wood. During the winter of 1917–18

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[1] Since potash is now greatly in demand, the quantity which may be obtained from wood ash is worth consideration.

The quantity of ashes obtained from a cord of wood varies with the conditions under which it is burned. About 30 cords of hardwood produce a ton of ashes equal in quantity to the Canadian wood ashes of commerce; but the same quantity of wood consumed as fuel in a cook stove or other small, closed burner would be far more completely reduced and would produce only about one-third to two-thirds of a ton of ash. On the other hand, commercial hardwood ashes contain only 5 per cent of the valuable fertilizer potash, whereas stove ashes contain from 10 to 15 per cent, so that the amount of potash to be had from a cord of wood is about the same however the wood is burned and regardless of the bulk of the resulting ash. Softwood ashes contain on an average about one-third less potash than hardwood ashes, and the quantity of ash obtained from softwoods is less than from the same bulk of hardwood. The present price of potash, about 25 cents a pound, or $500 a ton, almost prohibits its use in fertilizers.

It is important always to keep wood ashes under cover, as they leach rapidly if allowed to become damp. New ashes should be allowed to cool before they are dumped on the ash heap.

It is estimated that the ashes from a cord of northern hardwoods will furnish about 20 pounds of lime, more than 3 pounds of potash, and a half pound of phosphoric acid, and that they have a value at present prices of about $1.

H. J. Wilder, agriculturist of U. S. Department of Agriculture (letter to Mr. A. F. Hawes, July 18, 1918): Hardwood ashes which have not been wet analyze about 5 per cent potash, 30 to 35 per cent lime, both in desirable forms. Potash contents of softwoods is rarely below 3 per cent. Hardwood ashes have 600 to 700 pounds lime per ton of ashes. Mixture of coal ashes from factories would do no harm.

one factory which normally used 50 tons of soft coal a day used for a month in mid-winter a minimum of 15 tons of coal and 50 cords of mixed hardwood daily, from which the conclusion may be drawn that for steam production 1 cord of green hardwood is equal to seven-tenths of a ton of soft coal. Careful tests made in Georgia showed that to keep a room at a comfortable temperature with an open-hearth fireplace nearly 10 times as much wood must be consumed as when a stove is used. This plainly indicates that it is very uneconomical to depend on open fireplaces alone for heating houses.

WOOD FUEL FOR THE FUTURE.

GROWING TIMBER FOR FUEL.

There is probably a general impression that timber for firewood can be grown rather rapidly, within a period of 5 to 10 years. This will not hold true for general forest areas, especially hardwoods. From 20 to 50 years and even longer are required to produce a full stand. The sprout forests of southern New England will grow a crop of wood in 10 or 15 years and perhaps less; a full stand, however, requires more time. Planted catalpa on good soil will yield fairly well in 8 or 10 years; and eucalyptus or blue gum will produce a heavy growth in five or six years. Willow and cottonwood on suitable sites will yield firewood in from 10 to 15 years, but usually a longer time is required for large yields even with these rapidly growing species. Old field and white pine make rapid growth and yield heavily in a comparatively short time. With hardwoods like oak, hickory, maple, beech, birch, etc., not much can be expected in less than from 30 to 50 years.

An average of 1 cord of fuel wood per acre per annum is a large yield, taking the country as a whole. Hardwood forests will probably not average more than three-fourths of a cord growth per year and many will not make more than one-fourth of a cord. With the faster-growing species 2 cords per acre is a high average annual yield even on favorable sites. With average natural stands of cottonwood, cordwood can be obtained in about 16 years, with a total yield of approximately 42½ cords per acre, or an annual yield of 2.7 cords. Under particularly favorable conditions of growth the time may be shortened to 12 years, especially where thinning and cultivation are possible. Since stands cut for cordwood can be most easily renewed by coppicing, the second rotation should be much shorter than the first because of the more rapid growth of the sprouts. Eucalyptus in California is reported to yield as high as 7 cords per acre per annum on a comparatively short rotation. With the pines a yield of over 4 cords per acre per annum has been reached. Only on the best sites and under suitable climatic conditions can such yields be expected even with these species.

FORESTRY.

It will not do for communities in wooded regions to depend on the chance growth of wood for their future fuel supply. Already many communities, especially in the Northeast, are finding it necessary each year to go farther and farther back for their wood, or to cut smaller trees each succeeding year, because the available supply of standing wood is too small to allow the trees to grow to the proper size before they are cut.

It is not too much to expect that the time will come—and soon in some regions—when it will be necessary to provide definitely that certain areas be set aside to produce wood, and that they be so managed as to produce the maximum amount of wood possible within the shortest possible time. It is not desirable to devote good agricultural land to growing an annual supply of fuel; generally the inferior land on farms will grow sufficient fuel to supply regularly each year's needs. Farms with such land are numerous in the hilly sections of the country, and are found almost everywhere except in the prairie and plains regions and in limited areas in the river bottoms.

Meanwhile, the least that should be done is to see that fire and other destructive agents are kept out of growing woodland, and that when cutting is done for firewood only that material is taken out whose removal will not cause injury to the productive capacity of the remaining stand. Advice on these matters will be freely given by the various State forestry departments, or where they are not available, by the Forest Service of the United States Department of Agriculture.

MUNICIPAL FORESTS.

Acute need for fuel in emergencies furnishes one of the strongest arguments for maintaining municipal forests by cities or towns in wooded districts where this is possible. These emergencies may be expected periodically, and municipal forests serving as parks and pleasure grounds or as protection to water supplies can come into play as fuel reserves in time of stress when coal can not be obtained in sufficient quantities for the needs of the communities. It is a point well worth the thoughtful consideration of every community which has woodland adjacent to it suitable for this purpose. Some towns already own such tracts, and no doubt there will eventually be many of these forests in the older settled sections of the country when it is found how easily they are handled and how advantageous they are in many respects. Instead of being sources of expense, well-managed woodlands should quickly become sources of considerable revenue to the communities owning them.

PROMOTING USE OF WOOD FOR FUEL.

PUBLICITY.

Where wood fuel has been little used or its use has been discontinued for a long time, a great deal can be done toward developing a demand for it by means of newspapers, motion pictures, illustrated talks, "cut-a-cord" clubs, "cutting bees," and posters. Newspapers are usually most active in advertising the work when fuel conditions are acute. In the depth of winter when a shortage is severe it is a matter of news and is "played up" a great deal, but at other times it is difficult to use this medium of publicity. Motion pictures may be used, with short, pithy sentences embodying facts about wood fuel. Lantern slides are being used to illustrate talks on wood fuel given before clubs and various local organizations interested in the subject. Posters carrying catchy slogans and condensed information have been devised in several States and have been very effective.

"Cutting bees," so called, are organized efforts at getting out wood by a crowd and are in the nature of a picnic. They are carried on with great enthusiasm and rivalry, and well serve the purpose of advertising the need of wood fuel and the means of getting it. Other forms of organization can be used which suit the particular locality and the spirit of the people, or existing organizations can be turned in this direction.

"Cut-a-cord" club, as organized in New England and some other sections during the winter of 1917–18, carry the "cutting bee" idea still farther. Each member agrees to cut a definite amount of wood, either one cord or several. Organization is made semipermanent, so that the work is carried on more systematically than in the more or less spontaneous "bees."

Many other ways can, of course, be devised to suit local conditions and to arouse interest and action. The essential point is to arouse the public from its inertia.

When the public realizes the necessity of returning to wood fuel the advertising campaign is mainly finished. It should be succeeded by a campaign of instruction in methods of producing wood fuel and in organization for its production and distribution. With the population concentrated at a distance from its fuel supply, as a large part of it is to-day, and not accustomed to providing fuel in advance of need, individuals are not able to cope with an emergency brought on by war, prolonged congestion of transportation, or interference with coal production.

A number of different organizations have been developed to meet this situation, such as wood fuel committees, war fuel companies, municipal wood yards, and "cut-a-cord" clubs.

The wood fuel committees may be State, county, or community organizations. In some States all three are used and all work more or less closely with the Fuel Administration. Many municipalities appoint such committees temporarily during the emergency winter season to organize means of production and transportation of wood as well as to equalize its distribution and price. All these committees should be made permanent, for much effective work can be done by them during that part of the year when conditions are not so acute.

As usually organized, a war fuel company is a stock company made up of public-spirited citizens operating under a charter duly registered with the State. The object is to buy and sell wood and coal at a low rate of return on the money invested, for the purpose of alleviating the undesirable conditions that are bound to follow wherever sufficient fuel can not be had by families, business concerns, and public institutions. The rate of profit is sometimes limited to not more than 6 per cent and the proceeds are turned over to some public charity.

WOOD FUEL LEGISLATION.

Doubtless in many cases State legislation would help to promote the use of wood fuel. Price regulation, measuring, shipping, marketing, and other features may be aided by specific laws adapted to local conditions.

In Virginia an order has been issued by the Federal Fuel Administrator for the State prohibiting any person residing outside the cities or incorporated towns from obtaining coal except by special permit from the local administrator upon the execution of a statement to the effect that wood is not available. This was done to bring about the substitution of wood for coal to a very appreciable extent without imposing serious hardship on those required to use wood. Similar restrictions for most localities in the eastern United States would seem desirable as a reasonable means of bringing about a greater use of wood fuel by those who have wood around them or can obtain it readily. This method is sufficiently elastic to accomplish the object aimed at without working hardship on those who can not reach wood. It should be especially valuable in the matter of coal embargoes which may be suddenly found absolutely necessary in the depth of winter in a fuel crisis. When an embargo must be laid, it should be a flexible one and the heaviest restrictions placed on those localities where wood is available and on those consumers who can use wood fuel. In this way coal may be conserved and the evil effects of a blanket embargo avoided.

MUNICIPAL WOOD YARDS.

In many places municipalities themselves organize wood yards to purchase, manufacture, and distribute wood fuel, in order to supplement the regular supply where no other agencies exist to take the whole field. Wood handled by them is usually sold at cost.

In some States a grant of specific power is necessary before a municipality can engage in the fuel business. In many cases in the eastern United States last winter this fact was a serious obstacle which prevented cities and towns from taking active relief measures to keep the people warm and supply power to essential commercial enterprises. In two States, Maine and Mississippi, public fuel yards are specifically authorized by law. The Mississippi law, approved April 21, 1918, authorizes municipal wood and coal yards.[1] The essential features of this law are of especial interest in view of the country-wide effort being made to provide against a fuel shortage in the future. By this law—

(*a*) The authorities of every municipality are authorized to establish and operate wood and coal yards until one year after the close of the war, for the purpose of supplying the inhabitants with fuel.

(*b*) A municipality which establishes and operates a wood yard or coal yard has full power to create, fill, discontinue, or abolish all such offices or employments in connection therewith as may be deemed necessary or proper; to fix and pay salaries; to cut, purchase, transport, sell, and deliver wood or coal necessary for providing the inhabitants with fuel; from time to time to fix the selling prices and the terms of sale; and to make and enforce such rules and regulations as may be necessary for the carrying out of the act.

(*c*) The necessary funds are to be set aside out of the general municipal fund, or borrowed at interest on the credit of the municipality.

(*d*) In order to borrow money for this purpose the municipality is required to publish in local papers, for a period of ten days, a full statement of its intentions, stating the sum needed and rate of interest to be paid. In case a protest signed by at least 25 per cent of the qualified electors of the municipality is filed before the expiration of the period of advertisement, the question must then be submitted in an election requiring for passage the approval of a majority of the qualified electors.

Similar action by other States is desirable.

WOOD FUEL RESERVES.

There is considerable difficulty in getting wood into suitable form for fuel and transporting it to the market on short notice. It is only a matter of good business foresight for those communities which have the wood around them to see that some time during the season a sufficient supply is cut and hauled to where it may be easily available as a reserve for the winter season. The time to cut it is at any slack time during the year, preferably in the spring, so that it will have time to season thoroughly by the next winter.

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[1]Although Mississippi is the first State to respond with a law on the subject in the present emergency, it is not actually the first to pass such legislation. As early as 1903 Maine passed a law allowing cities to establish public yards for sale of wood, coal, and other fuel without financial profit. The Maine law has been sustained by the highest court in the State and also by the United States Supreme Court.

In this connection it is very desirable that reasonably close estimates be made in advance of the amount of wood which will be available to different communities from all sources. It would be a comparatively simple undertaking to secure estimates of the amount of fuel wood which is ready for use or which it is planned to cut for the next winter. The figures should include (1) the number of cords used in the previous year; (2) the number of cords cut, including the amount left over from the previous winter; (3) the number of cords to be cut for winter, say from September 1 to December 31. Such figures would afford valuable bases not only for organizing wood fuel work but also for allotting supplies of coal.

SUMMARY.

1. With enormous supplies of wood widely distributed over much of the United States, especially the eastern half, there is no excuse for suffering because of inability to get coal.

2. Wood is already widely used in rural districts; its use can and should be greatly extended, at least during the present crisis, to save coal and cars for more essential uses.

3. Wood can be substituted for coal with greatest public benefit in places where rail-hauled coal can be replaced with wagon-hauled wood. Long distance rail transportation of wood is not economical.

4. Domestic consumers in rural districts and small cities can most easily substitute wood fuel for coal. Most types of stoves and furnaces can be adapted to the use of wood.

5. Except in case of plants which use their own wood refuse, or others in the close vicinity of such plants, wood fuel is less economical than coal for factories. When coal can not be had, however, wood can be used with fairly satisfactory results, and is cheaper than shutting down the plant.

6 The widespread use of wood for fuel, if only such wood as is best fitted for this purpose be taken, will be of great benefit to our forests as well as a source of revenue to their owners.

7. To promote the use of wood fuel, especially where it is not now in general use, will require organized effort, preferably by community, municipal, or State organizations. Such effort should cover the stimulation of demand for wood and stimulation of production by private agencies, as well as direct organization of producing, transporting, and marketing of wood fuel by the community.

8. Reserves of wood fuel should be established in all districts where there is a possibility of fuel shortage. For the present these reserves will probably consist largely of wood purchased from producers; it may eventually be advisable for communities to own their own woodlands in order that they may more effectively regulate the cutting and the price of fuel wood.

APPENDIX.

PUBLICATIONS ON WOOD FUEL.

Early in 1917 publications began to appear treating wood fuel briefly with reference to local conditions. They were issued mostly by States, and State foresters were chiefly instrumental in getting them out. The first one appeared in June in the shape of a press bulletin by K. W. Woodward of the New Hampshire Agricultural College, Durham, N. H. This was followed by others until at least 20 have been published. Canada also published one early in 1918 modeled on those put out by the States. Future publications should go into detail as to the quantity of wood fuel available in the State and its distribution, as well as the amount of fuel wood cut and used by specific localities within the State.

RECENT PUBLICATIONS ON WOOD FUEL.

Emergency Fuel from the Farm Woodlot, by A. F. Hawes, Circular 79, Office of the Secretary, U. S. Department of Agriculture. (Contributed by the Forest Service, Washington, D. C., October, 1917.)

Firewood, by K. W. Woodward, Extension Circular 22, September, 1917, New Hampshire Agricultural College, Durham, N. H.

The Fuel Situation, by K. W. Woodward, Extension Press Bulletin 77, June, 1917, Agricultural College, Durham, N. H.

Wood Fuel, by Paul D. Kneeland and F. W. Rane, Massachusetts State Forester's Office, 1917, Boston, Mass.

Wood Fuel, by R. D. Forbes, Assistant Forester, Department of Conservation and Development of New Jersey, 1917, Trenton, N. J.

A press bulletin was issued October 13, 1917, by the State fuel administrator at Greensboro, N. C., urging the cities and towns of the State to furnish wood to consumers at cost as a war measure.

Wood as Emergency Fuel, by J. H. Foster and F. H. Millen, bulletin, department of forestry, Agricultural and Mechanical College, 3d series, vol. 4, No. 2, January 15, 1918, College Station, Tex.

Cordwood for Fuel, by J. H. Pratt and J. S. Holmes, Press Bulletin 160, North Carolina Geological and Economic Survey, January 30, 1918, Chapel Hill, N. C.

Wood Fuel, by William G. Howard, assistant superintendent of State forests, Bulletin 16, conservation commission of New York, 1918, Albany, N. Y.

Wood Fuel to Relieve the Coal Shortage in Eastern Canada, by Clyde Leavitt, chief forester, commission of conservation, Ottawa, Canada, 1918.

Municipal Woodyards, by the Federal Fuel Administrator (Wood Fuel Department for Georgia), Commerce, Ga., February, 1918.

Wood Fuel for Iowa, March, 1918, by Prof. G. B. McDonald, Iowa State College, Ames, Iowa (in cooperation with Charles Webster, Federal fuel administrator for Iowa.)

Coal Conservation and Wood Fuel, March, 1918, State fuel administrator for Minnesota.

Tamarack for Fuel, 1918, issued by the publicity department, Minnesota, commission of public safety, St. Paul, Minn.

Wood Fuel and Democracy, 1918, State fuel administrator of Minnesota, St. Paul, Minn.

Cordwood Producers, list furnished to Minnesota forest service for distribution, March 12, 1918.

Firewood to Relieve the Coal Shortage, Forestry Leaflet No. 19, February 15, 1918, by F. W. Besley, State forester, Maryland State board of forestry, Baltimore, Md.

Firewood and the Woodlot, Press Bulletin 1918, by Edmund Secrest, State forester, Wooster, Ohio.

The Price of Fuel Wood, by William K. Prudden, State fuel administrator, Lansing, Mich., March, 1918.

Wood and the Present Fuel Emergency, by John M. Briscoe, Maine Forestry Association, February 6, 1918, Bangor, Me.

Municipal Woodyards, Circular 2, by T. A. Parker and James B. Berry, of the wood fuel department of United States fuel administration for Georgia, May, 1918.

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Kollock, T.: Efficiency of Wood in Stoves and Open Fireplaces. (Forest, Fish, and Game, Athens, Ga., April, 1911, Vol. 3, No. 6, pp. 95–97.)

Kreisinger, Henry and others. Combustion of Coal and Design of Furnaces. 144 p. il., pl., diagrams. Washington, D. C., 1917. (U. S. Department of the Interior, Bureau of Mines. Bulletin 135.)

Kreisinger, Henry: Five Ways of Saving Fuel in Heating Houses. 13 p. Washington, D. C., 1918. (U. S. Department of the Interior, Bureau of Mines. Technical Paper 199.)

Pierson, Albert H.: Consumption of Firewood in the United States. 7 p. Washington, D. C., 1910. (U. S. Department of Agriculture, Forest Service. Circular 181.)

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Schenck, C. A.: Heating Power of Wood (in his Forest Utilization, Biltmore, N. C., Biltmore Forest School, 1904, pp. 64–65.)

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 754

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 26, 1919

INHERITANCE OF WAXY ENDOSPERM IN MAIZE.

By J. H. KEMPTON, *Assistant in Crop Acclimatization.*

CONTENTS.

ENDOSPERM TEXTURE IN MAIZE.

In 1908 Mr. G. N. Collins found in a variety of maize imported from China a new type of endosperm which was entirely unlike the endosperms of any other varieties previously known, being neither horny, starchy, nor sweet. This new texture of the endosperm was designated cereous or waxy, which well describes its appearance, the cut surface of the seed resembling a hard wax (3).[1]

[1] Serial numbers in parentheses refer to "Literature cited," page 99.

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In subsequent breeding work this waxy endosperm was found to be alternative to horny endosperm, behaving as a recessive character when crossed with American flint and dent varieties. The new endosperm character has proved to be adapted for investigation of some of the problems of heredity in maize. The inheritance is definitely alternative, no blending or intermediate stages having been found. This absence of intergradations between the new waxy endosperm and the other endosperm textures simplifies the classification of material and renders the numerical relations of this character more definite and hence of more significance than those observed with other Mendelian characters of maize thus far studied where intermediates are comparatively common.

In the first crosses that were made the behavior of the waxy endosperm was very similar to that of a Mendelian unit character, the approximation being so close that the deviations were at first considered accidental. But with the progress of the investigation and the accumulation of larger numbers of individuals it became apparent that the deviations from the theoretical Mendelian ratios, though never large, were too definite to be ascribed to chance. It further developed that a correlation existed between the waxy texture of the endosperm and the red and blue colors in the aleurone cells of the Chinese maize in crosses with other varieties.

This bulletin reports the results of a series of crosses between the Chinese variety and an African pop corn made for the further study of the correlation between the endosperm texture and the color of the aleurone. In these experiments large numbers of seeds were classified with respect to the endosperm and aleurone characters. While the results are in the main similar to those previously reported, the experiments now comprise such large numbers of individuals as to place the deviations from the expected ratios beyond question and also to establish more definitely the existence of the correlation between endosperm texture and aleurone color.

The subject became somewhat involved when it was found that the aleurone color had to be resolved into two factors, and it became necessary to analyze the behavior of correlated characters where the correlations are between factors. In attempting to understand the correlations of the characters, both the theory of reduplication (1) and the linkage theory (11) have been kept in mind.

The experiments have yielded a body of evidence that should be of value in testing the general applicability of current theories of the segregation or alternative inheritance of characters and also in testing explanations that may be advanced in the future. To be of value in this connection, it is necessary that the data should be placed on record in the most complete and available form. An effort has been made to tabulate the results in such a way that pedigrees can be traced readily, and it is hoped that the data may have a value apart from the explanations that are suggested or considered in the body of the bulletin.

CROSSES BETWEEN THE ALGERIA AND A CHINESE VARIETY.

FIRST GENERATION.

In 1911, pollen of a plant of the white Chinese variety with waxy endosperm, was used on a plant of a colored variety of pop corn that has been grown under the name Algeria.[1] The resulting ear was indistinguishable from pure seed ears of the Algeria, both the aleurone color and the horny texture of the endosperm of the latter showing complete dominance. This hybrid ear received the number Dh 237.

The same year a cross was made, using the white waxy Chinese variety as the female parent and the Algeria as the male parent. This hybrid ear received the designation Dh 234.

SECOND GENERATION.

Seeds from Dh 234 and Dh 237 were grown in 1912 and in 1913, and 96 hand-pollinated ears were produced. These 96 ears bore four classes of seeds: Colored waxy, white waxy, colored horny, and white horny. The color of the aleurone is discussed later and may therefore be disregarded in analyzing the inheritance of the endosperm texture. The numerical results are presented in Table I.

[1] The original seed of this variety was obtained from Dr. Trabut in Algeria by Mr. W. T. Swingle. Dr. Trabut has recently informed Mr. Swingle that the variety is not an Algerian variety, having been introduced into Algeria from Morocco.

TABLE I.—*Inheritance of endosperm texture in 96 ears of maize, the progeny of the two hybrids Dh 234 and Dh 237.*

[Lines bracketed together in pairs indicate ears borne on the same plant; ears selected for planting are designated by an asterisk (*).]

HYBRID DH 234, CHINESE VARIETY × ALGERIA.

Pedigree No. of—		Number of seeds.				D. ÷ E.	Percentage of waxy.
Progeny ear.	Self-pollinated ♂.	Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8
1099*	1106	657	160	164	−4	0.5	24.3
1100	1103	599	167	149	18	2.5	28.2
1101	1103	533	146	133	13	1.9	27.3
1102	Self	517	129	129	....	....	24.9
1103	...do	272	80	68	12	1.4	29.4
1104	1108	573	136	143	−7	1.0	23.7
1105	Self	609	161	152	9	1.2	26.4
1106	...do	690	182	172	10	1.3	26.3
1108	...do	691	183	172	11	1.4	26.4
1109	1112	402	86	100	−14	2.3	21.3
1110*	1132	745	204	186	18	2.2	27.5
1111*	Self	747	165	186	−21	2.6	22.2
1112	...do	733	201	183	18	2.2	27.4
1113	1118	643	181	160	21	2.8	28.1
1114	1118	428	120	107	13	2.1	28.0
1115	1112	508	137	127	10	1.5	27.9
1116	1118	322	83	80	3	.5	26.0
1117	Self	564	137	141	−4	.5	24.2
1118	...do	623	137	155	−18	2.4	21.9
1119	1108	414	107	103	4	.6	25.8
1120	1117	655	145	163	−18	2.4	22.1
1121	Self	687	152	172	−20	2.6	22.5
1515	...do	555	139	139	....	....	25.0
1518	1726	510	110	127	−17	2.6	21.5
1519	Self	605	143	151	−8	1.1	23.8
1522	1732	275	63	69	−6	1.2	22.9
1523	Self	571	119	143	−24	3.4	20.8
1524	1724	773	166	193	−27	3.3	21.5
1525	Self	212	45	53	−8	1.9	21.3
1526	1744	522	140	130	10	1.5	26.8
1527	Self	614	143	153	−10	1.4	23.3
1529	...do	334	71	83	−12	2.3	21.2
1530	1733	676	133	169	−36	4.7	19.7
1531	Self	659	149	165	−16	2.1	22.6
1532	1729	707	151	177	−26	3.4	21.4
1533	Self	679	154	170	−16	2.1	22.7
1534	...do	492	107	123	−16	2.5	21.7
1535	1742	440	100	110	−10	1.6	22.7
1536	1731	725	172	181	−9	1.1	23.7
1537	Self	592	136	148	−12	1.7	22.9
1538	1733	609	150	152	−2	.3	24.6
1539	Self	626	146	156	−10	1.4	23.3
1540	1736	679	152	170	−18	2.4	22.4
1541	1736	631	159	158	1	.1	25.2
1542	1723	515	120	129	−9	1.4	23.3
1543	Self	570	119	142	−33	4.7	20.9
1544	....	491	111	123	−12	1.9	22.6
1545	Self	417	101	104	−3	.5	24.2
1546	1747	800	205	200	5	.7	25.0
1547	1537	633	140	158	−18	2.5	22.2
1548	1748	607	146	152	−6	.8	24.0
1549	Self	479	118	120	−2	.3	24.6
1550	1740	383	79	96	−17	3.0	20.6
1551	Self	578	123	144	−21	3.0	21.2
Total	....	30,571	7,309	7,643	−334	7.5	23.9

TABLE I.—*Inheritance of endosperm texture in 96 ears of maize, the progeny of the two hybrids Dh 234 and Dh 237*—Continued.

HYBRID DH 237, ALGERIA × CHINESE VARIETY.

Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of waxy.
Progeny ear.	Self-pollinated ♂.	Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8
1122		648	139	162	− 23	3.7	21.4
1124		672	157	168	− 11	1.5	23.3
1125	Self	837	201	209	− 8	.9	24.0
1127	1125	723	177	181	− 4	.5	24.4
1128	Self	319	80	80			25.0
1129*	do	747	180	187	− 7	.8	24.1
1130*	1135	741	155	185	− 30	3.7	21.0
1131*	1117	584	134	146	− 12	1.7	22.9
1132	Self	575	134	144	− 10	1.4	23.3
1133	do	758	187	189	− 2	.2	24.6
1134*	1118	446	73	111	− 38	6.1	16.4
1135	Self	627	135	157	− 22	3.0	21.5
1136	1137	615	176	154	22	3.0	28.6
1137	Self	740	193	185	8	1.0	26.0
1138	1135	548	140	137	3	.4	25.1
1720	1515	459	141	115	26	4.2	30.7
1721	Self	712	165	178	− 13	1.7	23.2
1722	1543	677	162	169	− 7	.9	23.9
1723	Self	664	136	166	− 30	4.0	21.0
1724	1523	374	119	93	26	4.5	31.8
1725	1519	472	114	118	− 4	.6	24.2
1726	Self	560	122	140	− 18	2.6	21.6
1727	1926	503	110	126	− 16	2.4	21.9
1729	1533	613	169	153	16	2.2	27.1
1730	1539	401	92	100	− 8	1.4	22.9
1731	1536	532	126	133	− 7	1.0	23.7
1732	1522	419	95	105	− 10	1.7	22.7
1733	1741	634	161	158	3	.4	25.4
1734	1531	516	119	129	− 10	1.5	23.1
1735	1540	458	102	114	− 12	1.9	22.3
1736	Self	595	138	149	− 11	1.5	23.2
1738	do	472	119	118	1	.2	25.2
1740	1550	630	161	157	4	.6	25.6
1741	Self	485	110	121	− 11	1.7	22.7
1742	1535	559	119	140	− 21	3.0	21.3
1743	Self	575	118	144	− 26	3.7	20.5
1744	1526	512	133	128	5	.8	26.0
1745	Self	625	149	156	− 7	1.0	23.8
1746	1547	621	162	155	7	1.0	26.1
1747	Self	658	147	164	− 17	2.3	22.7
1748	1548	538	139	134	5	.7	25.8
1749	Self	342	90	85	5	.9	26.3
Total		24,186	5,779	6,047	−268	5.9	23.9
Total for both hybrids		51,759	13,088	13,690	−602	8.8	23.9

EXPLANATION OF TABLE I.

In column 1 of Table I is found the pedigree number of the individual ears. When it so happened that two ears borne on the same plant were pollinated in such a way that they both appear in the same table, they are bracketed together, thus facilitating a comparison of the behavior of two crosses having the same female parent and different male parents.

Column 2 gives the pedigree number of the ear that resulted from self-pollinating the plant that served as the male parent of the ear in column 1.

Thus, for example, the first two ears were borne on the same plant but were fertilized with pollen secured from different plants. The male parent of ear No. 1099 bore the self-pollinated ear No. 1106, while the male parent of ear No. 1100 bore the self-pollinated ear No. 1103. The seed classes of these self-pollinated ears can be found by referring to Nos. 1106 and 1103, where they occur in their numerical places in column 1.

In column 2 the word "Self" indicates that the ear represented in column 1 is the result of self-pollination.

As a further example, Nos. 1104 and 1105 may be taken. It is here possible to compare the result of crossing with a sister plant, the behavior of which, when self-pollinated, is shown under No. 1108, with the result of self-fertilizing the same plant.

Columns 3, 4, and 5 are self-explanatory. Column 6 gives the deviation of the observed from the expected number of seeds, on the assumption that horny and waxy were approximating a 3 to 1 ratio.

Column 7 (headed D÷E) gives the number of times the observed deviation (D) exceeds the probable error (E), and affords a basis for judging whether the difference between the observed and expected is a real or chance deviation. To facilitate the translating of D÷E into probabilities, reference may be made to Table II, which shows the values copied without recalculation from Pearl and Miner (12). It was not thought necessary in Table I to include the probable errors, which were calculated by the formula

$$0.6745\sqrt{0.25\times0.75}\times\sqrt{\text{total seeds}},$$

since their only present use is in comparison with the deviations.

The 96 ears shown in Table I were the results of self-pollinations, crosses between sister plants, or crosses between the two hybrids. In all cases the expected percentage of waxy seeds was 25. The progeny of the two hybrids have been examined and tabulated separately, but as no significant differences were found between them, it will save space to consider them as a single group.

The 96 ears produced a total of 54,759 seeds, of which 23.9 per cent were waxy. This deviation of 1.1 per cent from the expected

25 per cent, though seemingly small, is nevertheless 8.8 times the probable error and could be expected to occur as the result of chance only once in over a billion times. The percentage of the individual ears ranged from 16 to 32.

Table II.—*Probability of occurrence of statistical deviations of different magnitudes relative to the probable error.*[1]

Deviation (probable error).	Odds against the occurrence of a deviation as great as or greater than the designated one.	Deviation (probable error).	Odds against the occurrence of a deviation as great as or greater than the designated one.	Deviation (probable error).	Odds against the occurrence of a deviation as great as or greater than the designated one.
1.0	1.00 to 1.	2.5	9.89 to 1.	4.0	142.26 to 1.
1.1	1.18 to 1.	2.6	11.58 to 1.	4.1	174.75 to 1.
1.2	1.39 to 1.	2.7	13.58 to 1.	4.2	215.92 to 1.
1.3	1.63 to 1.	2.8	15.95 to 1.	4.3	267.10 to 1.
1.4	1.90 to 1.	2.9	18.80 to 1.	4.4	332.33 to 1.
1.5	2.21 to 1.	3.0	22.26 to 1.	4.5	415.67 to 1.
1.6	2.57 to 1.	3.1	26.40 to 1.	4.6	519.83 to 1.
1.7	2.98 to 1.	3.2	31.36 to 1.	4.7	656.89 to 1.
1.8	3.45 to 1.	3.3	37.46 to 1.	4.8	825.45 to 1.
1.9	4.00 to 1.	3.4	44.87 to 1.	4.9	1051.63 to 1.
2.0	4.64 to 1.	3.5	53.95 to 1.	5.0	1350.35 to 1.
2.1	5.38 to 1.	3.6	64.79 to 1.	6.0	19,230 to 1.
2.2	6.26 to 1.	3.7	78.37 to 1.	7.0	434,782 to 1.
2.3	7.28 to 1.	3.8	95.15 to 1.	8.0	Over a billion.
2.4	8.48 to 1.	3.9	116.23 to 1.		

[1] Copied without recalculation from Pearl and Miner (12).

One ear deviated below the expected by 6.1 times the probable error, but with 96 individuals the odds against a deviation of this magnitude would be about 190 to 1.

A similar shortage of waxy seeds has been observed throughout the experiments with this character.

In a previous publication (7) 45 ears were reported, representing many different crosses and having 22,339 seeds with 23.1 per cent waxy, the deviation from the expected 25 per cent being 9.24 times the probable error. Adding this group to the results obtained from the second generation of the two hybrids Dh 234 and Dh 237, there is a total of 77,098 seeds, 18,267 of which are waxy, while the expected is 19,274 waxy seeds, a shortage of 1,007±81 seeds, a deviation of 12.4 times the probable error. A deviation of this magnitude would be expected to occur as the result of chance only once in well over a billion times.

The approximation of the observed percentage of waxy seeds to the theoretical 25 per cent is very close for the individual ears of the hybrids Dh 234 and Dh 237, only two of the ears deviating by larger amounts than could be reasonably ascribed to chance, and of these one was below and the other above the expected percentage. The large number of individuals involved has made it possible to accurately measure small differences which ordinarily would escape unchallenged as very good approximations of actual observation to theory.

The percentages of waxy seeds shown by the individual ears for the first-generation hybrids and those previously reported (7) have been plotted in figure 1, which shows that the deviation from 25 per cent is not the result of a few aberrant ears. It readily can be seen that while the mode and mean are considerably below the expected 25 per cent, the curve very closely approximates the normal probability curve.

Although the graph (fig. 1) bears a striking resemblance to the normal probability curve, there is reason for believing that the indi-

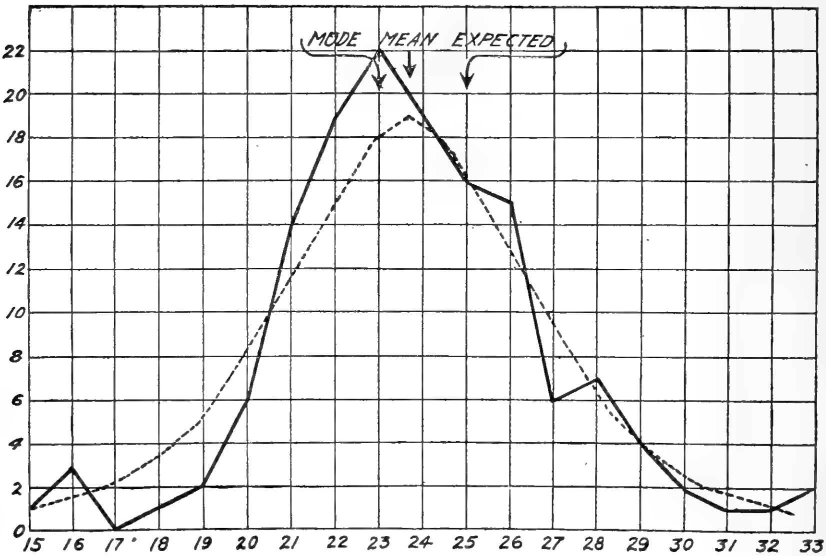


FIG. 1.—Diagram showing the percentage of waxy seeds on 141 ears obtained from the second generation of the hybrids Dh 234 and Dh 237 and the ears previously reported. The dotted line shows the probability curve for this population of 141 ears, the mean and standard deviations being the same.

viduals do not form a homogenous group deviating from a common mean.

As a means of determining whether the varying percentages of the individual ears are chance deviation from the mean of the entire group, a method has been proposed by Yule (16) by which a theoretical standard deviation is calculated, based on the harmonic mean of the observed individual ears.

The "goodness of fit" of the observed standard deviation to the calculated standard deviation is measured by the probable error of the former.

For the ears in the accompanying graph the calculated standard deviation is 1.95, and the observed standard deviation is 3.11. The difference is 8.5 times the probable error.

Since 45 of the individual ears represent crosses between the Chinese variety and horny varieties other than the Algeria, it may be well to examine the curve without these ears. Omitting these 45 ears, the standard deviation is reduced to 2.5, the mean remaining unchanged at 23.9. The theoretical standard deviation is also slightly reduced. The difference is now 5.2 times the probable error, a difference still too large to be ascribed to chance.

Thus while the mean percentage of waxy seeds reappearing in the second generation of waxy × horny hybrids is 23.9, which is too large a deviation from 25 per cent to be ascribed to chance, the individual ear approximations are not sufficiently close to the observed mean to be considered as chance departures from it. The explanation that at once presents itself is that through mistakes in classification a varying number of waxy seeds were being included in the horny group.

Endosperm texture is not subject to the minute spotting encountered in the aleurone color, and in the series of crosses here reported the classes were unusually good, owing to the fact that the Algeria parent was a pop corn and had a minimum of soft starch. Two instances where the endosperm was part horny and part waxy have been reported (5) and four additional seeds have since been found. When these mosaic seeds were planted and self-pollinated, they behaved as normal seeds heterozygous for horny endosperm.

Since mosaic endosperms are known to occur, it is of course conceivable that the horny or waxy portion of the seeds may be so reduced as to escape detection, but since such seeds are heterozygous, the only result could be to erroneously class heterozygous seeds as waxy, but this would increase rather than diminish the number of seeds classed as waxy.

A deficiency in the number of individuals with the recessive character does not readily admit of the explanation that the deviation is due to mistakes in classification. Such an explanation would require that some of the individuals exhibiting the dominant character were in reality homozygous recessives. Where a deficiency in the number of individuals with the dominant character occurs, such deviation could be the result of mistakes in classification, since it is conceivable that a failure or a partial failure of dominance results in some individuals exhibiting the dominant character to such a slight degree as to pass for homozygous recessives. If waxy seeds were being included in the horny group, some all-waxy ears would be secured in self-pollinating plants grown from the horny seeds.

Since the deviation observed was approximately 1 per cent, only one ear of every hundred would be expected to be all waxy. Several hundred ears, the result of self-pollinating plants grown from the horny seeds of waxy × horny hybrids, have been secured, but no all-waxy ears have been found.

The shortage of waxy seeds not only occurs where the expected ratio of horny to waxy is 3 to 1, but was also observed in crosses between waxy endosperm and sweet endosperm where the Mendelian dihybrid ratio was expected (8). Here the deviation was 1 per cent below the expected 18.75, and it should not occur as the result of chance oftener than once in 15,000 times.

THIRD GENERATION OF THE HYBRID DH 234.

Three ears were selected for planting from the hybrid Dh 234. These three ears are Nos. 1099, 1110, and 1111 in Table I. The last two ears were borne on the same plant. Ear No. 1110 represents a cross between the two hybrids and is discussed later, with the results from a similar ear taken from the hybrid Dh 237.

One of the two ears remaining, No. 1111, was self-pollinated, while No. 1099 was the result of pollen from another plant of the same hybrid. Both of these ears were close approximations of the expected 25 per cent waxy, as was also a self-pollinated ear secured from the male parent of No. 1099.

There were four classes of seeds on Nos. 1099 and 1111, colored and white horny and colored and white waxy. These classes were planted separately, and reciprocal crosses were made between white waxy and colored horny and colored waxy and white horny plants. Wherever possible, self-pollinated ears were secured from all the classes, but since the self-pollinated plants grown from waxy seeds resulted in ears all the seeds of which were waxy, these ears do not appear in the tables.

To avoid unnecessary complications, the inheritance of aleurone color is discussed separately from the behavior of the texture of the endosperm. The color of the aleurone appeared not to affect the behavior of the waxy endosperm as far as the percentage of waxy seeds was concerned. The progenies were examined with this point in mind, but since no differences were found it was not thought necessary to discuss the behavior of the colored seeds separately from the behavior of the white seeds.

The results obtained from the progeny of ears Nos. 1099 and 1111 were also examined separately, but presented no significant difference in their behavior, and to avoid unnecessary repetition the progeny of these two ears will be considered together. The progenies of the four classes of seeds from the two ears are separately indicated in Tables III and IV.

WAXY × HORNY.

The ears resulting from pollinating the plants grown from the waxy seeds of pedigree Nos. 1099 and 1111 with plants grown from the horny seeds of these same ears are shown in Table III. Column 1 of Table III gives the pedigree number of the progeny ear of Dh 234 from which the plants that produced the ears in that section of the table were grown. In this same column will be found symbol letters which indicate the character of the seeds from which the plants that produced the ears in the table were grown. The letters *W* and *C* indicate white or colored aleurone. The symbol used for waxy endosperm is *X* and for horny endosperm *H*.

The symbols given first indicate the character of the seeds from which the female parent of the ears in the table were grown. For

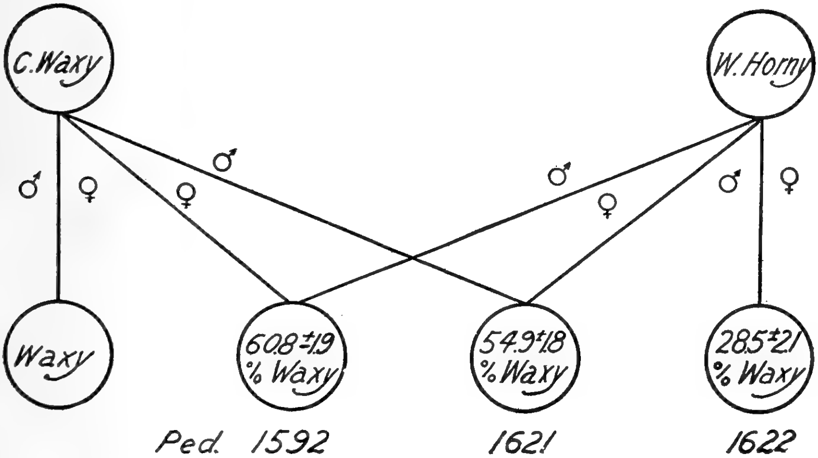


FIG. 2.—Diagram showing the relations of ears Nos. 1592, 1621, and 1622.

example, the first group of five ears which are separated from the following ears by a total are the result of crossing plants grown from the white waxy (*WX*) seeds with plants grown from the colored horny (*CH*) seeds of ear No. 1099. In this group the white waxy plants were used as the female parents. Column 3 in Table III gives the pedigree numbers of the ears representing the reciprocal cross. The classes of seeds produced by the reciprocals are found in Table IV.

There were 11,724 seeds on the 27 ears shown in Table III. The expectation of waxy seeds was 50 per cent, and the observed percentage was 49.5. The deviation of 60 seeds is 1.65 times the probable error and can, of course, be ascribed to chance. Three ears deviated from the expected percentage by more than 3 times the probable error, and one ear, No. 1592, showed a deviation above the expectation of 5.7 times the probable error.

The reciprocal of ear No. 1592 is No. 1621 (Table IV). There was also a self-pollinated ear from the male parent of No. 1592, No. 1622 (Table IV). The relations of these two ears are shown in figure 2.

The difference between the two reciprocal ears is 5.9±2.62 per cent. The self-pollinated ear obtained from the horny parent does not show a significant deviation from 25 per cent. The plant which bore ears Nos. 1621 and 1622 is shown by the cross with waxy to have 60.8 per cent of the male gametes bearing the waxy character and 54.9 per cent of the female gametes with this character.

The expected result of self-pollinating a plant with such a gametic series would be an ear with 33.4 per cent waxy, from which ear No. 1622 with 28.5 per cent deviates 4.9±2.1, a deviation which is not significant. The plant, then, which bore ears Nos. 1621 and 1622 produced an excess of gametes bearing the waxy character, this excess being greater in the male gametes. An excess of male gametes bearing the waxy character is contrary to the results obtained with most of the ears where it was found that the waxy gametes were below instead of above the expected percentage.

The observed excess of waxy seeds on ear No. 1592 might be explained by the assumption that a failure of the dominance of the horny endosperm resulted in some of the heterozygous horny seeds being classified as waxy. Another generation grown from the waxy seeds would throw light on this matter, since if the observed deviation was due to a failure of dominance 10 of every 100 plants grown from the waxy seeds, when self-pollinated, would be expected to result in ears with some horny seeds.

HORNY × WAXY.

As the result of pollinating plants grown from the horny seeds with plants grown from the waxy seeds of ears Nos. 1099 and 1111, 39 ears were obtained (Table IV). In this same table are also shown the ears resulting from self-pollinating the heterozygous horny plants. These ears will be discussed later, but it was thought advisable to include them in Table IV, since it makes possible the comparison of the behavior of the horny plants when self-pollinated with their behavior when pollinated with homozygous waxy. Although only 2 of the 29 ears deviated from the expected percentage in excess of three times the probable error, the deviation for the total number of seeds is 3.9 times the probable error.

TABLE III.—*Inheritance of endosperm texture in 27 ears of maize, the waxy × horny progeny of the two ears Nos. 1099 and 1111, the progeny of hybrid Dh 234.*

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Number of seeds.				D÷E.	Percentage of waxy.
	Self-pollinated ♂.	Reciprocal cross.	Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8	9
Ear No. 1099, *WX×CH:*								
1552	1644	1643	506	227	253	−26	3.4	44.8
1555	1705	None	230	120	115	5	.98	52.2
1563	None	do	257	109	128	−19	3.51	42.4
1564	do	do	438	220	219	1	.14	50.2
1565	1633	1632	114	56	57	− 1	.27	49.1
Total			1,545	732	772	−40	3.02	47.4
Ear No. 1111, *WX×CH:*								
1648	1696	None	712	381	356	25	2.77	53.5
1651	1644	do	286	139	143	− 4	.62	48.6
1652	1700	do	611	302	305	− 3	.36	49.4
1654	1705	do	387	202	193	9	1.3	52.2
1660	None	do	600	283	300	−17	2.06	47.2
Total			2,596	1,307	1,298	9	.52	50.4
Ear No. 1099, *CX×WH:*								
1567		1596	537	283	268	15	1.92	52.7
1569	None	None	404	204	202	2	.29	50.1
1572	1605	1604	127	53	63	−10	2.63	41.7
1574	None	None	645	327	322	5	.58	50.6
1576	1618	1617	519	253	259	− 6	.78	48.8
1579		1610	468	221	234	−13	1.78	47.2
1583	1612	None	503	246	251	− 5	.66	49.0
1584		1623	406	195	203	− 8	1.17	47.8
1590	1620	1619	580	291	290	1	.12	50.2
1592	1622	1621	307	187	153	34	5.7	60.8
1594	1612	1611	764	377	382	− 5	.53	49.4
Total			5,260	2,637	2,630	7	.28	50.1
Ear No. 1111, *CH×WH:*								
1663	None	1684	658	329	329			50.0
1665	1687	1686	403	205	201	4	.59	50.9
1667	None	None	87	45	43	2	.63	51.7
1671	do	do	352	170	176	− 6	1.0	48.3
1674	1612	do	342	153	171	−18	2.89	44.7
1676	None	1690	481	224	240	−16	2.16	46.6
Total			2,323	1,126	1,161	−35	2.15	48.5
Total of the above four groups			11,724	5,802	5,862	−60	1.65	49.6

From an examination of the crosses shown in Tables III and IV it is possible to determine whether the male and female gametes bearing waxy endosperm are produced in equal numbers. All the female gametes in Table III were bearing waxy endosperm, so that the results obtained are the ratios prevailing in the male gametes. In Table IV all the male gametes were bearing waxy endosperm, so that the ratios here represent the proportion prevailing in the female gametes.

TABLE IV.—*Inheritance of endosperm texture in 39 ears of the horny × waxy and 28 ears of the horny × self progeny of the two maize ears Nos. 1099 and 1111, the progeny of hybrid Dh 234.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Horny × waxy.						Horny × self.					
	Self-pollinated ♂.	Reciprocal cross.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1099, *CH × WX:*														
1625	Self								464	99	116	−17	2.7	21.3
1626	All waxy		427	227	214	13	1.86	52.9						
{1627			566	307	283	24	2.99	54.2						
{1628	Self								521	112	130	−18	2.7	21.5
{1629	All waxy		497	273	248	25	3.35	55.0						
{1630	Self								457	97	114	−17	2.7	20.6
{1631			397	213	198	15	2.26	53.6						
{1632	All waxy	1565	298	149	149			50.0						
{1633	Self								318	78	79	− 1	.19	24.5
{1635			703	356	351	5	.56	50.6						
{1636	Self								573	146	143	3	.43	25.5
{1637	All waxy		424	208	212	− 4	.57	49.0						
{1638	Self								573	139	143	− 4	.57	24.3
1639	All waxy		123	65	61	4	1.7	52.9						
{1641			396	196	198	− 2	.29	49.5						
{1642	Self								551	144	133	11		26.2
{1643	All waxy	1552	511	263	256	7	.92	51.4						
{1644	Self								652	166	163	3	.42	25.5
{1645	All waxy	1560	510	255	255			50.0						
{1646	Self								368	86	92	− 6	1.07	23.4
{1647	All waxy		387	193	193			50.0						
Total			5,239	2,705	2,620	85	3.48	51.6	4,477	1,067	1,119	−52	2.50	23.9
Ear No. 1099, *WH × CX:*														
1596	All waxy	1567	292	147	146	1	.17	50.1						
{1600			421	186	210	−24	3.46	44.2						
{1601	Self								270	74	67	7	1.46	27.4
{1602	All waxy	None	322	158	161	− 3	.49	49.0						
{1603	Self								457	118	114	4	.64	25.8
{1604	All waxy	1572	171	88	85	3	.68	51.4						
{1605	Self								365	101	91	10	1.97	27.7
{1606	All waxy	None	391	204	195	9	1.35	52.2						
{1607	Self								257	70	64	6	1.28	27.5
1610	None	1579	303	148	151	− 3	.51	48.8						
{1611	All waxy	1594	689	362	344	18	2.04	52.6						
{1612	Self								447	137	112	25	4.40	31.1
1613	do.								335	80	84	− 4	.75	23.9
{1617		1576	416	219	208	11	1.60	52.6						
{1618	Self								197	63	49	14	3.41	32.0
{1619	All waxy	1590	467	233	233			50.0						
{1620	Self								506	122	126	− 4	.68	24.1

TABLE IV.—*Inheritance of endosperm texture in 39 ears of the horny × waxy and 28 ears of the horny × self progeny of the two maize ears Nos. 1099 and 1111, the progeny of hybrid Dh 234*—Continued.

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Horny × waxy.						Horny × self.					
	Self-pollinated ♂.	Reciprocal cross.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1099, *WH × CX*—Continued.														
1621	All waxy	1592	348	191	174	17	2.7	54.9						
1622	Self								207	59	52	7	1.44	28.5
1623	All waxy	1584	497	263	248	15	1.99	53.0						
1624	do.	None	67	30	33	− 3	1.09	44.8						
Total			4,384	2,229	2,192	37	1.66	50.8	3,041	824	760	64	3.9	27.1
Ear No. 1111, *WH × CX:*														
1682	All waxy	None	448	236	224	12	1.68	52.7						
1683	Self								383	83	96	−13	2.27	21.7
1684	All waxy	1663	485	236	242	− 6	.80	48.7						
1685		None	462	228	231	− 3	.41	49.4						
1686	All waxy	1665	370	198	185	13	2.00	53.5						
1687	Self								565	145	141	4	.57	25.6
1690	All waxy	1676	600	298	300	− 2	.25	49.7						
1692	Self								533	128	133	− 5	.74	24.0
Total			2,365	1,196	1,182	14	.85	50.6	1,481	356	370	−14	1.24	24.0
Ear No. 1111, *CH × WX:*														
1694	Self								578	142	144	− 2	.28	24.6
1695	All waxy	None	393	212	196	16	2.39	53.9						
1696	Self								373	99	93	6	1.05	26.5
1698	do.								540	129	135	− 6	.88	23.9
1699	All waxy	None	511	245	255	−10	1.31	48.0						
1700	Self								451	110	113	− 3	.48	24.4
1704	All waxy	None	192	100	96	4	.85	52.1						
1708	do.	do.	248	121	124	− 3	.56	48.9						
1709	Self								569	156	142	14	2.05	27.4
1710	All waxy	None	458	240	229	11	1.52	52.4						
1711	Self								415	103	104	− 1	.16	24.8
1712	All waxy	None	181	94	90	4	.88	51.9						
1713	do.	do.	179	94	89	5	1.10	52.5						
1714	do.	do.	561	287	280	7	.82	51.2						
1715	do.	do.	304	141	152	−11	1.86	46.4						
1718	do.	do.	290	153	145	8	1.39	52.8						
1719	Self								549	128	137	− 9	1.31	23.3
Total			3,317	1,687	1,658	29	1.5	50.9	3,475	867	869	− 2	.1	24.95
Total of the above four groups			15,305	7,817	7,653	164	3.9	51.0	12,474	3,114	3,118	− 4		25.0

The horny × waxy crosses (Table IV) have a higher percentage of waxy seeds than the waxy × horny crosses (Table III). This difference is 1.4±0.41 per cent, a difference 3.9 times the probable error. While this difference could be expected as the result of chance once in 116 times, a more detailed examination of the material indicates that the difference observed for the totals is not thus to be explained. The four groups on Table IV are the reciprocals of the four groups on Table III. Thus the uppermost group on Table III is the reciprocal of the uppermost group on Table IV, etc.

A comparison of the four groups on Table III with the corresponding four groups on Table IV reveals the fact that in every case the groups on Table III have a lower percentage of waxy seeds. The percentages and probable errors for the four reciprocal groups are shown in Table V.

TABLE V.—*Inheritance of endosperm texture in the progeny of the two maize ears Nos. 1099 and 1111, by groups as shown in Table III and their reciprocals as shown in Table IV.*

Progeny of—	Nature of cross.	Percentage of waxy seeds.			D ÷ E.
		Table VI group.	Reciprocal cross.	Difference.	
Ear No. 1099	*WX* × *CH*	47.4±0.89	51.6±0.47	4.2 ± 1	4.2
Ear No. 1111	do	50.4± .67	50.9± .59	.5 ±0.89	.5
Ear No. 1099	*CX* × *WH*	50.1± .47	50.8± .51	.69± .69	1.0
Ear No. 1111	do	48.5± .7	50.6± .69	2.1 ± .98	2.1
Total	*X* × *H*	49.6± .31	50.6± .27	1.4 ± .41	3.9

Taking each group by itself, the only significant difference is that observed between the *WX* × *CH* and the *CH* × *WX* group from ear No. 1099. In this case the difference is 4.2 times the probable error and should occur as the result of chance but once in 217 times.

As above observed, however, the differences are uniform in that whenever the male parent is heterozygous for horny endosperm and the female parent homozygous for waxy endosperm the percentage of waxy seeds on the ears is lower than in the reciprocal group. This difference in reciprocals indicates a deficiency of effective male gametes bearing the waxy endosperm. This result could be brought about by a higher death rate for the gametes with the waxy character, or a less vigorous growth of the pollen tubes of such gametes, or a failure of the plants to form the gametes in equal numbers.

HORNY × SELF.

As the result of self-pollinating plants grown from the horny seeds of ears Nos. 1099 and 1111, 28 ears were obtained. (Table IV, columns 10 to 15.)

The ears resulting from self-pollinating the plants grown from horny seeds show a remarkably close approximation to the expected 25 per cent of waxy inheritance, the two individual ears that deviated in excess of three times the probable error being no more than could be expected in a group of 28 ears.

With 12,400 seeds the probable error for a 25 per cent ratio is 0.082 per cent. We may, therefore, feel reasonably certain that if the real ratio deviated from the expected by as much as three-tenths of 1 per cent the deviation could have been detected. Furthermore, the distribution of the percentages is as uniform as could be expected. Measured by the method proposed by Yule (16), the range is really smaller than the expected. In other and even larger groups it has been shown that there is a deviation of approximately 1 per cent; and since in these groups the deviation from the observed means was greater than the expected, it becomes almost certain that the deviations are due to the abnormal behavior of some of the individuals rather than to a small and consistent deviation. It would thus appear that the present group differed from the preceding by including none or very few of the aberrant individuals.

SUMMARY OF THE PROGENY OF DH 234.

The total number of ears representing the progeny of the hybrid Dh 234 and expected to have 50 per cent of the seeds waxy is 66. These 66 ears had 27,029 seeds with 50.4 per cent waxy, the deviation in this case being about 1.9 times the probable error.

While the observed percentage of waxy seeds for the 66 ears is a very close approximation to the expected percentage, we have seen that the two major groups, waxy × horny and horny × waxy, that make up this total, differ from each other by an amount that would be expected to occur as the result of chance but once in 116 times.

Had the crosses all been made in one direction—i. e., waxy by horny—there would have been a significant deviation below the expected number of waxy seeds. Had the crosses been confined to horny by waxy, the number of waxy seeds would have been in excess. Since the reciprocal crosses were made in approximately the same numbers, the fit of the observed percentage of waxy seeds for the total to the expected percentage appears good.

THIRD GENERATION OF THE HYBRID DH 237.

Four ears were selected for planting from the hybrid Dh 237. These four ears are Nos. 1129, 1130, 1131, and 1134 (Table I).

The last two ears represent crosses between Dh 237 and Dh 234, and their progenies are considered separately following the analysis of the progeny of ears Nos. 1129 and 1130. These last-mentioned ears were borne on the same plant. Ear No. 1129 was the result of self-pollinating a plant of Dh 237, while ear No. 1130 was the result of pollinating this same plant by another plant of the same hybrid.

Ear No. 1129 had 24.1 per cent of waxy seeds, a close approximation to the expected 25 per cent, the deviation being less than the probable error. The deviation of ear No. 1130 was 3.7 times the probable error below 25 per cent. The plant that served as the male parent of ear No. 1130 bore ear No. 1135, the result of self-pollination. The deviation of this ear was also below the expected 25 per cent by three times the probable error. This fact would indicate that the low percentage of waxy seeds observed on ear No. 1130 was due to the male parent, since there was also a deficiency of waxy seeds when the male parent was self-pollinated.

TABLE VI.—*Inheritance of endosperm texture in 20 ears of maize, the waxy × horny progeny of the two ears Nos. 1129 and 1130, the progeny of hybrid Dh 237.*

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of waxy.
	Self-pollinated ♂.	Reciprocal cross.	Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8	9
Ear No. 1129, *WX* × *CH*:								
1750	1794	None	242	124	121	3	0.57	51.2
1754	1800	do	500	235	250	−15	1.99	47.0
1758	1800	do	439	213	219	− 6	.85	48.6
1762	1798	do	537	240	268	−28	3.58	44.7
1764	1800	1799	498	250	249	1	.13	50.2
1765	1800	None	528	249	264	−15	1.93	47.2
Total			2,744	1,311	1,372	−61	3.45	47.9
Ear No. 1130, *WX* × *CH*:								
1804	None	1838	363	166	181	−15	2.33	45.7
1806	do	None	435	237	217	20	2.84	54.5
1807	do	do	275	136	137	− 1	.17	49.5
1810	do	do	441	238	220	18	2.54	54.0
1813	1851	1850	398	211	199	12	1.78	53.0
1815	None	1849	465	237	232	5	.69	51.0
1816	1855	1854	515	280	257	23	3.00	54.3
Total			2,892	1,505	1,446	59	3.25	52.0
Ear No. 1129, *CX* × *WH*:								
1766	1774	None	432	222	216	6	.65	51.4
1768	1776	1775	144	75	72	3	.74	52.0
1770	None	1783	492	253	246	7	.93	51.4
Total			1,068	550	534	16	1.45	51.5
Ear No. 1130, *CX* × *WH*:								
1818	1828	1827	754	366	377	−11	1.70	48.6
1820	1837	None	207	104	108	− 4	.82	48.0
1822	1837	1836	542	293	271	22	2.80	53.8
1825	None	1835	584	268	292	−24	2.75	46.0
Total			2,087	1,031	1,043	−12	.78	49.5
Total of the above four groups			8,791	4,397	4,395	2		49.9

If any difference in the behavior of the progenies of Nos. 1129 and 1130 occurred, a lower percentage of waxy seeds on the progeny of ear No. 1130 would be expected. A careful analysis of the progeny with this point in mind failed to reveal any significant differences, so that the differences observed in the percentage of waxy seeds of the two ears, Nos. 1129 and 1130, must, for the present, be ascribed to chance; at least it does not appear to be hereditary. There were four classes of seeds on ears Nos. 1129 and 1130—colored and white waxy and colored and white horny. The four classes from each of these ears were planted separately and are separated in the tabulation, but since no differences appeared in the percentage of seeds with waxy endosperm from the colored and white seeds, they are discussed together. To avoid repetition, the progeny of the two ears are considered together, since the differences found between them were slight. The ears secured from the progeny of ears Nos. 1129 and 1130 are shown in Tables VI and VII. There were no ears with aberrant ratios larger than might be due to chance.

TABLE VII.—*Inheritance of endosperm texture in 26 ears of the horny × waxy and 17 ears of the horny × self progeny of the two maize ears Nos. 1129 and 1130, the progeny of hybrid Dh 237.*

[Lines bracketed together in pairs indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Horny × waxy.						Horny × self.					
			Number of seeds.						Number of seeds.					
	Self-pollinated ♂.	Reciprocal cross.	Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.	Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1129, *WH × CX:*														
1772	None	None	448	209	224	−15	2.12	46.6						
{1773	...do	...do	613	309	306	3	.36	50.4						
{1774	Self								254	63	64	−1	0.01	24.7
{1775	None	1768	533	271	261	10	1.28	50.9						
{1776	Self								272	80	68	12	2.50	29.4
{1777	None	None	428	209	214	−5	.71	48.8						
{1778	Self								319	64	80	−16	3.07	20.0
{1779	None	None	476	234	238	−4	.54	49.2						
{1780	Self								474	114	118	−4	.63	23.6
{1781	None	None	477	233	238	−5	.68	48.9						
{1782	Self								475	118	119	−1	.15	24.9
1783	All waxy	1770	562	271	281	−10	1.25	48.2						
{1784	None	None	591	307	295	12	1.46	52.0						
{1785	Self								412	90	103	−13	2.20	21.8
{1786	None	None	446	211	223	−12	1.68	47.3						
{1787	Self								450	106	112	−6	.97	23.6
1788	None	None	386	180	193	−13	1.81	47.2						
Total			4,960	2,434	2,480	−46	1.8[illegible]	49.1	2,656	635	664	−29	1.90	23.9
Ear No. 1130, *WH × CX:*														
{1827	All waxy	1818	644	310	322	−12	1.40	48.2						
{1828	Self								404	109	101	8	1.36	27.0
1829	None	None	511	276	255	21	2.75	54.0						

TABLE VII.—*Inheritance of endosperm texture in 26 ears of the horny × waxy and 17 ears of the horny × self progeny of the two maize ears Nos. 1129 and 1130, the progeny of hybrid Dh 237*—Continued.

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Horny × waxy.						Horny × self.					
	Self-pollinated ♂.	Reciprocal cross.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.	Number of seeds. Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1130, *WH × CX*—Continued.														
{1833	All waxy	do	434	216	217	− 1	.14	49.8						
{1834	do	do	511	250	255	− 5	.66	49.0						
1835	do	1825	503	254	251	3	.39	50.5						
{1836	do	1822	297	127	148	− 21	3.61	42.8						
{1837	Self								541	126	135	− 9	1.32	23.3
Total			2,900	1,433	1,450	− 17	.94	49.5	945	235	236	− 1	.14	24.9
Ear No. 1129, *CH × WX:*														
1794	Self								634	172	158	14	1.90	27.1
{1795	None	None	553	268	276	− 8	1.01	48.5						
{1796	Self								296	66	74	− 8	1.59	22.3
{1797	None	None	230	117	115	2	.39	50.9						
{1798	Self								752	194	188	6	.75	26.2
{1799	None	1764	510	262	255	7	.92	51.4						
{1800	Self								755	191	189	2	.25	25.3
Total			1,293	647	647		2.6	50.0	2,437	623	609	14	.97	25.7
Ear No. 1130, *CH × WX:*														
1838	All waxy	1804	545	260	272	− 12	1.52	47.8						
{1839	do	None	415	208	207	1	.14	50.1						
{1840	Self								308	75	77	− 2	.39	24.3
1843	All waxy	None	537	282	268	14	1.79	52.6						
{1846	do	do	621	305	310	− 5	.59	49.2						
{1847	Self								721	155	180	−25	3.19	21.5
1849	All waxy	1815	581	299	290	9	1.15	51.4						
{1850	do	1813	561	273	280	− 7	.87	48.7						
{1851	Self								547	126	137	−11	1.61	23.0
{1854	All waxy	1816	614	306	307	− 1	.12	49.8						
{1855	Self								563	132	141	− 9	1.30	23.5
Total			3,874	1,933	1,937	− 4	.19	49.9	2,139	488	535	−47	3.48	22.8
Total of the above four groups			13,027	6,447	6,513	− 66	1.71	49.5	8,177	1,981	2,044	−63	2.40	24.3

The four groups in Table VII are the reciprocals of the four groups in Table VI. The first group in Table VI is *WX × CH* from ear No. 1129 and the first group in Table VII is *WH × CX* from the same ear.

Since one parent was homozygous for waxy endosperm, it becomes possible to test whether the same ratio of waxy to horny genes is found in the male gametes as in the female gametes of the heterozygous parent.

The percentage of waxy seeds in Table VI is the percentage of male gametes bearing this character, while the percentage of waxy seeds in Table VII is the percentage of female gametes bearing the waxy character.

The difference between these reciprocal groups is very small, indicating that for the progeny of the hybrid Dh 237 there is little or no difference in the percentage of male and female gametes bearing waxy endosperm.

The fact is further demonstrated when the individual groups are examined. Table VIII gives the percentage of waxy seeds for the four pairs of reciprocals, with the differences between them.

TABLE VIII.—*Inheritance of endosperm texture in the progeny of the two maize ears Nos. 1129 and 1130, by groups as shown in Table VI and their reciprocals as shown in Table VII.*

Progeny of—	Nature of cross.	Percentage of waxy seeds.			D ÷ E.
		Table VI group.	Reciprocal cross.	Difference.	
Ear No. 1129	*WX* × *CH*	47.9±0.64	50.0±0.94	2.1±1.14	1.85
Ear No. 1130	do	52.0± .63	49.9± .54	2.1± .83	2.53
Ear No. 1129	*CX* × *WH*	51.5±1.00	49.1± .68	2.1±1.21	1.73
Ear No. 1130	do	49.5± .74	49.5± .63		
Total	*X* × *H*	49.9± .36	49.5± .3	.4± .47	.85

In the first instance the percentage of waxy seeds is lower when heterozygous plants were used as male parents, but in the next two pairs of reciprocals this condition was reversed, the percentage of waxy seeds being higher when heterozygous plants were used as the male parents.

In none of the pairs of reciprocals was a significant difference found, so that the percentage of male and female gametes bearing waxy endosperm may be said to be alike for the progeny of the hybrid Dh 237.

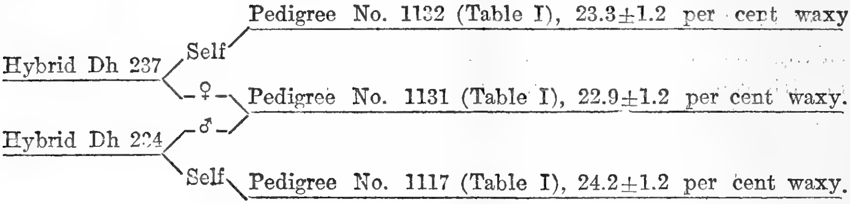
In this regard the progeny of the two hybrids differ. The progeny of the hybrid Dh 234 showed that a significant deficiency of male gametes bearing the waxy character occurred, while no such deficiency is found on the progeny of the hybrid Dh 237.

CROSSES BETWEEN THE TWO HYBRIDS DH 234 AND DH 237.

Three of the ears that were selected for planting were the result of crossing the two hybrids Dh 234 and Dh 237. These ears are Nos. 1110, 1131, and 1134 (Table I).

As only self-pollinated ears were secured from ear No. 1131, the progeny of this ear is discussed separately from the progenies of ears Nos. 1110 and 1134.

Ear No. 1131 had 22.9 per cent waxy seeds, while self-pollinated ears secured from the male and female parents had 24.2 and 23.3 per cent waxy, respectively, as shown by the following diagram:



As can be seen from the diagram, neither of the parents of ear No. 1131 deviated from the expected 25 per cent by a larger percentage than could be ascribed to chance, although both parents, as well as ear No. 1131, were below the expected percentage.

As ear No. 1131 was all colored, there were only two classes of seeds, horny and waxy. These were planted separately and self-fertilized by tubing (6). The waxy seeds when self-pollinated resulted in all waxy ears. Such ears, therefore, were not tabulated.

HORNY.

Four ears that were the result of self-pollinating horny plants were secured from the horny group. These ears are shown in Table IX.

Two ears were above and two below the expected 25 per cent of waxy seeds. The deviation on all of these ears could be ascribed to chance. The four ears had a total of 1,055 seeds, with 24.3 per cent waxy, the deviation of 0.7 per cent being 0.74 times the probable error.

TABLE IX.—*Inheritance of endosperm texture in ears Nos. 1893, 1894, 1895, and 1897, the progeny of maize ear No. 1131, self-pollinated, the progeny of a cross between the hybrids Dh 234 and Dh 237.*

Pedigree.	Number of seeds.				D ÷ E.	Percentage of waxy.
	Total.	Waxy.	Expected waxy.	Deviation.		
Ear No. 1893	337	94	84	10	1.61	27.9
Ear No. 1894	261	55	65	−10	1.83	21.1
Ear No. 1895	33	11	8	3	1.55	30.0
Ear No. 1897	424	97	106	− 9	1.51	22.6
Total	1,055	257	264	− 7	.74	24.3

There are two remaining ears that represent crosses between the two hybrids Dh 234 and Dh 237. These ears are Nos. 1110 and 1134 (Table I), as shown by the following diagram:

Hybrid Dh 234 — Self — Pedigree No. 1111 (Table I), 22.2±1.0 per cent waxy.
Hybrid Dh 234 ♀ × Hybrid Dh 237 ♂ — Pedigree No. 1110 (Table I), 27.5±1.1 per cent waxy.
Hybrid Dh 237 — Self — Pedigree No. 1132 (Table I), 23.3±1.2 per cent waxy.

Hybrid Dh 237 — Self — Pedigree No. 1133 (Table I), 24.6±1.0 per cent waxy.
Hybrid Dh 237 ♀ × Hybrid Dh 234 ♂ — Pedigree No. 1134 (Table I), 16.3±1.2 per cent waxy.
Hybrid Dh 234 — Self — Pedigree No. 1118 (Table I), 21.9±1.1 per cent waxy.

Ear No. 1110 and the two self-pollinated ears secured from the parents are all approximations of the expected 25 per cent. This is not true of ear No. 1134. The diagram shows that the female parent of the self-pollinated ear No. 1134 was a close approximation to the expected 25 per cent, while the self-pollinated ear from the male parent was below the expected by 3.1 per cent, which is almost three times the probable error. Although both parents could reasonably be said to approximate the expected 25 per cent, ear No. 1134 is below the expected by 8.7 per cent, which is 6.1 times the probable error.

There seems to be no very good explanation of this departure, either the female gametes selected male gametes bearing the horny endosperm or a differential death rate prevailed for the zygotes with waxy endosperm.

There was no difference in the behavior of the progeny of ears Nos. 1110 and 1134. The ears secured from self-pollinating plants grown from the horny seeds of No. 1134 bore 2,277 seeds, of which 25.5 per cent were waxy, the deviation being less than the probable error. Only one ear of the five secured deviated in excess of three times the probable error, and that ear, No. 1923 (Table XI), was in excess of the expected.

The 10 ears representing the progeny of ear No. 1134 that were expected to have an equal number of waxy and horny seeds had 4,943 seeds, with 49 per cent waxy. The deviation of 1 per cent is but 2.1 times the probable error. The progeny of ear No. 1134 failed to throw any light on the observed deficiency of waxy seeds in the parent ear.

The two ears, Nos. 1110 and 1134, that represent crosses between the two hybrids had but two classes of seeds, colored horny and colored waxy. These classes were planted separately. As no significant differences were found in the behavior of the progeny of the two ears, they will be considered together. The ears secured from the progeny of Nos. 1110 and 1134 are shown in tables X and XI. The ears resulting from pollinating homozygous waxy plants with heterozygous horny plants are extremely variable. Five of the eleven ears deviated from the expected percentage in excess of three times the probable error. With the exception of the ears shown in Table X the remaining ears show no significant deviation.

TABLE X.—*Inheritance of endosperm texture in 11 ears of maize, the waxy × horny progeny of ears Nos. 1110 and 1134, the progeny of crosses between hybrids Dh 234 and Dh 237.*

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of waxy.
	Self-pollinated ♂.	Reciprocal cross.	Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8	9
Ear No. 1110:								
1856	1878	1877	525	239	262	−23	2.97	45.6
1860	1875	1874	649	289	324	−35	4.07	44.6
1861	None	1871	450	204	225	−21	2.93	45.4
1863	do	None	679	306	339	−33	3.76	45.0
1865	1875	do	739	380	369	11	1.2	51.4
Total			3,042	1,418	1,521	−103	5.5	46.6
Ear No. 1134:								
1898	None	None	516	237	258	−21	2.74	45.9
1900	1921	1920	572	261	286	−25	3.10	45.6
1902	1918	1917	765	415	382	33	3.53	54.3
1904	None	None	443	219	221	−2	.28	49.5
1906	1923	1922	315	158	157	1	.17	50.1
1909	1925	1924	485	217	242	−25	3.36	44.7
Total			3,096	1,507	1,548	−41	2.19	48.7
Total of above two groups			6,138	2,925	3,069	−144	3.3	47,7

The two groups in Table XI are the reciprocals of the two groups in Table X and since one parent is homozygous for waxy endosperm it is again possible to determine whether a difference exists in the percentage of male and female gametes bearing the waxy endosperm.

The ears in Table X show the proportion of waxy to horny endosperm in the male gametes, while the ears in Table XI show the proportion of waxy to horny endosperm in the female gametes. Table XII shows the differences observed in the reciprocal groups.

Table XII shows that a difference exists between the male and female gametes in the proportion of gametes bearing waxy endosperm, the male gametes bearing the waxy character being deficient.

TABLE XI.—*Inheritance of endosperm texture in eight ears of the horny × waxy and eight ears of the horny × self progeny of the two maize ears Nos. 1110 and 1134, the progeny of crosses between hybrids Dh 234 and Dh 237.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Horny × waxy.						Horny × self.					
			Number of seeds.				D ÷ E.	Percentage of waxy.	Number of seeds.				D ÷ E.	Percentage of waxy.
	Self-pollinated ♂.	Reciprocal cross.	Total.	Waxy.	Expected waxy.	Deviation.			Total.	Waxy.	Expected waxy.	Deviation.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1110:														
1871	All waxy	1861	81	33	40	−7	2.3	40.6						
{1874	None	1860	137	71	68	3	.76	51.8						
{1875	Self								716	151	179	−28	3.1	21.1
{1876	None	None	377	201	188	13	2.13	53.4						
{1877	All waxy	1856	424	226	212	14	2.01	53.3						
{1878	Self								496	122	124	−2	.26	24.6
1882	do								136	28	34	−6	1.52	20.6
Total			1,019	531	509	22	2.04	52.2	1,348	301	337	−36	2.91	22.3
Ear No. 1134:														
{1917	All waxy	1902	452	250	226	24	3.24	55.3						
{1918	Self								345	93	86	7	1.16	27.0
{1920	All waxy	1900	559	254	279	−25	3.13	45.4						
{1921	Self								519	133	130	3	1.5	25.6
{1922	All waxy	1906	421	208	210	−2	.29	49.4						
{1923	Self								399	123	100	23	3.41	30.8
{1924	All waxy	1909	415	208	207	1	.14	50.6						
{1925	Self								457	110	114	−4	.55	24.1
1926	do								557	121	139	−18	2.25	21.7
Total			1,847	920	923	−3	.27	49.8	2,277	580	569	11	.68	25.5
Total of above two groups			2,866	1,451	1,433	18	1.0	50.7	3,625	881	856	25	1.42	24.3

TABLE XII.—*Inheritance of endosperm texture in the progeny of the two maize ears Nos. 1110 and 1134, by groups as shown in Table X and their reciprocals as shown in Table XI.*

Progeny of—	Nature of cross.	Percentage of waxy seeds.			
		Table X group.	Reciprocal cross.	Difference.	D ÷ E.
Ear No. 1110	*X* × *H*	46.6±0.61	52.2±1.0	5.6±1.27	4.4
Ear No. 1134	do	48.7± .61	49.8± .79	1.1±1.18	.9
Total		47.7± .43	50.7± .63	3.0± .76	3.9

Fourteen self-pollinated ears were also obtained from these same horny plants. With these data it is not only possible to determine whether a difference exists between the male and female gametes, in the proportion of gametes bearing the waxy character, but also to compare the relation of the percentage of waxy seeds on the self-pollinated ear from the heterozygous parent with the percentage of male gametes bearing the waxy character, as indicated by the percentage of waxy seeds on ears that result from crossing homozygous waxy plants with heterozygous horny plants.

These 14 ears are shown in Table XIII. Column 1 of the table gives the pedigree numbers of the ears borne on the homozygous waxy plants pollinated by heterozygous horny plants. Column 2 gives the percentage of waxy seeds observed on these cars. Column 3 gives the pedigree number of the reciprocal ears of those shown in column 1. The ears shown in column 3 were borne on heterozygous horny plants, the result of pollen from homozygous waxy plants. Column 4 gives the percentages of waxy seeds on the ears shown in column 3. Column 5 gives the difference in percentage of waxy seeds between the reciprocal ears. A minus sign is used in this column to indicate the ears that had a higher percentage of waxy seeds when the male parent was heterozygous horny than when the male parent was heterozygous waxy. Column 6 gives the number of times the difference observed exceeds the probable error. Column 7 gives the pedigree number of the ears which resulted from self-pollinating the heterozygous horny plants which bore the ears shown in column 3. Column 8 gives the percentage of waxy seeds observed on the ears shown in column 7, and column 9 shows the percentage of waxy seeds expected from the gamete classes of the parents in columns 2 and 4. Column 10 gives the number of times the deviation of the percentages in column 8 from the expected 25 per cent exceeds the probable error.

TABLE XIII.—*Inheritance of endosperm texture in 14 ears of maize, the reciprocal crosses between homozygous waxy and heterozygous horny plants.*

Waxy × horny.		Horny × waxy.				Horny × self.			
Pedigree No.	Percentage of waxy.	Pedigree No.	Percentage of waxy.	Difference in reciprocal.	D÷E.	Pedigree No.	Percentage of waxy: Observed.	Percentage of waxy: Expected.	D÷E.
1	2	3	4	5	6	7	8	9	10
1552	44.8	1643	51.4	6.6±2.1	3.1	1644	25.5	23.1	0.42
1565	49.1	1632	50.0	.9±3.7	.24	1633	24.5	24.5	.19
1572	41.7	1604	51.4	9.7±3.9	2.48	1605	27.7	21.5	1.97
1576	48.8	1617	52.6	3.8±2.2	1.72	1618	32.0	25.6	3.41
1590	50.2	1619	50.0	—.2±2.1	—.09	1620	24.1	25.1	.68
1592	60.8	1621	54.9	—5.9±2.3	—2.26	1622	28.5	33.4	1.44
1594	49.4	1611	52.6	3.2±1.8	1.81	1612	31.1	26.0	4.40
1665	50.9	1686	53.5	2.6±2.4	1.07	1687	25.6	27.2	.57
1856	45.6	1877	53.3	7.7±2.2	3.50	1878	24.6	24.3	.60
1860	44.6	1874	51.8	7.2±3.2	2.29	1875	21.4	23.2	3.00
1900	45.6	1920	45.4	—.2±2.5	—.08	1921	25.6	21.0	.50
1902	45.6	1917	55.3	9.7±2.0	4.86	1918	27.0	25.2	1.16
1906	50.2	1922	49.4	.8±2.5	—.28	1923	30.8	24.8	3.41
1909	44.7	1924	50.6	5.9±2.2	2.63	1925	24.1	22.6	.55
Total	48.8		51.5	2.7±.61	4.44		25.5	25.1	1.7
Total ♀ excess	48.0		52.4	4.4±.73	6.60		25.6	25.2	1.38
Total ♂ excess	50.6		49.4	1.2±1.1	1.00		27.0	25.0	2.69

DIFFERENCES IN RECIPROCALS.

It would appear from differences in the behavior of reciprocals in the progeny of Dh 234 and also in the progeny of crosses between the two hybrids that in the descendants of certain ears there is a significant deficiency of male gametes bearing the waxy character. This deficiency may be due to a differential death rate, a lack of vigor resulting in a slower growth of the pollen tube, or an unequal formation of gametes bearing waxy endosperm.

The difference observed is not of sufficient magnitude to account for the deficiency of waxy seeds in the perjugate generation of waxy × horny hybrids. There is evidence to show that the deficiency of waxy seeds observed in the perjugate generation of waxy × horny hybrids is not entirely due to this deficiency of effective male gametes bearing the waxy character. There were 14 pairs of reciprocal crosses between identical plants. One parent of these 28 ears was homozygous for waxy, the other parent was homozygous for horny endosperm.

Of the 14 ears shown in Table XIII, 10 indicate a difference between the male and female gametes in the percentage of gametes bearing the waxy character. In 9 of these 10 pairs the proportion of male gametes bearing the waxy character was below the expected percentage and the proportion of female gametes was above the expected, indicating that the difference between the male and female gametes was not only due to a deficiency of male gametes bearing waxy endosperm but also to an excess of female gametes bearing waxy endosperm.

The total for the 14 pairs of reciprocals shows a difference of 2.7 per cent between the male and female gametes in the number of gametes bearing the waxy character. A difference of this magnitude would be expected to occur as the result of chance but once in over 300 times. Ten of the 14 pairs show the percentage of male gametes bearing the waxy character to be lower than the percentage of female gametes bearing this character.

While the totals show dependable differences, there is but one case where the individual reciprocals differ by a significant amount. Nos. 1902 and 1917 differ by 9.7 ± 2.0, which is 4.86 times the probable error. The relations of the ears of this last pair are shown in figure 3. The difference in this case is due to both the male and female gametes. There is a deficiency of 4.4 per cent in the proportion of male gametes with waxy endosperm, while there is an excess of 5.53 per cent of female gametes bearing waxy endosperm.

Self-pollinating such an ear would be expected to result in an ear with 25.2 per cent waxy. Ear No. 1918, which is the result of self-pollinating the above heterozygous horny plant, had 27.0 per cent waxy, the deviation of 1.8 per cent from 25.2 per cent being no larger than could be ascribed to chance. As long as the deficiency in any class of gametes in one sex is made up in the other sex, the discrepancy would have to be relatively large before it could be detected in self-pollinated progeny. In an ear of 600 seeds, the deviation above and below 50 per cent would need to be as much as 38 per cent.

Summing up the inheritance of waxy endosperm for the third generation of the hybrids Dh 234 and Dh 237 and the crosses between them, we have 57 ears that are expected to have 25 per cent of the seeds waxy. The observed percentage for the total of 25,329 seeds is 24.6 per cent. The deviation from 25 per cent is 2.09 times the probable error.

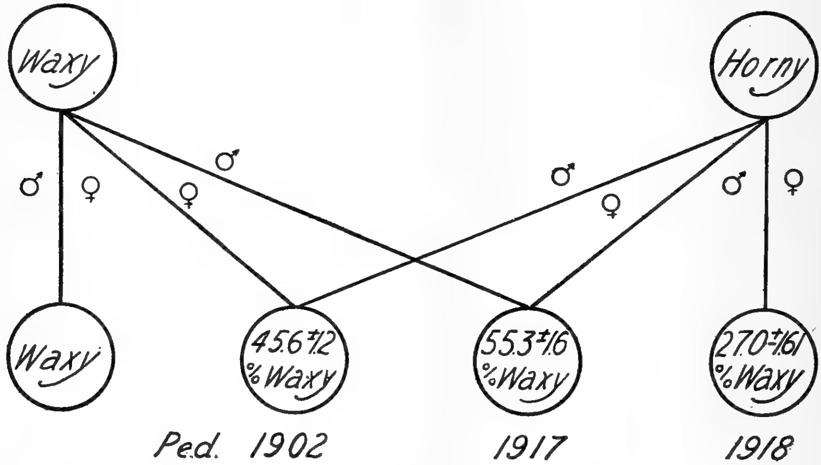


FIG. 3.—Diagram showing the relations of ears Nos. 1902, 1917, and 1918.

The second-generation ears of these bybrids, together with 45 ears previously published (7), determined the percentage of waxy seeds to be 23.7 per cent. The difference between the second and third generation ears is 0.9±0.21 per cent, which would be expected as the result of chance once in 142 times.

There were seven groups of ears that made up the total of 25,329 seeds (Table XIII). Of these seven groups, five were below and two above 25 per cent. From this we may conclude that the percentage of waxy seeds for the third generation of the hybrids was significantly below 25 per cent, but even with the 25,000 seeds involved, it is not possible to determine whether the percentage observed is approximating 23.7 per cent, the mean percentage found for the second-generation ears.

There are 131 ears of the third generation that are expected to have equal proportions of waxy and horny seeds (Table XIV). The 131 ears had 57,851 seeds, of which 49.8 per cent were waxy. The deviation of this percentage from 50 per cent is insignificant. The percentage of waxy seeds has been determined as 23.9 per cent for the 198 ears expected to have 25 per cent of the seeds waxy.

The proportion of gametes bearing the waxy character to the gametes bearing the horny character necessary to account for 23.9 per cent of waxy seeds on self-pollinated ears is 48.9 to 51.1.

The 131 ears on this basis are expected to have 48.9 per cent of waxy seeds. The deviation of the observed from this percentage would be expected to occur as the result of chance once in 25,000 times.

TABLE XIV.—*Inheritance of endosperm texture in all the maize ears.*

EARS EXPECTED TO HAVE 50 PER CENT OF THE SEEDS WAXY.

Nature of cross.	Number of ears.		Number of seeds.				D ÷ E.	Per-centage of waxy.
	Observed.	Below expected.	Total.	Waxy.	Expected waxy.	Deviation.		
Progeny of hybrid Dh 234:								
Ear No. 1099	40	15	16,428	8,303	8,215	88	2.03	50.6
Ear No. 1111	26	12	10,601	5,316	5,300	16	.46	50.1
Progeny of hybrid Dh 237:								
Ear No. 1129	22	12	10,065	4,942	5,031	− 89	2.60	49.0
Ear No. 1130	24	13	11,753	5,902	5,876	26	.71	50.2
Progeny of crosses between hybrids Dh 234 and Dh 237:								
Ear No. 1110	9	5	4,061	1,949	2,030	− 81	3.76	48.0
Ear No. 1134	10	6	4,943	2,427	2,471	− 44	1.85	49.0
Total	131	63	57,853	28,839	28,925	− 86	1.05	49.8

EARS EXPECTED TO HAVE 25 PER CENT OF THE SEEDS WAXY.

Nature of cross.	Observed.	Below expected.	Total.	Waxy.	Expected waxy.	Deviation.	D ÷ E.	Percentage of waxy.
Second generation ears (Table I):								
Hybrid Dh 234	54	36	30,571	7,309	7,643	− 334	7.5	23.9
Hybrid Dh 237	42	28	24,188	5,779	6,047	− 268	5.90	23.9
Previously reported	45	29	22,339	5,179	5,585	− 406	9.24	23.1
Total	141	93	77,098	18,267	19,274	−1,007	12.4	23.7
Progeny of hybrid Dh 234:								
Ear No. 1099	18	8	7,516	1,891	1,879	12	.47	25.2
Ear No. 1111	10	7	4,956	1,223	1,239	− 16	.67	24.6
Progeny of cross between hybrids Dh 234 and Dh 237:								
Ear No. 1110	3	3	1,348	301	337	− 36	2.91	22.3
Progeny of hybrid Dh 237:								
Ear No. 1129	11	6	5,093	1,258	1,273	− 15	.62	24.7
Ear No. 1130	6	5	3,084	725	771	− 46	2.84	23.5
Progeny of cross between hybrids Dh 237 and Dh 234:								
Ear No. 1131	4	2	1,055	257	264	− 7	.74	24.3
Ear No. 1134	5	2	2,277	580	569	11	.68	25.5
Total for third-generation ears	57	33	25,329	6,235	6,332	− 97	2.09	24.6
Total for both second and third generation ears	198	126	102,427	24,502	25,607	− 105	11.82	23.9

SUMMARY OF THE INHERITANCE OF WAXY ENDOSPERM.

A large amount of data has been secured that confirms previous observations on the inheritance of the waxy endosperm which had been found to reappear in deficient numbers in the perjugate generation of crosses with horny and with sweet varieties of maize.

By adding all of the ears expected to have 25 per cent of the seeds waxy, including the 45 ears previously reported (7), there are 198 ears having 102,427 seeds. The mean percentage of waxy seeds is 23.9 and the deviation of 1.1 per cent would be expected to occur as the result of chance but once in 10 raised to the fifteenth power.

This deviation though apparently small is certainly too large to be attributed to chance. The apparently slight deviation from 25 per cent and the large number of individuals necessary to establish the significance of such small deviations suggest the possibility that such departures may not be uncommon for other character pairs which have not been subjected to such an exhaustive test.

Although the observed deviation could not reasonably be expected to occur as the result of chance, all of the individuals do not approximate the mean percentage of the whole. An analysis of the "goodness of fit" of the individual ears to their observed mean by the use of the method proposed by Yule (16) showed that the individual plants did not form a single homogeneous group with a mean percentage of waxy seeds below 25 per cent, but that many of the individual ears could not be considered as merely chance deviations.

Thus in hybrids between waxy and horny individuals the mean percentage of waxy seeds reappearing in the perjugate generation is below the expected 25 per cent by an amount too large to be due to chance. The differences between individual plants with respect to this character are also too large to be due to chance.

Reciprocal crosses clearly indicated that in some cases the percentage of male gametes bearing the waxy character was below that expected. It has not been possible thus far to determine whether this observed deficiency is due to a higher death rate, reduced vigor, or a failure of equal segregation.

The deficiency of waxy seeds can not be due to a fractionation of this character, since such a fractionation could not result in horny seeds but should give seeds that were neither horny nor waxy.

INHERITANCE OF ALEURONE COLOR.

The crosses made between the white waxy Chinese variety and the colored pop variety also produced excellent material for the study of aleurone color. The results in a very striking manner conform to the Mendelian proportions expected in monohybrid and dihybrid ratios.

In many crosses involving aleurone color the inheritance is blended rather than alternative, and classification is more or less arbitrary. In the Algeria × Chinese hybrids the classes were exceptionally good, especially in the second generation, no ears difficult of classification being found.

In the third generation, however, this crisp difference partially disappeared. Several ears were found that were so minutely spotted that an accurate classification was impossible and therefore not undertaken. The deviations in the individual ears were also somewhat wider, a few being found that could not be considered as approximations of any Mendelian ratio founded on reasonable assumptions.

In presenting the results obtained, all possible precautions have been taken to eliminate personal error. There is always room for a slight difference of opinion in the classification of aleurone color, owing to the fact that some persons detect color where others fail.

The chief object of the investigation being to study the correlation between aleurone color and endosperm texture, it was desirable to reduce all unnecessary complications. For this reason, only ears that had definitely alternative classes were considered. The conclusions, therefore, are based on ears that had very distinct classes, eliminating the chance that aberrant ratios were due to inability to properly classify the seeds. Without doubt much could be learned from a careful study of the inheritance of aleurone color in the ears that did not have definitely alternative classes. This bulletin therefore does not present a complete study of aleurone color, since only a part of the material was analyzed. It is believed that the results do afford an accurate measure of the percentage of white seeds segregating from white × colored crosses on ears with distinct classes.

The number of individuals classified is believed to be larger than in any previous experiment with aleurone color. The numerical equality of the two classes of gametes at segregation has consequently been subjected to a more searching test.

Since faintly colored ears were discarded, it is not surprising that the inheritance of aleurone color for these hybrids admits of comparatively simple explanation. That two factors are concerned in the production of aleurone color is clearly indicated by these two hybrids. Most of the ears require an explanation no more complicated, but with the partial results of the season of 1914, all the ears of which are not at present completely classified, a third factor becomes necessary, with a possible fourth.

It can easily be seen that many complications are to be expected from the recombination of these factors; hence, this phase of the problem is just touched upon in this bulletin. That these complications eventually arise in the study of aleurone color, as with many other characters, certainly limits the general application of Mendelian explanations, but should not conceal the fact that Mendelian segregation does occur with respect to aleurone color and that the numerical relations are wonderfully exact.

GAMETIC COMPOSITION OF THE TWO HYBRIDS DH 234 AND DH 237.

The percentage of white seeds obtained in the second generation of the hybrid Dh 234 showed that the aleurone color of this hybrid was behaving as a unit character, all the ears approximating 25 per cent white. The second-generation plants of the hybrid Dh 237 fell into two main groups, approximately half of the plants having a monohybrid and the other half a dihybrid ratio of white to colored seeds.

When the two hybrids were crossed, two classes of ears resulted—one group all colored, the other group having the monohybrid ratio of white to colored seeds. To explain these phenomena, it becomes necessary to assume that aleurone color is the result of two factors. The hybrid Dh 234, all the plants of which, when self-pollinated or crossed with sister plants, resulted in ears with a monohybrid ratio of white to colored seeds, must have been homozygous for one color factor and heterozygous for the other. The plants of Dh 237 which when self-pollinated produced ears with a monohybrid ratio of white seeds were also heterozygous for one color factor and homozygous for the other.

Crosses between plants of this type with plants of the hybrid Dh 234 resulted in ears all the seeds of which were colored, indicating that the factor homozygous in Dh 234 was heterozygous in Dh 237. Since one-half of the plants of the hybrid Dh 237 when self-pollinated or crossed with sister plants produced ears with a dihybrid ratio of white and colored seeds, these plants must be heterozygous for both color factors. Crosses between plants of this nature and plants of the hybrid Dh 234 resulted in ears with a monohybrid ratio of white to colored seeds.

It will be recalled that self-pollinating plants of the hybrid Dh 237 resulted in two approximately equal classes of ears, one with a monohybrid ratio of white to colored seeds and one with a dihybrid ratio of white to colored seeds. The hybrid Dh 234 when self-pollinated produced only ears with a monohybrid ratio, but when crossed with plants of the hybrid Dh 237 two classes of ears again resulted, one class having all the seeds colored, while an equal number had a monohybrid ratio of white to colored seeds.

To explain the two classes of ears resulting from self-pollinating first-generation plants of the hybrid Dh 237 and at the same time to explain the results obtained when first-generation plants of the hybrid Dh 237 were crossed with first-generation plants of the hybrid Dh 234, it is necessary to assume somewhat involved gametic formulæ.

It is assumed that in the first cross (Dh 237) the Chinese parent had the gametic combination *cR cR* and the Algeria *CR Cr*, where

C and *R* are the presence of color factors and *cr* their absence, both *C* and *R* being necessary to produce color. Were this true, wherever *cR* fertilized *CR* a colored seed would result, and this seed when planted would make the gametes *CR* and *cR*, which would give a ratio of 3 colored to 1 white, when self-pollinated.

Wherever *cR* fertilized *Cr*, a colored seed would result, which when planted would make four kinds of gametes as follows: *CR*, *Cr*, *cR*, and *cr*. Self-pollinating such a plant would result in an ear with 9 colored to 7 white seeds.

In the second cross (Dh 234) it is assumed that the Chinese parent had the gametic composition of *Cr Cr*, while the Algeria parent had the gametic combination of *CR CR*. Wherever *Cr* fertilized *CR*, a colored seed would result, which when planted would make the gametes *CR* and *Cr*. Such a plant when self-pollinated would give 3 colored seeds to 1 white. As all the seeds of the hybrid Dh 234 have the combination *CC Rr*, nothing but 3 to 1 ratios could result from self-pollinating any of the plants of this hybrid.

When the combination *CR Cr* is pollinated with the other hybrid combination of *CR cR*, an all-colored ear would be the result, but when the combination of Dh 234 *CR Cr* is pollinated by the other combination of Dh 237, *CR*, *Cr*, *cR*, or *cr*, an ear having 3 colored seeds to 1 white would be the result. This fulfills the observed conditions. Whenever an Algeria plant with the gametic composition *CR Cr* is self-pollinated, there should result an ear with 3 colored seeds to 1 white. Nothing but all-colored ears have been obtained as a result of self-pollinating Algeria plants, but there have not been more than 10 or 12 self-pollinated Algeria plants, so that the failure to obtain an ear with 3 colored seeds to 1 white calls for no comment. Two other crosses described below do afford evidence, however, that Chinese plants of the gametic composition *cR cR* and Algeria plants with the composition *CR Cr* do occur. On the other hand, whenever a Chinese plant producing *Cr* gametes was pollinated with Chinese producing *cR* gametes an all-colored ear should result. We have never obtained any colored seed in crosses between two plants of white Chinese, although a large number of such crosses have been made, a fact which makes necessary the further assumption that plants with the gametic formula ascribed to one of the Chinese parent plants must be rare.

An F_1 plant of the hybrid Dh 234 was fertilized with pollen from a white waxy Chinese plant; the resulting ear was all colored. A second ear on the Chinese plant was self-pollinated and was all white, while a second ear on the hybrid Dh 234 was self-pollinated, producing 26 per cent white. These results accord with the idea that the Chinese plant was producing gametes *cR cR*. The cross is shown by the following diagram:

Chinese *cR* — Self — all white waxy (observed).
Chinese *cR* ♂ × Hybrid Dh 234 ♀ — all colored (observed).
Hybrid Dh 234 *CR, Cr* — Self — 25 per cent white (observed 26 per cent).

An F_1 plant of the hybrid Dh 237 was pollinated with Chinese, and the resulting ear had 54.1 per cent white, while a second ear of the Dh 237 plant, when self-pollinated, had 25.2 per cent white. As Dh 237 segregating 3 colored seeds to 1 white, when self-pollinated, has been assumed to have the composition *CR cR*, a Chinese plant producing only *cR* gametes would be expected to give 50 per cent white when crossed with Dh 237 segregating 3 colored to 1 white, as in the following diagram:

Chinese *cR* ♂ × Hybrid Dh 237 ♀ — 50 per cent white (observed 54.17 per cent).
Hybrid Dh 237 *CR, cR* — Self — 25 per cent white (observed 25.2 per cent).

COMPOSITION IN THE SECOND GENERATION OF THE HYBRID DH 234.

The hybrid Dh 234 had 46 ears, which were obtained from 31 plants, many plants having two ears. Of these 46 ears, 25 were the result of self-pollination, 12 were the result of fertilization by sister plants of the same hybrid, and 9 were the result of pollinating the hybrid Dh 234 with pollen from the hybrid Dh 237. There appeared to be no difference among these three groups as to the percentage of seeds with colored aleurone, so that they were all tabulated together and arranged numerically by pedigree numbers. Two ears from a single plant are indicated by a bracket inclosing the pedigree numbers of the ears.

The 46 ears are shown in Table XV. The total number of seeds for these ears is 26,383, with 25.8 per cent white, the expected being 25 per cent, a deviation of 0.8 per cent, which is 4.45 times the probable error. The individual ears ranged from 21.4 per cent white to 30.9 per cent white, making a continuous series. Five of the ears deviated above the expected in percentage by an excess of three times the probable error, two of these deviating by four times the probable error. Of the 46 ears, 30 had white seeds in excess of the expected number, 13 below the expected percentage, and 3 were exactly 25 per cent white.

Table XV.—*Inheritance of aleurone color in 46 maize ears, the second-generation progeny of the hybrid Dh 234, Chinese variety × Algeria.*

[Lines bracketed together in pairs indicate ears borne on the same plant; ears selected for planting are designated by an asterisk (*).]

Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of white.
Progeny ear.	Self-pollinated ♂	Total.	White.	Expected white.	Deviation.		
{1099*	1106	657	165	164	1	0.3	25.1
{1100	1103	599	172	149	23	3.2	28.7
1101	1103	533	165	133	32	4.7	30.9
1102	Self	517	148	129	19	2.8	28.0
1103	do	272	68	68			25.6
{1104	1108	573	151	143	8	1.0	26.3
{1105	Self	609	177	152	25	3.4	29.0
1106	do	690	178	176	2	.8	25.7
{1108	do	691	196	172	24	3.1	28.3
{1109	1112	402	113	100	13	2.2	28.0
1111*	Self	747	192	186	6	.8	25.8
{1112	do	733	215	183	32	4.0	29.3
{1113	1118	643	168	160	8	1.1	26.2
{1114	1118	428	112	107	5	.8	26.1
{1115	1112	508	134	127	7	1.1	26.3
{1116	1118	322	87	80	7	1.3	27.0
{1117	Self	564	144	141	3	.4	25.5
{1118	do	623	174	155	19	2.6	27.9
{1119	1108	414	117	103	14	2.3	28.2
{1120	1117	655	182	163	19	2.5	27.7
{1121	Self	687	191	172	19	2.5	27.8
1515	do	555	141	139	2	.3	25.4
{1518	1726	510	130	127	3	.4	24.5
{1519	Self	605	156	151	5	.7	25.8
1523	do	571	133	143	− 10	1.4	23.3
{1524	1724	773	189	193	− 4	.5	24.5
{1525	Self	212	53	53			25.0
1527	do	614	148	153	− 5	.7	24.1
1529	do	334	87	86	1	.2	26.0
{1530	1733	676	182	169	13	1.7	26.95
{1531	Self	659	176	165	11	1.4	26.7
{1532	1729	707	158	177	− 19	2.4	22.77
{1533	Self	679	175	169	6	.8	25.8
1534	do	492	127	123	4	.6	25.8
1537	do	592	148	148			25.0
{1538	1733	609	156	152	4	.5	25.6
{1539	Self	626	138	156	− 18	2.4	22.0
1540	1736	679	161	169	− 8	1.1	23.7
1541	1736	631	135	158	− 23	3.1	21.4
{1542	1723	515	114	128	− 14	2.1	22.1
{1543	Self	570	131	142	− 11	1.6	23.0
1545	do	417	109	104	5	.8	26.1
{1546	1747	800	196	200	− 4	.5	24.5
{1547	1537	633	115	158	− 13	1.8	22.8
1549	Self	479	138	119	19	2.9	28.8
1551	do	578	132	144	− 12	1.7	22.8
Total		26,383	6,807	6,596	211	4.5	25.8

The deviation of 4.45 times the probable error above the expected percentage for the total number of seeds, together with the large proportion of ears having an excess of white seeds, indicates a rather definite tendency toward a higher percentage of the recessive class than that called for by the Mendelian theory.

The inclination is to attribute such a small variation to a failure to properly classify the seeds, so that some faintly colored seeds were being included with the white seeds. The number of individuals necessary to detect such a slight error would be very large, so that the number of second-generation ears obtained is not sufficient to shed light on this matter.

COMPOSITION IN THE SECOND GENERATION OF THE HYBRID DH 237.

An examination of the zygotic formulæ for the hybrid Dh 237 will show that two equal groups of plants are to be expected in this hybrid—one group homozygous for the color factor *R* and heterozygous for the factor *C*, the other group being heterozygous for both of these factors. Representatives of both groups were obtained, 8 plants exhibiting a dihybrid and 19 plants a monohybrid ratio of white to colored seeds. Although these two ratios were expected in equal numbers, the deviation of 5 plants below the expected for the dihybrid ratio may be looked upon as a chance fluctuation.

In tabulating the plants, only 23 are shown in Tables XVI and XVII, as four plants, owing to the nature of the pollinations, produced all-colored ears only and were not tabulated. It will be recalled that all of the plants of the hybrid Dh 234 were alike in that they were homozygous for the factor *C* and heterozygous for the factor *R*.

Two groups of ears are to be expected in crossing these two hybrids: One group all colored, the result of crossing the plants of Dh 237 constituted *cC RR* with Dh 234 *CC Rr;* the other group with a monohybrid ratio of white to colored seeds, the result of crossing plants of Dh 237 constituted *Cc Rr* with Dh 234 *CC Rr*. In both cases self-pollinating plants of the hybrid Dh 234 show ears with a monohybrid ratio. In the first instance self-pollinated plants of the hybrid Dh 237 should also result in ears with monohybrid ratios and in the second instance in dihybrid ratios of white to colored seeds.

With this expectation it becomes possible to separate the plants of the hybrid Dh 237 when they were both crossed with the hybrid Dh 234 into two classes, one of which contains plants heterozygous for two color factors and the other with plants homozygous for one and heterozygous for the other factor.

Only four plants of the progeny of the hybrid Dh 237 were observed to have a dihybrid ratio of white to colored seeds. These are shown in Table XVII. However, an examination of Table XVI reveals the fact that eight plants were the result of crossing the hybrids Dh 237 and Dh 234. Since these eight plants resulted in ears with a monohybrid ratio of white to colored seeds, we must conclude from the gametic formula that had they been self-pollinated they would have given dihybrid ratios.

The four ears shown in Table XVII are the result of self-pollinating second ears borne on four of the eight plants just discussed. The plants which as the result of self-pollination produced ears Nos. 1132, 1133, 1721, 1741, 1743, and 1745 in Table XVI also produced second ears, the result of crossing Dh 237 with Dh 234. These latter ears were all colored.

Twenty-nine ears were borne on first-generation plants of the hybrid Dh 237 that may be compared with the monohybrid ratio of 3 colored to 1 white. As has been said before, some of these ears are self-pollinated, some are crosses between sister plants, and some are crosses between the hybrids Dh 237 and Dh 234. In this latter cross only plants of the hybrid Dh 237 that were heterozygous for two color factors would give a monohybrid ratio of white to colored seeds when crossed with the hybrid Dh 234.

It may not be immediately apparent that crosses between two groups of plants which when self-pollinated produce ears with 43.75 and 25 per cent, respectively, will give ears with 25 per cent white. A consideration of the gametic formulæ shows, however, that this is according to expectation. All crosses with this hybrid that resulted in other than all-colored ears approximated 25 per cent white and were therefore included with the self-pollinated and pure-seeded ears in Table XVI.

The 29 ears in Table XVI had a total of 16,947 seeds, with 25.4 per cent white, the deviation of 0.4 per cent in this case being only 1.84 times the probable error. Two of the ears deviated in excess of three times the probable error, both of these being above the expected percentage. The ears ranged from 21.6 per cent white to 28.7 per cent white, forming a well-connected series, and since the range is within four times the probable error, these ears may all be looked upon as deviations from the theoretical 25 per cent. This regularity is an exception to that encountered among most of our previous hybrids and provides an excellent opportunity to study the correlation between endosperm texture and aleurone color in crosses where the percentage of white to colored seeds is behaving in a regular manner.

The four ears resulting from self-pollinating plants of the hybrid Dh 237 that were heterozygous for two factors for color are shown in Table XVII. These four ears had a total of 2,477 seeds, with 43.3 per cent white. The deviation of 0.45 per cent from the expected percentage is less than the probable error. One ear, No. 1726, was slightly over 5 per cent in excess of the expected, the deviation in this case exceeding the probable error by 3.5 times. Another ear, No. 1747, was below the expected percentage by 3.3 times the probable error.

TABLE XVI.—*Inheritance of aleurone color in 29 maize ears, the second-generation progeny of the hybrid Dh 237, Algeria × Chinese variety (monohybrid).*

[Lines bracketed together in pairs indicate ears borne on the same plant; ears selected for planting are designated by an asterisk (*); ears borne on plants which when self-pollinated proved to be heterozygous for two color factors are indicated by a dagger (†); ears borne on plants which had they been self-pollinated would have proved to be heterozygous for two color factors are indicated by a double dagger (‡).]

Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of white.
Progeny ear.	Self-pollinated ♂.	Total.	White.	Expected white.	Deviation.		
1122	None	647	148	162	−14	1.9	22.8
1124	...do	672	171	168	3	.4	25.4
1125	Self	837	241	209	32	3.8	28.7
1127	1125	723	190	181	9	1.1	26.2
1128	Self	319	69	80	−11	2.1	21.6
1129*	...do	747	189	187	2	.3	25.1
1130*	1135	741	188	185	3	.4	25.3
1132	Self	575	160	144	16	2.3	27.8
1133	...do	758	175	189	−14	1.7	23.1
1135	...do	627	166	157	9	1.2	26.4
1136	1137	615	175	154	21	2.9	28.4
1137	Self	740	205	185	20	2.5	27.7
1138	1135	548	128	137	− 9	1.6	23.3
1721	Self	712	160	178	−18	2.3	22.5
1722†	1543	677	193	169	24	3.1	28.5
1724‡	1523	374	90	93	− 3	1.9	24.1
1725†	1519	472	125	118	7	1.1	26.5
1728‡	1903	421	105	105	....	....	24.9
1729‡	1533	613	148	153	− 5	.7	24.2
1730‡	1539	401	102	100	2	.3	24.9
1733‡	1741	634	164	158	6	.9	25.9
1734‡	1531	516	133	129	4	.6	25.8
1735†	1540	458	111	114	− 3	.5	24.2
1738	Self	472	119	118	1	.1	25.2
1741	...do	485	120	121	− 1	.1	24.7
1743	...do	575	127	144	−17	2.4	22.1
1745	...do	625	139	156	−17	2.4	22.2
1746†	1547	621	168	155	13	1.8	27.1
1749	Self	342	98	85	13	2.4	28.6
Total		16,947	4,307	4,237	70	1.8	25.4

TABLE XVII.—*Inheritance of aleurone color in four maize ears, the second-generation progeny of the hybrid Dh 237, Algeria × Chinese variety (dihybrid).*

Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of white.
Progeny ear.	Self-pollinated ♂.	Total.	White.	Expected white.	Deviation.		
1723	Self	664	284	290	− 6	0.7	42.75
1726	...do	560	273	245	28	3.5	48.8
1736	...do	595	256	260	− 4	.5	43.0
1747	...do	658	259	288	−29	3.3	39.4
Total		2,477	1,072	1,083	−11	.66	43.3

COMPOSITION IN THE THIRD GENERATION OF THE HYBRID DH 234.

Three ears were selected from the progeny of hybrid Dh 234 and planted the following season. Two of these ears are Nos. 1099 and 1111, in Table XVIII. The third ear was a cross between the two hybrids Dh 234 and Dh 237, and since it was all colored it does not appear in Table XVIII. The progeny of this last-mentioned ear are considered later in connection with two similar ears borne on plants of the hybrid Dh 237. The ear numbered 1099 was a cross between two sister plants and had almost exactly the expected percentage of white seeds. A self-pollinated ear secured from the male parent also was a close approximation to the expected 25 per cent.

The ear numbered 1111 in Table XVIII was the result of self-pollination. This ear also had white seeds, closely approximating 25 per cent. There were four classes of seeds on both the ears Nos. 1099 and 1111. These four classes were planted separately. An examination of the data failed to show any significant differences in the behavior of aleurone color due to the texture of the endosperm, making it possible to disregard the endosperm texture in analyzing the aleurone colors.

The progeny from the two ears behaved practically alike, no significant differences being found. Hand-pollinated ears to the number of 85 that had both colored and white seeds were obtained, 50 ears being from the progeny of ear No. 1099 and 35 ears from the progeny of ear No. 1111.

WHITE × COLORED.

Twenty-nine of the 85 ears obtained from the progeny of ears Nos. 1099 and 1111 were the result of crossing plants grown from the white seeds with plants grown from the colored seeds of the same ears (Table XVIII). The table is so arranged that the progeny from each of the four groups of each ear may be examined separately, if desired. In column 1 is found the number of the progeny ear from which the plants that produced the ears whose pedigree numbers are there given were grown. In this same column are also found the symbol letters for the characters. Thus the first six ears in Table XVIII, which are separated from the remaining three groups by a total, are the result of crossing plants grown from the white waxy (*WX*) seeds with plants grown from the colored horny (*CH*) seeds of ear No. 1099. The symbols mentioned first indicate the character of the seeds from which the female parents were grown. The expected proportion of white seeds is 50 per cent. The 29 ears had 11,949 seeds with 47.2 per cent white, the deviation being more than 9.4 times the probable error. A deviation of this magnitude would not be expected to occur as the result of chance more than once in over a billion times.

Two of the four groups that make up the total deviated below the expected by an amount too large to be due to chance. In one of these groups the result of crossing white horny by colored waxy seeds from ear No. 1099, the deviation of 6.9 times the error is due in a large measure to two ears, both below the expected by an amount more than eight times the probable error. One other ear, No. 1653, deviated below the expected by more than seven times the probable error, having only 39.3 per cent white. A reexamination of these ears failed to reveal errors in classification.

TABLE XVIII.—*Inheritance of aleurone color in 29 ears of maize, the white × colored progeny of the two ears Nos. 1099 and 1111, the progeny of hybrid Dh 234.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Number of seeds.				D÷E.	Per centage of white.
	Self-pollinated ♂.	Reciprocal cross.	Total.	White.	Expected white.	Deviation.		
1	2	3	4	5	6	7	8	9
Ear No. 1099, *WX × CH:*								
1552	1644	1643	506	232	253	−21	2.8	45.8
1555	1705	None	230	113	115	−2	.4	49.1
1558	None	1634	562	296	281	15	1.9	52.7
1562	do	None	415	205	207	−2	.3	49.4
1563	do	do	257	128	128			50.0
1564	do	do	438	212	219	−7	1.0	48.4
Total			2,408	1,186	1,204	−18	1.1	49.4
Ear No. 1111, *WX × CH:*								
1648	1696	None	712	345	356	−11	1.2	48.5
1651	1694	do	286	149	143	6	1.1	52.1
1652	1700	do	611	282	305	−23	2.7	46.2
1653	1703	do	502	198	251	−53	7.0	39.3
1654	1705	do	387	177	193	−16	2.4	45.7
{1658	1707	do	491	227	245	−18	2.4	46.3
{1660	None	do	600	310	300	10	1.2	51.6
Total			3,589	1,688	1,794	−106	5.0	47.0
Ear No. 1099, *WH × CX:*								
1602	1582	None	322	150	161	−11	1.8	46.6
1604	1573	1572	171	88	85	3	.7	51.5
1606	1571	None	391	196	195	1	.2	50.1
1608	1578	1577	460	215	230	−15	2.1	46.8
1610	None	1579	303	104	151	−47	8.4	34.3
1614	1589	1584	384	183	192	−9	1.4	47.6
1615	None	None	484	178	242	−64	8.7	36.8
1616	1575	do	502	259	251	8	1.1	51.6
1619	1591	1590	467	222	233	−11	1.5	47.6
1621	1593	1592	348	160	174	−14	2.2	46.0
1623	1585	1584	497	254	248	6	.8	51.5
1624	1593	None	67	36	33	3	1.1	53.8
Total			4,396	2,045	2,198	−153	6.9	46.6
Ear No. 1111, *WH × CX:*								
1678	1666	None	297	128	148	−20	3.4	43.1
1681	1670	do	441	199	220	−21	3.0	45.1
1682	None	do	448	205	224	−19	2.7	45.8
1686	1666	1665	370	179	185	−6	.9	48.4
Total			1,556	711	778	−67	5.0	45.6
Total of the above four groups			11,949	5,630	5,974	−344	9.4	47.2

The percentages for the three ears are 39.3, 34.3, and 36.8 white. These figures are closer approximations to the Mendelian dihybrid proportion of 43.75 per cent than to the expected 50 per cent white. The nature of the crosses, however, prohibits a dihybrid ratio.

Three ears, Nos. 1610, 1615, and 1653, were all borne on plants grown from white seeds and were pollinated with plants grown from colored seeds of the hybrid Dh 234. The plants grown from the white seeds could be making but one class of gametes, *Cr*, and the plants grown from the colored seeds were making two classes of gametes, *CR* and *Cr*.

A self-pollinated ear, No. 1703, was secured from the male parent of ear No. 1653. If the 39.3 per cent of white seeds on ear No. 1653 was due to the male parent being equally deficient in both male and female gametes bearing one of the two color factors the expected per-

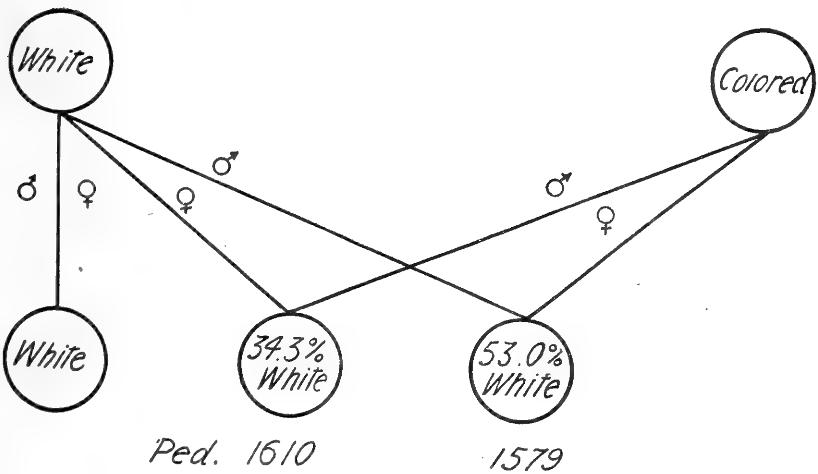


FIG. 4.—Diagram showing the relations of ears Nos. 1610 and 1579.

centage of white seeds on a self-pollinated ear would be 15.45 per cent, but since the deficiency was observed only for the male gametes a percentage of 19.65 per cent could be expected. The observed proportion on ear No. 1703 was 22.3 per cent, which is not a significant departure from the monohybrid 25 per cent or the 19.65 per cent indicated by the deficiency of colored seeds in ear No. 1653.

Further analysis is also possible for ear No. 1610, which had a reciprocal ear in No. 1579. This reciprocal ear gives a close approximation to the expected 50 per cent, while ear No. 1610 was below the expected by 8.4 times the probable error. The difference between these two reciprocals is 18.7±2.4 per cent, a difference of 7.8 times the probable error. No analysis is possible for ear No. 1615, but for the two ears numbered 1610 and 1653 there is indicated either a failure of dominance in some of the seeds or a deficiency on the part of the male parent of gametes bearing one of the color factors.

This deficiency could be due to a differential death rate, a lessened vigor resulting in a slower growth of the pollen tube, or to a failure of the plant to produce gametes in equal proportions. It will be recalled that the plants heterozygous for colored aleurone are presumed to be making two classes of gametes, *CR* and *Cr*; a deficiency of white seeds when plants of this nature are used as male parents on plants making one class of gametes (*Cr*) indicates a deficiency of gametes bearing *Cr*. The relations of those ears are shown in figures 4 and 5.

The large deviation for the total seeds of the 29 ears is due to a great extent to the three ears that deviated by more than seven times the probable error. These ears must stand as definite excep-

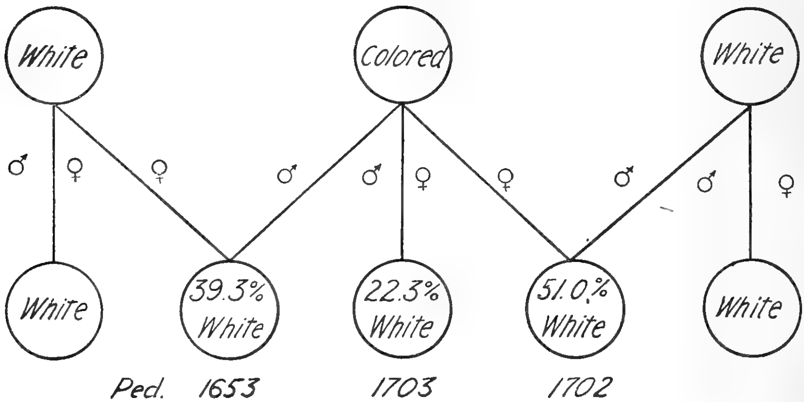


FIG. 5.—Diagram showing the relations of ears Nos. 1653, 1703, and 1702.

tions to the general agreement of the material with theory, but since they stand rather apart from the remaining ears it may be well to exclude them and then examine the totals.

Omitting the data relating to these ears from the total number of seeds for the 29 ears, the percentage of white becomes 48.5. This deviation is 4.6 times the probable error and is still too large to occur as the result of chance. That there is a tendency toward too few white seeds when heterozygous colored plants are used as male parents is demonstrated for this group, even omitting the ears with obviously aberrant ratios.

Table XIX.—*Inheritance of aleurone color in 31 ears of the colored × white and 24 ears of the colored × self progeny of the two maize ears Nos. 1099 and 1111, the progeny of hybrid Dh 234.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Colored × white.						Colored × self.					
	Self-pollinated ♀.	Reciprocal cross.	Number of seeds. Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.	Number of seeds. Seeds.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1099, *CH × WX:*														
1625	Self								464	137	116	21	3.3	29.5
1626	All white	None.	427	219	214	5	0.7	51.0						
1634	do	1558	454	222	227	− 5	.7	48.9						
{1635	None.	None.	703	348	351	− 3	.3	49.5						
{1636	Self								573	151	143	8	1.1	26.4
{1637	All white	None.	424	218	212	6	.9	51.4						
{1638	Self								573	146	143	3	.4	25.5
1639	All white	None.	123	60	61	− 1	.3	48.8						
{1641	None.	None.	396	199	198	1	.2	50.2						
{1642	Self								551	134	138	− 4	.6	24.6
{1643	All white	1552	511	262	256	6	.8	51.3						
{1644	Self								652	183	163	20	2.3	28.6
{1645	All white	None.	510	236	255	−19	2.5	46.3						
{1646	Self								368	79	92	−13	2.3	21.5
{1647	All white	None.	387	165	193	−28	4.2	42.6						
Total			3,935	1,929	1,968	−39	1.8	49.0	3,181	830	795	35	2.1	26.1
Ear No. 1111, *CH × WX:*														
1694	Self								578	149	144	5	.7	25.8
{1695	All white	None.	393	191	196	− 5	.8	48.6						
{1696	Self								373	89	93	− 4	.7	23.8
{1699	All white	None.	511	252	255	− 3	.4	49.3						
{1700	Self								451	128	113	15	2.4	28.4
{1702	All white	None.	239	122	119	3	.6	51.0						
{1703	Self								533	119	133	−14	2.1	22.3
1704	All white	None.	192	104	96	8	1.7	54.2						
{1706	do	None.	443	218	221	− 3	.4	49.2						
{1707	Self								582	140	145	− 5	.7	24.0
{1710	All white	None.	458	220	229	− 9	1.3	48.0						
{1711	Self								415	92	104	−12	2.7	22.2
{1712	All white	None.	181	98	90	8	1.8	54.1						
{1713	do	None.	179	98	89	9	2.0	54.7						
1714	do	None.	561	286	280	6	.8	51.0						
1715	do	None.	304	149	152	− 3	.5	49.0						
{1718	do	None.	290	150	145	5	.9	51.7						
{1719	Self								549	137	137			25.0
Total			3,751	1,888	1,875	13	.6	50.3	3,481	854	870	−16	.9	24.5

TABLE XIX.—*Inheritance of aleurone color in 31 ears of the colored × white and 24 ears of the colored × self progeny of the two maize ears Nos. 1099 and 1111, the progeny of hybrid Dh 234*—Continued.

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Colored × white.						Colored × self.					
			Number of seeds.						Number of seeds.					
	Self-pollinated ♀.	Reciprocal cross.	Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.	Seeds.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1099, *CX × WH:*														
1571	Self								450	125	115	10	1.6	27.8
1572	All white	1604	127	62	63	− 1	.3	48.8						
1573	Self								379	95	95			25.0
1574	None	None.	645	317	323	− 6	.7	49.2						
1575	Self								539	149	135	14	2.1	27.6
1577	All white	1608	596	298	298			50.0						
1578	Self								557	140	139	1	.1	25.1
1579	None	1610	468	248	234	14	1.9	53.0						
1582	Self								397	106	99	7	1.2	26.7
1584	None	1623	406	214	203	11	1.6	52.4						
1585	Self								565	148	141	7	1.0	26.2
1588	None	1614	118	61	59	2	.6	51.6						
1589	Self								458	112	114	− 2	.3	24.5
1590	All white	1619	580	287	290	− 3	.4	49.4						
1591	Self								483	122	121	1	.2	25.2
1592	All white	1621	307	147	153	− 6	1.0	47.9						
1593	Self								243	61	61			25.0
Total			3,247	1,634	1,623	11	.6	50.3	4,071	1,058	1,018	40	2.1	26.0
Ear No. 1111, *CX × WH:*														
1665	All white	1686	403	206	201	5	.7	51.1						
1666	Self								494	128	121	7	1.1	25.9
1667	None	None.	87	40	43	− 3	1.0	46.0						
1668	Self								576	136	144	− 8	1.1	23.6
1669	All white	None.	768	374	384	−10	1.1	48.7						
1670	Self								743	205	186	19	2.4	27.6
Total			1,258	620	629	− 9	.8	49.3	1,813	469	453	16	1.2	25.9
Total of the above four groups			12,191	6,071	6,096	25	.7	49.8	12,546	3,211	3,136	75	2.3	25.6

COLORED × WHITE.

As the result of pollinating plants grown from the heterozygous colored seeds with pollen from plants grown from the white seeds of ears Nos. 1099 and 1111, 31 ears were obtained. These ears are shown in Table XIX. The 31 ears had 12,193 seeds with 49.8 per cent white, the deviation being 0.7 times the probable error. Fourteen ears exceeded the expected, sixteen were below the expected, and one was exactely 50 per cent white. The fit was therefore extremely good.

Only one ear, No. 1647, deviated by an excess of four times the probable error, being 8.4 per cent below the expected.

Three ears were borne on the plant that produced ear No. 1647. One ear, No. 1646, was the result of self-pollination and had 21.5 per cent white, the expected being 25 per cent. The other ear was pollinated by a homozygous white plant and had 46.3 per cent white. Although these last two ears did not deviate by a number too large to be ascribed to chance, the fact that they were both below the expected taken in conjunction with the fact that ear No. 1647 was significantly lower than the expected would seem fairly conclusive evidence that there was a deficiency of female gametes bearing white aleurone on the plant that produced these three ears.

The four groups that make up the total in Table XIX are the reciprocals of the four groups that make up the total in Table XVIII. With the exception of the first group, the families resulting from pollinating plants grown from heterozygous colored seeds with plants grown from homozygous white seeds have a higher percentage of white seeds than the reciprocal cross.

The percentages for the families and the difference between the reciprocals are shown in Table XX.

TABLE XX.—*Inheritance of aleurone color in the progeny of the two maize ears Nos. 1099 and 1111, by groups as shown in Table XVIII and their reciprocals as shown in Table XIX.*

[The minus sign (—) denotes a difference between reciprocal groups, the opposite of the remaining differences.]

Progeny of—	Nature of cross.	Percentage of white seeds.			
		Table XVIII group.	Reciprocal cross.	Difference.	D ÷ E.
Ear No. 1099	*WX* × *CH*	49.4±0.69	49.0±0.54	−0.4±0.87	0.46
Ear No. 1111	do.	47.0± .56	50.3± .55	3.3± .78	4.25
Ear No. 1099	*WH* × *CX*	46.6± .50	50.3± .59	3.7± .78	4.77
Ear No. 1111	do.	45.6± .85	49.3± .95	3.7±1.28	2.90
Total		47.2± .31	49.8± .31	2.6± .43	6.0

The difference between the reciprocal groups of 2.6 per cent should be expected to occur as the result of chance but once in more than 19,000 times. With the one exception, the groups representing crosses between homozygous white plants and heterozygous colored plants had a lower percentage of white seeds when the heterozygous colored plants were used as the male gametes. This would indicate a deficiency of male gametes bearing the colorless aleurone or an excess of the female gametes bearing colored aleurone.

In analyzing the inheritance of waxy endosperm, a deficiency of male gametes bearing the waxy character was observed for the progeny of the hybrid Dh 234. The fact that male gametes bearing colorless aleurone are below the expected would seem to indicate that the gametes bearing recessive characters are less vigorous than those bearing the dominant characters. The observed differences could also be explained by assuming the plant to be making an unequal proportion of male gametes bearing colored and colorless aleurone.

As the result of self-pollinating plants grown from the heterozygous colored seeds of ears Nos. 1099 and 1111, 24 ears were obtained. These ears are shown in Table XIX.

The expected percentage of white seeds is 25 and the observed 25.6. The deviation in this case is only 2.3 times the probable error. Only one ear deviated from the expected percentage by more than three times the probable error, all the ears showing a remarkable uniformity.

Reciprocal crosses between heterozygous colored plants and homozygous white plants showed that for the heterozygous colored plants the male gametes bearing colorless aleurone were 3 per cent below the expected proportion. These same crosses showed the female gametes to be approximately normal. From these facts it would be expected that self-pollinating these heterozygous colored plants would result in ears having approximately 23.5 per cent white. The observed percentage of 25.6 can not be considered as a chance deviation from 23.5 per cent, since the deviation of 2.1 per cent is 8.1 times the probable error.

To explain these conflicting results it is necessary to make the assumption that the gametes bearing the recessive color find a better medium for growth in the stigmas of the heterozygous plant than in those of the homozygous white plants. An adequate test of this assumption would require numbers in excess of 10,000, making it very unlikely that the hypothesis will soon be put to the test.

COMPOSITION IN THE THIRD GENERATION OF THE HYBRID DH 237.

Four ears from the hybrid Dh 237 were selected for planting. Two of the four ears are shown in Table XVII as Nos. 1129 and 1130. The other two ears were the result of crossing Dh 237 by Dh 234, and since all the seeds were colored on both these latter ears, they do not appear in Table XVI. Their progeny are discussed later with the progeny of a similar ear from the hybrid Dh 234.

Ear No. 1129, grown in 1913, was the result of self-pollinating a plant of the hybrid Dh 237. This ear had 747 seeds with 25.1 per cent white, the percentage being almost exactly the expected 25 per cent. Since this ear is demonstrated to be segregating in a normal monohybrid ratio, the progeny plants of the heterozygous seeds are expected to behave in a like manner.

Ear No. 1130 was a second ear on the same plant that bore No. 1129, but instead of being the result of self-pollination as was No. 1129, ear No. 1130 was the result of pollen from a sister plant. The plant that served as the male parent of ear No. 1130 bore a self-pollinated ear, No. 1135. This ear No. 1135, had 26.4 per cent white, the deviation only slightly exceeding the probable error.

Since we have already seen that the plant which bore ear No. 1130 was segregating in a regular Mendelian monohybrid ratio and since the male parent was also a close approximation to the monohybrid ratio, the progeny might also be expected to behave in a regular manner.

There were four classes of seeds on ears Nos. 1129 and 1130—colored and white horny and colored and white waxy. The four classes were planted separately and crosses made between plants grown from the white waxy seeds and plants grown from the colored horny seeds and also between plants grown from the white horny seeds and plants grown from the colored waxy seeds. Self-pollinated ears were obtained from all the classes, but since the self-pollinated plants grown from white seed resulted in white ears only these ears were not tabulated.

The results of the different crosses were examined separately, but since no significant differences were found in the behavior of aleurone color between waxy and horny seeds the endosperm textures may be disregarded. Further, there appeared to be no significant differences between the progeny of the two ears, so that they also may be considered together.

WHITE × COLORED.

As the result of pollinating plants grown from the white seeds with plants grown from the heterozygous colored seeds of ears Nos. 1129 and 1130 thirty ears were obtained (Table XXI). These 30 ears totaled 14,227 seeds, with 50.1 per cent white. This is a remarkably close approximation to the expected 50 per cent. Of the 30 ears, 16 were below, 13 were above, and 1 equaled the expected 50 per cent. Three ears deviated in excess of three times the probable error, all being above the expected 50 per cent. One of these ears, No. 1784, exceeded the expected proportion by 7.3 per cent, and must stand as an exception. A deviation of this magnitude would be expected to occur as the result of chance but once in more than 1,500 times.

COLORED × WHITE.

From the progeny of ears Nos. 1129 and 1130 that were the result of pollinating plants grown from the heterozygous colored seeds with plants grown from the homozygous white seeds 20 ears were obtained (Table XXII).

TABLE XXI.—*Inheritance of aleurone color in 30 ears of maize, the white × colored progeny of the two ears Nos. 1129 and 1130, the progeny of hybrid Dh 237.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Number of seeds.				D ÷ E.	Percentage of white.
	Self-pollinated ♀.	Reciprocal cross.	Total.	White.	Expected white.	Deviation.		
1	2	3	4	5	6	7	8	9
Ear No. 1129, *WX × CH:*								
1752	1802	1801	536	255	268	−13	1.7	52.5
1754	1800	None	500	237	250	−13	1.7	47.4
1758	1800	do	439	216	219	− 3	.4	49.2
1762	1798	do	537	258	268	−10	1.3	48.0
1764	1800	1799	498	251	249	2	.3	50.4
1765	1800	None	528	251	264	−13	.9	47.6
Total			3,038	1,468	1,514	−46	2.5	48.4
Ear No. 1130, *WX × CH:*								
1804	None	1838	363	179	181	− 2	.3	49.3
1806	do	None	435	232	217	15	2.1	53.3
1807	do	do	275	127	137	−10	1.8	46.2
1810	do	do	441	243	220	23	3.3	55.0
1815	do	1849	465	224	232	− 8	1.1	48.2
1816	1855	1854	515	272	257	15	2.0	52.8
Total			2,494	1,277	1,247	30	1.8	51.2
Ear No. 1129, *WH × CX:*								
1772	None	None	448	215	224	− 9	1.7	48.0
1773	do	do	613	304	306	− 2	.2	49.6
1775	do	1768	533	266	266			50.0
1777	do	do	428	194	214	−20	2.9	45.3
1779	do	do	476	262	238	24	3.3	55.0
1781	do	do	477	242	238	4	.5	50.4
1784	do	do	591	339	295	44	5.4	57.3
1786	do	do	446	214	223	− 9	1.3	48.0
1788	do	do	386	189	193	− 4	.3	49.0
Total			4,398	2,225	2,199	26	.1	50.7
Ear No. 1130, *WH × CX:*								
1827	1819	1818	644	333	322	11	1.3	51.7
1829	None	None	511	262	255	7	.9	51.3
1830	1821	do	642	307	321	−14	1.6	47.8
1831	None	do	385	186	192	− 6	.9	48.3
1832	do	do	370	203	185	18	2.8	54.9
{1833	1824	do	435	214	217	− 3	.4	49.3
{1834	1821	do	511	256	255	1	.1	50.5
1835	None	1825	503	256	251	5	.7	50.9
1836	do	1822	297	149	148	1	.2	50.1
Total			4,298	2,166	2,148	18	.8	50.3
Total of the above four groups			14,228	7,136	7,114	22	.6	50.1

The expected percentage of white seeds is 50 and the observed 50.1. Only one ear deviated from the expected percentage by three times the probable error, the remaining ears being very close approximations of the 50 per cent. Ten ears were below, eight above, and two equaled the expected. The four groups of ears shown in this table are the reciprocals of the four groups shown in Table XXI.

There are no significant differences between the groups, all showing a remarkable uniformity, the percentage of white seeds for the totals being exactly alike. The reciprocal groups are shown in Table XXIII. This is a striking contrast with the behavior of reciprocal groups in the progeny of Dh 234, in which a deficient number of male gametes bearing colorless aleurone were found.

TABLE XXII.—*Inheritance of aleurone color in 20 ears of the colored × white and 14 ears of the colored × self progeny of the two maize ears Nos. 1129 and 1130, the progeny of hybrid Dh 237.*

[Lines bracketed together indicate ears borne on the same plant.]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Colored × white.						Colored × self.					
	Self-pollinated ♂.	Reciprocal cross.	Number of seeds. Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.	Number of seeds. Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1129, *CX × WH:*														
1766	All white.	None	432	214	216	−2	0.3	49.6						
1767	Self								425	110	106	4	0.2	25.9
1768	All white.	1775	144	68	72	−4	1.0	47.2						
1769	Self	None							127	31	32	−1	.3	24.4
Total			576	282	288	−6	.1	49.2	552	141	138	3	.4	25.5
Ear No. 1130, *CX × WH:*														
1818	All white.	1827	754	367	377	−10	1.1	48.7						
1819	Self								568	143	142	1	.1	25.2
1820	All white.	None	207	109	108	1	.2	49.8						
1821	Self								619	132	155	−23	3.2	21.4
1822	All white.	1836	542	271	271			50.0						
1823	None	None	566	307	283	24	3.0	54.2						
1824	Self								520	133	130	3	.5	25.6
1825	None	1835	584	287	292	−5	.6	49.2						
Total			2,653	1,341	1,326	15	.9	50.5	1,707	408	427	−19	1.6	23.9
Ear No. 1129, *CH × WX:*														
1790	All white.	None	512	238	256	−18	2.4	46.5						
1791	Self								296	76	74	2	.4	25.6
1792	All white.		487	228	243	−15	2.0	46.8						
1795	None	None	553	281	276	5	.6	50.5						
1796	Self								296	65	74	−9	1.8	21.9
1797	None	None	230	125	115	10	2.0	54.4						
1798	Self								752	178	188	−10	1.3	23.7
1799	None	1764	510	271	255	16	2.1	53.2						
1800	Self								755	215	189	26	3.2	28.5
1801	All white.	1752	381	190	190			49.9						
1802	Self								247	65	62	3	.7	26.3
1803	None	None	244	130	120	10	.9	53.3						
Total			2,917	1,463	1,458	5	.3	50.2	2,346	599	586	−13	.9	25.4
Ear No. 1130, *CH × WX:*														
1838	All white.	1804	545	271	272	−1	.1	49.8						
1839	do	None	415	220	207	13	1.9	53.0						
1840	Self								308	84	77	7	1.4	27.5
1841	All white.	None	583	283	291	−8	1.0	48.6						
1842	Self								451	101	113	−12	1.9	22.4
1846	All white.	None	621	299	310	−11	1.3	48.2						
1847	Self								721	180	180			25.0
1849	All white.	1815	581	301	290	11	1.4							
1854	do	1816	614	299	307	−8	1.0	48.7						
1855	Self								563	132	141	−9	1.3	23.5
Total			3,359	1,673	1,679	−6	.3	49.9	2,043	497	511	−14	1.1	24.6
Total of the above four groups			9,505	4,759	4,752	7	.2	50.1	6,648	1,645	1,662	−17	.7	24.6

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COLORED × SELF.

Fourteen self-pollinated ears were obtained that were expected to have 25 per cent white. These ears are also shown in Table XXII, columns 10 to 15. Two ears deviated slightly in excess of three times the probable error, but the remaining ears were very close approximations to the expected 25 per cent. Seven ears were above, six below, and one equaled the expected percentage.

TABLE XXIII.—*Inheritance of aelurone color in the progeny of the two maize ears Nos. 1129 and 1130, by groups as shown in Table XXI and other reciprocals as shown in Table XXII.*

[The minus sign (—) denotes a difference between reciprocal groups, the opposite of the remaining differences.]

Progeny of—	Nature of cross.	Percentage of white seeds.			
		Table XXI group.	Reciprocal cross.	Difference.	D÷E.
Ear No. 1129	*WX* × *CH*	48.4±0.61	49.2±1.4	0.8±1.53	0.5
Ear No. 1130	do	51.2± .68	50.5± .66	— .7± .94	.75
Ear No. 1129	*WH* × *CX*	50.7± .51	50.2± .63	— .5± .81	.62
Ear No. 1130	do	50.5± .52	49.9± .58	— .6± .78	.77
Total	*W* × *C*	50.1± .28	50.1± .34	0	

SUMMARY OF THE HYBRID DH 237.

From the progeny of the hybrid Dh 237 there were in all 48 plants that produced 64 ears. Of these, 32 ears were below, 28 above, and 4 equaled the expected percentages. There were only 6 ears that must be considered exceptions. While the ratios on these 6 ears can not be brought into accord with the other results, the progeny of hybrid Dh 237 is strikingly uniform as compared with the sister hybrid Dh 234.

PROGENY OF THE CROSSES BETWEEN THE TWO HYBRIDS DH 234 AND DH 237.

EARS NOS. 1110, 1131, AND 1134.

Three ears representing crosses between the two hybrids Dh 234 and Dh 237 were selected for planting. These three ears were all colored and therefore do not appear in the second-generation tables. The ear numbered 1110 was borne on a plant of the hybrid Dh 234, which, when self-pollinated, produced ear No. 1111, the progeny of which have been considered on pages 39 to 46.

The ears are shown in the following diagram:

Hybrid Dh 234 *CC Rr* — Self — Pedigree No. 1111, 25.8 per cent. white.
Hybrid Dh 234 *CC Rr* ♀ × Hybrid Dh 237 *Cc RR* ♂ — Pedigree No. 1110, all colored.
Hybrid Dh 237 *Cc RR* — Self — Pedigree No. 1132, 27.8 per cent. white.

Hybrid Dh 237 *Cc RR* — Self — Pedigree No. 1132, 27.8 per cent. white.
Hybrid Dh 237 *Cc RR* ♀ × Hybrid Dh 234 *CC Rr* ♂ — Pedigree No. 1131, all colored.
Hybrid Dh 234 *CC Rr* — Self — Pedigree No. 1117, 25.5 per cent. white.

Hybrid Dh 237 *Cc RR* — Self — Pedigree No. 1133, 23.1 per cent. white.
Hybrid Dh 237 *Cc RR* ♀ × Hybrid Dh 234 *CC Rr* ♂ — Pedigree No. 1134, all colored.
Hybrid Dh 234 *CC Rr* — Self — Pedigree No. 1118, 27.9 per cent. white.

The same explanation will apply to all three ears, Nos. 1110, 1131, and 1134. Self-pollinated ears were obtained from the male and female parents of each of the ears, and the results showed all of the plants to be segregating in a regular manner, producing the unit character ratio of 3 colored to 1 white.

It has been assumed that the hybrid Dh 234 was producing gametes *CR Cr*, and that the hybrid Dh 237 was producing gametes *CR cR*. Either hybrid, self-pollinated, would result in a monohybrid ratio, while if crossed it would result in ears with all of the seeds colored. If this assumption is correct the expected result of planting the seeds from a cross between two such plants and self-pollinating them would be one ear all colored, two having 3 colored seeds to 1 white, and one having 9 colored seeds to 1 white.

PROGENY OF EAR NO. 1131.

As only self-pollinated ears were obtained from the progency of ear No. 1131, these ears will be discussed separately.

There were two classes of seeds on ear No. 1131, colored horny and colored waxy. These two classes were planted separately. The ears obtained from both classes are shown in Table XXIV. The upper group of four ears was obtained from self-pollinating plants grown from the waxy seeds, and the lower group is the result of self-pollinating plants grown from the horny seeds. The 10 ears do not afford a sufficient number to determine whether 1 all-colored ear, 2 ears segregating 3 colored to 1 white, and 1 ear segregating 9 colored to 7 white are obtained.

No all-colored ears were obtained. Nine of the 10 ears are approximating 25 per cent white, while the remaining ear, No. 1892, approximates the Mendelian dihybrid ratio. The total number of seeds for the nine monohybrid ears is 2,158, with 24.7 per cent white, the deviation being less than the probable error. None of the ears deviated in excess of three times the probable error, 5 were below, and 4 above the expected.

TABLE XXIV.—*Inheritance of aleurone color in 10 ears of the colored × self progeny of maize ear No. 1131, the progeny of a cross between hybrids Dh 234 and Dh 237.*

Character of cross and pedigree No. of progeny.	Number of seeds.				D ÷ E.	Percentage of white.
	Total.	White.	Expected white.	Deviation.		
Colored waxy × self:						
1887	269	69	67	2	0.4	25.6
1888	279	75	69	6	1.2	26.9
1889	257	58	64	−6	1.3	22.5
1890	47	10	12	−2	1.0	21.3
Total	852	212	213	−1	.1	24.9
Colored horny × self:						
[a]1892	36	18	15	3	1.5	50.0
1893	337	69	84	−15	2.8	20.5
1894	261	69	65	4	.9	26.4
1895	33	5	8	−3	1.8	15.1
1896	251	75	63	12	2.6	29.8
1897	424	105	106	−1	.2	24.8
Total	1,306	323	326	−3	.4	24.7
Total for both groups	2,158	535	539	−4	.29	24.7

[a] Ear No. 1892 is assumed to be approximating 43.75 per cent white and is not included in the totals.

PROGENY OF EARS NOS. 1110 AND 1134.

There were also two classes of seeds on ears Nos. 1110 and 1134, colored horny and colored waxy. These two classes were planted separately, and crosses were made between them. Self-pollinated ears were also secured from each class.

The progeny of the two ears were examined separately, but no significant differences were found, so the progeny are tabulated together.

COLORED × COLORED.

As the result of crossing plants grown from the colored horny seeds with the plants grown from the colored waxy seeds of ears Nos. 1110 and 1134, 24 ears were obtained (Table XXV). The crosses were made using the waxy plants as both male and female parents, but as no significant differences were found the endosperm textures may be disregarded. Five all-colored ears were obtained that are not tabulated. The 25 ears tabulated were borne on 23 plants.

The expected proportions for these 28 individual plants is 15.75 plants all colored, 10.5 plants with a monohybrid ratio, and 1.75 plants with a dihybrid ratio. The observed plants fell into two groups only, 5 ears all colored and 23 with a monohybrid ratio. The deviation, though too large to be ascribed to chance, may, nevertheless, be the result of accident.

The observed deviation would be expected to occur as the result of chance but once in 500 times. Although this deviation would seem significant, it is, in fact, merely accidental. Self-pollinating these plants proved that they were in the expected proportion of 1 homozygous for both color factors, 2 heterozygous for one and homozygous for the other, and 1 heterozygous for both factors. The deviations noted from this grouping would be expected to occur as the result of chance eight times in a hundred.

The large deviation from the expected grouping for the crosses between sister plants was probably the result of an unconscious selection of the male parents, since we have seen that the plants were present in the expected proportions. Seven of these 23 ears were borne on plants that were shown by means of self-pollinated ears to be heterozygous for two color factors. But since these seven ears were all the result of pollen from plants that were homozygous for one color factor and heterozygous for the other, they had approximately 25 per cent of the seeds white.

One of the four groups that comprise the total deviated in excess of the expected percentage by 3.7 times the probable error. The deviation in this group is due to an excess of white seeds on ear No. 1876. This ear had 32.4 per cent of the seeds white. The deviation of 7.4 per cent above the expected 25 per cent is 4.9 times the probable error. The plant that produced the ear in question bore two other ears, Nos. 1874 and 1875. No. 1874, like 1876, was the result of pollen secured from a plant grown from the colored waxy seeds of ear No. 1110. The third ear, No. 1875, was the result of self-pollinating the female parent of ears Nos. 1874 and 1876. The self-pollinated ear No. 1875 had 41.6 per cent white, demonstrating the female parent of these three ears to be heterozygous for the two factors for color. Unfortunately, an ear was not secured from the male parent of No. 1876, so the gametic constitution of this plant can not be definitely determined. Ear No. 1876, however, with 32.4 per cent white, is closer to a monohybrid ratio than a dihybrid ratio, but it stands almost midway between the two ratios and can scarcely be referred to either. The relations of these ears are shown in figure 6.

TABLE XXV.—*Inheritance of aleurone color in 24 ears of the colored waxy × colored horny and 28 ears of the colored waxy × self progeny of the two maize ears Nos. 1110 and 1134, the progeny of crosses between hybrids Dh 234 and Dh 237.*

[Lines bracketed together indicate ears borne on the same plant; ears that were considered as approximations of 43.75 per cent white are marked with an asterisk (*); ears that were pollinated by sister plants are marked with a dagger (†).]

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Colored waxy × colored horny.						Colored waxy × self.					
			Number of seeds.						Number of seeds.					
	Self-pollinated ♂.	Reciprocal cross.	Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.	Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1110, *CX × CH*:														
{1856	1878	1877	525	143	131	12	1.8	25.4						
{1857	Self								433	91	108	−17	2.4	21.0
{1858	1880	None	491	121	123	− 2	.3	24.7						
{1859	Self								*477	207	208	− 1	.1	43.4
1860	1875	1874	649	164	162	2	.3	25.3						
{1861	None	1871	450	109	112	− 3	.5	24.2						
{1862	Self								*532	193	233	−40	5.2	36.3
{1863	None	None	679	174	170	4	.5	25.6						
{1864	Self								*556	253	244	9	1.1	45.5
1865	1875	None	739	181	185	− 4	.5	24.5						
1866	Self								676	158	169	−11	1.3	23.4
1867	...do								69	22	17	5	2.4	31.9
1868	...do								95	21	24	− 3	1.1	22.1
1869	...do								*135	60	57	3	1.2	44.4
1870	...do								*51	18	22	− 4	1.7	35.3
Total			3,533	892	883	9	.5	25.2	1,273	292	318	−26	2.5	23.0
Total, marked ears									*1,751	731	765	−34	2.4	41.7
Ear No. 1134, *CX × CH*:														
1899									*695	284	304	−20	2.3	40.9
{1902	1918	1917	765	215	191	24	2.9	28.1						
{1903	Self								55	9	14	− 5	2.3	16.3
1904	None	None	443	115	111	4	.7	26.0						
1905	1934	1935	366	82	91	− 9	1.6	22.4						
1906	1923	1922	315	87	79	8	1.5	27.6						
1907†									560	143	140	3	.4	25.5
{1909	1925	1924	485	103	121	−18	2.8	21.3						
{1910	Self								*502	211	219	− 8	1.1	42.0
{1911	1934	1933	484	129	121	8	1.3	26.6						
{1912	Self								562	134	140	− 6	.9	249.
{1913†	1912								619	144	155	−11	1.5	23.3
{1914	Self								*513	272	220	52	6.5	53.0
{1905	...do								525	133	131	2	.3	25.3
Total			2,858	731	712	19	1.2	25.6	2,321	563	580	−17	1.2	24.2
Total, marked ears									*1,710	767	748	19	1.3	44.8
Total, two *X × H* groups			6,391	1,623	1,598	25	1.1	25.4	3,594	855	898	−43	2.4	23.8
Total, marked ears									*3,461	1,498	1,513	−15	.7	43.3

TABLE XXV.—*Inheritance of aleurone color in 24 ears of the colored waxy × colored horny and 28 ears of the colored waxy × self progeny of the two maize ears Nos. 1110 and 1134, the progeny of crosses between hybrids Dh 234 and Dh 237*—Continued.

Parent ear and pedigree No. of progeny.	Pedigree No. of—		Colored waxy × colored horny.						Colored waxy × self.					
	Self-pollinated ♂.	Reciprocal cross.	Number of seeds: Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.	Number of seeds: Total.	White.	Expected white.	Deviation.	D ÷ E.	Percentage of white.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ear No. 1110, *CH × CX*:														
1871	1862	1861	81	21	20	−1	.4	25.9						
{1872	1862	None	538	144	134	10	1.5	26.8						
{1873	Self								73	19	18	1	.4	26.0
{1874	None	1860	137	41	34	7	2.1	29.9						
{1875	Self								*716	298	306	−8	1.0	41.6
{1876	None	None	377	122	94	28	4.9	32.4						
{1877	1857	1856	424	101	106	−5	.8	23.9						
{1878	Self								496	136	124	12	1.8	27.4
1880	...do								371	87	93	−6	1.1	23.4
1882	...do								*136	61	58	3	.8	44.8
Total			1,557	429	387	42	3.7	27.5	940	242	235	7	.8	25.8
Total, marked ears									*852	359	372	−13	1.3	42.2
Ear No. 1134, *CH × CX*:														
{1917	1903	1902	452	120	113	7	1.1	26.5						
{1918	Self								345	92	86	6	1.1	26.6
{1922	None	1906	421	109	105	4	.7	26.6						
{1923	Self								399	113	100	13	2.2	28.3
{1924	1910	1909	415	108	104	4	.7	26.9						
{1925	Self								457	111	114	−3	.5	24.3
1928	...do								397	88	99	−11	1.9	22.1
1929	None	None	332	88	83	5	.9	26.5						
1932	1912	...do	477	112	119	−7	1.1	23.5						
{1933	1912	1911	324	101	81	20	3.8	31.2						
{1934	Self								*346	161	151	10	1.6	46.6
{1935	1912	1911	222	66	55	11	2.5	29.7						
1937	Self								*443	188	194	−6	.9	42.4
Total			2,643	704	661	43	2.9	26.6	1,598	404	400	4	.3	25.3
Total, marked ears									*789	349	345	4	.4	44.3
Total, two *H* × *X* groups			4,200	1,113	1,050	63	3.3	26.5	2,538	646	635	11	.8	25.4
Total, two groups, marked ears									*1,641	708	718	−10	.7	43.1
Total, four *C* × *C* groups			10,591	2,736	2,648	88	2.9	25.8	6,132	1,501	1,533	−32	1.4	24.5
Total, four groups, marked ears									*5,102	2,206	2,230	−24	1.0	43.2

The probable error is so high on ear No. 1874 that the deviation from 25 per cent is insignificant, although the percentage of white seeds on this ear approximates the percentage observed on ear No. 1876 more closely than that observed on the reciprocal ear, No. 1860; the deviation from either is insignificant.

It becomes of interest to note that there is one other case where a plant heterozygous for two color factors when pollinated with pollen from a plant heterozygous for one color factor and homozygous for the other has a percentage of white seeds intermediate between 25 and 43.75. The ears are Nos. 1933 and 1935, Table XXV. The plant that bore these ears also bore ear No. 1934. The ear numbered 1935 had for a male parent the same plant which served as the male parent of No. 1933. Both of these ears had white seeds in excess of the expected. Ear No. 1934 was the result of self-pollinating the female parent of ears Nos. 1933 and 1935. This self-pollinated ear had 46.6 per cent of its seeds white, demonstrating the plant to be heterozygous for two color factors.

The male parent of ears Nos. 1933 and 1935 produced an ear the result of self-pollination, No. 1912. This ear had 24.9 per cent of its

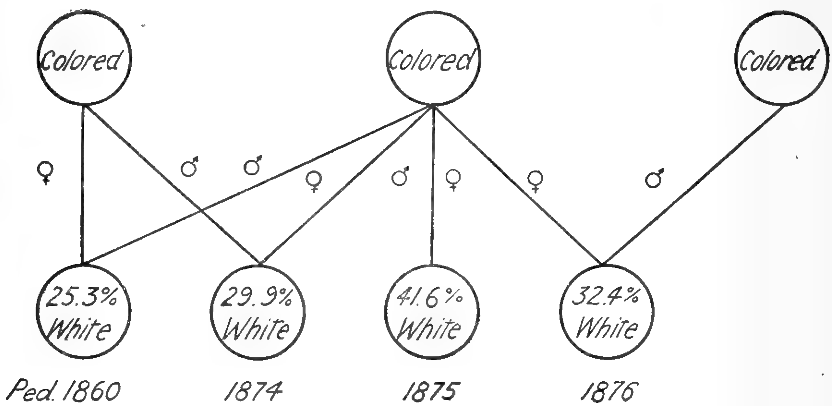

FIG. 6.—Diagram showing the relations of ears Nos. 1860, 1874, 1875, and 1876.

seeds white, demonstrating the male parent to be approximating the percentage expected if the plant were heterozygous for one color factor and homozygous for the other.

A reciprocal cross was also made between the plant which produced ears Nos. 1933, 1934, and 1935 and the plant which produced ear No. 1912. The ear representing the reciprocal cross of ears Nos. 1933 and 1935 is No. 1911. This latter ear had 26.6 per cent of its seeds white, the deviation from 25 per cent being only slightly in excess of the probable error. The difference between the reciprocal ears (averaging Nos. 1933 and 1935) is 4.1 per cent, a difference that would be expected as the result of chance once in six times. The relations of these ears are shown in figure 7 .

The seeds from three ears, Nos. 1876, 1933, and 1935, were reexamined and the classification was found to be correct. The distinction between white and colored seeds was very good, no doubtful seeds being encountered. Ears Nos. 1876, 1933, and 1935 indicate that the deviation is constitutional, as all the ears are near enough to the same ratio to be placed in a single group. This affords evidence that one of the factors for color is varying, and the rather definite deviation indicates that the change is in the nature of fractionation.

If definite segregation of hereditary units is a fact, then the number of white seeds reappearing in the second generation of white × colored crosses will approximate certain percentages. If these percentages are not approximated, two explanations are possible on the basis of equal segregation:

(1) The predication of additional factors, inhibitors, and assumptions. By this method any percentage is possible, though when more than three factors are required it is seldom possible to test the explanation, since the number of individuals necessary to measure accurately small differences is extremely large. Immediate percentages may be explained by the use of additional fac-

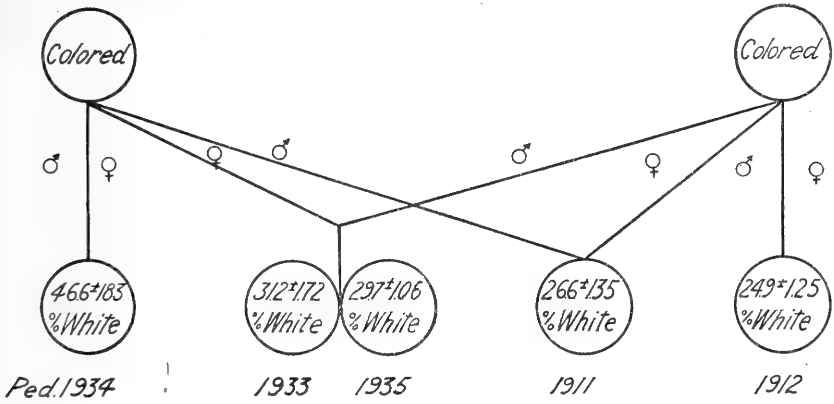

FIG. 7.—Diagram showing the relations of ears Nos. 1934, 1933, 1935, 1911, and 1912.

tors, but in most cases it becomes impossible to reconcile the explanation with the behavior of the same individual in other combinations. Not infrequently individual ears of maize are found that seem to fulfill certain comparatively simple explanations, but when the related pedigrees are analyzed a frequent result is to find incompatible individuals.

(2) "Failure of dominance" is the term often used to explain an excess of the recessive character, but this explanation will not serve when the recessive character is deficient. If the fact that hereditary units undergo change during hybridization requires any further evidence than that presented by Castle and Phillips (2) this frequent "failure of dominance" in generations succeeding the first would seem to furnish this evidence. If in a cross between a colored and a white plant the color proves to be dominant in the first generation, but in subsequent generations this complete dominance partially disappears, as it actually does, it seems natural to assume that either the color or the white, or both, have undergone some change, so that they do not stand as unalterably opposed as at first. In other words, a partial blend has taken place. Such a theory without doubt "strikes at the very heart of Mendelism," but the facts as they are must be acknowledged.

In demonstrating that an excess of white seeds is due to a failure of dominance the seeds bearing this character are planted, and upon the appearance of some seeds with the dominant character the "failure of dominance" is considered demonstrated. This is all very well, but it is also just what would be expected if segregation were not definite or complete. The finding of some seeds bearing the dominant character on plants grown from the suspected seeds does not explain the discrepancies observed in the parent stock unless the proper proportion of plants show the dominant character. In most cases the actual number of plants necessary to determine whether this proportion is as expected is so large that investigators have been content when some of the plants exhibited the expected dominant character.

COLORED × SELF.

Twenty-eight ears were obtained from self-pollinating plants grown from the heterozygous colored seeds of ears Nos. 1110 and 1134. Of these 28 ears, 17 were considered as approximations of the monohybrid ratio of 3 colored to 1 white. The total number of seeds secured from these 17 ears was 6,132, with 25 per cent white.

The individual ears are also shown in Table XXV. The ears marked with a star are those considered as approximations of some percentage other than 25 per cent. Of the 17 ears, none deviated from the 25 per cent in excess of three times the probable error. The remaining 11 ears with two exceptions were close approximations to the dihybrid percentage of 43.75 per cent white. The total number of seeds obtained from the 11 ears was 5,102, with 43.2 per cent white. The deviation of 0.55 per cent below the expected just equals the probable error. With the exception of ears Nos. 1914 and 1862 none of the 11 ears deviated from the 43.75 per cent white in excess of three times the probable error. The deviations noted on ears Nos. 1914 and 1862 practically balance each other. No. 1862 being 5.2 times the probable error below the expected and No. 1914 being 6.5 times above the expected ratio.

Ear No. 1862 has a percentage of white seeds 11.3 per cent above the 25 per cent expected ratio for a monohybrid and 7.45 per cent below the 43.75 per cent expected on a dihybrid ratio. The probable error is ± 1.4 and the deviation is 5.3 times the probable error from the dihybrid percentage, which the ear more nearly approximates.

The same plant which produced ear No. 1862 also produced ear No. 1861, which was the result of pollen from the plant which produced ear No. 1871. These ears, Nos. 1861 and 1871, are reciprocals, and are very close approximations to the monohybrid percentage of 25. If the plant which produced ear No. 1862 was heterozygous for two color factors, pollinating this plant with one homozygous for one color factor and heterozygous for the other would result in an ear with 25 per cent of its seeds white. This same percentage of white seeds would of course be the result if both the plants in question were homozygous for the same color factor and heterozygous for the other. The percentage of white seeds is a fairly close approximation of 31.25 per cent expected on a 11 to 5 ratio, but the assumptions necessary to account for this ratio on ears that result from self-pollination are too absurd to permit such an explanation. The relations of these ears are shown in figure 8.

Here again we have evidence of a change in the effect produced by the factors, but since the same plant behaved normally when crossed with a sister plant in respect to both male and female gametes we must assume that whatever the change it was not sufficient to affect the results except where the changed gamete was received from both parents.

If we look upon ear No. 1862 as being a deviation from a dihybrid ratio, there is an excess of colored seeds. If the assumption

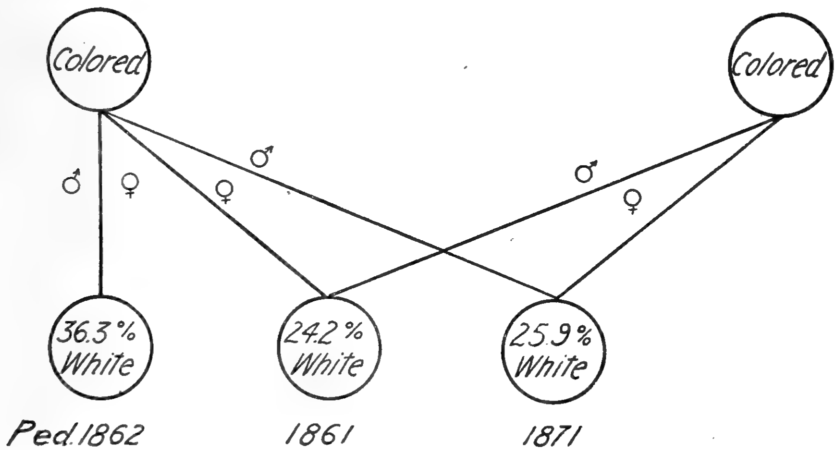

FIG. 8.—Diagram showing the relations of ears Nos. 1862, 1861, and 1871.

is made that this excess is due to a fractionation of one of the factors, this altered factor must be the one for which the plant which bore No. 1871 was homozygous.

Thus the plant which bore ear No. 1862 was forming gametes *CR*, *Cr*, *cR*, and *cr*. If we assume that a sufficient amount of the factor *R* was included in the gamete *Cr′* to make the union of the two gametes *Cr′* result in a colored zygote the ratio of white to colored seeds would be altered and the percentage would be 39.06 white, a percentage closely approximated by ear No. 1862. (See Table XXVI.) This change, however, was not sufficient to produce color when combined with a pure *Cr* gamete obtained from the sister plant, as is shown by ears Nos. 1861 and 1871.

TABLE XXVI.—*Possible effect of self-fertilizing a plant in which the color factor has become fractionated in such a way as to make the union of the gametes result in a colored zygote.*

[The percentage of white seeds is 39.06.]

Gametes.	CR.	CR′.	Cr′.	Cr.	cR.	cR′.	cr′.	cr.
CR	Colored	Colored	Colored	Colored	Colored	Colored	Colored	Colored.
CR′	do	do	do	do	do	do	do	Do.
Cr′	do	do	do	White	do	do	do	White.
Cr	do	do	White	do	do	do	White	Do.
cR	do	do	Colored	Colored	White	White	do	Do.
cR′	do	do	do	do	do	do	do	Do.
cr′	do	do	do	White	do	do	do	Do.
cr	do	do	White	do	do	do	do	Do.

The other aberrant ear, No. 1914, which is shown in figure 9, is a very close approximation of the 1 to 1 ratio, the deviation being but slightly in excess of two times the probable error. The deviation is also insignificant from the 56.25 per cent white expected on a 7 to 9 ratio, while the expected ratio was 9 to 7 or 43.75 per cent white. Here again we may be dealing with a fractionation of the factor *R* in such a way perhaps that enough has been separated from the factor *R* to occasionally prevent the normal color reaction with the

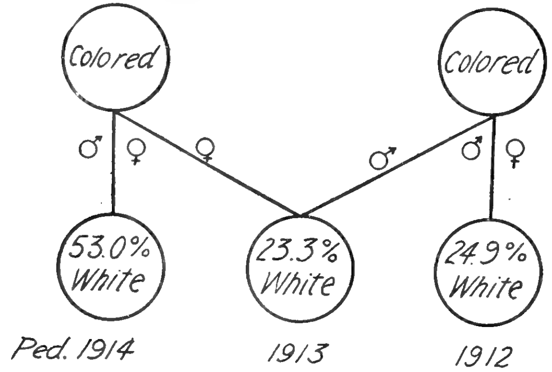

FIG. 9.—Diagram showing the relations of ears Nos. 1914, 1913, and 1912.

factor *C*. (See Table XXVII.) If this assumption is made, the expected percentage of white seeds is 53.1, which is indeed a very close approximation to the observed 53 per cent.

With the assumption that the plant which bore ear No. 1914 was of the type indicated in Table XXVII, such a plant if crossed with one heterozygous for the factor *C* and homozygous for the normal *R* factor would give an ear with the monohybrid ratio of white to colored seeds which fits the observed results, as is shown in figure 9.

TABLE XXVII.—*Possible effect of self-fertilizing a plant in which the color factor has become fractionated in such a way as to prevent the normal reaction.*

[The percentage of white seeds is 53.125.]

Gametes.	CR.	CR′.	Cr′.	Cr.	cR.	cR′.	cr′.	cr.
CR	Colored	Colored	Colored	Colored	Colored	Colored	Colored	Colored.
CR′	do	do	do	White	do	do	do	White.
Cr′	do	do	White	do	do	do	White	Do.
Cr	do	White	do	do	do	White	do	Do.
cR	do	Colored	Colored	Colored	White	do	do	Do.
cR′	do	do	do	White	do	do	do	Do.
cr′	do	do	White	do	do	do	do	Do.
cr	do	White	do	do	do	do	do	Do.

SUMMARY OF THE INHERITANCE OF ALEURONE COLOR.

The total number of ears expected to have 25 per cent of their seeds white was 163. This number includes both the second and the third generation of the two hybrids. The groups are shown in Table XXVIII. The 163 ears had a total of 81,336 seeds, with 25.5 per cent white. This percentage is misleading, for, while it is only

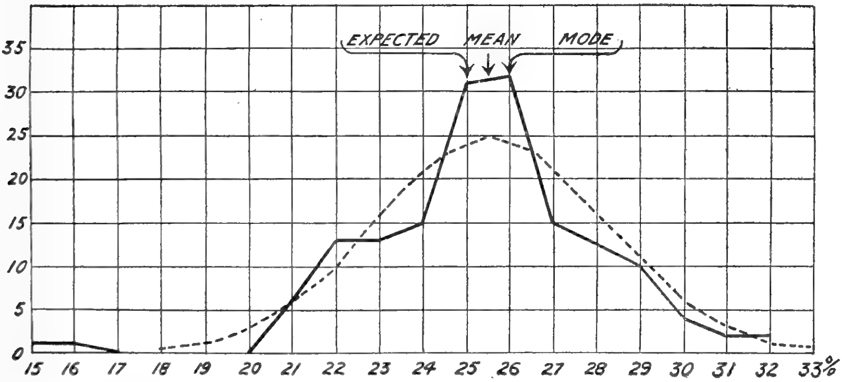

FIG. 10.—Diagram showing the percentages of white seeds on 163 ears expected to have 25 per cent of the seeds white compared with the normal probability curve.

0.5 per cent above the expected ratio, the deviation for the number of seeds involved is almost five times the probable error.

A deviation of this magnitude should not occur as the result of chance oftener than once in 666 times. The deviation, then, demands an explanation. That this deviation is not the result of a few aberrant ears is shown by the curves in figure 10. Only 11 of the 163 ears deviated in excess of three times the probable error, and only 3 exceeded four times the probable error, although with 163 ears we would expect 8 to deviate in excess of three times the probable error. There is undoubtedly a tendency to produce an excess of white seeds among most of the groups expected to segregate in a normal Mendelian monohybrid ratio. This tendency to produce an excess of white seeds is more evident in the hybrid Dh 234 and its progeny than in the hybrid Dh 237.

TABLE XXVIII.—*Inheritance of aleurone color in all the maize ears expected to have 25 per cent of the seeds white.*

Nature of cross.	Number of ears—		Number of seeds.				D÷E.	Percentage of white.
	Observed.	Below expected.	Total.	White.	Expected white.	Deviation.		
Progeny of hybrid Dh 234:								
Ear No. 1099	15	3	7,252	1,888	1,813	75	3.01	26.0
Ear No. 1111	10	5	5,294	1,323	1,323			25.0
Progeny of hybrid Dh 237:								
Ear No. 1129	7	3	2,898	740	724	16	1.02	25.5
Ear No. 1130	7	3	3,750	905	937	−32	1.79	24.1
Progeny of Dh 234 × Dh 237:								
Ear No. 1110	18	9	7,234	1,833	1,808	25	1.00	25.3
Progeny of Dh 237 × Dh 234:								
Ear No. 1131	9	5	2,158	535	539	−4	.29	24.7
Ear No. 1134	22	7	9,420	2,402	2,355	47	1.66	25.5
Second generation:								
Hybrid Dh 234	46	13	26,383	6,807	6,596	211	4.45	25.8
Hybrid Dh 237	29	11	16,947	4,307	4,237	70	1.84	25.4
Total	163	59	81,336	20,740	20,334	406	4.88	25.5

One explanation of this deviation would be that through mistakes in classification colored seeds were being included among the white. If this were the case, the white seeds planted and self-pollinated would be expected to result in some ears having colored seeds. The deviation is so small, however, that only one such ear could be expected in growing and self-pollinating 200 of the so-called white seeds.

If seeds bearing color had been classified as white, crosses between plants grown from the white seeds with plants grown from the colored seeds would be expected to result in some ears with a monohybrid ratio of white to colored seeds, instead of equal numbers of white and colored seeds. Several hundred ears representing the above crosses were obtained without finding any ears with a monohybrid ratio.

The possibility, then, that some of the seeds classified as white were in reality colored is remote. In hybrids involving endosperm texture the significant deviations observed have been with the recessive class below the expected (5, 7, and 8).

This significant departure above the expected number of recessives is not supported by the remainder of the progeny expected by the nature of the crosses to have equal numbers of white and colored seeds (Table XXIX).

There were 110 ears of the progeny of both the hybrids that were expected to be segregating in a 1 to 1 ratio. These ears had 47,872 seeds, with 49.2 per cent white. Here again the seemingly close approximation of the observed percentage to that expected by theory is misleading. The deviation of 0.8 per cent is 5.10 times the probable error and is evidently too large to be ascribed to chance. Only 4 of the 110 ears deviated from the expected percentage in excess of three times the probable error, and with 110 ears 5 such ears would be expected.

The deviation in this case can not be explained by assuming that colored seeds are being classified as white, as the colored seeds are in excess. It is hardly reasonable to assume that white seeds were being included in the colored class. The second-generation plants from the colored groups failed to produce any all-white ears, which would be the case if the excess of colored seeds resulted from mistakes in classification.

TABLE XXIX.—*Inheritance of aleurone color in all the maize ears expected to have 50 per cent of the seeds white.*

Nature of cross.	Number of ears.		Number of seeds.				D÷E.	Percentage of white.
	Observed.	Below expected.	Total.	White.	Expected white.	Deviation.		
Progeny of hybrid Dh 234:								
Ear No. 1099	35	20	13,986	6,794	6,994	−200	5.01	48.6
Ear No. 1111	25	16	10,154	4,907	5,077	−170	5.00	48.3
Progeny of hybrid Dh 237:								
Ear No. 1129	24	14	10,929	5,438	5,463	− 25	.71	49.7
Ear No. 1130	26	12	12,803	6,457	6,401	56	1.46	50.4
Total	110	62	47,872	23,596	23,937	−341	5.10	49.2

One parent of each of the ears having equal numbers of white and colored seeds must be homozygous for white aleurone, and is, therefore, making white gametes only. When these gametes unite with gametes produced by plants heterozygous for colored aleurone, the resulting seeds are expected to be white and colored in equal proportions, but this has not proved to be the case. A deficit too large to be due to chance occurs in the number of white seeds. It becomes of interest to note that the largest deviations below the expected percentage occur in the progeny of the hybrid Dh 234. This is all the more remarkable, since the hybrid in question has been shown to be producing an excess of white seeds on the first-generation ears as well as on the second-generation ears, expected to have but 25 per cent of their seeds white.

Since the variation in the percentage of white seeds, noted for the 47,872 seeds forming the total for the 110 ears which were expected to have equal numbers of white and colored seeds, was of necessity confined to one parent, it became of interest to know whether that parent was defaulting equally in the number of male and female gametes carrying white aleurone. The progeny of ear No. 1099 had 6,804 seeds born on homozygous white plants, but pollinated with pollen from heterozygous colored plants. The percentage of these white seeds was 47.5. The heterozygous colored plants grown from seeds of ear No. 1099 bore 7,182 seeds that were the result of pollen from the homozygous white plants. The percentage of these white seeds was 49.6.

The difference between the white plants pollinated with pollen from the colored plants and the colored plants pollinated with pollen from the white plants is 2.1±0.571 per cent. This difference is 3.67 times the probable error and would seem to indicate that the heterozygous colored plants were making the expected proportions of female gametes with the observed shortage occurring in the male gametes.

A similar analysis of the progeny of ear No. 1111 shows the percentage of male gametes bearing white aleurone to be below the expected by 5.2 times the probable error.

The homozygous white plants of ear No. 1129 bore 7,434 seeds that were the result of pollen from heterozygous colored plants of this same progeny. The observed percentage of white seeds is 49.7. The heterozygous colored plants bore 3,493 seeds that were the result of pollen from the homozygous white plants. The observed percentage was 50. The difference between these two groups is but 0.3 per cent and can not be considered significant, though the variation is in the same direction as the cases previously considered.

The progeny of ear No. 1130, progeny of the hybrid Dh 237, varied slightly in the other direction, the male parents proving to have a higher percentage of white than of colored gametes, and while the white female gametes also were in excess, the excess of white male gametes exceeded that of the white female gametes by 0.5 per cent, which is not significant.

Combining the progeny considered above, there were 26,174 seeds which were borne on homozygous white plants, but the result of pollen from heterozygous colored plants. The observed proportion of white seeds in these was 48.8 per cent.

The heterozygous colored plants which were the result of pollen from homozygous white plants bore 21,698 seeds. The observed percentage of white seeds in these is 50. The difference between these two groups is 1.2±0.31 per cent. This difference is 3.87 times the probable error, which is a rather large difference to be ascribed to chance.

The hybrid Dh 237 seems to be much more regular in behavior, at least as regards the proportions of white and colored seeds, though this hybrid produced ears segregating in a dihybrid ratio, as well as ears approximating a monohybrid ratio; usually in dealing with two color factors it is found that the inheritance of color is most irregular, the ratios often exhibiting a great range of variation.

Fifteen ears that were assumed to be segregating approximately 9 colored to 7 white are shown in Table XXX. These 15 ears had 6,519 seeds with 43.0 per cent white, the deviation of 0.75 per cent being 1.55 times the probable error and no larger than can be reasonably ascribed to chance.

TABLE XXX.—*Inheritance of aleurone color in all the maize ears expected to have 43.75 per cent of the seeds white.*

Nature of cross.	Number of ears.		Number of seeds.				D÷E.	Percentage of white.
	Observed.	Below expected.	Total.	White.	Expected white.	Deviation.		
Hybrid Dh 237, Algeria × Chinese variety:								
Second generation	4	2	2,477	1,072	1,083	−11	0.66	43.3
Hybrid Dh 234 × Dh 237:								
Progeny of ear No. 1110	6	3	2,020	879	854	25	1.65	43.5
Hybrid Dh 237 × Dh 234:								
Progeny of ear No. 1131	1	....	36	18	15	3	1.50	50.0
Progeny of ear No. 1134	4	3	1,986	839	868	−29	1.95	42.2
Total	15	8	6,519	2,808	2,850	−42	1.55	43.0

CORRELATION BETWEEN ENDOSPERM TEXTURE AND ALEURONE COLOR.

In several hundred crosses between American varieties of maize with horny endosperm and the Chinese variety with waxy endosperm a correlation has always been found to exist between the texture of the endosperm and the color of the aleurone. The results of a number of these crosses have been previously reported (7 and 4).

The study of correlation which had been relegated to the background upon the appearance of Mendelism with its theory of independent units received fresh impetus with the announcement of Bateson and Punnett that the mathematical regularity common in Mendelism was also to be found in the relationships between characters. These authors found that correlations were gametic, the parental combinations being found to occur in the gametes more frequently together than separated. To account for this difference in the gametic ratios they have assumed that the cells bearing the parental characters divide or reduplicate more frequently than the cells bearing the characters derived from different parents. For some inexplicable reason they assumed that the ratio between the number of gametes in which the parental combinations occurred together to the number in which they were separated would fit a definite series composed of the familiar Mendelian ratios of 3 to 1, 7 to 1, 15 to 1, etc. From this arbitrary series they have evolved an elaborate system of cell division to account for the gametic associations.

As higher couplings were secured these authors came to the realization that an insufficient number of cell divisions occurred between synapsis and the formation of the gametes to give these higher ratios. As a consequence they have assumed that segregation takes place earlier in the life history of the organism.

Working on the same problem, Morgan came to the conclusion that correlations were due to the fact that the correlated characters were located on the same chromosome (11). At synapsis the chromosomes derived from one parent pair with those from the other parent and presumably twist around each other. At the maturation division these pairs of twisted chromosomes split, resulting in the genes that are located close together along the chromosome falling together more often than apart. The degree of correlation depends upon the distance separating the character determiners, or genes. This distance is determined by the percentage of gametes bearing the characters derived from opposite parents which are called "crossovers." Thus the adherents of this theory would explain a gametic ratio of 3–1–1–3 as the result of the correlated characters lying 25 units apart on the chromosome.

Morgan and his coworkers, unhampered by an arbitrary gametic series and in fact working with material very unsuited for such an analysis owing to differential death rates, have amassed a wealth of material which has certainly served to put the linkage theory in an exceptionally strong position.

These authors claim no definite gametic series, and in the present status of the theory such a series would be meaningless, but while the theory makes little provision for such a series, it does not preclude it.

Once having established the number of units separating the correlated characters, deviations too large to be ascribed to chance are looked upon as the mutation of the locus of one or both of the characters, the value of the theory resting upon the infrequency of such departures. Whether we look upon a given gametic series as the result of unequal cell division or whether we assume that the gametic ratios are the result of the correlated characters lying a certain distance apart on the same chromosome, the question arises, Is the correlation of the same intensity between two characters for the individual ears of a given family? Both theories require that this be true and that the correlation between any given pair of characters remain constant.

In this bulletin there is evidence to show that at least in the second generation the correlations observed are for the most part explained by assuming a gametic series of 3–1–1–3.

METHOD OF MEASURING CORRELATIONS.

It has been the common practice to test the "goodness of fit" of couplings by contrasting the observed series with the calculated series and trusting to the eye to detect the agreement.

The danger of this method has been effectively pointed out by Collins (4), who proposed using Yule's coefficient of association with its probable error as a quantitative method of making the comparisons. For the higher degrees of coupling the coefficient of association with its probable error does not afford a satisfactory method of comparison, since the differences between the higher couplings, when measured by the coefficient of association, are extremely small.

With couplings of this nature and where more than two coupled characters occur, a method proposed by Pearson (13) can be used. By the use of Elderton's tables (9) the method is very simple. Caution, however, should be observed in applying this method as a measure of correlation where the characters are departing from the Mendelian expected ratios. This method does not distinguish between departures from the Mendelian proportions and differences in the way the characters are combined. Since the behavior of the individual characters from a Mendelian standpoint need not affect their association with each other, we are not concerned with any discrepancies between the observed and expected percentages of these characters, desiring only to know whether the characters under discussion are correlated or associated in a given proportion. It is obvious, then, that to measure the "goodness of fit" of the observed association to the theoretical association by the use of Pearson's formula (13) and Elderton's tables we must first eliminate any differences between the observed proportion of the individual characters and the Mendelian expected ratios, otherwise an injustice will be done to the agreement of the observed with the theoretical association.

Mr. G. Udney Yule has recognized this difficulty in applying Pearson's formula to testing the "goodness of fit" of a coupling ratio where the Mendelian ratios of the characters are skew, and in a letter to Mr. Collins suggested another method (15, pp. 585–590).

This method very satisfactorily corrects the material to the proper Mendelian proportions without altering the degree of association, but it seems to offer little advantage in cases of a low degree of coupling over Yule's coefficient of association, which is not affected by the Mendelian proportions of the characters.

As all our observed associations more nearly approximate the lower coupling series of 3–1–1–3 than any of the others proposed, the degree of association has been measured by Yule's coefficient of association (14), which has proved very satisfactory except in cases where one class is unusually low. This method has the advantage of being easily executed and comparatively rapid, which is no small item in figuring the association for hundreds of individuals, though its general application has been challenged by Heron (10).

As we are primarily concerned with comparing observed correlation with theoretical expectation rather than accurately measuring the degree of correlation, there can be no real objection to the formula proposed by Yule, which has been used throughout in comparing individuals with a common ancestry.

GAMETIC CORRELATIONS IN THE TWO HYBRID DH 234 AND DH 237.

In all the early crosses between the Chinese variety with waxy endosperm and American horny varieties the second-generation seed showed a correlation between the color of the aleurone and the texture of the endosperm. The first exception occurred in the hybrid Dh 234. The reciprocal hybrid Dh 237 had, however, the usual correlation between colored aleurone and horny endosperm.

The gametic formulas for the aleurone color have already been considered on pages 32 and 33, where the hypothesis was adopted that in the hybrid Dh 237 the gametic composition of the Chinese parent was *cR cR* and of the Algeria parent *Cr cr*. Adding the symbol *H* for horny endosperm texture and *h* for the waxy texture, we have for the Chinese *cRh cRh* and for the Algeria *CRH CrH*.

In crossing *cRh* and *CRH* a colored horny seed would result which when planted would make gametes *CRH*, *CHh*, *cRH*, and *cRh*, and when self-pollinated would result in ears having 3 colored seeds to 1 white and 3 horny seeds to 1 waxy. Wherever *cRh* and *CrH* are crossed, a colored horny seed would result, which when planted would make eight classes of gametes, *CRH*, *CRh*, *CrH*, *Crh*, *cRH*, *cRh*, *crH*, and *crh*, and when self-pollinated would result in an ear having 9 colored seeds to 7 white and 3 horny seeds to 1 waxy. This has been found to be true with respect to this hybrid, with the additional fact that a correlation exists between endosperm texture and aleurone color.

The Chinese parent of the second hybrid Dh 234 was assumed to have the gametic composition *Crh Crh*, while the gametic composition of the Algeria parent was assumed to be *CRH CRH*. All the seeds of a cross between the Chinese variety and Algeria would be colored horny. These seeds would all produce four classes of gametes, *CRH*, *CRh*, *CrH*, and *Crh*, resulting in ears with 3 colored seeds to 1 white and 3 horny seeds to 1 waxy when self-pollinated. This was found to be the case for all the ears secured, but no correlation was found between endosperm texture and aleurone color.

Since the aleurone color of the hybrids Dh 234 and Dh 237 is shown to be the result of two independent factors, it becomes apparent at once that the correlation previously reported as between aleurone color and endosperm texture must be looked upon as a correlation between endosperm texture and one of the factors for aleurone color.

CORRELATION IN THE SECOND GENERATION OF THE HYBRID DH 234.

The homozygous color factor in the hybrid Dh 234 was designated *C* and the heterozygous factor was called *R*. Second-generation seed from this hybrid produced 37 ears, the result of self-fertilization or of crosses between sister plants in the same hybrid. (Table XXXI.)

If the association were between the endosperm texture and the factor for color *R*, these ears would show a correlation, but should the association be between the color factor *C* and the horny endosperm texture the 37 ears obtained would exhibit no correlation, since all the gametes are homozygous for this factor. The correlation between aleurone color and horny endosperm texture for the 20,483 seeds borne on the 37 ears was 0.004 ± 0.013, which is less than the probable error. Two individuals among these 37 ears showed correlations more than four times the probable error.

Two correlations, however, exceeding the probable error by 4.6 and 4.1 times would be expected to occur as the result of chance in 37 observations once in about 19 times. As this chance is small, these correlations may be considered as the result of chance. The remaining ears showed no significant correlations; 16 of the 37 ears had negative and the remainder positive correlations between colored aleurone and horny endosperm.

The results from the self-pollinated ears of the hybrid Dh 234 would indicate that there is no correlation between endosperm texture and the color factor which is heterozygous in this maize hybrid. This factor has been designated *R*.

TABLE XXXI.—*Correlation between the endosperm texture and the aleurone color of self-pollinated and pure-seeded ears of maize in the second generation of the hybrid Dh 234.*

[Lines bracketed together in pairs indicate ears borne on the same plant; ears selected for planting are designated by an asterisk (*).]

Pedigree No. of—		Total.	Number of seeds.				Correlation, $W+X$.	Probable error.	Percentage of—	
Progeny ear.	Self-pollinated ♂.		*WX.*	*WH.*	*CX.*	*CH.*			Waxy.	White.
1	2	3	4	5	6	7	8	9	10	11
1099*	1106	657	38	127	122	370	−0.019	0.071	24.3	25.1
1100	1103	599	43	129	124	303	.102	.068	28.2	28.7
1101	1103	533	39	126	107	261	.139	.072	27.3	30.9
1102	Self	517	41	107	88	281	.105	.074	24.9	28.6
1103	...do	272	19	49	61	143	− .047	.103	29.4	25.0
1104	1108	573	30	121	106	316	− .149	.077	23.7	26.3
1105	Self	609	44	133	117	315	− .057	.069	26.4	29.0
1106	...do	690	46	132	136	376	− .019	.075	26.3	25.7
1108	...do	691	44	152	139	356	− .124	.063	26.4	28.3
1109	1112	402	17	96	69	220	− .277	.093	21.3	28.0
1111*	Self	747	43	149	122	433	− .256	.065	22.2	25.8
1112	...do	733	70	145	131	387	.201	.057	27.4	29.3
1113	1118	643	48	120	133	342	.014	.068	28.1	26.2
1114	1118	428	34	78	86	230	.070	.081	28.0	26.1
1115	1112	508	41	93	96	278	.121	.074	27.9	26.3
1116	1118	322	22	65	61	174	.017	.096	26.0	27.0
1117	Self	564	42	102	95	325	.122	.072	24.2	25.5
1118	...do	623	40	134	97	352	.076	.071	21.9	27.9
1119	1108	414	31	86	76	221	.023	.084	25.8	28.2
1120	1117	655	39	143	106	367	− .064	.072	22.1	27.7
1121	Self	687	45	146	107	389	.056	.068	20.5	24.2
1515	...do	555	37	104	102	312	− .003	.075	25.0	25.4
1519	...do	605	33	123	110	339	− .095	.075	23.8	25.8
1523	...do	571	28	105	91	347	.008	.082	20.8	23.3
1525	...do	212	12	41	33	126	.055	.088	21.3	25.0
1527	...do	614	35	113	108	358	.014	.075	23.3	24.1
1529	...do	334	22	65	49	198	.156	.097	21.2	26.0
1531	...do	659	26	150	123	360	− .327	.071	22.6	26.7
1533	...do	679	40	135	114	390	.007	.071	22.7	25.7
1534	...do	492	28	99	79	286	.059	.083	21.7	25.7
1537	...do	592	32	116	104	340	− .052	.075	22.9	25.0
1539	...do	626	30	108	116	372	− .057	.078	23.3	22.0
1543	...do	570	27	104	92	347	− .008	.082	20.9	23.0
1545	...do	417	32	77	69	239	.180	.082	24.2	26.1
1547	1537	633	37	108	103	385	.123	.073	22.2	22.8
1549	Self	479	30	108	88	253	− .112	.079	24.6	28.8
1551	...do	578	30	102	93	353	.054	.062	21.2	22.8
Total		20,483	1,295	4,091	3,653	11,444	− .004	.0125	24.2	26.3

CORRELATION IN THE SECOND GENERATION OF THE HYBRID DH 237.

If the correlation is between the color factor *C* and horny endosperm, the self-pollinated ears of the hybrid Dh 237 should exhibit a correlation between aleurone color and endosperm texture, since this hybrid has been assumed to be heterozygous for the factor *C*. From this hybrid 20 ears were obtained that had approximately 25 per cent of the seeds white, indicating that these plants were homozygous for the color factor *R* (Table XXXII). These 20 ears had a total of 12,394 seeds with a correlation of 0.769±0.006 between colored aleurone and horny endosperm. The lowest correlation secured in any individual ear was 0.697±0.35, which is certainly a significant correlation.

The correlation for the combined seeds of these 20 ears was a very close approximation of the 0.766 expected on the assumption that the correlation is the result of a 3–1–1–3 reduplication in the gametes. One ear, No. 1128, has a correlation exceeding the expected 0.766 by 3.8 times the probable error, but the remaining ears are exceptionally close approximations of the 3–1–1–3 coupling, and with 20 ears one such deviation is not surprising.

TABLE XXXII.—*Correlation between the endosperm texture and the aleurone color of self-pollinated and pure-seeded ears of maize having approximately 25 per cent of the seeds white in the second generation of the hybrid Dh 237.*

[Lines bracketed together in pairs indicate ears borne on the same plant; ears selected for planting are designated by an asterisk (*).]

Pedigree No. of—		Number of seeds.					Correlation, $W+X$.	Probable error.	Percentage of—	
Progeny ear.	Self-pollinated ♂.	Total.	*WX.*	*WH.*	*CX.*	*CH.*			Waxy.	White.
1	2	3	4	5	6	7	8	9	10	11
1122	None	647	74	74	65	434	0.741	0.032	21.4	22.8
1124	...do	672	94	77	63	438	.789	.026	23.3	25.4
1125	Self	837	129	112	72	524	.786	.023	24.0	28.7
{1127	1125	723	102	88	75	458	.751	.027	24.4	26.2
{1128	Self	319	46	23	34	216	.868	.027	25.0	21.6
{1129*	...do	747	102	87	78	480	.766	.026	24.1	25.1
{1130*	1135	741	96	92	59	494	.794	.025	21.0	25.3
1132	Self	575	80	80	54	361	.739	.033	23.3	27.8
1133	...do	758	104	71	83	500	.798	.024	24.6	23.0
{1135	...do	627	83	83	52	409	.774	.029	21.5	26.4
{1136	1137	615	104	71	72	368	.764	.028	28.6	28.4
{1137	Self	740	125	80	68	467	.829	.023	26.0	27.7
{1138		548	70	58	70	350	.715	.037	25.1	23.3
1721	Self	712	89	71	76	476	.774	.027	23.2	22.5
1733	1741	634	85	79	76	394	.697	.035	25.4	25.9
1738	Self	472	60	59	45	308	.749	.036	25.2	25.2
1741	...do	485	63	57	47	318	.759	.036	23.6	24.7
1743	...do	575	59	68	59	389	.702	.039	20.5	22.1
1745	...do	625	82	57	67	419	.799	.030	23.8	22.2
1749	...do	342	58	40	32	212	.818	.031	26.3	28.6
Total		12,394	1,705	1,427	1,247	8,015	.769	.0064	23.8	25.3

Since the hybrid Dh 234 with the gametic composition *Crh CRH* did not show a correlation between endosperm texture and aleurone color and the hybrid Dh 237 with the gametic composition *cRh CRH* did show a correlation, we can assume that the correlation is between the color factor *C* and endosperm texture. Additional evidence that the correlation is between a factor for color and endosperm texture is obtained from the self-pollinated ears of the hybrid Dh 237 that had approximately 43.75 per cent white seeds, indicating that the plants in question were heterozygous for both color factors *C* and *R*.

If the correlations were independent of the gametic composition, we might expect no consistent differences in the degree of correlation between the monohybrid and dihybrid ears; but if, on the contrary, the correlation is between a factor for color and endosperm texture, the correlation should be reduced in a definite degree on the dihybrid ears. The reason for this reduction in the degree of correlation follows.

A plant which when self-pollinated produces an ear with a dihybrid ratio of colored to white seeds and a monohybrid ratio of horny to waxy seeds must be heterozygous for both color factors and endosperm texture.

If we assume that the association is between a color factor *C* and horny endosperm *H*, and if we further assume that the association results in the combination *CH* being formed three times as often as the combination *Ch*, we then have the above plant making the following gametic classes: 3 *CRH*, 1 *CRh*, 3 *CrH*, 1 *Crh*, 1 *cRH*, 3 *cRh*, 1 *crH*, and 3 *crh*.

The union of the gametes *CrH* and *crh* will result in a white horny zygote; and since *C* and *H* are the associated factors, these seeds will be produced in relatively large numbers, resulting in a reduction in the degree of correlation between colored aleurone and horny endosperm.

A plant which when self-pollinated produces an ear with a monohybrid ratio of white to colored seeds, as well as a monohybrid ratio of horny to waxy seeds, must be homozygous for one color factor and heterozygous for the other color factor as well as endosperm texture. If we assume the heterozygous color factor to be the one which is associated with endosperm texture, we have the above plant making the following gametic classes: 3 *CRH*, 1 *CRh*, 1 *cRH*, and 3 *cRh*. The union of gametes *CRH* with *cRH* results in a colored horny zygote.

Thus every gamete carrying the color factor *C* results in a colored zygote, and the correlation is the same as if it were between color and texture rather than a factor for color and texture, and the normal 41–7–7–9 zygotic grouping is expected, and the correlation between colored aleurone and horny endosperm is 0.766.

When the dihybrid ratio of white to colored seeds is obtained, all of the gametes bearing the factor for color *C* do not result in colored seeds, and the zygotic classes are altered from the above 41–7–7–9 to 123–21–69–43 and the correlation is reduced from 0.766 to 0.570.

From the hybrid Dh 237 four self-pollinated ears were obtained that had the percentage of white seeds closely approximating 43.75, the expected ratio where two independent factors are required to produced a colored seed (Table XXXIII).

TABLE XXXIII.—*Correlation between the endosperm texture and the aleurone color of self-pollinated ears of maize having approximately 43.75 per cent of the seeds white in the second generation of the hybrid Dh 237.*

Pedigree No. of—		Number of seeds.					Correlation, $W+X$.	Probable error.	Percentage of—	
Progeny ear.	Self-pollinated ♂.	Total.	*WX.*	*WH.*	*CX.*	*CH.*			Waxy.	White.
1	2	3	4	5	6	7	8	9	10	11
1723	Self	664	94	190	42	338	0.60	0.045	21.0	42.75
1726	...do	560	94	179	28	259	.653	.046	21.6	48.2
1736	...do	595	93	163	45	294	.577	.046	23.2	43.0
1747	...do	658	96	163	51	348	.601	.033	22.3	39.3
Total		2,477	377	695	166	1,239	.603	.023	21.9	43.2

The total number of seeds for the four ears are grouped as follows:

Class.	Number of seeds.				Correlation.
	CH.	*CX.*	*WH.*	*WX.*	
Observed	1,239	166	695	377	0.603±0.0229
Expected	1,190	203	668	416	.570

The agreement is very close, the deviation of 0.033 being but slightly larger than the probable error, and none of the four ears comprising the group deviated in excess of twice the probable error.

CORRELATION IN CROSSES BETWEEN THE TWO HYBRIDS DH 234 AND DH 237.

If the above explanation is correct and the association is between the factor for color C and horny endosperm H, a cross between the two first-generation hybrids should result in two groups of ears, one group all colored, the other group with four classes of seeds, but no correlation. Both these groups were obtained; the all-colored group has been previously discussed under aleurone color, and the progeny of three such ears are considered from the standpoint of correlations on pages 88 to 95.

Nine ears were obtained with the hybrid Dh 234 as the female parent and eight ears were secured with the same hybrid used as the male parent. These 17 ears showed four classes of seeds, indicating that the plants of the hybrid Dh 237 were heterozygous for the color factor C as well as endosperm texture. None of the correlations are above 0.1, 9 being plus and 7 minus correlations. The two groups are shown in Table XXXIV. Together they aggregate 10,032 individuals with a correlation of 0.0149±0.0166.

TABLE XXXIV.—*Correlation between the endosperm texture and the aleurone color of ears of maize, crosses between the hybrids Dh 234 and Dh 237, using each as the male and as the female parent.*

CROSSES BETWEEN HYBRIDS DH 234 × DH 237.

Pedigree No. of—				Number of seeds.					Correlation, W + X.	Probable error.	Percentage of—	
Progeny ear.	Self-pollinated. ♂	Self-pollinated. ♀	Reciprocal cross.	Total.	*WX.*	*WH.*	*CX.*	*CH.*			Waxy.	White.
1	2	3	4	5	6	7	8	9	10	11	12	13
1518	1726	1519	1725	510	28	102	82	298	0.014	0.083	21.5	24.5
1524	None	1525	None	773	40	149	126	458	—.012	.069	21.5	24.5
1530	1733	1531	1734	676	36	146	97	397	.005	.073	19.7	26.9
1532	None	1533	1729	707	35	123	116	433	.033	.073	21.4	22.4
1538	do	1539	None	609	33	123	117	336	—.107	.075	24.6	25.6
1540	1736	None	1735	679	37	124	115	403	.023	.072	22.4	23.7
1541	None	do	None	631	36	99	123	373	.048	.074	25.2	21.4
1542	1723	1543	1722	515	24	90	96	305	—.028	.087	23.3	22.1
1546	1747	1547	1746	800	42	154	163	441	—.151	.066	25.0	24.5
Total				5,900	311	1,110	1,035	3,444	—.035	.024	22.8	24.1

CROSSES BETWEEN HYBRIDS DH 237 × DH 234.

Progeny ear.	♂	♀	Reciprocal cross.	Total.	*WX.*	*WH.*	*CX.*	*CH.*	Correlation	Probable error.	Waxy.	White.
1725	1519	1726	1518	472	34	91	80	267	.109	.079	24.2	26.5
1734	1531	1733	1530	516	27	106	92	291	—.124	.082	23.1	25.8
1729	1533	None	1532	613	40	108	129	336	—.019	.071	27.1	24.2
1735	None	1736	1540	458	25	86	77	270	.010	.088	22.3	24.2
1722	1543	1723	1542	677	41	152	121	363	—.106	.068	23.9	28.5
1746	1547	1747	1546	621	47	121	115	338	—.069	.068	26.1	27.1
1730	None	None	None	401	27	75	65	234	.129	.088	22.9	24.9
1724	do	do	do	374	30	60	89	195	.041	.087	31.8	24.1
Total				4,132	271	799	768	2,294	.015	.027	25.1	26.0

With an association between one of two factors for color and endosperm texture, a variety of zygotic ratios may be obtained, even though the assumption is made that the gametic reduplication is only of the series 3–1–1–3. Table XXXV gives the degrees of correlation expected between endosperm texture and aleurone color where the assumption is made that the reduplication in the gametes between endosperm texture and a factor for color (*C*) is of the series 3–1–1–3. The minus sign is used to indicate a correlation between colored aleurone and waxy endosperm; the other correlations are between colored aleurone and horny endosperm. Column 4 gives the gametic composition of the two parents which, when crossed, give the zygotic classes shown in column 5 and the correlations shown in column 1. The letters *C* and *R* represent color factors. *H* represents the dominant character, horny endosperm, and *h* waxy endosperm.

TABLE XXXV.—*Possible degree of correlation between aleurone color and endosperm texture, the gametic reduplication being 3–1–1–3.*

[A correlation between colored aleurone and waxy endosperm is indicated by the minus sign in column 1; the other correlations are between colored aleurone and horny endosperm.]

Degree of correlation.	Percentage of—		Gametic composition of parents.	Zygotic classes.[1]
	White.	Waxy.		
1	2	3	4	5
0.800	50	50	*CcRrHh CcRRhh*	3- 1- 1- 3
— .800	50	50	*CcRrHh CcRRhh*	1- 3- 3- 1
.766	25	25	*CcRRHh CcRRHh*	41- 7- 7- 9
— .744	25	25	*CcRRHh CcRRHh*	33-15-15- 1
.615	25	50	*CcRRHh CcRrhh*	7- 5- 1- 3
— .615	25	50	*CcRRHh CcRrhh*	5- 7- 3- 1
.615	50	25	*CcRRHh ccRRHh*	7- 5- 1- 3
— .615	50	25	*CcRRHh ccRRHh*	5- 7- 1- 3
.570	43.75	25	*CcRrHh CcRrHh*	123-21-69-43
— .380	43.75	25	*CcRrHh CcRrHh*	99-45-93-19
.270	43.75	50	*CcRrHh CcRrhh*	21-15-11-17
— .270	43.75	50	*CcRrHh CcRrhh*	15-21-17-11
0	50	50	*CcRrhh ccRRHh*	1- 1- 1- 1
0	50	25	*CCrrHh ccRrHh*	3- 1- 3- 1

[1] The first figure in column 5 is the colored horny, followed by the colored waxy, the white horny, and the white waxy zygotes, respectively.

CORRELATION IN THE THIRD GENERATION OF THE HYBRID DH 234.

Two ears from each of the two first-generation hybrids were selected for planting. The four classes of seeds from each ear were planted in separate rows. Crosses were made between plants from the white waxy and colored horny seeds and between plants from the colored waxy and white horny seeds. Self-pollinated ears were also obtained from all the classes, but the ears resulting from self-pollinating the colored horny seeds are the only self-pollinated ears that exhibit four classes of seeds.

The two ears grown from the hybrid Dh 234 are shown in Table XXXI as pedigree Nos. 1099 and 1111. Ear No. 1099 was the result of pollinating a plant of the hybrid Dh 234 with pollen from a plant of the same hybrid which when self-pollinated produced ear No. 1106. Both these ears curiously enough have exactly the same degree of association, or, rather, lack of association, -0.019 ± 0.07.

The other ear, No. 1111, was the result of self-pollinating a plant of hybrid Dh 234 and had a correlation of -0.256 ± 0.063, heretofore referred to as one of the two ears that might be held to show a significant correlation.

TABLE XXXVI.—*Correlation between the endosperm texture and the aleurone color of 32 ears of maize, the progeny of ear No. 1099 of the third generation of the hybrid Dh 234.*

Progeny ear.	Pedigree No. of— Self-pollinated. ♂	Pedigree No. of— Self-pollinated. ♀	Pedigree No. of— Reciprocal cross.	Number of seeds. Total.	Number of seeds. *WX.*	Number of seeds. *WH.*	Number of seeds. *CX.*	Number of seeds. *CH.*	Correlation, *W+X.*	Probable error.	Percentage of— Waxy.	Percentage of— White.
1	2	3	4	5	6	7	8	9	10	11	12	13
WHITE WAXY × COLORED HORNY.												
1552	1644	All white waxy.	1643	506	113	119	114	160	0.145	0.061	44.8	45.8
1555	1705	do	None	230	60	53	60	57	0.036	0.088	52.2	49.1
1563	None	None	do	257	56	72	53	76	.045	.085	43.4	51.0
1564	do	do	do	438	92	120	128	98	−.260	.061	50.2	48.4
Total				1,431	321	364	355	391	−.102	.035	47.2	47.8
COLORED WAXY × WHITE HORNY.												
1572	All white	1573	1604	127	22	40	31	34	−.247	.115	41.7	48.8
1574	None	1575	None	645	166	151	161	167	.067	.053	50.6	49.2
1579	do	None	1610	468	114	134	107	113	−.054	.062	47.2	53.0
1584	do	1585	1623	406	111	103	84	108	.162	.065	47.8	52.4
1590	All white	1591	1619	580	145	142	146	147	.014	.056	50.2	49.4
1592	do	1593	1621	307	86	61	101	59	−.104	.078	60.8	47.9
Total				2,533	644	631	630	628	.009	.027	50.7	50.7
WHITE HORNY × COLORED WAXY.												
1602	All waxy	1603	None	322	76	74	82	90	.018	.075	49.0	46.6
1604	do	1605	1572	171	46	42	42	41	.046	.103	51.4	51.5
1606	do	1607	None	391	95	101	109	86	−.148	.069	52.2	50.1
1610	None	None	1579	303	44	60	104	95	−.197	.079	48.8	31.5
1619	All waxy	1620	1590	467	110	112	123	122	−.013	.062	50.0	47.6
1621	do	1622	1592	348	86	74	105	83	−.042	.072	54.9	46.0
1623	do	None	1584	497	134	120	129	114	−.044	.062	53.0	51.5
1624	do	do	None	67	17	19	13	18	.108	.054	44.8	53.7
Total				2,566	608	602	707	649	−.037	.027	51.3	47.2
COLORED HORNY × WHITE WAXY.												
1626	All waxy	None	None	427	112	107	115	93	.068	.088	51.0	52.9
1635	None	1636	do	703	179	169	177	178	.032	.051	49.5	50.6
1637	All waxy	1638	do	424	109	109	99	107	.042	.088	51.4	49.0
1639	do	None	do	123	32	28	33	30	.019	.121	48.8	52.9
1641	None	1642	do	396	106	93	90	107	.151	.066	50.2	49.5
1643	All waxy	1644	1552	511	133	129	130	119	.044	.059	51.3	51.4
1645	do	1646	1560	510	120	116	135	139	.034	.060	46.3	50.0
1647	do	None	None	387	80	85	113	109	.047	.070	42.6	50.0
Total				3,481	871	836	892	882	.014	.023	50.5	49.0
COLORED HORNY × SELF.												
1625	Self	Self		464	27	110	72	255	−.068	.059	29.5	21.3
1636	do	do		573	49	102	97	325	.239	.066	26.4	25.5
1638	do	do		573	34	112	105	322	.030	.076	25.5	24.3
1642	do	do		551	31	103	113	304	−.152	.076	24.6	26.2
1644	do	do		652	45	138	121	348	.009	.067	28.1	25.5
1646	do	do		368	21	58	65	224	.195	.095	21.5	23.4
Total				3,181	207	623	573	1,778	.0152	.031	26.1	24.5

TABLE XXXVII.—*Correlation between the endosperm texture and the aleurone color of 23 ears of maize, the progeny of ear No. 1111 of the third generation of the hybrid Dh 234.*

Pedigree No. of—			Number of seeds.					Correlation, $W+X$	Probable error.
Progeny ear.	Self-pollinated ♂.	Reciprocal cross.	Total.	*WX.*	*WH.*	*CX.*	*CH.*		
1	2	3	4	5	6	7	8	9	10
WHITE WAXY × COLORED HORNY.									
1648	1696	None	712	179	166	202	165	−0.062	0.049
1651	1694	do	286	77	72	62	75	.128	.078
1652	1700	do	611	142	140	160	169	.035	.068
1654	1705	do	387	97	80	105	105	.098	.068
1660	None	do	600	155	155	128	162	.119	.055
Total			2,596	650	613	657	676	.044	.026
COLORED WAXY × WHITE HORNY.									
1665	1687	1686	403	105	101	100	97	0.005	0.067
1667	None	None	87	20	20	25	22	− .064	.144
Total			490	125	121	125	119	− .009	.061
WHITE HORNY × COLORED WAXY.									
1682	All waxy	None	448	110	95	126	117	0.040	0.064
1686	do	1665	370	90	89	108	83	− .125	.071
Total			818	200	184	234	200	− .036	.047
COLORED HORNY × WHITE WAXY.									
1695	All waxy	None	393	95	96	117	85	−0.164	0.067
1699	do	do	511	126	126	119	140	.081	.060
1704	do	do	192	51	53	49	39	− .350	.078
1710	do	do	458	114	106	126	112	− .022	.085
1712	do	do	181	56	42	38	45	.223	.096
1713	do	do	179	57	41	37	44	− .246	.096
1714	do	do	561	36	150	151	124	.147	.056
1715	do	do	304	168	81	73	82	− .029	.077
1718	do	do	290	77	73	76	64	− .060	.079
Total			3,069	780	768	786	735	− .024	.024
COLORED HORNY × SELF.									
1694	Self		578	39	110	103	326	0.057	0.073
1696	do		373	23	66	76	208	− .025	.092
1700	do		451	31	97	79	244	− .007	.081
1711	do		415	26	66	77	246	.115	.089
1719	do		549	35	102	93	319	.081	.076
Total			2,366	154	441	428	1,343	.050	.036

As no correlation was found on the second-generation ears of this hybrid, none was to be expected on the third-generation ears. Fifty-five ears were obtained, representing many combinations. With the possible exception of two ears, Nos. 1564 (Table XXXVI) and 1704 (Table XXXVII), no correlations were obtained. The individual ears shown in these tables are so arranged that the ears resulting from the same cross may be readily compared. Ear No. 1564 had a correlation of 0.260±0.06. A correlation of this magnitude would be expected to occur as the result of chance once in 267 times, but since it occurs in a group of four, it would be expected as the result of chance once in 67 times.

Ear No. 1704 had a correlation of 0.350±0.078, which is 4.5 times the probable error, and should occur as the result of chance once in 415 times, but since it is but 1 in a group of 10 individuals, the odds against its chance occurrence are 42 to 1. We may with some propriety conclude that the correlations found on these two ears are accidental. The results, then, as shown by the third-generation ears support the assumption that this hybrid is homozygous for the color factor *C*.

CORRELATION IN THE THIRD GENERATION OF THE HYBRID DH 237.

Two ears were selected and grown from the hybrid Dh 237. These two ears are shown in Table XXXII, pedigree Nos. 1129 and 1130. Ear No. 1129 was the result of self-pollinating a plant of the hybrid Dh 237, and ear No. 1130 is a second ear from this same plant. The male parent of this latter ear, when self-pollinated, produced ear No. 1135. Ear No. 1129 had the exact degree of correlation which is expected on a 3–1–1–3 coupling, 0.766±0.026, while the second ear of the same plant, No. 1130, had a correlation of 0.794 ±0.025. The male parent of ear No. 1130 had a correlation of 0.774 ±0.029. These two ears are very close approximations of the 0.766 correlation which is expected on a 3–1–1–3 coupling. There were, of course, four classes of seeds on each of these two ears. The different classes were planted separately.

Crosses were made between plants from the white waxy seeds and plants from the colored horny seeds from the same ear. These crosses were made, using white waxy plants as the female parent, and also as the male parent. Self-pollinated ears were also secured from all the plants to make sure that they were of the type expected. The self-pollinated colored horny ears, however, are the only self-pollinated ears that would have all four classes of seeds. The three ears obtained from self-pollinated plants grown from colored horny seeds of ear No. 1129 are shown in Table XXXVIII.

The correlation for these three ears is 0.770±0.017. This correlation is certainly a close approximation of the expected 0.766, but upon examining the three ears that make up the total we find the difference between the extremes to be 0.384±0.06, a difference of more than six times the probable error, which can hardly be ascribed to chance fluctuation. The ear with the lowest correlation (No. 1796, correlation 0.450±0.063) deviates from the expected 0.766 by

0.316, which is slightly in excess of five times the probable error. The correlation of 0.45 is rather close to the expected 0.57 where a plant heterozygous for two color factors is self-pollinated, but the percentage of white seeds, 21.9, precludes this explanation.

Fortunately another ear borne on the same plant was pollinated by a plant grown from a homozygous white waxy seed. If ear No. 1796, deviating from the expected correlation of 0.766 by five times the probable error, represents but a chance fluctuation from this correlation, then the first ear of this same plant should, when crossed with white waxy, produce an ear with a correlation approximating 0.8. The ear representing this cross is ear No. 1795. (Table XXXIX.) The correlation found was 0.387±0.05, certainly not an approximation of 0.8. These correlations show that the two ears of the plant were producing the same excess of gametes bearing colored waxy and white horny genes. The relations of these ears are shown in figure 11.

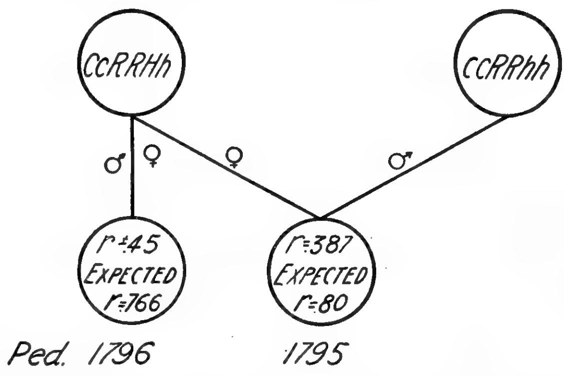

FIG. 11.—Diagram showing the relations of ears Nos. 1796 and 1795.

Since the male parent of ear No. 1795 was a homozygous recessive, the zygotic ratio observed on this ear is also the gametic ratio of the female gametes within the range of chance fluctuation.

To determine the gametic ratio of this ear as accurately as possible the sum of the two reduplicated groups was divided by the sum of the nonreduplicated groups and the gametic ratio found to be 1.5 to 1, or 3 to 2. The expected correlation on an ear the result of self-pollinating a plant with the gametic ratio of 3–2–2–3 is 0.517. Ear No. 1796 is the result of self-pollinating the plant which bore ear No. 1795 with the above gametic ratio. The observed correlation on ear No. 1796 is 0.45, which deviates from a 0.517 correlation by 0.067±0.063, the deviation being insignificant. The plant, then, which produced ears Nos. 1795 and 1796 may with propriety be considered as having formed gametes in the proportion of 3–2–2–3, while the majority of ears with a correlation have been shown to approximate the gametic series 3–1–1–3.

The adherents of the linkage theory would look upon this departure from the expected as a mutation of the locus of one or both of the characters, resulting in the distance separating them being widened from 25 to 40 units. To explain this gametic ratio on the reduplication theory requires but a simple alteration of the series of cell division, assumed to account for 3–1–1–3 couplings.

The 3–1–1–3 gametic ratio is assumed to be the result of the type of cell division shown in figure 12, and the 3–2–2–3 coupling merely requires that the cells *Ab* and *aB* divide once while the cells *AB*, *ab* are undergoing two divisions. (Fig. 13.)

The fact that both of these ears had approximately the expected percentage of both white and waxy seeds demonstrates beyond doubt that the distributions observed are not due to a failure to properly classify the material or to the presence of other factors that would influence the expected proportions. If these correlations are to be

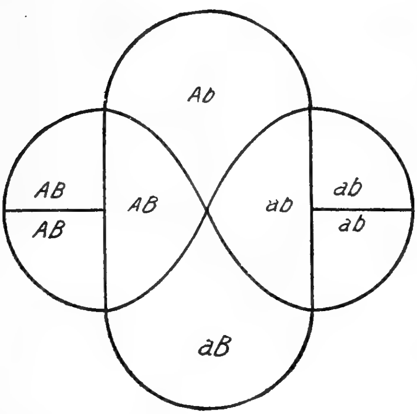

FIG. 12.—Diagram showing the type of cell division proposed by Punnett to explain a 3–1–1–3 gametic coupling.

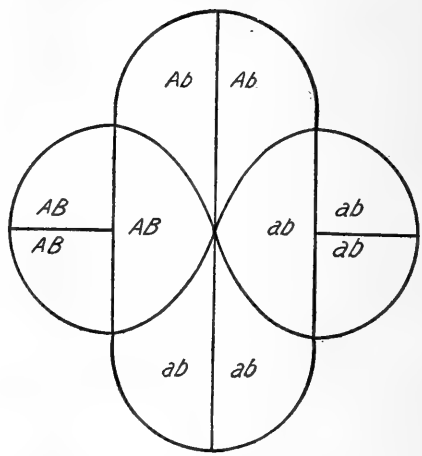

FIG. 13.—Diagram showing a possible modification of figure 12 to account for a 3–2–2–3 coupling.

looked upon as the result of reduplication the only explanation is to admit other series than those proposed. The remaining two ears of the three self-pollinated horny plants are sufficiently close approximations of the expected 0.766.

Five ears were secured from plants grown from the white waxy seeds of pedigree No. 1129 that were the result of pollinating these plants with plants grown from the colored horny seeds of the same ear. Three ears were also obtained where the parentage was reversed. These eight ears are shown in Table XXXIX.

The first group had a correlation 0.806±0.017 between colored and horny, the expected being 0.8. Of the individual ears only one deviated in excess of four times the probable error, that one—No. 1764—deviating by eight times the probable error. The correlation of 0.91, observed on this ear, is intermediate between the 0.8 expected on a 3–1 coupling and the 0.96 expected on a 7–1 coupling, though it is a closer approximation of the latter. The deviation of 0.06±0.013 from the 7–1 coupling is, however, 4.6 times the probable error.

Ear No. 1764 has a reciprocal ear in No. 1799. This ear had a correlation of 0.7, a deviation of 0.1±0.03 from the expected 0.8, and differing from No. 1764 by 0.21±0.048, which is almost 4.5 times the probable error. A self-pollinated ear was obtained from the same plant that bore ear No. 1799. This self-pollinated ear is No. 1800 (Table XXXVIII). The correlation of 0.834 observed on this ear is higher than the expected 0.766. The deviation of 0.068±0.02 from 0.766 is 3.4 times the probable error, which is rather large to be attributed to chance. The relations of these ears are shown in figure 14.

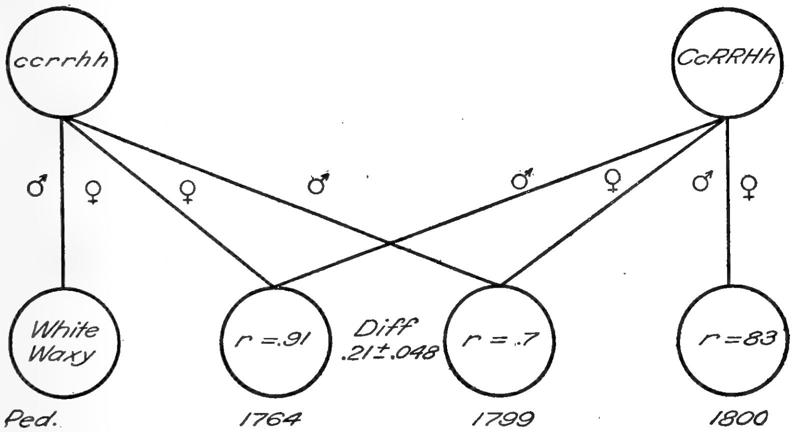

FIG. 14.—Diagram showing the relations of ears Nos. 1764, 1799, and 1800.

Since the female parent of ear No. 1764 was homozygous for waxy endosperm texture, the correlation of 0.91 represents the reduplication in the gametes of the male parent. This reduplication is higher than the expected, the degree of correlation indicating the reduplication to be closer to a 7–1 than a 3–1; in reality the series very closely approximates 4.5–1. The reciprocal ear of No. 1764—No. 1799—has a lower reduplication series than 3–1–1–3, being in reality 2.4–1.

The correlation of 0.834 on ear No. 1800, the self-pollinated ear of the heterozygous colored horny parent, indicates a gametic series intermediate between the 4.5–1 and 2.4–1.

The expected correlation in self-pollinating a plant with a male gametic series of 203–44–45–206 and a female gametic series of 168–71–80–191 is 0.788. Ear No. 1800, which represents such a self-pollinated ear, has a correlation of 0.834±0.02, the deviation of 0.046 from 0.788 being no larger than is to be expected.

This difference between the male and female gametes in the degree of reduplication could be brought about by a higher death rate prevailing in the pollen grains carrying white horny and colored waxy, the combinations that came from opposite parents. It might be urged that these combinations reacted in an unfavorable way, lessening the life of the pollen grain or so reducing it in vigor as to have a larger proportion of the ovaries fertilized by the parental, white waxy and colored horny combinations.

It would be necessary that the death rate be alike for the two combinations, colored waxy and white horny, or the percentages of white and waxy would be found deficient. This is in itself an argument against this explanation, since it seems improbable that *CX* and *WH* should happen to be equally weak. The percentages of white to waxy seeds for the three ears are sufficiently close approximations to the expected to indicate that the two combinations were retarded about equally.

Ear No. 1764 had 50.2 per cent waxy and 50.4 per cent white seeds, certainly very close to the expected 50 per cent. The reciprocal ear, No. 1799, had 51.4 per cent waxy and 53.2 per cent white seeds. The differences between white and waxy percentages of these two reciprocals are not significant. The percentage of waxy seeds on the self-pollinated ear (No. 1800) is almost exactly the expected percentage, while the percentage of white seeds is in excess of the expected by more than three times the probable error. That the excess of white seeds on this ear is not brought about by a failure of the pollen grains carrying colored waxy combinations is demonstrated by the percentage of waxy seeds, which is normal. In other words, if the high percentage of white seeds is due to a high mortality of the pollen grains carrying colored aleurone, this mortality must have been equal in the pollen grains carrying colored-waxy and colored-horny combinations.

The expected grouping compared with that observed for the 755 seeds is as follows:

Class.	Number of seeds.			
	CH.	*CX.*	*WH.*	*WX.*
Expected	484	82.5	82.5	106
Observed	476	64	88	127

As can be seen, there was a failure of both colored horny and colored waxy gametes, but greater in the colored waxy than in the colored horny, while a corresponding increase is noted in both the white horny and white waxy combinations, though the increase is much larger in the latter case. The figures would seem to indicate that the higher correlation was due to the weak growth of the pollen grains carrying the odd character combinations. If this be the case, it should also be observed on ear No. 1764, but not on ear No. 1799, as the male parent of this ear was making but one kind of pollen grains—white waxy.

The grouping for ear No. 1764 is as follows:

Class.	Number of seeds.			
	CH.	*CX.*	*WH.*	*WX.*
Expected	186.7	62.3	62.3	186.7
Observed	203	44	45	206

These figures would certainly seem to indicate that the odd combinations *CX* and *WH* were in some way at a disadvantage when compared with *CH* and *WX*.

The grouping for ear No. 1799 is as follows:

Class.	Number of seeds.			
	CH.	*CX.*	*WH.*	*WX.*
Expected	191.3	63.7	63.7	191.3
Observed	168	71	80	191

The low correlation on this ear is obviously due to paucity of colored horny female gametes, a combination that would not be expected to be deficient. No question of the vigor of part of the pollen grains is concerned on this ear, since they were all alike. A shortage in the colored horny gametes was indicated on the self-pollinated ear (No. 1800), but not to the extent noted on ear No. 1799, while an increase was observed of the white waxy gametes on ear No. 1800, which was also found on ear 1764, but not in such an increased degree as would naturally be expected.

Summing up the three ears, we find ear No. 1799 indicating that the female gametes were deficient in the colored horny combination, practically the expected proportion of white waxy gametes, and a slight excess of the two odd combinations. The male gametes, as indicated on ear No. 1764, were in excess in both the colored horny and white waxy combinations and deficient in the odd combinations.

From these two ears we would expect the self-pollinated ear to be deficient in colored horny seeds, in excess in white waxy seeds. Using the zygotic ratios of the male and female parents as representing the actual gametic ratios, we find the white waxy combination in excess by 20 in the male gametes and equal in the female gametes; so we would expect an excess of about 20 in the self-pollinated ear, and we find an excess of 21.

The colored horny combination in the male gametes was in excess by 17 and deficient in the female gametes by 21; so a deficiency of 4 would be expected on the self-pollinated ear, and we find a deficiency of 8.

The colored waxy combination in the male gametes is deficient by 18; in the female gametes this same combination is in excess by 8; so a deficiency of 10 would be expected in the self-pollinated ear, and a deficiency of 18 is noted.

The white horny combination is deficient by 17 in the male gametes and in excess by 17 in the female gametes; so that they would be expected in the theoretical proportion on the self-pollinated ear, and we find an excess of 6. This agreement of evidence derived from so many different sources would indicate that the departures observed were the result of a definite and unexpected gametic series formed by the plant which bore ears Nos. 1799 and 1800, rather than fluctuations due to chance.

The three ears that were obtained when plants grown from white waxy seeds were used as the male parent had a total of 1,293 seeds with a correlation of 0.610 ± 0.025, but since one ear of the three has been shown to be of entirely different coupling this ear should not be included in the totals. Omitting, then, this one ear, No. 1795, which is outstanding and does not belong to the series, the total number of seeds then becomes 740, with a correlation of 0.737 ± 0.025—a deviation from the expected 0.8 of but 2.5 times the probable error.

Nine ears were secured from plants grown from the colored waxy seeds as the male parent, and two ears were secured from plants grown from the white horny seeds as the male. These ears are also shown in Table XXXVI. The correlation for the total number of seeds is not significant. One ear, however, No. 1781, has a negative association between C and H of 0.220 ± 0.059, a deviation from a zero correlation by 3.7 times the probable error. This ear could in all probability be looked upon as the result of chance fluctuation in sampling, though closely approximating the 0.27 expected when a plant heterozygous for the color factors C and R and horny endosperm texture with a 3–1–1–3 coupling between the factor C and waxy endosperm is crossed with a homozygous waxy plant heterozygous for the two factors for color.

As a test of the possibilities of securing a correlation when crossing two plants, one heterozygous for endosperm texture and without the factor for color C, the other homozygous for endosperm texture and heterozygous for the factor C, crosses were made between plants from white horny seeds and plants from colored waxy seeds. These crosses were made, using the colored waxy plants as the female parent and also as the male parent.

It is obvious that no coupling could occur in the gametes, but Collins (4) reported significant correlations on two ears representing a similar cross that as yet can not be explained. It would be possible, however, to obtain a correlation by crossing a plant grown from a white horny seed with a plant grown from a colored waxy seed where two factors are required to produce color, and the correlation is between one of these color factors and endosperm texture.

TABLE XXXVIII.—*Correlation between the endosperm texture and the aleurone color of 22 ears of maize, the progeny of ear No. 1129 of the third generation of the hybrid Dh 237.*

Progeny ear.	Pedigree No. of— Self-pollinated. ♂	Pedigree No. of— Self-pollinated. ♀	Pedigree No. of— Reciprocal cross.	Number of seeds. Total.	*WX.*	*WH.*	*CX.*	*CH.*	Correlation, *W+X.*	Probable error.	Percentage of— Waxy.	Percentage of— White.
1	2	3	4	5	6	7	8	9	10	11	12	13
						COLORED HORNY × SELF.						
1796	....	....	....	296	24	41	42	189	0.450	0.063	23.3	21.9
1798	....	....	....	752	107	71	87	487	.788	.025	26.2	23.7
1800	....	....	....	755	127	88	64	476	.834	.020	25.3	28.5
Total				1,803	258	200	193	1,152	.770	.017	......	......
						WHITE WAXY × COLORED HORNY.						
1754	1800	....	None	500	178	59	67	196	0.797	0.025	47.0	47.4
1758	1800	....	...do	439	165	51	48	175	.790	.030	48.6	49.1
1762	1798	....	...do	537	170	88	70	209	.704	.032	44.7	48.0
1764	1800	....	1799	498	206	45	44	203	.910	.014	50.2	50.4
1765	1800	....	None	528	177	74	72	205	.705	.033	47.2	47.6
Total				2,502	896	317	301	988	.806	.017	......	......
						COLORED HORNY × WHITE WAXY.						
1795	None	1796	None	553	164	117	104	168	0.387	0.050	48.5	50.5
1797	...do	....	...do	230	93	32	24	81	.810	.036	50.9	54.4
1799	...do	1800	1764	510	191	80	71	168	.700	.034	51.4	53.2
Total				1,293	448	229	199	417	.610	.025	......	......
						COLORED WAXY × WHITE HORNY.						
1766	All white	....	None	432	112	102	110	108	0.038	0.065	51.4	49.6
1768	...do	....	1775	144	33	35	42	34	—.135	.112	52.0	47.2
Total				576	145	137	152	142	—.009	.056	......	......
						WHITE HORNY × COLORED WAXY.						
1772	None	....	None	448	95	120	114	119	—0.095	0.064	46.6	48.0
1773	...do	....	...do	613	146	158	161	148	— .082	.055	50.4	49.6
1775	...do	....	1768	533	128	138	143	124	— .096	.058	50.8	50.0
1777	...do	....	None	428	97	97	112	122	.043	.065	48.8	45.3
1779	...do	....	...do	476	127	135	107	107	— .036	.062	49.2	55.0
1781	...do	....	...do	477	105	137	128	107	— .220	.059	48.9	50.4
1784	...do	....	...do	591	174	165	133	119	— .029	.056	52.0	57.3
1786	...do	....	...do	446	101	113	110	122	— .004	.064	47.3	48.0
1788	...do	....	...do	386	87	102	95	102	— .044	.069	47.2	49.0
Total				4,398	1,060	1,165	1,103	1,070	— .061	.020	......	......

The assumption can then be made that the white horny plant is producing gametes *CHr*, *Chr*, *cHr*, and *chr*, with a correlation between *C* and *H*. Such a plant, if self-pollinated, would produce an all-white ear with 3 horny seeds to 1 waxy.

The colored waxy plant might be making gametes *CRh Crh*. A cross between a colored waxy plant of this nature and a white horny plant such as has been described would result in an ear with four classes of seeds: *CH*, 7; *CX*, 5; *WH*, 1; *WX*, 3; correlation, 0.615. In this case, however, the percentage of white seeds is but 25, and the correlation is 0.615, while in the two ears reported by Collins, one had 30.1 per cent white with a correlation of 0.373±0.057, and the other had 48 per cent white and a correlation of 0.47±0.056. It is at once apparent that neither of these ears could be looked upon as approximations of the above zygotic arrangement.

From the second ear of the hybrid Dh 237, No. 1130, from which the six classes of seeds were planted, three self-pollinated ears from colored horny plants were secured that had four classes of seeds (Table XXXIX). These three ears had a correlation of 0.725±0.017, slightly lower than the expected 0.766. None of the three ears deviated from the expected in excess of three times the probable error, though all three were below the expected. As the result of crossing plants grown from white waxy seeds with plants grown from colored horny seeds of ear No. 1130, six ears were obtained by using the white waxy plants as the female parents, and five ears were obtained by using the white waxy plants as the male parents. These 11 ears are also shown in Table XXXIX.

The 6-ear group had a correlation of 0.809±0.01, which is a very close approximation of the expected 0.8. None of the individual ears of this group deviated from the expected correlation by as much as three times the probable error.

The ears of the 5-ear group had with one exception lower correlations than the lowest obtained in the 6-ear group. The correlation for the five ears was 0.76±0.01, which differs from the 0.809 correlation obtained in the reciprocal ears by 0.049±0.015. None of the ears in the 5-ear group deviated by as much as three times the probable error from the expected correlation. These two groups, together with the three self-pollinated ears from the colored horny plants, are certainly very close approximations of the expected results where the coupling is of the form 3–1–1–3. The individual ears exhibit a remarkably uniform grouping of the four classes of seeds.

Crosses were also made between plants from the colored waxy seeds and plants from the white horny seeds, which should result in ears with no correlation.

TABLE XXXIX.—*Correlation between the endosperm texture and the aleurone color of 14 ears of maize, the progeny of ear No. 1130 of the third generation of the hybrid Dh 237.*

[Lines bracketed together indicate ears borne on the same plant.]

Progeny ears.	Pedigree No. of— Self-pollinated. ♂	Pedigree No. of— Self-pollinated. ♀	Pedigree No. of— Reciprocal cross.	Number of seeds. Total.	*WX.*	*WH.*	*CX.*	*CH.*	Correlation, $W+X$	Probable error.	Percentage of— Waxy.	Percentage of— White.
1	2	3	4	5	6	7	8	9	10	11	12	13
COLORED HORNY × SELF.												
1840	Self			308	38	46	37	187	0.615	0.060	24.3	27.5
1847	do			721	83	97	72	469	.695	.084	21.5	25.0
1855	do			563	76	56	56	375	.740	.035	23.5	23.5
Total				1,592	197	199	165	1,031	.725	.017	22.75	24.9
COLORED HORNY × WHITE WAXY.												
1838	All waxy		1804	545	193	78	67	207	.768	.027	47.8	49.8
1839	do	1840	None	415	153	67	55	140	.706	.037	50.1	53.0
1846	do	1847	do	621	219	80	86	236	.765	.025	49.2	48.2
1849	do		1815	581	222	79	77	203	.754	.027	51.4	51.8
1854	do	1855	1816	614	223	76	83	232	.784	.024	49.8	48.7
Total				2,776	1,010	380	368	1,018	.760	.012	50.1	52.0
WHITE WAXY × COLORED HORNY.												
1804	None		1838	363	132	47	34	150	.850	.027	45.7	49.3
1806	do		None	435	180	52	57	146	.799	.027	54.5	53.3
1807	do		do	275	95	32	41	107	.775	.037	49.5	46.2
1810	do		do	441	183	60	55	143	.776	.028	54.0	55.0
1815	do		1849	465	164	60	53	188	.814	.025	51.0	48.2
1816	1855		1854	515	215	57	65	178	.824	.023	54.3	52.8
Total				2,494	969	308	305	912	.809	.011	51.0	51.2
COLORED WAXY × WHITE HORNY.												
1818	All white		1827	754	185	182	181	206	0.074	0.049	48.6	48.7
1820	do		None	207	57	52	47	51	.086	.095	48.0	49.8
1822	do		1836	542	136	135	157	114	−.155	.057	53.8	50.0
1825	None		1835	584	139	148	129	168	.100	.055	46.0	49.2
Total				2,087	517	517	514	539	.042	.029	49.6	49.4
WHITE HORNY × COLORED WAXY.												
1827	All waxy		1818	644	170	163	140	171	0.119	0.053	48.2	51.7
1829	None		None	511	134	128	142	107	−.117	.059	54.0	51.3
{1833	All waxy		do	434	116	98	100	120	.173	.063	49.8	49.3
{1834	do		do	511	128	128	122	133	.043	.060	49.0	50.5
1835	do		1825	503	125	131	129	118	−.068	.060	50.5	50.9
1836	do		1822	297	58	91	69	79	−.156	.077	42.8	50.1
Total				2,900	731	739	702	728	.013	.025	49.4	50.6

As the result of such crosses 10 ears were obtained, 4 with the colored waxy plants as the female parent and 6 with colored waxy plants as the male parent (Table XXXIX). The highest correlation secured was 0.173 ± 0.063 on ear No. 1833, which can not be considered significant, being less than three times the probable error.

The results obtained from the progeny of the two ears, Nos. 1129 and 1130, of the hybrid Dh 237 were, with a few exceptions, fairly close approximations of the expected results on the assumption that the gametes were formed in a series of 3–1–1–3.

SECOND GENERATION OF THE CROSSES BETWEEN THE TWO HYBRIDS DH 234 AND DH 237.

Aside from the two first-generation hybrids between the Algeria and the Chinese varieties of maize, Dh 234 and Dh 237, and their immediate progeny, the result of self-pollination or crosses between two plants of the same hybrid there were 34 ears, the result of crossing the two first-generation hybrids. Seventeen of these ears were all colored with both horny and waxy seeds.

Three of these all-colored ears were grown the following season. One ear, resulting from using the hybrid Dh 234 as the female parent and the hybrid Dh 237 as the male parent, was renumbered cross Dh 330 and grown under that symbol. The other two ears grown were the result of using the hybrid Dh 237 as the female parent and the hybrid Dh 234 as the male parent. These two ears were known as crosses Dh 333 and Dh 334. The female parent of the cross Dh 333 was used as the male parent of the cross Dh 330.

On each of these three all-colored ears there are 16 classes of zygotes, only 6 of which will exhibit, when self-pollinated, ears with all 4 classes of seeds, colored and white horny and colored and white waxy.

All 6 of these classes of zygotes when planted and self-pollinated are expected to have horny and waxy seeds in the proportion of 3 to 1, while 4 of the 6 are expected to have colored and white in the proportion of 3 to 1. The remaining 2 classes are expected to have colored and white seeds in the proportion of 9 to 7.

For the 6 classes of zygotes, 4 very different degrees of correlation are expected, in the following proportions: Four ears with no correlation between the colored aleurone and horny endosperm, 3 ears with a correlation of 0.766 between colored aleurone and horny endosperm, one with a correlation of 0.744 between colored aleurone and waxy endosperm, and one with a correlation of 0.380 between colored aleurone and waxy endosperm. Of the 16 zygotic combinations represented on the all-colored ears, only 2 classes of seeds could be distinguished, namely, horny and waxy. These were planted separately.

When the colored horny plants are crossed with the colored waxy plants, 6 of the 16 zygotic combinations are expected to exhibit all 4 classes, and since there are three classes of waxy, 14 combinations result, as shown in Table XLII. Of these 14 ears, 12 are expected to have colored and white in the proportion of 3 to 1 and horny and waxy seeds in equal numbers, while the remaining 2 ears are expected to have colored and white seeds in the proportion of 9 to 7, with equal numbers of waxy and horny seeds. The 14 classes of ears are expected to be divided into five groups, with different degrees of correlation, as follows: Twenty ears with no correlation, 27 ears with a correlation of 0.615 between colored and horny, 9 with a correlation of 0.270 between colored and horny, 9 with a correlation of 0.615 between colored and waxy, 3 with a correlation of 0.270 between colored and waxy. The classes of zygotes are represented in Table XL.

TABLE XL.—*Classes of zygotes on the all-colored ears resulting from crossing the hybrids Dh 234 and Dh 237.*

Gametes.	Hybrid Dh 234.			
	CRH.	*CRh.*	*CrH.*	*Crh.*
Hybrid Dh 237:				
3 *CRH*	①	②	③	④
1 *CRh*	⑤	⑥	⑦	⑧
1 *cRH*	⑨	⑩	⑪	⑫
3 *cRh*	⑬	⑭	⑮	⑯

The italic letters in the column boxes of the table represent the gametic combinations formed by the hybrid Dh 234, and those in the left-hand column represent the gametic combinations formed by the hybrid Dh 237. The figures 3, 1, 1, and 3 preceding the italic letters in the left-hand column indicate the proportion in which each of these gametic combinations are formed in the hybrid Dh 237. Owing to the reduplication of certain combinations, resulting in an association of the color factor *C* and the endosperm texture *H*, there was no reduplication in the hybrid Dh 234.

Each circle in the table represents one of 16 zygotic combinations formed by crossing the two hybrids Dh 234 and Dh 237. The circles are numbered for convenience of reference. Thus, owing to the reduplication, the zygotic combinations represented by circles 1, 2, 3, and 4 are present on the ears three times as often as the combinations represented by circles 5, 6, 7, and 8. It must be borne in mind that two factors are required to produce colored seeds; these factors are represented by the letters *C* and *R*. The endosperm textures horny and waxy are represented by the letters *H* and *h*.

Table XLI shows the expected result of self-fertilizing the 16 classes of zygotes in Table XL. When horny and waxy seeds are both present on a self-pollinated ear the expected proportion is always 3 horny seeds to 1 waxy, within the range of chance fluctuation.

TABLE XLI.—*Expectation of seed classes resulting from the self-fertilization of the zygotes enumerated in Table XL.*

Circle.	Class of seeds.	Circle.	Class of seeds.
No. 1	All colored. horny.	Nos. 8 and 14	3 colored to 1 white, all waxy.
Nos. 2 and 5	All colored, horny, and waxy.	No. 11	9 colored to 7 white, all horny.
Nos. 3 and 9	3 colored to 1 white, all horny.	Nos. 12 and 15	9 colored to 7 white, horny, and waxy.
Nos. 4, 7, 10, and 13.	3 colored, 1 white, horny and waxy.	No. 16	9 colored to 7 white, all waxy.
No. 6	All colored, waxy.		

The following list shows the circles that would have four classes of seeds when self-pollinated, together with the degree of correlation expected:

Circles Nos. 4 and 7, no correlation.
Circle No. 10, correlation, colored and waxy, 0.744.
Circle No. 12, correlation, colored and waxy, 0.380.
Circle No. 13, correlation, colored and horny, 0.766.
Circle No. 15, correlation, colored and horny, 0.570.

The proportions in which the different degrees of correlation are expected are as follows:

No correlation	4 ears.
Correlation between colored and horny, 0.766	3 ears.
Correlation between colored and horny, 0.570	3 ears.
Correlation between colored and waxy, 0.744	1 ear.
Correlation between colored and waxy, 0.380	1 ear.

Table XLII shows the expected results of crossing colored horny with colored waxy plants when the ears obtained exhibit four classes of seeds, the expectation being that these ears are to have horny and waxy seeds in equal numbers.

TABLE XLII.—*Expectation of seed classes resulting from the crossing of colored horny with colored waxy maize plants whose ears exhibit four classes of seeds.*

Circle.	Color.	Texture.	Correlation.
Number 4 × 8	3 colored, 1 white	Horny and waxy	None.
Number 7 × 8	do	do	Do.
Number 12 × 8	do	do	Do.
Number 15 × 8	do	do	Do.
Number 10 × 14	do	do	Colored and waxy. 0.615.
Number 12 × 14	do	do	Do.
Number 13 × 14	do	do	Colored and horny, 0.615.
Number 15 × 14	do	do	Do.
Number 4 × 16	do	do	None.
Number 7 × 16	do	do	Do.
Number 10 × 16	do	do	Colored and waxy, 0.615.
Number 12 × 16	9 colored, 7 white	do	Colored and waxy, 0.270.
Number 13 × 16	3 colored, 1 white	do	Colored and horny, 0.615.
Number 15 × 16	9 colored, 7 white	do	Colored and horny, 0.270.

The proportions in which the different degrees of correlation are expected where colored horny is crossed with colored waxy are as follows:

No correlation	20 ears.
Correlation between colored and horny, 0.615	27 ears.
Correlation between colored and horny, 0.270	9 ears.
Correlation between colored and waxy, 0.615	9 ears.
Correlation between colored and waxy, 0.270	3 ears.

It can readily be seen that a very large number of individuals would be necessary to determine whether the ratios, together with the expected degrees of correlation, were obtained in the correct proportions. The results obtained from the cross Dh 333 can be disposed of rather easily, since only four self-pollinated ears were secured from the colored horny group (Table XLIII). With three of these ears it is not possible to accurately determine the degree of correlation to which to refer them, since the number of individuals is small. The fourth ear seems to have rather too high a degree of correlation between colored and horny to be referred to the expected 0.766, but the chances of such a deviation being due to an error in sampling are about 5.5 in 10. It can therefore be assumed that the four ears secured from the cross Dh 333 do not in any way conflict with the expected results.

The remaining crosses, Dh 330 and Dh 334, have a slightly larger number of ears with which to further test the fit of observed to theory, but it is not the number of ears, which indeed are far short of sufficient numbers to make an accurate test of proportions, but from the way in which they are related that the most interesting results are obtained.

TABLE XLIII.—*Correlation between the endosperm texture and the aleurone color in four ears of maize, the progeny of colored horny seeds of cross Dh 333 self-pollinated.*

Progeny ear.	Number of seeds.					Corre-lation, $W+X$.	Prob-able error.	Percentage of—	
	Total.	*WX.*	*WH.*	*CX.*	*CH.*			Waxy.	White.
1	2	3	4	5	6	7	8	9	10
1893	337	16	53	78	190	−0.153	0.103	27.9	20.5
1894	261	14	55	41	151	− .032	.117	21.1	26.4
1895	33	2	3	9	19	.169	.270	33.3	15.2
1897	424	58	47	39	280	.800	.031	22.9	24.7

At first glance the degrees of correlation obtained with the cross Dh 330 by pollinating the colored waxy individuals with the colored horny individuals and the reverse, together with the few self-pollinated horny plants, seem to very nearly approximate those expected on theory, as all of the correlations obtained could be referred to some of the expected degrees of association.

The first ear shown in Table XLIV, No. 1856, has an exact reciprocal in ear No. 1877, and the self-pollinated colored horny parent is ear No. 1878, both of the same table. All three of these ears show practically no correlation, and the Mendelian ratios approximate the expected proportions. This group can be said to fulfill the expected results where either circles 4, 7, 12, 15 are crossed with circle 8, or where circles 4 or 7 are crossed with circle 16 (Table XLII).

The second group consists of ear No. 1860, its exact reciprocal ear No. 1874, together with the self-pollinated colored horny parent ear No. 1875 (Table XLIV).

TABLE XLIV.—*Correlation between the endosperm texture and the aleurone color of 12 ears of maize, the progeny of the cross Dh 330.*

Progeny ear.	Pedigree No. of— Self-pollinated. ♂	Pedigree No. of— Self-pollinated. ♀	Pedigree No. of— Reciprocal cross.	Number of seeds. Total.	*WX.*	*WH.*	*CX.*	*CH.*	Correlation, W + X.	Probable error.	Percentage of— Waxy.	Percentage of— White.
1	2	3	4	5	6	7	8	9	10	11	12	13
COLORED WAXY × COLORED HORNY.												
1856	1878		1877	525	69	74	170	212	0.075	0.067	45.6	25.4
1860	1875		1874	649	119	45	170	315	.653	.039	44.6	25.3
1861	None		1871	450	51	58	153	188	.034	.074	45.4	24.2
1863	...do		None	679	72	102	234	271	−.114	.059	45.0	25.6
1865	1875		...do	739	143	38	237	321	.670	.031	51.4	24.5
COLORED HORNY × COLORED WAXY.												
1871	All waxy	None	1861	81	10	11	23	37	0.188	0.053	40.6	25.9
1874		1875	1860	137	25	16	46	50	.259	.120	51.8	29.9
1876	None	None	None	377	86	36	115	140	.491	.064	53.4	32.4
1877	All waxy	1878	1856	424	51	50	175	148	−.074	.076	53.3	23.9
COLORED HORNY × SELF.												
1875	Self			716	104	194	47	371	0.605	0.042	21.1	41.6
1878	...do			496	32	104	90	270	−.040	.080	24.6	27.4
1882	...do			136	19	42	9	66	.538	.077	20.6	44.8

Since the self-pollinated ear from the colored horny parent of the above reciprocals had approximately 9 colored to 7 white seeds with a correlation of 0.605 between C and H, it could have come only from circle 15 (Table XL). The expected correlation upon self-pollinating circle 15 is 0.570, of which 0.605±0.04 can reasonably be considered an approximation.

There are three classes of waxy seeds with which circle 15 may be crossed that will result in ears with four classes of seeds. These seeds are represented by circles 8, 14, and 16 in Table XL. Circle 8 can be eliminated, since a cross between it and circle 15 would result in an ear with no correlation. The choice lies between 14 and 16. The result of crossing circles 15 and 14 would be an ear with a correlation approximating 0.615 between *C* and *H*. This is a fairly close approximation to the 0.653±0.039 obtained with ear No. 1860, but the correlation of 0.259±0.12 obtained with the exact reciprocal of ear No. 1860, namely, No. 1874, is a very close approximation to the expected 0.270, when circles 15 and 16 are crossed. In this case, as is shown on page 90, the expected ratio of colored to white seeds is 9 to 7, while on the ear concerned, No. 1874, the colored seeds are approximately three times the number of white seeds. The correlation of 0.259 certainly can not be looked upon as a chance fluctuation from the correlation 0.615 expected when circles 15 and 14 are crossed. A case parallel to this is found in the cross Dh 334. The colored waxy parent pollinated by the colored horny is represented by ear No. 1902, the exact reciprocal is ear No. 1917, and the self-pollinated colored horny parent is ear No. 1918 (Table XLV).

TABLE XLV.—*Correlation between the endosperm texture and the aleurone color of 10 ears of maize, the progeny of the cross Dh 334.*

COLORED WAXY × COLORED HORNY.

Progeny ear.	Pedigree No. of— Self-pollinated. ♂	♀	Reciprocal cross.	Number of seeds. Total.	*WX.*	*WH.*	*CX.*	*CH.*	Correlation, *W*+*X*.	Probable error.	Percentage of— Waxy.	White.
1	2	3	4	5	6	7	8	9	10	11	12	13
1902	1918	1903	1917	765	166	49	249	301	0.640	0.038	54.3	28.1
1904	None	None	None	443	57	58	162	166	.002	.073	49.5	26.0
1906	1923	...do	1922	315	40	41	112	116	.076	.085	50.1	27.6
1909	1925	1910	1924	485	71	32	146	236	.563	.042	44.7	21.3
COLORED HORNY × COLORED WAXY.												
1917	All waxy	1918	1902	452	80	40	170	162	.348	.067	55.3	26.5
1922	...do	1923	1906	421	56	53	156	160	.040	.046	49.4	26.5
1924	...do	1925	1909	415	83	25	125	182	.658	.049	50.6	26.9
COLORED HORNY × SELF.												
1918	Self			345	46	46	47	206	.628	.054	27.0	26.6
1923	...do			399	42	71	81	205	.199	.077	30.8	28.3
1925	...do			457	59	52	51	295	.736	.037	24.1	24.3

The self-pollinated colored horny ear had approximately 3 colored seeds to 1 white and a correlation of 0.628±0.054 between *C* and *H*. This correlation is about midway between that expected for self-pollinating circles 13 and 15, though it is slightly closer to the latter. Self-pollinating circle 15 would have an expected ratio of 9 colored to 7 white seeds, but since the ear in question is a fairly close approximation to the ratio of 3 colored to 1 white it fits the expected proportions when circle 13 is self-pollinated.

Assuming the plant in question to be the result of planting circle 13, there are two classes of waxy seeds with which it may be crossed that will result in ears with four classes of seeds. These classes are represented by circles 14 and 16.

The ears secured by either cross would be alike, both having 3 colored seeds to 1 white and a correlation of 0.615 between *C* and *H*. Ear No. 1902, with a correlation of 0.64±0.038, is a close approximation to the expected results on this basis, but the exact reciprocal ear, No. 1917, with a correlation of 0.348±0.067, can hardly be looked upon as approximating the expected 0.615. This correlation is much closer to that expected when circles 15 and 16 are crossed, but the ratio of white to colored seeds would in that case be as 7 to 9, and the observed ratio is a close approximation to the 3 to 1 ratio. In both the cases where the reciprocals differ in the degree of correlation the lowest correlation is found where the colored horny plant served as the female parent, indicating a higher correlation in the male gametes. This tendency has been observed with ear No. 1764 (Table XXXVIII), where a significant difference was observed in reciprocals, and also with ears Nos. 1804, 1815, and 1816 (Table XXXIX), where smaller differences in this direction were observed.

This difference may be due to a higher death rate for the pollen grains bearing the character combinations resulting from different parents, or it may be that such pollen grains are less vigorous or that the male gametes are not being formed in the expected proportions.

The remaining ear of cross Dh 330 that resulted from pollinating colored horny individuals by colored waxy is ear No. 1876. There is no reciprocal of this cross nor is there a self-pollinated ear from the colored horny parent. The ratio of white to colored seeds is rather closer to a 3 to 1 than a 7 to 9, and the correlation, 0.491 ±0.064, though low, may be looked upon as an approximation of the expected 0.615, when circles 13 and 16, 13 and 14, or 15 and 14 are crossed.

Of the three self-pollinated ears of the cross Dh 330, one ear, No. 1875, has already been discussed. Ear No. 1878, having no significant correlation, could be the result of self-pollinating circles 4 or 7. Ear No. 1882, with an approximate ratio of 9 colored to 7 white seeds and a correlation of 0.538 between *C* and *H*, is a very close approximation of the expected 0.570 when circle 15 is self-pollinated. The remaining ears of the cross Dh 334 also seem to approximate the expected correlations.

Ears Nos. 1906, 1904, and 1922 are all close approximations to the expected results of crossing circles 4, 7, 12, or 15 with circle 8 or 4 or circle 7 with 16. Ears Nos. 1906 and 1922 are exact reciprocals, and as such agree as well as could be expected. The colored horny parent of these last-mentioned ears had a self-pollinated ear, No. 1923, which could have been the result of the self-pollination of circles 4 or 7, so that ears Nos. 1906 and 1922 are probably the result of crossing circles 4 or 7 with circles 8 or 16. Ears Nos. 1909 and 1924 are exact reciprocals, and with the self-pollinated ear from the colored horny parent, No. 1925, make a complete group. The self-pollinated colored horny parent is a very close approximation to the result expected when circle 13 is self-pollinated. The reciprocals, Nos. 1909 and 1924, are in fairly close agreement with each other and are close approximations to the expected result of crossing circle 13 with either circle 14 or 16.

SUMMARY OF THE CORRELATIONS BETWEEN ENDOSPERM TEXTURE AND ALEURONE COLOR.

The preceding experiments were undertaken in the spring of 1910 with the view to determining whether the previously observed coherence between endosperm texture and aleurone color could be referred to the 3–1–1–3 reduplication series of Bateson and Punnett. The intention was to obtain a number of individuals large enough to determine definitely the degree of reduplication, as well as to decide whether all plants gave the same reduplication ratio.

The experiments have now been carried to the third generation, and the degree of correlation with 17,015 seeds has been found to be 0.762 ± 0.0057. This correlation is a very close approximation to the 0.766 expected if the reduplication was of the series 3–1–1–3. Some plants have been found, however, which gave reduplications other than 3–1–1–3, and it is possible that succeeding generations of these will throw additional light on this complicated subject. In some cases the departures could be readily explained by slightly modifying the theory proposed by Punnett as to the type of cell division, which resulted in the 3–1–1–3 ratio, but in other cases an extremely complicated theory of cell divisions would be required to give an adequate explanation of the observed ratios.

To explain the aberrant cases by Morgan's linkage hypothesis, we would be forced to believe that at least one of the characters was insecurely located on the chromosome, since with the widely different correlations obtained it is necessary to assume that the mutation of the locus of at least one of the characters is of frequent occurrence.

With a new series of hybrids between these same varieties comprising some 20,000 seeds, a correlation has been obtained which more nearly approximates a 4–1–1–4 than a 3–1–1–3 gametic series. The correlation for these last hybrids differs from that obtained in the original crosses by more than eight times the probable error. From this we must conclude that the correlation between the same characters differs widely in different families, though the individuals within a family seem to approximate the same mean.

We must further conclude that the association between these two characters in maize does not always fit the arbitrary series of 3 to 1, 7 to 1, etc., proposed by Bateson, but that in some instances the couplings more nearly approximate the intermediate points of this series, such as 4 to 1, 5 to 1, etc.

It is not intended to imply that the reduplication found in the gametes is the direct result of unequal cell division, although the observed results can be explained on such a hypothesis. The assumption that for the higher coupling ratios segregation must take place before synapsis in order to permit of the proper number of cell divisions seems thus far unwarranted by any cytological evidence.

A study of the Mendelian behavior of the aleurone color has led to the realization that since characters are the result of many factors more or less independent the correlations must also be between these invisible factors rather than between the visible characters.

The fact that correlations are between factors which can be detected only when in combination with certain other factors permits of many different degrees of correlation and lessens the degree of confidence to be placed in conclusions regarding both the factorial composition and the correlations or couplings. There is danger of explaining aberrant Mendelian ratios by the predication of correlations and to explain aberrant coupling ratios by assuming changes in the factorial composition. Because of this fact, great care must be given to the analysis of correlated characters from the standpoint of their Mendelian behavior, since much depends upon the number of factors involved.

Reciprocal crosses between plants heterozygous for endosperm texture and aleurone color and plants homozygous for the recessive characters waxy endosperm and colorless aleurone have shown in many cases that certain character combinations are deficient in the male gametes. It is suggested that this deficiency may be due to a higher death rate, less vigor, or a failure of the plant to produce these odd combinations in the proper proportions.

If we can assume that correlations are the result of unequal cell division, we can further assume that the reduplicated character combinations are also the most vigorous. Thus the tubes from the pollen grains bearing the reduplicated characters may grow more rapidly than the pollen tubes from the grains bearing the odd combinations. Such a difference in the rate of growth would not occur in the female gametes, and they would be present in the theoretical proportions unless a differential death rate supervened.

It does not seem unreasonable to believe that any reaction, which causes the more rapid division of the cells bearing the correlated characters, may also cause the gametes with these same combinations to be more vigorous. In most cases when an ear is pollinated there are enough pollen grains on each stigma to insure the presence of all gametic combinations, and if any difference in the rate of growth prevailed for a certain gametic combination most of the seeds would be fertilized by that combination.

CONCLUSION.

A thorough understanding of the laws of heredity is essential in determining the most effective methods of breeding plants and animals with the special characters that are needed for purposes of commercial production under different environmental conditions. It is of general interest to practical breeders at the present time to know the extent to which it is possible to rely upon the application of the Mendelian principles of heredity. Assurance has been given by certain writers that analysis and recombination of characters of varieties by the Mendelian methods could be substituted to advantage for the methods of selection that have been considered as the most effective means of obtaining improved strains.

An adequate investigation of the current theories in regard to the laws of heredity requires the detailed analysis of results derived from the study of large numbers of individuals. In this respect the seeds of maize offer unusual opportunities. Instead of a single offspring, or a few, from 400 to 800 seeds result from a single application of pollen, and the technique of hybridization is extremely simple. In addition to the ease of manipulation and the relatively large numbers obtained, maize seeds offer the further advantage of several alternative characters which permit rapid and accurate classification. This makes possible the definite determination of questions which depend upon the regularity of the proportions in which the characters are represented in the various hybrid stocks.

With these possibilities in view, the experiments reported in this bulletin were undertaken in 1910, to analyze further the inheritance of contrasted characters and to obtain a clearer understanding of the nature of the interrelations or correlations between such characters. The characters chosen were the waxy endosperm texture found in a variety of maize from China and the colors of the aleurone cells with which this endosperm texture was known to be associated.

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The results of this analysis show that the number of seeds with the waxy endosperm reappearing in the perjugate generation of waxy × horny crosses is less than the expected for a simple Mendelian character, but this deviation, though significant, is too small to warrant the predication of additional factors. In making this determination, more than 100,000 seeds were classified, and it has been possible therefore to establish the actual percentage within 0.3 of 1 per cent.

The same material was used to test the inheritance of aleurone color, which also was found to depart from the theoretical ratios. Unlike the waxy endosperm texture, no definite trend above or below the expected ratios was observed, but many abnormal ratios were obtained which necessitated further refinements in the factorial analysis of this character.

From the results of the Mendelian analysis of aleurone color and endosperm texture it must be concluded that in many cases uniform Mendelian reactions are obtained which allow certain predictions to be made with respect to the behavior of these characters in subsequent generations. But that these predictions based upon the gametic analysis will be uniformly fulfilled must not be supposed. As we have seen, aberrant behavior is far from uncommon, increasing with the progress of investigation and the refinement of analysis. The fact is coming to be appreciated that instead of a few simple unassociated factors most characters are composed of many complex units which may no longer be considered singly but that their interrelations or correlations must be taken into account.

The present investigations show that certain of the more definitely alternative characters of maize are subject to variation or fluctuating behavior that renders these supposed Mendelian factors too irregular to justify a belief that the very definite relationship predicted in theories of gametic coupling could exist between such characters. There can be little doubt, however, that at least with several combinations of characters the gametic ratios are to a certain extent regular, but that these ratios fit any arbitrary series is not so well demonstrated.

For the breeder of crop plants where most of the desired characters are almost infinitely complex, seldom alternative, and often intangible, Mendelism seems to have little of practical value to offer, whether the attempt of some investigators to so extend the theory to embrace such characters be approved or not. While Mendelism may assist in making desired combinations, there is nothing to show that it can serve as a substitute for selection either in finding the best stocks or in preserving them from subsequent deterioration.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 755

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. ▼ March 19, 1919

GEOGRAPHICAL PHASES OF FARM PRICES: OATS.

By L. B. Zapoleon, *formerly of the Division of Crop Records.*

CONTENTS.

INTRODUCTION.

The price a farmer gets for his products varies greatly according to the section of the country in which he is situated. For some crops—the staples even—twice as high a price level frequently prevails in one part of the United States as in another.

The charting of geographic variations in farm or producers' prices has possibilities of practical usefulness. General price levels of most agricultural products fluctuate constantly, of course; but as between two sections the difference in the farmers' price of a product remains approximately the same. This price advantage or disadvantage differs with each product, so that a region of high prices for one may have low prices for another.

In this bulletin a survey is made of the sectional differences throughout the United States in the producers' prices of oats. Some consideration is also given to the influence of producing areas, trade routes and consuming centers upon such variations, and to local factors which qualify price advantage—factors such as relative yields in bushels to the acre and costs of production.

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PRICE MAPS.

Sectional differences in the farmers' price of oats have been charted on Maps 1 and 2. In Map 1 a price unit of 10 cents has been used to show tendencies due to broad general influences, as distinct from the minor variations due to local factors. Minor variations are shown in Map 2, which is more detailed.

The farm prices of oats, by counties, which form the base of these maps—averages by counties for the five years, 1910–1914—are given in the Appendix; also a further explanation of data and methods.

SURVEY OF REGIONAL DIFFERENCES IN FARM PRICES OF OATS.

Lowest prices paid for oats to farmers are along the northern boundary of the United States, from Ohio westward. The minimum price (Map 2) is seen in adjoining parts of North Dakota and Minnesota, in the north-central part of the country. From this zone the price levels of oats graduate upward in the various directions. Eastward through the grain belt, as far as Ohio, prices rise slowly, but through the Atlantic States a more rapid rise takes place; the increases are gradual westward also, toward the Pacific coast. It is in the South that the higher prices are most noteworthy. Highest prices are paid to growers of oats in the southeast—in Florida, Georgia, and South Carolina—where the prices are more than twice as high as in the zone of minimum price.

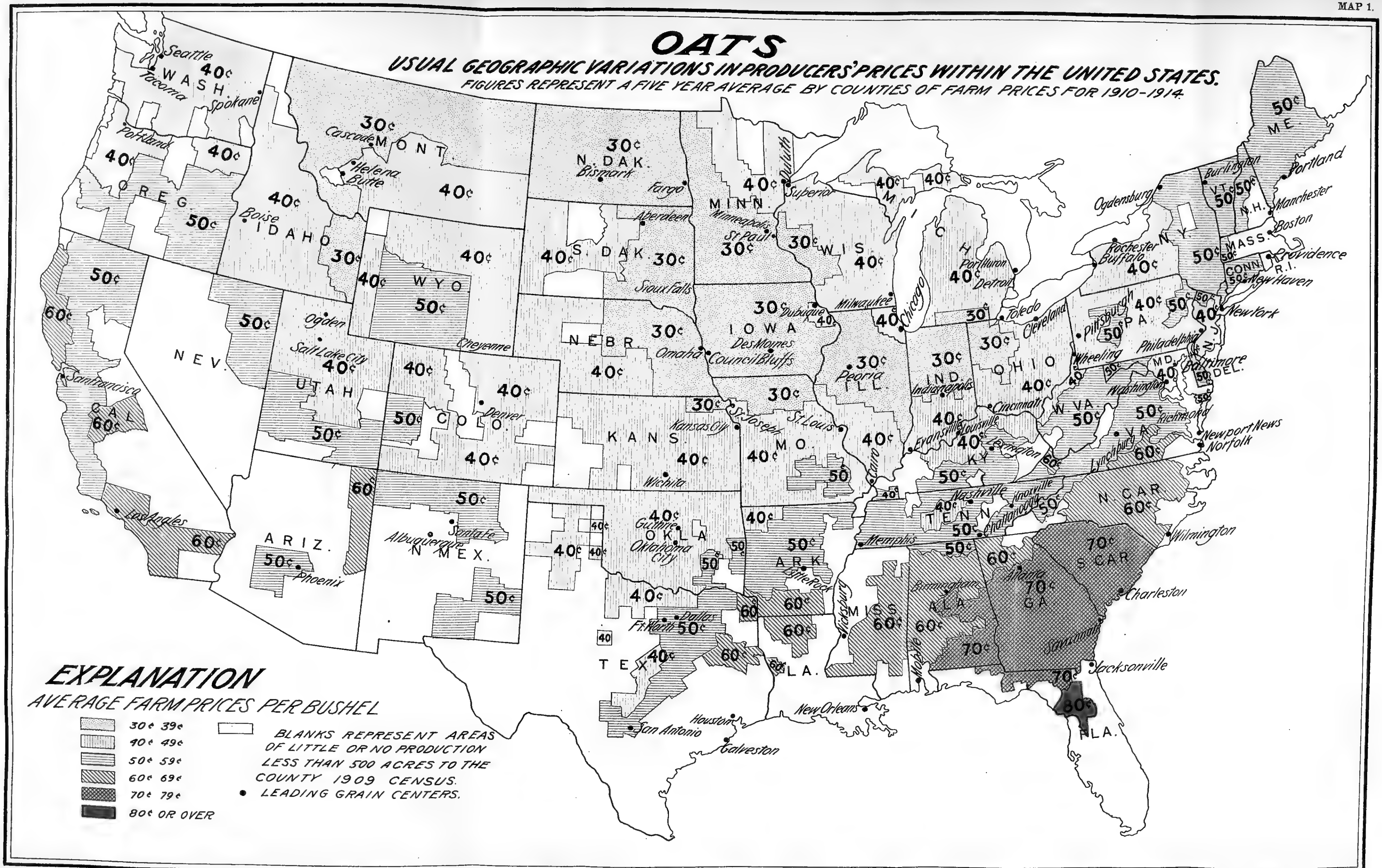
PRICE LEVELS AND TRADE ROUTES.

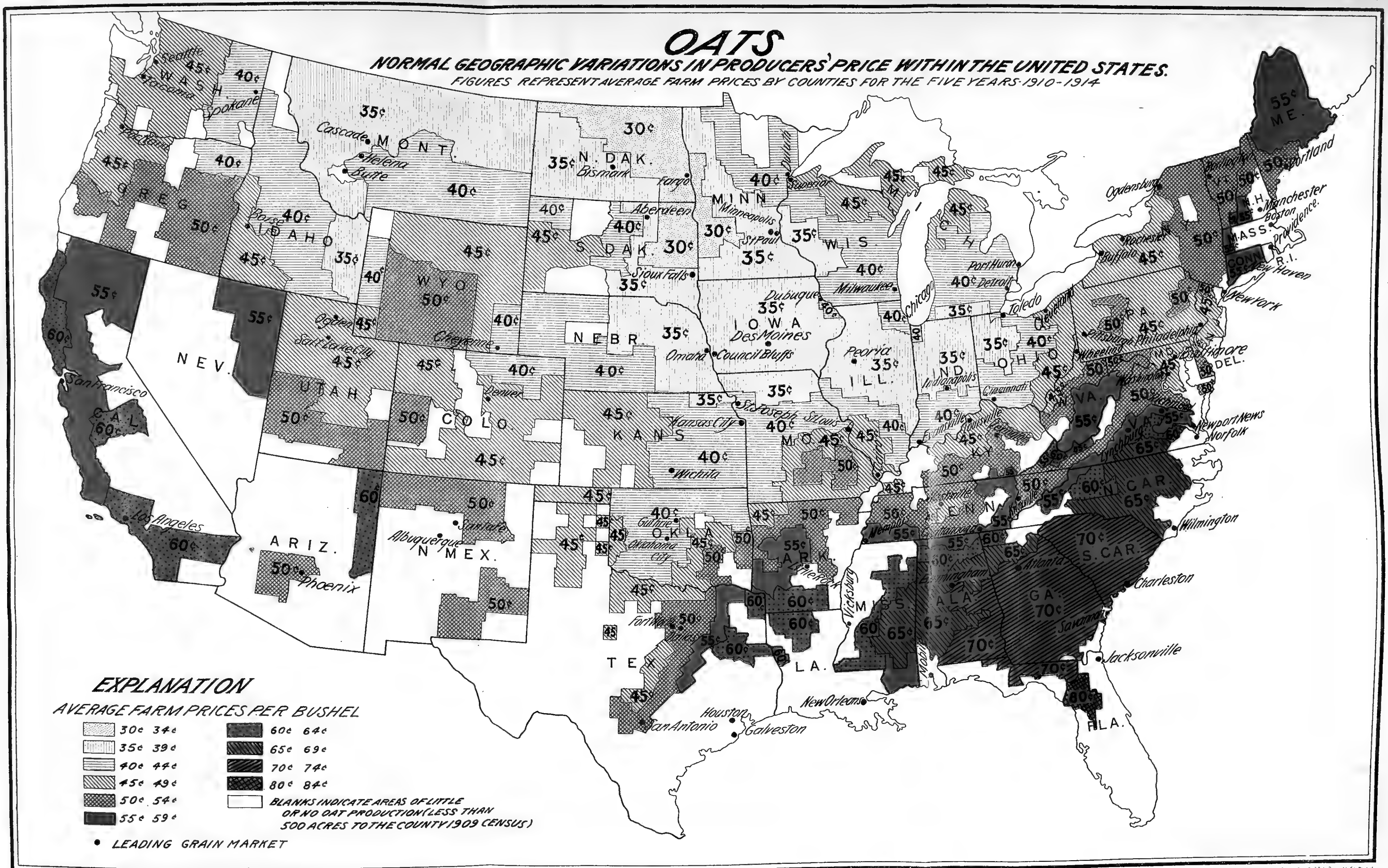
Map 3 shows the relative importance of different parts of the United States in the production of oats, according to the census for the year 1909.

Although oats are a northern crop, their production within the United States is more general than that of any of the other cereals, because they can be grown on a variety of soils, because they fit readily into crop rotations, and because the practice of fall sowing in the South has made it possible to grow oats with good returns in that section. But the great bulk of the crop is produced in the sections of lowest price.

It will be observed that the zones of low price coincide with areas of dense and surplus production. A price divide appears between sections which ship to the East and South and those which ship to the West and South. The line of demarcation is indicated, roughly, by the territory of minimum price, which is remotely situated with regard to the markets in either direction.

Prices paid to producers of oats attain higher levels toward all points of the compass, rising steadily, as a rule, with distance from this region of lowest price. Emerging from the sections of large


OATS
USUAL GEOGRAPHIC VARIATIONS IN PRODUCERS' PRICES WITHIN THE UNITED STATES.
FIGURES REPRESENT A FIVE YEAR AVERAGE BY COUNTIES OF FARM PRICES FOR 1910-1914.
EXPLANATION
AVERAGE FARM PRICES PER BUSHEL
30¢ 39¢
40¢ 49¢
50¢ 59¢
60¢ 69¢
70¢ 79¢
80¢ OR OVER
BLANKS REPRESENT AREAS OF LITTLE OR NO PRODUCTION LESS THAN 500 ACRES TO THE COUNTY 1909 CENSUS.
LEADING GRAIN CENTERS.
WASH.
OREG.
CAL.
NEV.
IDAHO
MONT.
WYO.
UTAH
COLO.
ARIZ.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KANS.
OKLA.
TEX.
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S. CAR.
N. CAR.
VA.
W. VA.
PA.
N.Y.
N.J.
MD.
DEL.
CONN.
R.I.
MASS.
VT.
N.H.
ME.
Seattle
Tacoma
Spokane
Portland
Boise
Cascade
Helena
Butte
Ogden
Salt Lake City
San Francisco
Los Angeles
Phoenix
Albuquerque
Santa Fe
Cheyenne
Denver
Bismark
Fargo
Aberdeen
Sioux Falls
Omaha
Council Bluffs
Kansas City
St. Joseph
Wichita
Guthrie
Oklahoma City
Dallas
Ft. Worth
San Antonio
Houston
Galveston
New Orleans
Duluth
Superior
Minneapolis
St. Paul
Dubuque
Des Moines
Milwaukee
Chicago
Peoria
St. Louis
Cairo
Little Rock
Memphis
Vicksburg
Mobile
Birmingham
Atlanta
Savannah
Jacksonville
Charleston
Wilmington
Nashville
Knoxville
Chattanooga
Louisville
Lexington
Evansville
Indianapolis
Cincinnati
Toledo
Detroit
Port Huron
Cleveland
Pittsburgh
Wheeling
Philadelphia
Baltimore
Washington
Richmond
Lynchburg
Newport News
Norfolk
Ogdensburg
Rochester
Buffalo
New York
New Haven
Providence
Boston
Manchester
Portland
Burlington


OATS
NORMAL GEOGRAPHIC VARIATIONS IN PRODUCERS' PRICE WITHIN THE UNITED STATES.
FIGURES REPRESENT AVERAGE FARM PRICES BY COUNTIES FOR THE FIVE YEARS 1910-1914
EXPLANATION
AVERAGE FARM PRICES PER BUSHEL
30¢ 34¢
35¢ 39¢
40¢ 44¢
45¢ 49¢
50¢ 54¢
55¢ 59¢
60¢ 64¢
65¢ 69¢
70¢ 74¢
80¢ 84¢
BLANKS INDICATE AREAS OF LITTLE OR NO OAT PRODUCTION (LESS THAN 500 ACRES TO THE COUNTY 1909 CENSUS)
• LEADING GRAIN MARKET
WASH.
Seattle
Tacoma
Spokane
Portland
OREG.
IDAHO
Boise
MONT.
Cascade
Helena
Butte
N. DAK.
Bismark
Fargo
S. DAK.
Aberdeen
Sioux Falls
MINN.
Minneapolis
St. Paul
Superior
Duluth
WIS.
Milwaukee
MICH.
Port Huron
Detroit
WYO.
Cheyenne
NEV.
CAL.
San Francisco
Los Angeles
UTAH
Ogden
Salt Lake City
COLO.
Denver
NEBR.
Omaha
Council Bluffs
IOWA
Dubuque
Des Moines
ILL.
Peoria
Chicago
IND.
Indianapolis
Evansville
OHIO
Toledo
Cleveland
Cincinnati
KANS.
Kansas City
St. Joseph
Wichita
MO.
St. Louis
KY.
Louisville
Lexington
ARIZ.
Phoenix
N. MEX.
Albuquerque
Santa Fe
OKLA.
Guthrie
Oklahoma City
TEX.
Fort Worth
Dallas
Houston
Galveston
San Antonio
ARK.
Little Rock
LA.
New Orleans
MISS.
Vicksburg
TENN.
Memphis
Nashville
Chattanooga
Knoxville
ALA.
Birmingham
Mobile
GA.
Atlanta
Savannah
FLA.
Jacksonville
S. CAR.
Charleston
N. CAR.
Wilmington
VA.
Lynchburg
Richmond
Newport News
Norfolk
W. VA.
Wheeling
MD.
Baltimore
DEL.
PA.
Pittsburgh
Philadelphia
N.Y.
Ogdensburg
Rochester
Buffalo
New York
CONN.
New Haven
R.I.
Providence
MASS.
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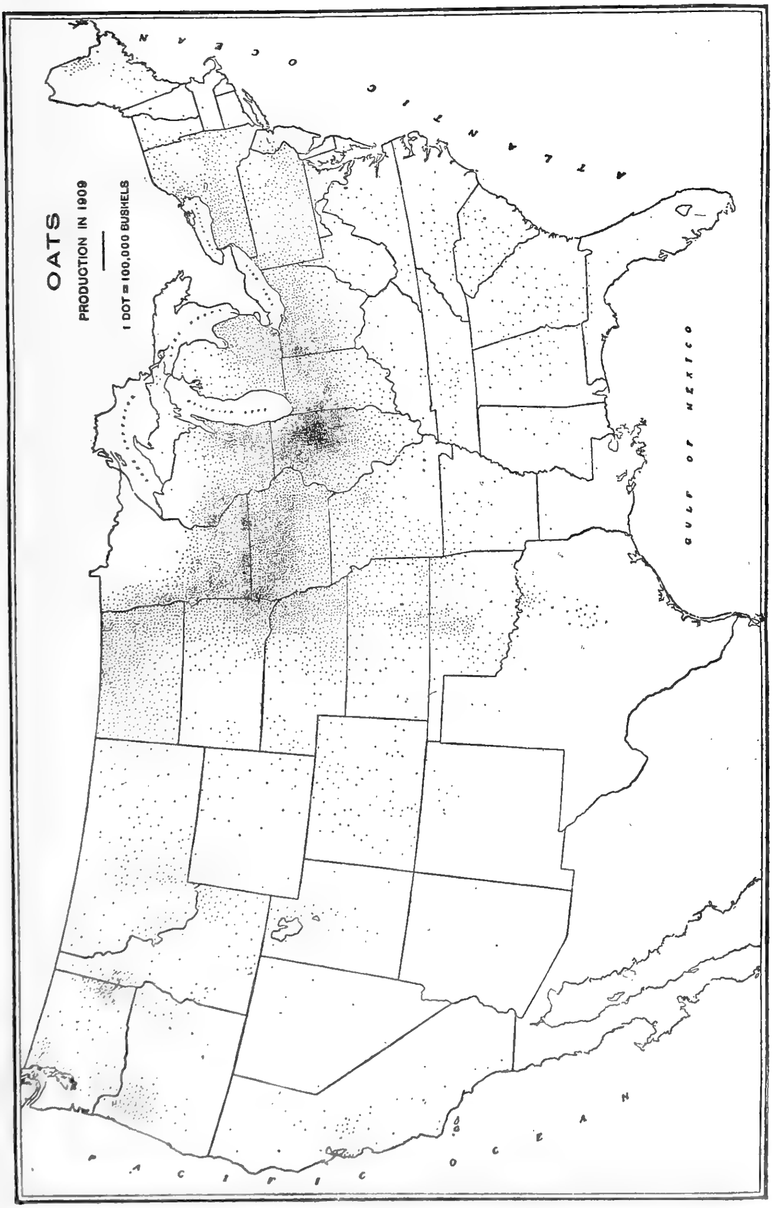
production, the upward movement in the price levels becomes more pronounced. In deficiency regions near the main channels of trade, price increases are small. Highest prices are paid to producers in the southeastern cotton States—areas of insufficient oat production which are farthest removed from the surplus-producing sections.



MAP 3.

Compared to such products as corn or vegetables, gradual elevation in the price levels of oats is a distinguishing characteristic, as well as comparative regularity in the upward slope of prices from the region of minimum price. In the commerce in oats, a weight per bushel nearly half that of wheat or corn lowers the freight charges. Moreover, the rate per 100 pounds is sometimes less than for wheat, consequently oats move at nearly half the expense of other cereals, and the greater the distance the more marked does this difference in costs of transportation become.

The trend of the price levels is evidently closely related to such influences as the location of areas of surplus and deficient production, the local uses of oats, and to the group of factors which enter into the distributive movement.

DISPOSITION OF UNITED STATES OAT CROP.

The price of oats is dominated by the demand for them as a feedstuff; as such by far the larger part of the crop is consumed on farms, and second in importance is the consumption by live stock in cities. Imports and exports are normally unimportant, and only a small part of the crop is used for human food and for seed.

A few general phases of the uses and distributive movement of oats are shown in Table 1.

TABLE 1.—*Oats: Approximate distribution of the harvest of the United States.*

[Figures are five-year averages for the years 1911 to 1915. Number of bushels rounded to the nearest million.]

Item.	Per cent.	Bushels.
Production	100.0	1,229,000,000
Shipped out of counties where grown[1]	29.0	361,000,000
Remaining in counties where grown[1]	71.0	868,000,000
Farm consumption:[2]		
Horses and mules	46.4	570,000,000
Milch cows	5.0	61,000,000
Other cattle	1.8	22,000,000
Swine	1.8	22,000,000
Sheep	1.8	22,000,000
Poultry	2.2	27,000,000
Human beings	.9	12,000,000
Seed	7.6	94,000,000
Other or doubtful	4.5	55,000,000
Total	72.0	885,000,000
Not used on farms:		
Exports	3.9	48,000,000
Consumed in merchant flour mills	4.1	50,000,000
Other urban uses, principally consumption by over 3,000,000 horses in cities, also human food (rolled oats and "breakfast foods")	20.0	246,000,000
Total	28.0	344,000,000

[1] In the census year 1909, total sales of oats from farms constituted 32.7 per cent of the crop. As in the same year shipments out of counties where grown amounted to 25.9 per cent, the difference represents approximately the local sales, amounting to 6.8 per cent of the crop.
[2] U. S. Department of Agriculture. Farmers' Bulletin 629, p. 8. (1914.)

As less than 4 per cent of the national production was exported in 1911–1915, on an average, it is evident that domestic requirements absorbed nearly the entire crop.

Farm consumption absorbs 72 per cent of the crop. According to the 1909 census only a third of the harvest is sold, the remaining two-thirds never leaving the counties in which it is produced. A small part of the third sold is shipped back to farms for consumption.

Urban markets receive about a third of the national production. This third includes the export oats and the small percentage shipped to farms, but most of it is for urban consumption. In urban consumption the chief item is the requirement for horses. Other items are the quantity which enters merchant flour mills, about 50 million bushels, and the uses for human food in the form of rolled oats and breakfast foods. The latter uses take up the higher grades of oats. The census for 1909 reported 50 million bushels consumed in merchant flour mills, of which 36 million bushels were manufactured "chiefly for human food" and 14 million bushels "chiefly for stock feed." In 1909 the quantity entering custom flour mills was reported to be 13 million bushels.

Uses of oats may be grouped under the four headings: (1) Live stock consumption, (2) seed, (3) human consumption, and (4) export. Many million bushels are required for seed, human consumption, and export, but such uses do not absorb normally more than one-fourth of the crop.

Requirements for live stock, according to an estimate made in 1914, took up approximately three-fourths of the production of the United States, of which more than half a billion bushels, or over 60 per cent of the oats used on farms, were fed to horses and mules. Adding to this figure the quantities fed to animals not on farms, the aggregate consumption by horses and mules was possibly at least one-half of the national production.

LOCAL VARIATION IN USES OF OATS.

There is much variation throughout the country in farm practice as to feeding or selling, in the various uses of oats, and in methods of marketing. Used interchangeably with other crops, consumption in any section depends upon price, local production, and the abundance of other feeds.

Where corn is scarce and high in price, as in the Pacific States, a larger use is made of oats and barley for feeding purposes. In many sections of the West and South, oats are cut for hay. A special investigation for the State of Tennessee[1] showed that about 49 per cent of the crop of the State was fed in the straw and 51 per cent was thrashed.

[1] Monthly Crop Report, March, 1916, p. 21.

PRODUCTION, CONSUMPTION, AND MARKETINGS, BY STATES AND SECTIONS.

An idea of the relation of production to consumption, surplus and deficiency in each State and section, and the direction of the trade currents may be gained from Table 2.

It will be noted that three-fourths of the national oat crops of 1911–1915 were produced within the two divisions comprising the North Central States, which contain but 17 per cent of the total land area. This area embraces the regions of lowest farm price. It is the greatest grain and live-stock producing region, and most of the oats raised is consumed locally. However, the fraction of the crop which moves from this section constitutes the bulk of the commercial crop in the United States.

"Shipments out of counties where grown" in Table 2 may be said as a rule to represent the fraction which enters commercial channels, the rest of the crop remaining for local consumption.

In the census report for the year 1909, the sales of oats from farms were reported as 32.7 per cent of production. In the same year shipments out of counties where grown amounted to 25.9 per cent. The difference, 6.8 per cent of the crop, would appear to constitute the local sales.

Nearly 84 per cent of all the oats entering general trade channels originates within the North Central States. Yet this 84 per cent of the total commercial oats constitutes only a third of the production of this region, the remaining two-thirds being consumed on the farms where grown. The oat crop of the Pacific Northwest, with that of adjacent territory, enters normally into a distinct trade westward, the surplus over domestic needs being exported via the Pacific. If from the total commercial oats the figures for the far Western States be deducted, the concentration of production in the North Central States becomes still more pronounced compared with the rest of the country. The surplus from this north central section evidently supplements deficient production in other regions east of the Rocky Mountains and furnishes the bulk of the export oats. All other sections produce less than requirements, although some small areas therein produce surpluses. Details are given in Table 2.

LOCAL PRICE FACTORS.

THE GENERAL PRICE TREND AND LOCAL VARIATIONS.

Map 2, showing geographic differences in the farm price of oats, is designed to show local variations in the general price zones. It is based upon the same data as Map 1, except that a 5-cent unit has been used to throw into relief local deviations and minor counter-currents to the general drift of the price movement. The basic figures and an explanation as to methods are given in the appendix (pp. 21–28).

TABLE 2.—*Oats: Production and commercial movement.*

[Five-year average, 1911–1915.]

State and geographic division.	Production.			Shipped out of counties where grown.		
	Quantity.	Per cent of United States production.	Per capita.	Quantity.	Per cent of production of State or division.	Per cent of total shipments.
	Thousand bushels.		*Bushels.*	*Thousand bushels.*		
United States	1,228,765	100.0	12.6	360,560	29	100.0
New England	9,789	.8	1.4	149	2	[1]
Middle Atlantic	80,401	6.5	3.9	4,930	6	1.4
South Atlantic	32,461	2.6	2.5	1,385	4	.4
East North Central	395,331	32.2	20.8	144,601	37	40.1
West North Central	527,674	42.9	43.8	157,009	30	43.5
East South Central	21,558	1.8	2.5	1,856	9	.5
West South Central	60,946	5.0	6.4	15,813	26	4.4
Mountain	65,282	5.3	22.2	20,442	31	5.7
Pacific	35,323	2.9	7.4	14,375	41	4.0
New England:						
Maine	5,452	.4	7.2	112	2	[1]
New Hampshire	441	[1]	1.0	4	1	[1]
Vermont	3,178	.3	8.8	32	1	[1]
Massachusetts	305	[1]	.1	1	[1]	[1]
Rhode Island	58	[1]	.1	0	0	0
Connecticut	355	[1]	.3	0	0	0
Middle Atlantic:						
New York	42,500	3.4	4.4	2,331	5	.6
New Jersey	2,024	.2	.7	216	11	.1
Pennsylvania	35,877	2.9	4.4	2,383	7	.7
South Atlantic:						
Delaware	121	[1]	.6	12	10	[1]
Maryland	1,309	.1	1.0	167	13	.1
Virginia	4,108	.3	1.9	295	7	.1
West Virginia	2,774	.2	2.1	60	2	[1]
North Carolina	4,864	.4	2.1	97	2	[1]
South Carolina	7,988	.7	5.1	296	4	.1
Georgia	10,429	.8	3.8	439	4	.1
Florida	868	.1	1.1	19	2	[1]
East North Central:						
Ohio	64,308	5.2	13.0	21,668	34	6.0
Indiana	54,731	4.5	19.8	23,801	43	6.6
Illinois	145,962	11.9	24.7	72,156	49	20.0
Michigan	50,948	4.1	17.3	12,411	24	3.4
Wisconsin	79,382	6.5	32.8	14,565	18	4.1
West North Central:						
Minnesota	104,457	8.5	47.9	30,449	29	8.4
Iowa	175,081	14.2	78.8	77,507	44	21.5
Missouri	27,807	2.3	8.3	3,772	14	1.0
North Dakota	73,436	6.0	111.1	13,200	18	3.7
South Dakota	44,507	3.6	69.2	13,992	31	3.9
Nebraska	57,977	4.7	47.0	12,439	21	3.4
Kansas	44,409	3.6	25.2	5,650	13	1.6
East South Central:						
Kentucky	3,893	.3	1.7	172	4	[1]
Tennessee	6,967	.6	3.1	1,313	19	.4
Alabama	7,455	.6	3.3	212	3	.1
Mississippi	3,243	.3	1.7	159	5	[1]
West South Central:						
Louisiana	1,429	.1	.8	166	12	[1]
Texas	29,803	2.5	7.1	10,433	35	2.9
Oklahoma	23,653	1.9	12.2	4,953	21	1.4
Arkansas	6,061	.5	3.7	261	4	.1
Mountain:						
Montana	23,103	1.9	55.1	7,243	31	2.0
Wyoming	8,179	.7	50.2	1,846	23	.5
Colorado	11,587	.9	13.1	3,040	26	.8
New Mexico	1,867	.1	5.0	381	20	.1
Arizona	298	[1]	1.3	37	12	[1]
Utah	4,340	.4	10.7	1,103	25	.3
Nevada	499	[1]	5.3	83	17	[1]
Idaho	15,409	1.3	40.7	6,709	44	1.9
Pacific:						
Washington	14,035	1.1	10.4	6,409	46	1.8
Oregon	14,040	1.2	18.5	4,570	33	1.3
California	7,248	.6	2.7	3,396	47	.9
United States	1,228,765	100.0	12.6	360,560	29	100.0
Exports (including oatmeal)	48,291	3.9				
Imports	5,3[illegible]3	.4				

[1] Less than one-tenth of 1 per cent.

Examination of Map 2 will disclose an irregular slope in the price levels in a number of instances. A varying rate of increase in the upward trend is also in evidence. The deviations from the general trend are not so frequent or pronounced as in the case of farm products which have comparatively local markets, or where cost of transportation, incident to greater bulk, represents a larger proportion of market values. This lower cost of shipping oats from one section to another tends to regulate and reduce the price differences between the two sections.

Price levels are more irregular and rise more rapidly southward than to the east or west. A number of factors contribute to this condition. On the north, the Canadian surplus is a factor to be reckoned with; other factors in this section are cheaper water transportation via the Great Lakes, availability of other feeds, and the organization of the grain trade.

ISOLATED AREAS.

The existence or absence of adequate transportation facilities has a strong influence on the price zones. An isolated region has practically a local market, influenced little by outside market conditions. The prices in the mountainous areas are out of line with prices in surrounding territory. Illustrations of this are seen in Appalachian Mountain regions and the Ozark section in Missouri.

LOCAL VARIATIONS IN DEMAND.

The elasticity of domestic demand and supply and the availability of substitutes are indicated by the fact that during the years 1911 to 1916 the annual variation in consumption of oats ranged from 20 million to 600 million bushels.

Much variation exists throughout the country in the relation of production to consumption, in farm practice as to feeding or selling, and in the various uses of oats and methods of marketing. Used interchangeably with other crops, consumption in any section depends upon price, local production, and the abundance of other feeds. Thus in the important oat-producing States west of the Mississippi—which are unfavorably situated as to the trade routes owing to distance and higher costs of transportation—a considerably larger proportion of the crop is retained for farm consumption than in the important surplus-producing States east of the Mississippi. The great variation, section by section, in the farm consumption of oats was indicated in Table 2 in the quantities remaining in the counties where grown.

COSTS OF HAULING TO SHIPPING POINTS.

Prices are influenced also by distance from shipping points, condition of wagon roads, and other things affecting wagon transportation.

Table 3 gives cost of hauling as estimated for 1906. Such costs are frequently higher than the costs of long shipments by rail or water.

TABLE 3.—*Average cost of hauling oats from farms to shipping points.*[1]

[Cost refers to expense for round trips.]

State and geographic division.	Number of counties reported.	Average—					From most remote farms to shipping points—				
		Miles to shipping point.	Days for round trip.	Pounds in one load.	Cost per load.	Cost per 100 pounds.	Miles to shipping point.	Days for round trip.	Pounds in one load.	Cost per load.	Cost per 100 pounds.
North Atlantic:											
New York	8	7.8	0.6	2,619	$2.21	$0.08	25.0	1.5	3,000	$6.75	$0.22
Pennsylvania	24	7.1	.7	2,875	2.48	.09	20.0	1.0	2,000	2.50	.12
South Atlantic:											
Virginia	8	7.5	.7	2,644	2.28	.09	18.0	2.0	2,200	5.00	.23
West Virginia	5	10.0	.8	2,410	3.12	.13	20.0	2.0	1,750	6.00	.34
Georgia	8	12.7	1.1	1,575	2.62	.17	30.0	2.5	2,000	5.00	.25
North Central:											
Ohio	46	6.2	.6	3,120	1.96	.06	30.0	2.0	2,000	8.00	.40
Indiana	46	6.6	.6	3,021	1.75	.06	25.0	1.5	3,000	4.50	.15
Illinois	58	5.7	.5	2,847	1.47	.05	24.0	1.5	3,500	6.00	.17
Michigan	44	7.8	.6	2,710	1.81	.07	30.0	2.0	3,500	6.00	.17
Wisconsin	35	8.8	.7	2,588	2.09	.08	30.0	2.0	2,500	6.00	.24
Minnesota	44	8.3	.7	2,916	2.25	.08	30.0	2.0	3,000	7.00	.23
Iowa	73	6.1	.6	2,354	1.78	.08	16.0	2.0	3,500	7.00	.20
Missouri	42	8.6	.8	2,335	2.03	.09	25.0	2.0	2,000	5.00	.25
North Dakota	20	10.7	.7	3,738	3.23	.09	35.0	2.0	2,700	6.00	.22
South Dakota	32	12.7	.9	2,880	3.23	.11	50.0	2.5	2,500	15.00	.60
Nebraska	51	9.1	.7	2,826	2.14	.08	30.0	1.5	2,500	5.25	.21
Kansas	30	7.6	.6	2,835	1.69	.06	25.0	2.0	3,000	7.00	.23
South Central:											
Kentucky	18	10.5	1.1	2,256	2.99	.13	30.0	3.0	1,250	9.00	72
Tennessee	24	9.8	.8	1,888	1.86	.10	30.0	3.0	1,600	6.00	.38
Alabama	2	15.5	1.4	1,500	3.50	.23	25.0	2.0	1,500	4.00	.27
Texas	43	13.8	1.1	2,358	3.02	.13	42.5	3.0	2,500	4.50	.18
Indian Territory	2	8.8	.6	1,900	1.65	.09	15.0	.5	2,000	1.38	.07
Oklahoma	12	12.9	.9	2,354	2.51	.11	45.0	3.0	2,000	7.50	.38
Western:											
Montana	17	13.9	1.3	3,076	5.69	.19	35.0	3.5	2,500	10.50	.42
Wyoming	7	22.1	1.9	2,829	7.03	.25	55.0	6.5	4,500	22.75	.51
Colorado	27	12.5	1.1	3,307	4.50	.14	70.0	7.0	2,500	35.00	1.40
New Mexico	4	18.0	1.7	2,212	5.42	.25	37.5	3.0	2,750	10.50	.38
Arizona	2	13.8	1.3	4,250	7.15	.17	27.5	2.5	4,500	18.75	.42
Utah	10	21.9	2.2	3,665	6.71	.18	100.0	14.0	7,000	35.00	.50
Nevada	1	12.0	1.4	6,000	10.50	.18	17.0	2.0	6,000	15.00	.25
Idaho	9	13.6	1.1	3,278	4.86	.15	27.5	1.5	2,500	6.75	.27
Washington	14	9.8	1.0	2,654	4.00	.15	60.0	7.0	2,000	28.00	1.40
Oregon	15	10.3	.9	3,783	3.24	.09	30.0	2.0	4,000	6.00	.15
California	17	9.9	.9	6,229	4.31	.07	32.0	3.0	4,000	12.75	.32
Geographic division:											
North Atlantic	32	7.5	.6	2,713	2.18	.08	......	......	......	......	......
South Atlantic	21	9.4	.8	2,318	2.56	.11	......	......	......	......	......
North Central	521	6.9	.6	2,766	1.82	.07	......	......	......	......	......
South Central	101	13.0	1.0	2,289	2.74	.12	......	......	......	......	......
Western	123	11.5	1.1	3,683	4.55	.12	......	......	......	......	......
States represented	798	7.3	.6	2,772	1.82	.07	......	......	......	......	......

[1] From "Costs of hauling crops from farms to shipping points," by Frank Andrews. Bul. 49, Bureau of Statistics, U. S. Dept. Agr.

URBAN MARKETS.

A large part of the commercial oat crop is first concentrated in a few large primary markets, most of which are located in the region of large production. Each market has a tributary territory, and farm prices in the sections shipping to each market tend to differ in proportion to costs of transportation. As this grain business is on a highly competitive basis, the price levels in surrounding sections (see price levels in North Central States) are comparatively even.

RECEIPTS, SHIPMENTS, AND CONSUMPTION OF CHIEF MARKETS.

In Table 4 are assembled data as to receipts, shipments, and apparent consumption in the most important grain centers. Allowing for duplication in reports of receipts, the degree of concentration in a few primary markets in the North Central States is manifest in comparing the total of receipts with the "shipments out of counties where grown" (Table 2).

While the great markets such as Chicago, St. Louis, and New York consume large quantities of oats, they are also points for concentration and reshipment.

TABLE 4.—*Oats: Receipts and shipments in leading markets.*

[Figures are five-year averages, 1911 to 1915, unless otherwise noted.]

Market.	Receipts.	Shipments.	Excess, receipts over shipments.
EAST OF THE ROCKY MOUNTAINS.			
Primary markets:	*Bushels.*	*Bushels.*	*Bushels.*
Chicago	121,774,000	104,622,000	17,152,000
St. Louis	22,117,000	15,409,000	6,708,000
Minneapolis	21,513,000	20,218,000	1,295,000
Milwaukee	19,620,000	18,125,000	1,495,000
Omaha	13,266,000	[1] 13,599,000	....
Peoria	10,391,000	[1] 11,717,000	....
Kansas City	7,719,000	6,203,000	1,516,000
Cleveland	7,419,000	1,606,000	5,813,000
Cincinnati	7,188,000	5,076,000	2,112,000
Duluth	6,592,000	[1] 6,626,000	....
Indianapolis	6,242,000	2,405,000	3,837,000
Louisville	6,037,000	4,240,000	1,797,000
Toledo	4,561,000	3,770,000	791,000
Detroit	3,823,000	743,000	3,080,000
Total [2]	258,262,000	214,359,000	45,596,000
Other markets:			
Buffalo	12,685,000	(3)	(3)
		Exports.	
New York	27,071,000	8,001,000	19,070,000
Baltimore	15,726,000	12,310,000	3,416,000
Philadelphia	11,143,000	3,567,000	7,576,000
Boston	4,539,000	789,000	3,750,000
New Orleans	3,089,000	700,000	2,389,000
PACIFIC MARKETS.			
Seattle	2,344,000	764,000	1,580,000
San Francisco	2,049,000	259,000	1,790,000
Portland, Oreg. [4]	2,286,000	1,327,000	959,000

[1] In these cases shipments apparently exceed receipts, according to the original reports.
[2] Allowance should be made for some duplication in receipts due to such causes as intermediate markets crediting themselves with through shipments.
[3] No data.
[4] Data for 1915 only.

PRICE ZONES FLEXIBLE.

In concluding the brief summary of a few of the more general facts concerning regional price differences it appears necessary to direct attention to the changeable character of the price zones. The price differences as charted on Maps 1 and 2 represent the usual conditions as established by averages for the five years 1910 to 1914. These averages, which are based upon average prices for individual counties, indicate price zones which are fairly definite, but whose boundaries and price averages are subject to change. Unusual harvest or market conditions may change the price in one section as compared with another. Especially is this true for comparatively isolated sections, which are somewhat out of line with general trade currents. However, a comparison of the prices of many hundreds of counties during 1910–1914 shows that in individual years the price zones were substantially the same as those based upon the average prices of the five years.

SECTIONAL PRICE RATIOS CHANGING WITH ECONOMIC TRANSFORMATIONS.

The differences in price between one region and another, as indicated by the five-year averages in Table 5, reflect economic conditions that are changing; and the character of these changes in economic conditions since 1871–1875 are to a considerable extent indicated by the varying difference in price in one section as compared with another.

Transportation costs have declined greatly; other distributive expenses have dropped also; areas which formerly produced sufficient quantities for local needs must now bring in supplies. Sectional price differences have narrowed notably. The farmers' price of oats has become lower in areas of insufficient production, coincident with cheaper transportation from regions of surplus; on the other hand, prices have increased in areas of surplus production.

RETROSPECTIVE VIEW, 1871 TO 1915.

CHANGES IN REGIONAL PRICE DIFFERENCES.

In Table 5 the regional differences in the price of oats during the period 1871 to 1915 can be observed. The center of oat production has shifted to the west and north. The minimum farm price of oats has followed in the same direction. In the period 1871–1875 the lowest farm price appeared in Iowa, in 1882–1886 in Nebraska, and in 1911–1915 in North Dakota. The farm price in Massachusetts was 34 cents higher than in Iowa in 1871–1875, but only 18 cents higher in 1911–1915. In the surplus-producing North Central States, west of the Mississippi River, prices have increased, absolutely as well as relatively, but in the areas of insufficient production in the Southern and Mountain States prices have declined. Tendencies can best be followed through the percentage based upon the average for the United States at each period taken as 100 per cent. Details follow in Table 5.

TABLE 5.—*Farm prices of oats, 1871 to 1915.*

[A review, by States and sections, of the trend of geographic price differences.]

State and geographic division.	Farm prices per bushel, in 5-year averages.					Measurement of changes in percentages of the United States average as base (100 per cent)				
	1911–1915.	1901–1905.	1891–1895.	1882–1886.[1]	1871–1875.[2]	1911–1915.	1901–1905.	1891–1895.	1882–1886.[1]	1871–1875.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
United States	**39**	**33**	**29**	**31**	**36**	**100**	**100**	**100**	**100**	**100**
New England	53	46	43	46	54	136	139	148	148	150
Middle Atlantic	47	40	36	38	44	121	121	124	123	122
South Atlantic	59	48	44	48	58	151	145	152	155	161
East North Central	39	33	28	30	32	100	100	97	97	89
West North Central	36	29	25	25	27	92	88	86	81	75
East South Central	57	47	42	47	61	146	142	145	152	169
West South Central	50	44	41	50	78	128	133	141	161	217
Mountain	47	52	40	53	......	121	158	138	171	......
Pacific	46	45	37	45	64	118	136	128	145	177
New England:										
Maine	52	46	43	45	53	133	139	148	145	147
New Hampshire	55	47	43	46	54	141	142	148	148	150
Vermont	53	44	42	42	46	136	133	145	135	128
Massachusetts	53	47	43	48	57	136	142	148	155	158
Rhode Island	52	46	45	48	54	133	139	155	155	150
Connecticut	54	45	41	45	57	138	136	141	145	158
Middle Atlantic:										
New York	47	40	35	38	43	121	121	121	123	119
New Jersey	49	41	37	39	46	126	124	128	126	128
Pennsylvania	46	38	35	38	42	118	115	121	123	117
South Atlantic:										
Delaware	49	42	36	39	40	126	127	124	126	111
Maryland	49	38	35	37	41	126	115	121	119	114
Virginia	54	42	36	42	44	138	127	124	135	122
West Virginia	52	43	38	38	39	133	130	131	123	108
North Carolina	63	51	44	48	58	162	155	152	155	161
South Carolina	69	59	54	56	77	177	179	186	181	214
Georgia	68	58	52	56	74	174	176	179	181	206
Florida	71	54	60	69	90	182	164	207	223	250
East North Central:										
Ohio	40	34	30	33	33	103	103	103	106	92
Indiana	38	31	29	29	30	97	94	100	94	83
Illinois	38	32	26	26	27	97	97	90	84	75
Michigan	40	35	31	33	36	103	106	107	106	100
Wisconsin	39	32	26	28	32	100	97	90	90	89
West North Central:										
Minnesota	34	28	25	26	30	87	85	86	84	83
Iowa	35	28	23	24	23	90	85	79	77	64
Missouri	41	33	26	27	28	105	100	90	87	78
North Dakota	31	28	25	} 28	......	79	85	86	} 90	......
South Dakota	34	28	25			87	85	86		
Nebraska	36	28	24	20	25	92	85	83	65	69
Kansas	41	33	26	24	27	105	100	90	77	75
East South Central:										
Kentucky	49	39	34	35	41	126	118	117	113	114
Tennessee	51	41	34	37	41	131	124	117	119	114
Alabama	66	56	51	58	76	169	170	176	187	211
Mississippi	63	53	48	58	86	162	161	166	187	239
West South Central:										
Louisiana	58	49	46	56	98	149	148	159	181	272
Texas	48	47	38	47	76	123	142	131	152	211
Oklahoma	41	37	......	......	......	105	112	......	......	......
Arkansas	52	45	39	47	61	133	136	134	152	169
Mountain:										
Montana	36	39	40	53	......	92	118	138	171	......
Wyoming	44	46	......	50	......	113	139	......	161	......
Colorado	43	46	37	51	......	110	139	128	165	......
New Mexico	51	61	51	56	......	131	185	176	181	......
Arizona	63	67	......	......	......	162	203	......	......	......
Utah	45	48	36	46	......	115	145	124	148	......
Nevada	58	65	......	58	95	149	197	......	187	264
Idaho	36	46	38	54	......	92	139	131	174	......
Pacific:										
Washington	41	41	34	43	......	105	124	117	139	......
Oregon	41	42	34	43	53	105	127	117	139	147
California	55	51	44	49	74	141	155	152	158	206

[1] 1882-1886 taken instead of 1881-1885 because of availability of statistics for a larger number of states beginning 1882.
[2] Values reduced to gold basis.

TREND OF YIELDS TO THE ACRE.

Yields in bushels to the acre must be taken into consideration as a qualifier of price advantage or disadvantage. The trend of yields, by States and geographic divisions, is shown in Table 6.

Increases in yield are general. It is only in the West North Central States, the western part of the great surplus-producing section, that diminishing yields appear. In this section large areas have been added to the cultivated land between 1875 and 1915, and the average yields of 1915 include areas not included in 1875. The most pronounced increases in yields per acre are seen in the Mountain and Southern States, offsetting declining price advantages in those sections.

TREND OF VALUES TO THE ACRE.

Prices and average yields have been correlated in Table 7 to show average values to the acre. For the period under review, values have increased in nearly all States and sections, but in varying ratios. The most pronounced improvement in this respect is seen in the Southern States. The average for the United States shows an increase, but declines are shown in the States of the industrial East and the far West.

SECTIONAL CHANGES IN PRODUCTION OF OATS.

The changes in the location of the chief oat-producing sections from 1871 to 1915 and the relation of production to population and other factors are indicated in Table 8.

During the period under review, production has increased fivefold. It has been concentrated to an increasing degree in the North Central States, which in 1871–1875 grew 60 per cent of the national crop of oats, and in 1911–1915, 75 per cent. The most marked relative increases during the last decade are shown in the Mountain and Southern States, but in relation to the United States total these sections are still comparatively unimportant. The three States constituting the Middle Atlantic section produced nearly one-fourth the total in 1871–1875, and in 1911–1915 their proportion dropped to about one-fifteenth.

PRICE VS. COST OF PRODUCTION.

Difference in costs of production is an independent factor which modifies sectional differences in producers' prices of oats. Costs are qualified by varying productivity as expressed by yields in bushels to the acre. High yields to the acre may reduce high acre-costs to low bushel-costs, and conversely. In the Southern States, for instance, the favorable combination of highest price and lowest costs to the acre is offset by relatively low yields to the acre; hence these States show the highest costs per bushel of oats and the minimum net returns.

TABLE 6.—*Oats: Trend of yields per acre, 1871–1915.*

[Limitations of soil and climate, reflected in yields per acre, as qualifying price factors.

State and geographic division.	Yields per acre, in five-year averages.					Comparisons in percentages of the United States average as base.				
	1911–1915	1901–1905	1891–1895	1882–1886 [1]	1871–1875	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
United States	**32**	**31**	**26**	**27**	**28**	**100**	**100**	**100**	**100**	**100**
New England	35	34	33	31	32	109	110	127	115	114
Middle Atlantic	31	30	28	28	29	97	97	108	104	104
East North Central	34	34	29	32	30	106	110	112	119	107
West North Central	29	31	26	32	32	91	100	100	119	114
South Atlantic	23	18	16	13	15	72	58	62	48	54
East South Central	21	18	16	14	17	66	58	62	52	61
West South Central	24	23	20	18	22	75	74	78	67	79
Mountain	42	35	31	31	......	131	113	119	115	......
Pacific	41	36	31	30	33	128	116	119	111	118
New England:										
Maine	39	38	35	29	26	122	123	135	107	93
New Hampshire	37	32	34	34	36	116	103	131	126	129
Vermont	40	38	37	35	36	125	123	142	130	129
Massachusetts	35	32	34	31	33	109	103	131	115	118
Rhode Island	29	30	30	28	32	91	97	115	104	114
Connecticut	31	32	28	29	32	97	103	108	107	114
Middle Atlantic:										
New York	33	33	27	30	34	103	106	104	111	121
New Jersey	29	28	29	27	25	91	90	112	100	89
Pennsylvania	32	30	27	28	29	100	97	104	104	104
East North Central:										
Ohio	36	36	30	32	28	112	116	115	119	100
Indiana	32	31	27	29	25	100	100	104	107	89
Illinois	34	32	30	35	30	106	103	115	130	107
Michigan	34	34	27	33	31	106	110	104	122	111
Wisconsin	35	35	32	31	35	109	113	123	115	125
West North Central:										
Minnesota	35	36	32	35	34	109	116	123	130	121
Iowa	35	30	32	34	36	109	97	123	126	129
Missouri	23	23	24	26	29	72	74	92	96	104
North Dakota	32	35	28	} 34	......	{ 100	113	108	} 126	......
South Dakota	27	36	23			{ 84	116	88		
Nebraska	26	29	22	32	31	81	94	85	119	111
Kansas	25	25	23	32	31	78	81	88	119	111
South Atlantic:										
Delaware	30	25	21	23	19	94	81	81	85	68
Maryland	29	25	21	20	17	91	81	81	74	61
Virginia	21	17	14	11	14	66	55	54	41	50
West Virginia	25	24	22	18	23	78	77	85	67	82
North Carolina	19	14	12	9	13	59	45	46	33	46
South Carolina	21	15	12	10	11	66	48	46	37	39
Georgia	21	14	13	9	12	66	45	50	33	43
Florida	17	13	11	10	12	53	42	42	37	43
East South Central:										
Kentucky	22	22	21	19	22	69	71	81	70	79
Tennessee	22	19	17	13	17	69	61	65	48	61
Alabama	20	15	13	11	13	62	48	50	41	46
Mississippi	20	17	13	10	15	62	53	50	37	54
West South Central:										
Arkansas	23	19	19	17	23	72	61	73	63	82
Louisiana	22	16	15	13	16	69	52	58	48	57
Oklahoma	21	30	......	......	......	66	97	......	......	......
Texas	31	28	26	24	28	97	90	100	89	100
Mountain:										
Montana	46	42	34	36	......	144	135	131	133	......
Idaho	46	40	33	33	......	144	129	127	122	......
Wyoming	38	35	31	30	......	119	113	119	111	......
Colorado	38	33	27	33	......	119	106	104	122	......
New Mexico	36	24	29	22	......	112	77	112	81	......
Arizona	42	33	......	......	......	131	106	......	......	......
Utah	45	36	30	30	......	141	116	115	111	......
Nevada	45	36	......	32	34	141	116	......	119	121
Pacific:										
Washington	49	47	37	38	......	153	152	142	141	......
Oregon	39	28	28	27	33	122	90	108	100	118
California	35	32	29	26	33	109	103	112	96	118

[1] See note 1, Table 5.

TABLE 7.—*Oats: Gross returns per acre.*

[A review of the trend of returns per acre of oats, 1871–1915, and measurement of tendencies in absolute and relative figures.]

State and geographic division.	Gross returns per acre in five-year averages.					Comparisons in percentages of the United States average as base (100).				
	1911–1915	1901–1905	1891–1895	1882–1886 [1]	1871–1875	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875
	Dolls.	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
United States	**12.48**	**10.23**	**7.54**	**8.37**	**10.08**	**100**	**100**	**100**	**100**	**100**
New England	18.55	15.64	14.19	14.26	17.28	149	153	188	170	171
Middle Atlantic	14.57	12.00	10.08	10.64	12.76	117	117	134	127	127
East North Central	13.36	11.22	8.12	9.60	9.60	107	110	108	115	95
West North Central	10.44	8.99	6.50	8.00	8.64	84	88	86	96	86
South Atlantic	13.57	8.64	7.04	6.24	8.70	109	84	93	75	86
East South Central	11.97	8.46	6.72	6.58	10.37	96	83	89	79	103
West South Central	12.00	10.12	8.20	9.00	17.16	96	99	109	108	170
Mountain	19.74	18.20	12.40	16.43	......	158	178	164	196	......
Pacific	18.86	16.20	11.47	13.50	21.12	151	158	152	161	210
New England:										
Maine	20.28	17.48	15.05	13.05	13.78	162	171	200	156	137
New Hampshire	20.35	15.04	14.62	15.64	19.44	163	147	194	187	193
Vermont	21.20	16.72	15.54	14.70	16.56	170	163	206	176	164
Massachusetts	18.55	15.04	14.62	14.88	18.81	149	147	194	178	187
Rhode Island	15.08	13.80	13.50	13.44	17.28	121	135	179	161	171
Connecticut	16.74	14.40	11.48	13.05	18.24	134	141	152	156	181
Middle Atlantic:										
New York	15.51	13.20	9.45	11.40	14.62	124	129	125	136	145
New Jersey	14.21	11.48	10.73	10.53	11.50	114	112	142	126	114
Pennsylvania	14.72	11.40	9.45	10.64	12.18	118	111	125	127	121
East North Central:										
Ohio	14.40	12.24	9.00	10.56	9.24	115	120	119	126	92
Indiana	12.16	9.61	7.83	8.41	7.50	97	94	104	100	74
Illinois	12.92	10.24	7.80	9.10	8.10	104	100	103	109	80
Michigan	13.60	11.90	8.37	10.89	11.16	109	116	111	130	111
Wisconsin	13.65	11.20	8.32	8.68	11.20	109	109	110	104	111
West North Central:										
Minnesota	11.90	10.08	8.00	9.10	10.20	95	99	106	109	101
Iowa	12.25	8.40	7.36	8.16	8.28	98	82	98	97	82
Missouri	9.43	7.59	6.24	7.02	8.12	76	74	83	84	81
North Dakota	9.92	9.80	7.00	} 9.52	......	79	96	93	} 114	......
South Dakota	9.18	10.08	5.75			74	99	76		
Nebraska	9.36	8.12	5.28	6.40	7.75	75	79	70	76	77
Kansas	10.25	8.25	5.98	7.68	8.37	82	81	79	92	83
South Atlantic:										
Delaware	14.70	10.50	7.56	8.97	7.60	118	103	100	107	75
Maryland	14.21	9.50	7.35	7.40	6.97	114	93	97	88	69
Virginia	11.34	7.14	5.04	4.62	6.16	91	70	67	55	61
West Virginia	13.00	10.32	8.36	6.84	8.97	104	101	111	82	89
North Carolina	11.97	7.14	5.28	4.32	7.54	96	70	70	52	75
South Carolina	14.49	8.85	6.48	5.60	8.47	116	87	86	67	84
Georgia	14.28	8.12	6.76	5.04	8.88	114	79	90	60	88
Florida	12.07	7.02	6.60	6.90	10.80	97	69	88	82	107
East South Central:										
Kentucky	10.78	8.58	7.14	6.65	9.02	86	84	95	79	89
Tennessee	11.22	7.79	5.78	4.81	6.97	90	76	77	57	69
Alabama	13.20	8.40	6.63	6.38	9.88	106	82	88	76	98
Mississippi	12.60	9.01	6.24	5.80	12.90	101	88	83	69	128
West South Central:										
Arkansas	11.96	8.55	7.41	7.99	14.03	96	84	97	95	139
Louisiana	12.76	7.84	6.90	7.28	15.68	102	77	92	87	156
Oklahoma	8.61	11.10	......	......	......	69	109	......	......	......
Texas	14.88	13.16	9.88	11.28	21.28	119	129	131	135	211
Mountain:										
Montana	16.56	16.38	13.60	19.08	......	133	160	180	228	......
Idaho	16.56	18.40	12.54	17.82	......	133	180	166	213	......
Wyoming	16.72	16.10	......	15.00	......	134	157	......	179	......
Colorado	16.34	15.18	9.99	16.83	......	131	148	132	201	......
New Mexico	18.36	14.64	14.79	12.32	......	147	143	196	147	......
Arizona	26.46	22.11	......	......	......	212	216	......	......	......
Utah	20.25	17.28	10.80	13.80	......	162	169	143	165	......
Nevada	26.10	23.40	......	18.56	32.30	209	229	......	222	320
Pacific:										
Washington	20.09	19.27	12.58	16.34	......	161	188	167	195	......
Oregon	15.99	11.76	9.52	11.61	17.49	128	115	126	139	174
California	19.25	16.32	12.76	12.74	24.42	154	160	169	152	242

[1] See note 1, table 5.

TABLE 8.—*Oats: A statistical review, from 1871 to 1915, by States and geographic divisions: Changes in domestic sources of supply, in absolute and relative figures; trend of per capita production; per cent of improved land in oats.*

State and geographic division.	Geographic distribution of oat production in five-year averages.					Averages, 1911–1915 as compared with 1901–1905 (100 per cent).	Average per capita production.[1]					Distribution of oat production, in percentages of United States totals.					Per cent of all improved land occupied by oats.[2]			
	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875		1911–1915	1901–1905	1891–1895	1882–1886	1871–1875	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875	1909	1899	1889	1879
	1,000 bu.	*1,000 bu.*	*1,000 bu.*	*1,000 bu.*	*1,000 bu.*	*Per cent.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
United States	**1,228,765**	**871,311**	**705,049**	**579,344**	**278,503**	**141**	**12.6**	**10.8**	**10.5**	**10.5**	**6.6**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**7.3**	**7.1**	**7.9**	**5.7**
New England	9,789	8,309	10,923	9,130	8,497	118	1.4	1.4	2.2	2.1	2.3	0.8	1.0	1.6	1.6	3.1	3.1	2.6	2.7	2.1
Middle Atlantic	80,401	80,512	72,005	80,062	65,497	100	3.9	4.8	5.3	7.0	7.0	6.5	9.2	10.2	13.8	23.5	8.6	8.4	9.0	7.9
South Atlantic	32,461	16,813	30,377	27,920	17,226	193	2.5	1.5	3.3	3.4	2.7	2.6	1.9	4.3	4.8	6.2	2.8	2.8	5.3	6.2
East North Central	395,331	323,137	227,176	216,013	109,226	122	20.8	19.4	16.0	17.8	11.2	32.2	37.1	32.2	37.3	39.2	12.6	11.6	11.3	6.6
West North Central	527,674	346,003	294,645	191,246	58,372	153	43.8	32.2	31.5	26.3	12.8	42.9	39.7	41.8	33.0	21.0	9.6	8.9	10.4	6.3
East South Central	21,558	13,375	26,283	24,535	12,086	161	2.5	1.7	3.9	4.1	2.5	1.8	1.5	3.7	4.2	4.3	2.0	2.1	4.8	4.5
West South Central	60,946	43,968	22,742	15,547	1,808	139	6.4	6.1	4.3	4.0	.7	5.0	5.1	3.2	2.7	.7	2.2	3.7	2.8	2.3
Mountain	65,282	18,458	8,090	5,210	76	354	22.2	9.4	6.0	5.9	.2	5.3	2.1	1.2	0.9	(3)	7.3	4.9	3.9	4.4
Pacific	35,323	20,736	12,808	9,681	4,245	170	7.4	7.0	6.3	6.8	5.3	2.9	2.4	1.8	1.7	1.5	3.6	2.9	1.9	1.8
The Territories	......	......	......	......	1,470	......	......	......	......	......	......	......	......	......	......	0.5	......	......	......	......
New England:																				
Maine	5,452	4,366	4,355	2,439	1,723	125	7.2	6.2	6.5	3.7	2.7	.4	.5	.6	.4	.6	5.1	4.6	4.0	2.3
New Hampshire	441	392	1,006	1,046	1,098	112	1.0	.9	2.6	2.9	3.4	(3)	(3)	.2	.2	.4	1.2	1.2	1.5	1.3
Vermont	3,178	2,958	4,120	3,654	3,781	107	8.8	8.5	12.3	11.0	11.4	.3	.3	.6	.7	1.4	4.4	3.5	3.8	3.0
Massachusetts	305	213	560	727	729	143	.1	.1	.2	.4	.5	(3)	(3)	.1	.1	.3	.7	.5	.9	1.0
Rhode Island	58	49	140	169	150	118	.1	.1	.4	.6	.6	(3)	(3)	(3)	(3)	(3)	1.0	.8	1.3	1.9
Connecticut	355	331	742	1,095	1,016	107	.3	.3	.9	1.6	1.8	(3)	(3)	.1	.2	.4	1.0	.9	1.8	2.2
Middle Atlantic:																				
New York	42,500	42,226	37,364	40,437	31,653	101	4.4	5.4	5.9	7.4	6.9	3.4	4.8	5.3	7.0	11.4	8.8	8.5	8.6	7.1
New Jersey	2,024	1,803	3,295	3,620	3,359	112	.7	.9	2.1	2.9	3.4	.2	.2	.5	.6	1.2	4.0	3.8	6.1	6.6
Pennsylvania	35,877	36,483	31,346	36,005	30,485	98	4.4	5.4	5.6	7.7	8.1	2.9	4.2	4.4	6.2	10.9	9.0	8.9	9.9	9.2
South Atlantic:																				
Delaware	121	115	470	481	388	105	.6	.6	2.7	3.1	2.9	(3)	(3)	.1	.1	.1	.6	.7	2.5	2.3
Maryland	1,309	945	2,046	2,122	2,569	139	1.0	.8	1.9	2.2	3.1	.1	.1	.3	.4	.9	1.5	1.3	2.9	3.0
Virginia	4,108	3,495	6,799	7,078	4,991	118	1.9	1.8	4.0	4.5	3.8	.3	.4	.9	1.2	1.8	2.1	2.7	5.4	6.6
West Virginia	2,774	2,032	3,084	2,351	2,255	137	2.1	2.0	3.8	3.5	4.6	.2	.2	.4	.4	.8	1.9	1.8	4.0	3.3
North Carolina	4,864	3,103	6,306	5,247	2,908	157	2.1	1.6	3.7	3.5	2.5	.4	.4	.9	.9	1.1	2.6	3.3	6.9	7.7
South Carolina	7,988	3,147	4,033	3,694	644	254	5.1	2.3	3.3	3.5	.8	.7	.4	.6	.6	.2	5.3	3.9	5.9	6.3
Georgia	10,429	3,563	7,096	6,444	3,357	293	3.8	1.5	3.6	3.9	2.6	.8	.4	1.0	1.1	1.2	3.3	3.0	5.4	7.5
Florida	868	413	543	503	114	210	1.1	.7	1.3	1.6	.5	.1	(3)	.1	.1	.1	2.4	2.1	3.7	5.1

East North Central:																				
Ohio	61,308	40,021	28,534	28,140	23,327	161	13.0	9.2	7.5	8.3	8.3	5.2	4.6	4.0	4.8	8.4	9.3	5.8	6.6	5.0
Indiana	54,731	41,490	28,801	24,175	13,178	132	19.8	16.1	12.6	11.7	7.4	4.5	4.8	4.1	4.2	4.7	9.9	6.1	7.3	4.5
Illinois	145,962	122,926	90,551	102,338	44,762	119	24.7	24.3	22.0	30.3	16.6	11.9	14.1	12.8	17.7	16.1	14.9	16.5	15.1	7.5
Michigan	50,948	33,362	25,792	19,720	9,539	153	17.3	13.1	11.8	10.8	7.2	4.1	3.8	3.7	3.4	3.4	11.1	8.6	11.0	6.5
Wisconsin	79,382	85,338	53,498	41,640	18,420	93	32.8	39.7	29.6	28.4	16.3	6.5	9.8	7.6	7.2	6.6	18.2	21.0	16.6	10.4
West North Central:																				
Minnesota	104,457	76,530	53,201	35,155	10,915	136	47.9	41.4	36.9	35.4	20.1	8.5	8.8	7.5	6.1	3.9	15.2	11.9	14.2	8.5
Iowa	175,081	116,923	114,678	70,569	21,730	150	78.8	52.4	57.1	40.6	16.4	14.2	13.4	16.3	12.2	7.8	15.8	15.7	14.8	7.6
Missouri	27,807	18,273	27,337	30,022	16,030	152	8.3	5.8	9.7	12.6	8.6	2.3	2.1	3.9	5.2	5.8	4.4	4.0	8.5	5.8
North Dakota	73,436	30,493	14,618	11,659	......	241	111.1	77.0	63.8	39.4	......	6.0	3.5	2.1	2.0	......	10.5	8.1	8.6	6.8
South Dakota	44,507	25,370	16,494			175	69.2	55.6	45.3	......	......	3.6	2.9	2.3	......	......	9.8	6.1	8.3	
Nebraska	57,977	55,399	35,076	19,757	2,322	105	47.0	50.2	33.0	28.4	10.5	4.7	6.4	5.0	3.4	.8	9.7	10.4	9.9	4.5
Kansas	44,409	23,015	33,241	24,084	7,375	193	25.2	15.0	23.1	20.6	13.3	3.6	2.6	4.7	4.1	2.7	3.1	3.6	6.6	4.1
East South Central:																				
Kentucky	3,893	5,350	11,127	8,479	6,101	73	1.7	2.4	5.7	4.9	4.3	.3	.6	1.6	1.4	2.2	1.2	2.3	5.5	3.8
Tennessee	6,967	3,238	7,988	8,042	4,694	215	3.1	1.6	4.3	4.9	3.5	.6	.4	1.1	1.4	1.7	3.1	2.3	6.3	5.5
Alabama	7,455	3,002	4,873	4,694	720	248	3.3	1.6	3.0	3.4	.7	.6	.3	.7	.8	.2	2.7	2.5	4.5	5.1
Mississippi	3,243	1,785	2,295	3,320	571	182	1.7	1.1	1.7	2.8	.6	.3	.2	.3	.6	.2	1.1	1.1	1.9	3.8
West South Central:																				
Louisiana	1,429	498	593	438	35	287	.8	.3	.5	.4	(4)	.1	.1	.1	.1	(3)	.6	.6	.7	1.0
Texas	29,803	24,869	16,101	11,117	1,041	120	7.1	7.5	6.5	6.0	1.0	2.5	2.9	2.3	1.9	.4	1.6	4.3	2.5	1.9
Oklahoma	23,653	[5] 14,379	......	......	......	164	12.2	13.7	......	......	......	1.9	1.6	......	......	......	3.5	3.7	.8	......
Arkansas	6,061	4,222	6,048	3,992	732	144	3.7	3.0	5.1	4.3	1.3	.5	.5	.8	.7	.3	2.4	4.0	5.3	4.6
Mountain:																				
Montana	23,103	6,817	2,594	1,562		339	55.1	24.1	15.0	19.3		1.9	.8	.4	.3		9.2	7.7	5.8	9.4
Wyoming	8,179	1,374	[1] 482	71		595	50.2	12.6	6.8	1.9		.7	.2	.1	(3)		9.9	3.4	3.1	1.0
Colorado	11,587	4,497	2,772	1,359		258	13.1	7.3	6.1	4.8		.9	.5	.4	.2		6.4	5.3	4.8	3.7
New Mexico	1,867	344	330	289	(6)	543	5.0	1.5	1.9	2.1	(6)	.1	(3)	(3)	(3)	(6)	2.3	4.8	3.5	3.9
Arizona	298	48	......	......		621	1.3	.3	......	......		(3)	(3)	......	(3)		1.7	.6	1.4	.1
Utah	4,340	1,639	923	684		265	10.7	5.4	4.0	4.0		.4	.2	.1	.1		5.9	4.2	4.1	4.7
Nevada	499	218	......	241	76	229	5.3	4.0	......	4.3	1.6	(3)	(3)	......	(3)	(3)	1.0	.8	.5	1.7
Idaho	15,409	3,521	989	1,004	(6)	438	40.7	16.7	9.0	18.3	......	1.3	.4	.1	.2	(6)	10.9	4.6	3.6	6.7
Pacific:																				
Washington	14,035	7,476	4,048	2,689	(6)	188	10.4	10.6	10.0	14.3	......	1.1	.9	.6	.5	(6)	4.2	3.7	3.6	7.8
Oregon	14,040	8,017	6,829	5,003	2,164	17[illegible]	18.5	16.3	19.6	21.6	18.7	1.2	.9	.9	.9	.8	7.9	7.9	6.2	6.9
California	7,248	5,243	1,931	1,989	2,081	138	2.7	3.0	1.5	2.0	3.2	.6	.6	.3	.3	.7	1.7	1.3	.5	.5
The Territories	......	......	......	......	1,470	......	......	......	......	......	......	......	......	......	......	.5	......	......	......	......
Domestic exports, including oatmeal:																				
Quantity	48,291	16,090	7,289	3,725	752	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Per cent of production	3.93	1.85	1.03	.64	.27	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

[1] Four-year average.
[2] From the decennial census returns.
[3] Less than one-tenth of 1 per cent.
[4] Less than one-tenth bushel.
[5] Includes Indian Territory.
[6] Included in "The Territories."

TABLE 9.— *Oats: Geographic differences in prices and costs of production.*[1]

State and geographic division.	Price and cost of production, **per bushel.**			Average yield per acre, 1911–1915.	Gross returns and costs of production, **per acre.**					Ratio of returns per acre to cost. (Cost=100 per cent.)[3]	Measurement of relationships in percentages of the United States average as base (100 per cent).						
	Average farm price, 1911–1915.	Cost of production, 1909.[2]			Average returns per acre of grain 1911–1915. (Price×yield.)	Value of by-products, 1909.[1]	Cost of production, 1909.[1]				Price per bushel.	Cost per bushel.		Yields per acre.	Gross returns per acre.	Cost of production per acre.	
		Excluding land rental or interest.	Including land rental or interest.				Excluding land rental or interest.	Including land rental or interest.	Commercial fertilizer in costs per acre.			Excluding land rental or interest.	Including land rental or interest.			Excluding land rental or interest.	Including land rental or interest.
	Cents.	*Cents.*	*Cents.*	*Bush.*	*Doll.*	*Doll.*	*Doll.*	*Doll.*	*Doll.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
United States	39	22	34	32	12.48	1.42	7.13	10.91	0.40	175	100	100	100	100	100	100	100
New England	53	44	54	35	18.70	5.85	15.54	18.83	2.07	120	136	200	159	109	154	218	173
Middle Atlantic	47	36	47	31	14.81	4.20	11.09	14.49	1.74	134	121	164	138	97	119	156	133
South Atlantic	59	38	56	23	13.26	1.90	8.85	12.89	1.84	150	151	173	165	72	106	124	118
East North Central	39	21	34	34	13.35	1.70	7.26	11.55	.42	184	100	95	100	106	107	102	106
West North Central	36	21	32	29	10.33	.77	6.13	9.34	.08	169	92	95	94	91	83	86	86
East South Central	57	35	48	21	11.95	.66	7.38	10.17	.92	162	146	159	141	66	96	104	93
West South Central	50	29	40	24	12.05	.72	6.90	9.69	.32	175	128	132	118	75	97	97	89
Mountain	47	24	33	42	19.67	1.10	9.90	13.95	.14	199	121	109	97	131	158	139	128
Pacific	46	21	30	41	18.44	1.05	8.60	12.48	.12	214	118	95	88	128	148	121	114
New England:																	
Maine	52	44	53	39	20.28	4.54	17.20	20.64	3.83	118	133	200	156	122	162	241	189
New Hampshire	55	42	47	37	20.35	5.25	15.49	17.30	1.12	131	141	191	138	116	163	217	159
Vermont	53	40	47	40	21.20	6.48	15.99	18.99	2.07	133	136	182	138	125	170	224	174
Massachusetts	53	46	56	35	18.55	6.00	15.96	19.66	2.00	116	136	209	165	109	149	224	180
Rhode Island	52	...	...	29	15.08	...	...	...	...	...	133	...	...	91	121	...	...
Connecticut	54	42	57	31	16.74	7.00	13.05	17.55	1.31	128	138	191	168	97	134	183	161
Middle Atlantic:																	
New York	47	37	47	33	15.51	4.71	12.37	15.59	1.99	125	120	168	138	103	124	173	143
New Jersey	49	36	48	29	14.21	4.56	10.35	13.98	1.56	137	126	164	141	91	114	145	128
Pennsylvania	46	33	43	32	14.72	3.34	10.55	13.89	1.67	140	118	150	126	100	118	148	127
South Atlantic:																	
Delaware	49	31	43	30	14.70	3.30	9.42	12.82	2.00	156	126	141	126	94	118	132	118
Maryland	49	32	78	29	14.21	3.12	9.36	22.57	1.92	152	126	145	229	91	114	131	207
Virginia	54	39	51	21	11.34	1.51	8.14	10.69	1.62	139	138	177	150	66	91	114	98
West Virginia	52	37	48	25	13.00	1.38	9.15	11.99	1.10	142	133	168	141	78	104	128	110
North Carolina	63	41	55	19	11.97	.99	7.73	10.37	1.39	155	162	186	162	59	96	108	95
South Carolina	69	47	62	21	14.49	1.35	9.79	12.97	2.80	148	177	214	182	66	116	137	119

Georgia	68	41	55	21	14.28	1.67	8.62	11.48	2.30	166	174	186	162	66	114	121	105
Florida	71	50	60	17	12.07	1.92	8.56	10.23	1.55	141	182	227	176	53	97	120	94
East North Central:																	
Ohio	40	22	34	36	14.40	1.69	8.06	12.10	.85	179	103	100	100	112	115	113	111
Indiana	38	20	35	32	12.16	1.24	6.53	11.19	.48	186	97	91	103	100	97	92	103
Illinois	38	17	33	34	12.92	1.23	5.80	11.34	.12	223	97	77	97	106	104	81	104
Michigan	40	25	35	34	13.60	2.19	8.42	11.83	.56	162	103	114	103	106	109	118	108
Wisconsin	39	21	32	35	13.65	2.16	7.51	11.27	.08	182	100	95	94	109	109	105	103
West North Central:																	
Minnesota	34	20	27	35	11.90	.83	6.93	9.59	.16	172	87	91	79	109	95	97	88
Iowa	35	17	30	35	12.25	1.30	6.01	10.51	.05	204	90	77	88	109	98	84	96
Missouri	41	25	38	23	9.43	.75	5.64	8.77	.17	167	105	114	112	72	76	79	80
North Dakota	31	20	27	32	9.92	.52	6.54	8.71	.03	152	79	91	79	100	79	92	80
South Dakota	34	22	33	27	9.18	.65	5.97	8.87	.05	154	87	100	97	84	74	84	81
Nebraska	36	21	36	26	9.36	.76	5.56	9.24	.08	168	92	95	106	81	75	78	85
Kansas	41	25	39	25	10.25	.61	6.27	9.68	.01	163	105	114	115	78	82	88	89
East South Central:																	
Kentucky	49	30	44	22	10.78	.70	6.49	9.63	.56	166	126	136	129	69	86	91	88
Tennessee	51	31	44	22	11.22	.83	6.76	9.59	.74	166	131	141	129	69	90	95	88
Alabama	66	42	54	20	13.20	.56	8.37	10.78	1.41	158	169	191	159	62	106	117	99
Mississippi	63	39	53	20	12.60	.55	7.89	10.69	.98	160	162	177	156	62	101	111	98
West South Central:																	
Louisiana	58	35	46	22	12.76	.50	7.75	10.07	1.00	165	149	159	135	69	102	109	92
Texas	48	22	33	31	14.88	.92	6.83	10.11	.07	218	123	100	97	97	119	96	93
Oklahoma	41	30	41	21	8.61	.58	6.28	8.97	.02	137	105	136	121	66	69	88	82
Arkansas	52	29	42	23	11.96	.89	6.72	9.61	.21	178	133	132	124	72	96	94	88
Mountain:																	
Montana	36	18	26	46	16.56	.75	8.43	11.73	...	196	92	82	76	144	133	118	108
Wyoming	44	22	30	38	16.72	.75	8.30	11.50	.05	201	113	100	88	119	134	116	105
Colorado	43	21	32	38	16.34	1.21	7.87	12.08	.05	208	110	95	94	119	131	110	111
New Mexico	51	24	33	36	18.36	1.62	8.56	12.05	...	214	131	109	97	112	147	120	110
Arizona	63	33	41	42	26.46	...	13.70	17.20	...	193	162	150	121	131	212	192	158
Utah	45	27	42	45	20.25	1.17	12.23	18.90	.42	166	115	123	124	141	162	172	173
Nevada	58	...	...	45	26.10	...	...	...	...	...	149	...	...	141	209	...	...
Idaho	36	22	31	46	16.56	1.13	10.18	14.22	.06	163	92	100	91	144	133	143	130
Pacific:																	
Washington	41	20	30	49	20.09	1.24	9.76	14.79	.18	206	105	91	88	153	161	137	136
Oregon	41	20	29	39	15.99	1.10	7.66	11.16	.06	209	105	91	85	122	128	107	102
California	55	24	33	35	19.25	.81	8.38	11.45	...	230	141	109	97	109	154	118	105

[1] Costs of production from a special inquiry of the Bureau of Crop Estimates ("Crop Reporter," June, 1911, p. 47). Although the data apply to the year 1909, they were collated on a uniform and comparable basis, and for the present purpose of comparing average cost conditions in one State or section with another they possess particular value.

[2] Cost per bushel obtained by dividing costs per acre, as given in the inquiry cited, by average yield 1911-1915. It is believed that costs per acre are comparatively stable.

[3] Excluding by-products in returns and land rental in costs. Values of by-products were considered as being offset, roughly, by values of farm manure applied.

Such factors are assembled in Table 9, which gives an idea as to sectional differences in costs per bushel and per acre, also yields and returns. The table is divided into two parts; the first shows costs in absolute figures, the second affords a comparison through percentages based upon the average for the United States taken as 100 per cent. The varying advantage or disadvantage in prices, costs, and yields can be followed more easily in these percentages. Taking Iowa as an illustration, it will be observed that price per bushel is 90 per cent of the United States average, yields 109, and the two combined in returns per acre 98. But the cost per acre, excluding land rental or interest, is only 84, and the ratio of returns to cost is high—204 per cent.

APPENDIX.

The data which follow, form the bases of Maps 1, 2, and 3, and are explained on pages 2 and 6.

Counties have been used as the smallest effective unit of measurement, for the reason that the usual State prices are frequently averages for large expanses of territory with dissimilar physical and price conditions. The basic figures were compiled from returns of some 30,000 township reporters for each of the five years 1910–1914, as of December 1. Observations for this period and for a like date of each year were employed to distinguish normal geographic variations from temporary deviations; and to further conduce thereto the price averages have been rounded to a five-cent unit to overcome occasional minor differences due to such causes as local variations in grade.

As the figures are designed to show geographic variation in prices paid to oat producers, counties with little or no oat production have been omitted (those with less than 500 acres in oats, according to the 1909 census).

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910–1914.

[Cents per bushel.]

ALABAMA:
55–59 cents—
Jackson.
Lauderdale.
Limestone.
Madison.
60–64 cents—
Colbert.
Cullman.
Dekalb.
Franklin.
Lawrence.
Marshall.
Morgan.
Walker.
Winston.
65–69 cents—
Autauga.
Blount.
Calhoun.
Cherokee.
Choctaw.
Clarke.
Clay.
Cleburne.
Dallas.
Etowah.
Fayette.
Greene.
Hale.
Jefferson.
Lamar.
Lowndes.
Macon.
Marengo.
Marion.
Monroe.
Montgomery.
Perry.
Pickens.
Saint Clair.
Sumter.
Talladega.
Tuscaloosa.
Wilcox.
70–74 cents—
Barbour.
Bibb.
Bullock.

ALABAMA—Continued.
70–74 cents—Contd.
Butler.
Chambers.
Chilton.
Coffee.
Conecuh.
Coosa.
Covington.
Crenshaw.
Dale.
Elmore.
Escambia.
Geneva.
Henry.
Houston.
Lee.
Pike.
Randolph.
Russell.
Shelby.
Tallapoosa.

ARIZONA:
50–54 cents—
Maricopa.
60–64 cents—
Apache.

ARKANSAS:
45–49 cents:
Benton.
Boone.
Carroll.
Madison.
Washington.
50–54 cents—
Arkansas.
Baxter.
Clay.
Cleburne.
Craighead.
Crawford.
Franklin.
Fulton.
Greene.
Independence.
Izard.
Johnson.
Lonoke.
Marion.

ARKANSAS—Continued.
50–54 cents—Contd.
Montgomery.
Newton.
Prairie.
Randolph.
Scott.
Searcy.
Sebastian.
Sharp.
Stone.
White.
55–59 cents—
Clark.
Conway.
Faulkner.
Garland.
Hempstead.
Hot Spring.
Howard.
Logan.
Perry.
Pike.
Polk.
Pope.
Pulaski.
Saline.
Sevier.
Van Buren.
Yell.
60–64 cents—
Ashley.
Bradley.
Calhoun.
Columbia
Drew.
Lafayette.
Little River.
Miller.
Nevada
Ouachita.
Union.

CALIFORNIA:
55–59 cents—
Alameda.
Amador.
Colusa.
Contra Costa.
Glenn.

CALIFORNIA—Contd.
55–59 cents—Contd.
Lassen.
Merced.
Modoc.
Monterey.
Napa.
Plumas.
Sacramento.
San Benito.
San Francisco.
San Joaquin.
San Luis Obispo.
San Mateo.
Santa Barbara.
Santa Clara.
Santa Cruz.
Shasta.
Siskiyou.
Solano.
Stanislaus.
Sutter.
Tehama.
Trinity.
Yolo.
60–64 cents—
Fresno.
Humboldt.
Lake.
Los Angeles.
Madera.
Marin.
Mendocino.
Orange.
Riverside.
San Diego.
Sonoma.
Ventura.

COLORADO:
40–44 cents—
Larimer.
Logan.
Morgan.
Phillips.
Sedgwick.
Washington.
Weld.
45–49 cents.
Adams.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910–1914—Continued.

COLORADO—Continued.
45–49 cents—Contd.
Arapahoe.
Archuleta.
Bent.
Boulder.
Chaffee.
Conejos.
Costilla.
Crowley.
Custer.
Denver.
Douglas.
Eagle.
Elbert.
El Paso.
Garfield.
Huerfano.
Jefferson.
Kit Carson.
La Plata.
Las Animas.
Lincoln.
Moffat.
Montezuma.
Otero.
Pitkin.
Prowers.
Pueblo.
Rio Blanco.
Rio Grande.
Routt.
Saguache.
Yuma.
50–54 cents.
Delta.
Mesa.
Montrose.
Ouray.
San Miguel.
CONNECTICUT:
55–59 cents.
Fairfield.
Hartford.
Litchfield.
Middlesex.
New London.
Tolland.
Windham.
DELAWARE:
45–49 cents.
New Castle.
50–54 cents.
Kent.
Sussex.
FLORIDA:
70–74 cents.
Columbia.
Gadsden.
Hamilton.
Holmes.
Jackson.
Jefferson.
Leon.
Liberty.
Madison.
Suwanee.
80–84 cents.
Alachua.
Bradford.
Levy.
Marion.
Sumter.
GEORGIA:
60–64 cents.
Catoosa.
Dade.
Murray.
Walker.
Whitfield.
65–69 cents.
Banks.
Bartow.
Chattooga.
Cherokee.
Dawson.

GEORGIA—Continued.
65–69 cents—Contd.
Floyd.
Forsyth.
Gordon.
Habersham.
Hall.
Haralson.
Milton.
Pickens.
Polk.
White.
70–74 cents.
Appling.
Baker.
Baldwin.
Ben Hill.
Berrien.
Bibb.
Bleckley.
Brooks.
Bryan.
Bulloch.
Burke.
Butts.
Calhoun.
Campbell.
Carroll.
Chatham.
Chattahoochee.
Clarke.
Clay.
Clayton.
Clinch.
Cobb.
Coffee.
Colquitt.
Columbia.
Coweta.
Crawford.
Crisp.
Decatur.
Dekalb.
Dodge.
Dooly.
Dougherty.
Douglas.
Early.
Effingham.
Elbert.
Emanuel.
Fayette.
Franklin.
Fulton.
Glasscock.
Grady.
Greene.
Gwinnett.
Hancock.
Harris.
Hart.
Heard.
Henry.
Houston.
Irwin.
Jackson.
Jasper.
Jeff Davis.
Jefferson.
Jenkins.
Johnson.
Jones.
Laurens.
Lee.
Liberty.
Lincoln.
Lowndes.
McDuffie.
Macon.
Madison.
Marion.
Meriwether.
Miller.
Mitchell.
Monroe.
Montgomery.

GEORGIA—Continued.
70–74 cents—Contd.
Morgan.
Muscogee.
Newton.
Oconee.
Oglethorpe.
Paulding.
Pierce.
Pike.
Pulaski.
Putnam.
Quitman.
Randolph.
Richmond.
Rockdale.
Schley.
Screven.
Spalding.
Stephens.
Stewart.
Sumter.
Talbot.
Taliaferro.
Tattnall.
Taylor.
Telfair.
Terrell.
Thomas.
Tift.
Toombs.
Troup.
Turner.
Twiggs.
Upson.
Walton.
Ware.
Warren.
Washington.
Wayne.
Webster.
Wheeler.
Wilcox.
Wilkes.
Wilkinson.
Worth.
IDAHO:
35–39 cents—
Bannock.
Bear Lake.
Bingham.
Bonneville.
Fremont.
40–44 cents—
Blaine.
Boise.
Cassia.
Clearwater.
Custer.
Franklin.
Gooding.
Idaho.
Kootenai.
Latah.
Lemhi.
Lewis.
Lincoln.
Minidoka.
Nez Perce.
Oneida.
Power.
45–49 cents—
Ada.
Adams.
Canyon.
Elmore.
Owyhee.
Twin Falls.
Washington.
ILLINOIS:
35–39 cents—
Boone.
Brown.
Bureau.
Carroll.
Cass.

ILLINOIS—Continued.
35–39 cents—Contd.
Champaign.
Christian.
Clark.
Coles.
Crawford.
Cumberland.
Dekalb.
Dewitt.
Douglas.
Edgar.
Edwards.
Ford.
Fulton.
Grundy.
Hancock.
Henderson.
Henry.
Iroquois.
Jasper.
Jo Daviess.
Kankakee.
Kendall.
Knox.
La Salle.
Lawrence.
Lee.
Livingston.
Logan.
McDonough.
McLean.
Macon.
Marshall.
Mason.
Menard.
Mercer.
Morgan.
Moultrie.
Ogle.
Peoria.
Piatt.
Putnam.
Richland.
Rock Island.
Sangamon.
Schuyler.
Scott.
Shelby.
Stark.
Stephenson.
Tazewell.
Vermilion.
Wabash.
Warren.
Whiteside.
Will.
Winnebago.
Woodford.
40–44 cents—
Adams.
Bond.
Calhoun.
Clay.
Cook.
Dupage.
Effingham.
Fayette.
Gallatin.
Greene.
Hamilton.
Hardin.
Jefferson.
Jersey.
Johnson.
Kane.
Lake.
McHenry.
Macoupin.
Marion.
Montgomery.
Pike.
Pope.
Saline.
Wayne.
White.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910–1914—Continued.

ILLINOIS—Continued.
45–49 cents—
Alexander.
Clinton.
Franklin.
Jackson.
Madison.
Massac.
Monroe.
Perry.
Pulaski.
Randolph.
Saint Clair.
Union.
Washington.
Williamson.

INDIANA:
35–39 cents—
Adams.
Allen.
Benton.
Blackford.
Boone.
Carroll.
Cass.
Clinton.
Dekalb.
Delaware.
Elkhart.
Fountain.
Fulton.
Grant.
Hamilton.
Hancock.
Hendricks.
Henry.
Howard.
Huntington.
Jasper.
Jay.
Kosciusko.
Lagrange.
Laporte.
Madison.
Marshall.
Miami.
Montgomery.
Newton.
Noble.
Parke.
Porter.
Pulaski.
Putnam.
Randolph.
Rush.
Saint Joseph.
Starke.
Steuben.
Tippecanoe.
Tipton.
Vermilion.
Wabash.
Warren.
Wayne.
Wells.
White.
Whitley.
40–44 cents—
Bartholomew.
Brown.
Clark.
Clay.
Crawford.
Daviess.
Dearborn.
Decatur.
Dubois.
Fayette.
Floyd.
Franklin.
Gibson.
Greene.
Harrison.
Jackson.
Jefferson.
Jennings.
Johnson.

INDIANA—Continued.
40–44 cents—Contd.
Knox.
Lake.
Lawrence.
Marion.
Martin.
Monroe.
Morgan.
Ohio.
Orange.
Owen.
Perry.
Pike.
Posey.
Ripley.
Scott.
Shelby.
Spencer.
Sullivan.
Switzerland.
Union.
Vanderburg.
Vigo.
Warrick.
Washington.

IOWA:
35–39 cents—
Adair.
Adams.
Allamakee.
Appanoose.
Audubon.
Benton.
Blackhawk.
Boone.
Bremer.
Buchanan.
Buena Vista.
Butler.
Calhoun.
Carroll.
Cass.
Cedar.
Cerro Gordo.
Cherokee.
Chickasaw.
Clarke.
Clay.
Clayton.
Clinton.
Crawford.
Dallas.
Davis.
Decatur.
Delaware.
Des Moines.
Dickinson.
Emmet.
Fayette.
Floyd.
Franklin.
Fremont.
Greene.
Grundy.
Guthrie.
Hamilton.
Hancock.
Hardin.
Harrison.
Henry.
Howard.
Humboldt.
Ida.
Iowa.
Jasper.
Jefferson.
Johnson.
Jones.
Keokuk.
Kossuth.
Lee.
Linn.
Louisa.
Lucas.
Lyon.
Madison.

IOWA—Continued.
35–39 cents—Contd.
Mahaska.
Marion.
Marshall.
Mills.
Mitchell.
Monona.
Monroe.
Montgomery.
Muscatine.
O'Brien.
Osceola.
Page.
Palo Alto.
Plymouth.
Pocahontas.
Polk.
Pottawattamie.
Poweshiek.
Ringgold.
Sac.
Scott.
Shelby.
Sioux.
Story.
Tama.
Taylor.
Union.
Van Buren.
Wapello.
Warren.
Washington.
Wayne.
Webster.
Winnebago.
Winneshiek.
Woodbury.
Worth.
Wright.
40–44 cents—
Dubuque.
Jackson.

KANSAS:
35–39 cents—
Brown.
Doniphan.
Marshall.
Nemaha.
40–44 cents—
Allen.
Anderson.
Atchison.
Bourbon.
Butler.
Chase.
Chautauqua
Cherokee.
Clay.
Cloud.
Coffey.
Cowley.
Crawford.
Dickinson.
Douglas.
Elk.
Franklin.
Geary.
Greenwood.
Harper.
Harvey.
Jackson.
Jefferson.
Jewell.
Johnson.
Kingman.
Labette.
Leavenworth.
Linn.
Lyon.
McPherson.
Marion.
Miami.
Montgomery.
Morris.
Neosho.
Osage.

KANSAS—Continued.
40–44 cents—Contd.
Pottawatomie.
Reno.
Republic.
Rice.
Riley.
Sedgwick.
Shawnee.
Sumner.
Wabaunsee.
Washington.
Wilson.
Woodson.
Wyandotte.
45–49 cents—
Barber.
Barton.
Cheyenne.
Clark.
Decatur.
Edwards.
Ellis.
Ellsworth.
Ford.
Gove.
Graham.
Hodgeman.
Lane.
Lincoln.
Logan.
Meade.
Mitchell.
Ness.
Norton.
Osborne.
Ottawa.
Pawnee.
Phillips.
Pratt.
Rawlins.
Rooks.
Rush.
Russell.
Saline.
Scott.
Sheridan.
Sherman.
Smith.
Stafford.
Trego.

KENTUCKY:
45–49 cents—
Anderson.
Boone.
Boyd.
Boyle.
Bracken.
Breckinridge.
Bullitt.
Campbell.
Carroll.
Carter.
Daviess.
Elliott.
Fleming.
Franklin.
Fulton.
Gallatin.
Grant.
Graves.
Greenup.
Hancock.
Hardin.
Henry.
Hickman.
Jefferson.
Johnson.
Kenton.
Larue.
Lawrence.
Lewis.
Marion.
Mason.
Meade.
Mercer.
Nelson.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910-1914—Continued.

KENTUCKY—Continued.
- 45-49 cents—Contd.
  - Ohio.
  - Oldham.
  - Owen.
  - Pendleton.
  - Robertson.
  - Rowan.
  - Shelby.
  - Spencer.
  - Trimble.
  - Washington.
- 50-54 cents—
  - Adair.
  - Allen.
  - Barren.
  - Bath.
  - Bourbon.
  - Butler.
  - Casey.
  - Christian.
  - Clay.
  - Edmonson.
  - Fayette.
  - Garrard.
  - Grayson.
  - Greene.
  - Harrison.
  - Hart.
  - Jackson.
  - Jessamine.
  - Knox.
  - Laurel.
  - Lincoln.
  - Logan.
  - Madison.
  - Menefee.
  - Metcalfe.
  - Monroe.
  - Montgomery.
  - Morgan.
  - Nicholas.
  - Owsley.
  - Pulaski.
  - Rockcastle.
  - Scott.
  - Simpson.
  - Taylor.
  - Todd.
  - Warren.
  - Wolfe.
  - Woodford.
- 55-59 cents—
  - McCreary.
  - Wayne.
  - Whitley.

LOUISIANA:
- 60-64 cents—
  - Bienville.
  - Bossier.
  - Claiborne.
  - Jackson.
  - Lincoln.
  - Ouachita.
  - Sabine.
  - Union.
  - Webster.
  - Winn.

MAINE:
- 50-54 cents—
  - Androscoggin.
  - Cumberland.
  - Kennebec.
  - Knox.
  - Lincoln.
  - Oxford.
  - Sagadahoc.
  - Waldo.
  - York.
- 55-59 cents—
  - Aroostook.
  - Franklin.
  - Hancock.
  - Penobscot.
  - Piscataquis.
  - Somerset.
  - Washington.

MARYLAND:
- 45-49 cents—
  - Anne Arundel.
  - Baltimore.
  - Caroline.
  - Cecil.
  - Frederick.
  - Harford.
  - Howard.
  - Kent.
  - Montgomery.
  - Prince Georges.
- 50-54 cents—
  - Allegany.
  - Garrett.
  - Somerset.
  - Washington.
  - Worcester.

MASSACHUSETTS:
- 55-59 cents—
  - Berkshire.

MICHIGAN:
- 35-39 cents—
  - Branch.
  - Cass.
  - Hillsdale.
  - Lenawee.
  - St. Joseph.
- 40-44 cents.
  - Alcona.
  - Allegan.
  - Arenac.
  - Barry.
  - Bay.
  - Berrien.
  - Calhoun.
  - Clare.
  - Clinton.
  - Eaton.
  - Genesee.
  - Gladwin.
  - Gratiot.
  - Huron.
  - Ingham.
  - Ionia.
  - Iosco.
  - Isabella.
  - Jackson.
  - Kalamazoo.
  - Kent.
  - Lapeer.
  - Livingston.
  - Macomb.
  - Mecosta.
  - Midland.
  - Missaukee.
  - Monroe.
  - Montcalm.
  - Muskegon.
  - Newaygo.
  - Oakland.
  - Oceana.
  - Ogemaw.
  - Osceola.
  - Oscoda.
  - Ottawa.
  - Saginaw.
  - St. Clair.
  - Sanilac.
  - Shiawassee.
  - Tuscola.
  - Van Buren.
  - Washtenaw.
  - Wayne.
  - Wexford.
- 45-49 cents.
  - Alpena.
  - Antrim.
  - Baraga.
  - Benzie.
  - Charlevoix.
  - Cheboygan.
  - Chippewa.
  - Crawford.
  - Delta.
  - Dickinson.
  - Emmet.

MICHIGAN—Continued.
- 45-49 cents—Contd.
  - Grand Traverse.
  - Houghton.
  - Kalkaska.
  - Keweenaw.
  - Lake.
  - Leelanau.
  - Luce.
  - Mackinac.
  - Manistee.
  - Marquette.
  - Mason.
  - Menominee.
  - Montmorency.
  - Ontonagon.
  - Otsego.
  - Presque Isle.
  - Roscommon.

MINNESOTA:
- 30-34 cents—
  - Bigstone.
  - Chippewa.
  - Clay.
  - Grant.
  - Kandiyohi.
  - Lac Qui Parle.
  - Lincoln.
  - Lyon.
  - Norman.
  - Renville.
  - Stevens.
  - Swift.
  - Traverse.
  - Wilkin.
  - Yellow Medicine.
- 35-39 cents.
  - Anoka.
  - Becker.
  - Benton.
  - Blue Earth.
  - Brown.
  - Carver.
  - Chisago.
  - Cottonwood.
  - Dakota.
  - Dodge.
  - Douglas.
  - Faribault.
  - Fillmore.
  - Freeborn.
  - Goodhue.
  - Hennepin.
  - Houston.
  - Isanti.
  - Jackson.
  - Kittson.
  - Lesueur.
  - McLeod.
  - Mahnomen.
  - Marshall.
  - Martin.
  - Meeker.
  - Millelacs.
  - Morrison.
  - Mower.
  - Murray.
  - Nicollet.
  - Nobles.
  - Olmsted.
  - Ottertail.
  - Pennington.
  - Pipestone.
  - Polk.
  - Pope.
  - Ramsey.
  - Red Lake.
  - Redwood.
  - Rice.
  - Rock.
  - Scott.
  - Sherburne.
  - Sibley.
  - Stearns.
  - Steele.
  - Todd.
  - Wabasha.
  - Wadena.

MINNESOTA—Contd.
- 35-39 cents—Contd.
  - Waseca.
  - Washington.
  - Watonwan.
  - Winona.
  - Wright.
- 40-44 cents—
  - Aitkin.
  - Beltrami.
  - Carlton.
  - Cass.
  - Clearwater.
  - Crow Wing.
  - Hubbard.
  - Kanabec.
  - Pine.
  - Roseau.
  - St. Louis.

MISSISSIPPI:
- 60-64 cents—
  - Amite.
  - Attala.
  - Calhoun.
  - Chickasaw.
  - Choctaw.
  - Clay.
  - Copiah.
  - Hinds.
  - Itawamba.
  - Lawrence.
  - Lincoln.
  - Madison.
  - Marion.
  - Monroe.
  - Pike.
  - Pontotoc.
  - Rankin.
  - Union.
  - Webster.
  - Wilkinson.
  - Yalobusha.
- 65-69 cents—
  - Clarke.
  - Covington.
  - Forrest.
  - Jasper.
  - Jefferson Davis.
  - Jones.
  - Kemper.
  - Lauderdale.
  - Leake.
  - Lowndes.
  - Neshoba.
  - Newton.
  - Noxubee.
  - Oktibbeha.
  - Perry.
  - Scott.
  - Simpson.
  - Smith.
  - Wayne.
  - Winston.

MISSOURI:
- 35-39 cents—
  - Adair.
  - Atchison.
  - Caldwell.
  - Clark.
  - Daviess.
  - Gentry.
  - Grundy.
  - Harrison.
  - Holt.
  - Knox.
  - Lewis.
  - Linn.
  - Livingston.
  - Macon.
  - Mercer.
  - Nodaway.
  - Putnam.
  - Schuyler.
  - Scotland.
  - Shelby.
  - Sullivan.
  - Worth.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910-1914—Continued.

MISSOURI—Continued.
40-44 cents—
Andrew.
Audrain.
Barry.
Barton.
Bates.
Benton.
Boone.
Buchanan.
Callaway.
Carroll.
Cass.
Cedar.
Chariton.
Clay.
Clinton.
Cooper.
Dade.
Dekalb.
Greene.
Henry.
Hickory.
Howard.
Jackson.
Jasper.
Johnson.
Lafayette.
Lawrence.
Lincoln.
McDonald.
Marion.
Moniteau.
Monroe.
Montgomery.
Morgan.
Pettis.
Pike.
Platte.
Polk.
Ralls
Randolph.
Ray.
St. Charles.
St. Clair.
Saline.
Stone.
Vernon.
Warren.
45-49 cents—
Bollinger.
Butler.
Camden.
Cape Girardeau.
Christian.
Cole.
Crawford.
Dallas.
Douglas.
Franklin.
Gasconade.
Howell.
Jefferson.
Laclede.
Maries.
Miller.
Oregon.
Osage.
Ozark.
Perry.
Ripley.
St. Genevieve.
St. Louis.
Scott.
Shannon.
Stoddard.
Taney.
Webster.
50-54 cents—
Carter.
Dent.
Iron.
Madison.
Phelps.
Pulaski.
Reynolds.
St. Francois.

MISSOURI—Continued.
50-54 cents—Contd.
Texas.
Washington.
Wayne.
Wright.
MONTANA:
35-39 cents—
Beaverhead.
Blaine.
Cascade.
Chouteau.
Dawson.
Flathead.
Granite.
Hill.
Lewis & Clark.
Lincoln.
Madison.
Missoula.
Powell.
Ravalli.
Sanders.
Sheridan.
Teton.
Valley.
40-44 cents—
Big Horn.
Broadwater.
Carbon.
Custer.
Fergus.
Gallatin.
Jefferson.
Meagher.
Musselshell.
Park.
Rosebud.
Stillwater.
Sweet Grass.
Yellowstone.
NEBRASKA:
35-39 cents—
Antelope.
Blaine.
Boone.
Boyd.
Brown.
Burt.
Butler.
Cass.
Cedar.
Clay.
Colfax.
Cuming.
Custer.
Dakota.
Dixon.
Dodge.
Douglas.
Fillmore.
Gage.
Garfield.
Greeley.
Hamilton.
Holt.
Jefferson.
Johnson.
Keyapaha.
Knox.
Lancaster.
Loup.
Madison.
Merrick.
Nance.
Nemaha.
Nuckolls.
Otoe.
Pawnee.
Pierce.
Platte.
Polk.
Richardson.
Rock.
Saline.
Sarpy.
Saunders.

NEBRASKA—Continued.
35-39 cents—Contd.
Seward.
Stanton.
Thayer.
Thurston.
Valley.
Washington.
Wayne.
Wheeler.
York.
40-44 cents—
Adams.
Banner.
Box Butte.
Buffalo.
Chase.
Cherry.
Cheyenne.
Dawes.
Dawson.
Deuel.
Dundy.
Franklin.
Frontier.
Furnas.
Garden.
Gosper.
Hall.
Harlan.
Hayes.
Hitchcock.
Howard.
Kearney.
Keith.
Kimball.
Lincoln.
Logan.
Morrill.
Perkins.
Phelps.
Redwillow.
Scotts Bluff.
Sheridan.
Sherman.
Sioux.
Webster.
NEW JERSEY:
45-49 cents—
Burlington.
Camden.
Gloucester.
Hunterdon.
Mercer.
Middlesex.
Morris.
Salem.
Somerset.
Warren.
50-54 cents—
Sussex.
NEW HAMPSHIRE:
50-54 cents—
Coos.
Grafton.
55-59 cents—
Cheshire.
Sullivan.
NEW MEXICO:
50-54 cents—
Chaves.
Colfax.
Mora.
Otero.
Rio Arriba.
San Juan.
San Miguel.
Taos.
NEW YORK:
45-49 cents—
Allegany.
Broome.
Cattaraugus.
Cayuga.
Chautauqua.
Chemung.
Chenango.

NEW YORK—Contd.
45-49 cents—Contd.
Cortland.
Erie.
Genesee.
Jefferson.
Lewis.
Livingston.
Madison.
Monroe.
Niagara.
Onondaga.
Ontario.
Orleans.
Oswego.
Schuyler.
Seneca.
Steuben.
Tioga.
Tompkins.
Wayne.
Wyoming.
Yates.
50-54 cents—
Albany.
Clinton.
Columbia.
Delaware.
Dutchess.
Essex.
Franklin.
Fulton.
Greene.
Herkimer.
Montgomery.
Oneida.
Orange.
Otsego.
Rensselaer.
St. Lawrence.
Saratoga.
Schenectady.
Schoharie.
Sullivan.
Ulster.
Warren.
Washington.
NEVADA:
55-59 cents—
Elko.
White Pine.
NORTH CAROLINA:
55-59 cents—
Alleghany.
Ashe.
Avery.
Buncombe.
Haywood.
Mitchell.
Watauga.
Yancey.
Madison.
60-64 cents—
Alexander.
Burke.
Caldwell.
Catawba.
Davidson.
Davie.
Iredell.
Rowan.
Surry.
Wilkes.
Yadkin.
65-69 cents—
Alamance.
Anson.
Cabarrus.
Caswell.
Chatham.
Cleveland.
Columbus.
Cumberland.
Durham.
Edgecombe.
Forsyth.
Franklin.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910-1914—Continued.

NORTH CAROLINA—Con.
65-69 cents—Contd.
Gaston.
Granville.
Greene.
Guilford.
Halifax.
Harnett.
Hoke.
Johnston.
Lee.
Lenoir.
Lincoln.
Mecklenburg.
Montgomery.
Moore.
Nash.
Orange.
Person.
Pitt.
Randolph.
Richmond.
Robeson.
Rockingham.
Rutherford.
Scotland.
Stanly.
Stokes.
Union.
Vance.
Wake.
Warren.
Wayne.
Wilson.

NORTH DAKOTA:
30-34 cents—
Barnes.
Benson.
Bottineau.
Burke.
Cass.
Cavalier.
Divide.
Eddy.
Foster.
Grand Forks.
Griggs.
McHenry.
Nelson.
Pembina.
Pierce.
Ramsey.
Ransom.
Renville.
Richland.
Rolette.
Sargent.
Sheridan.
Steele.
Stutsman.
Towner.
Traill.
Walsh.
Ward.
Wells.

35-39 cents—
Adams.
Billings.
Bowman.
Burleigh.
Dickey.
Dunn.
Emmons.
Golden Valley.
Hettinger.
Kidder.
La Mcure.
Logan.
McIntosh.
McKenzie.
McLean.
Mercer.
Mountrail.
Morton.
Oliver.
Stark.
Williams.

OHIO:
35-39 cents—
Allen.
Auglaize.
Champaign.
Crawford.
Defiance.
Fulton.
Hancock.
Hardin.
Henry.
Logan.
Madison.
Marion.
Mercer.
Paulding.
Putnam.
Seneca.
Shelby.
Union.
Van Wert.
Williams.
Wood.
Wyandot.
40-44 cents—
Adams.
Ashland.
Brown.
Butler.
Clark.
Clermont.
Clinton.
Coshocton.
Darke.
Delaware.
Erie.
Fairfield.
Fayette.
Franklin.
Greene.
Hamilton.
Highland.
Hocking.
Holmes.
Huron.
Knox.
Licking.
Lorain.
Lucas.
Medina.
Miami.
Montgomery.
Morrow.
Ottawa.
Pickaway.
Pike.
Preble.
Richland.
Ross.
Sandusky.
Scioto.
Stark.
Tuscarawas.
Warren.
Wayne.
45-49 cents—
Ashtabula.
Athens.
Belmont.
Carroll.
Columbiana.
Cuyahoga.
Gallia.
Geauga.
Guernsey.
Harrison.
Jackson.
Jefferson.
Lake.
Lawrence.
Mahoning.
Meigs.
Monroe.
Morgan.
Muskingum.
Noble.
Portage.
Summit.

OHIO—Continued.
45-49 cents—Contd.
Trumbull.
Vinton.
Washington.

OKLAHOMA:
40-44 cents—
Adair.
Alfalfa.
Blaine.
Caddo.
Canadian.
Cherokee.
Cleveland.
Comanche.
Cotton.
Craig.
Custer.
Delaware.
Dewey.
Ellis.
Garfield.
Garvin.
Grady.
Grant.
Harper.
Jackson.
Jefferson.
Kay.
Kingfisher.
Kiowa.
Logan.
McClain.
Major.
Mayes.
Murray.
Noble.
Nowata.
Oklahoma.
Osage.
Ottawa.
Pawnee.
Payne.
Pottawatomie.
Rogers.
Stephens.
Tillman.
Tulsa.
Wagoner.
Washington.
Washita.
Woods.
Woodward.
45-49 cents—
Beaver.
Beckham.
Bryan.
Carter.
Cimarron.
Coal.
Greer.
Harmon.
Haskell.
Hughes.
Johnston.
Lincoln.
McIntosh.
Marshall.
Muskogee.
Okfuskee.
Okmulgee.
Pontotoc.
Roger Mills.
Seminole.
Texas.
50-54 cents—
Atoka.
Choctaw.
Le Flore.
Pittsburg.
Sequoyah.

OREGON:
40-44 cents—
Umatilla.
Union.
Wallowa.
45-49 cents—
Benton.

OREGON—Continued.
45-49 cents—Contd.
Clackamas.
Columbia.
Lane.
Linn.
Marion.
Multnomah.
Polk.
Sherman.
Wasco.
Washington.
Yamhill.
50-54 cents—
Baker.
Crook.
Douglas.
Grant.
Harney.
Klamath.
Malheur.

PENNSYLVANIA:
45-49 cents—
Adams.
Allegheny.
Armstrong.
Beaver.
Bedford.
Berks.
Blair.
Bradford.
Bucks.
Butler.
Center.
Chester.
Clarion.
Clinton.
Columbia.
Crawford.
Cumberland.
Dauphin.
Delaware.
Erie.
Fayette.
Franklin.
Fulton.
Greene.
Huntingdon.
Jefferson.
Juniata.
Lancaster.
Lawrence.
Lebanon.
Lehigh.
Lycoming.
McKean.
Mercer.
Miffln.
Monroe.
Montgomery.
Montour.
Northampton.
Northumberland.
Perry.
Philadelphia.
Potter.
Snyder.
Somerset.
Sullivan.
Susquehanna.
Tioga.
Union.
Venango.
Warren.
Washington.
Westmoreland.
Wyoming.
York.
50-54 cents—
Cambria.
Cameron.
Carbon.
Clearfield.
Elk.
Forest.
Indiana.
Lackawanna.
Luzerne.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910–1914—Continued.

PENNSYLVANIA—Contd.
50–54 cents—Contd.
Pike.
Schuylkill.
Wayne.
SOUTH CAROLINA:
70–74 cents—
Abbeville.
Aiken.
Anderson.
Bamberg.
Barnwell.
Beaufort.
Berkeley.
Calhoun.
Charleston.
Cherokee.
Chester.
Chesterfield.
Clarendon.
Colleton.
Darlington.
Dillon.
Dorchester.
Edgefield.
Fairfield.
Florence.
Georgetown.
Greenville.
Greenwood.
Hampton.
Horry.
Jasper.
Kershaw.
Lancaster.
Laurens.
Lee.
Lexington.
Marion.
Marlboro.
Newberry.
Oconee.
Orangeburg.
Pickens.
Richland.
Saluda.
Spartanburg.
Sumter.
Union.
Williamsburg.
York.
SOUTH DAKOTA:
30–34 cents—
Beadle.
Brookings.
Clark.
Codington.
Day.
Deuel.
Grant.
Hamlin.
Jerauld.
Kingsbury.
Lake.
Marshall.
Miner.
Moody.
Roberts.
Sanborn.
35–39 cents—
Aurora.
Bonhomme.
Brown.
Brule.
Buffalo.
Charles Mix.
Clay.
Davison.
Douglas.
Gregory.
Hand.
Hanson.
Hutchinson.
Lincoln.
McCook.
McPherson.

SOUTH DAKOTA—Con.
35–39 cents—Contd.
Minnehaha.
Spink.
Tripp.
Turner.
Union.
Yankton.
40–44 cents—
Campbell.
Edmunds.
Faulk.
Harding.
Hughes.
Hyde.
Lyman.
Perkins.
Potter.
Sully.
Walworth.
45–49 cents—
Butte.
Custer.
Fall River.
Lawrence.
Meade.
Pennington.
Stanley.
TENNESSEE:
45–49 cents—
Davidson.
Hickman.
Lewis.
Maury.
Rutherford.
Smith.
Williamson.
Wilson.
50–54 cents—
Bedford.
Blount.
Cannon.
Carroll.
Carter.
Cheatham.
Claiborne.
Clay.
Cocke.
Coffee.
Crockett.
Decatur.
Dekalb.
Dickson.
Dyer.
Franklin.
Gibson.
Giles.
Grainger.
Greene.
Grundy.
Hamblen.
Hancock.
Hawkins.
Haywood.
Henderson.
Henry.
Humphreys.
Jackson.
Jefferson.
Johnson.
Knox.
Lauderdale.
Lawrence.
Lincoln.
Macon.
Madison.
Marshall.
Monroe.
Montgomery.
Moore.
Obion.
Perry.
Putnam.
Robertson.
Sevier.
Sullivan.

TENNESSEE—Contd.
50–54 cents—Contd.
Sumner.
Trousdale.
Unicoi.
Union.
Van Buren.
Warren.
Washington.
Wayne.
Weakley.
White.
55–59 cents—
Anderson.
Bradley.
Campbell.
Chester.
Fayette.
Fentress.
Hamilton.
Hardeman.
Hardin.
James.
Loudon.
McMinn.
McNairy.
Marion.
Meigs.
Overton.
Pickett.
Polk.
Rhea.
Roane.
Scott.
Shelby.
Tipton.
TEXAS:
45–49 cents—
Archer.
Armstrong.
Baylor.
Blanco.
Bosque.
Briscoe.
Burnet.
Carson.
Clay.
Collingsworth.
Cooke.
Coryell.
Deaf Smith.
Floyd.
Foard.
Gillespie.
Gray.
Grayson.
Hale.
Hamilton.
Hansford.
Hardeman.
Haskell.
Hemphill.
Hutchinson.
Kendall.
Knox.
Lampasas.
Montague.
Ochiltree.
Potter.
Randall.
Sherman.
Swisher.
Taylor.
Wichita.
Wilbarger.
Young.
50–54 cents—
Bandera.
Bell.
Bexar.
Collin.
Comal.
Dallas.
Denton.
Ellis.
Fannin.

TEXAS—Continued.
50–54 cents—Contd.
Hays.
Hill.
Hunt.
Johnson.
Kaufman.
Kerr.
McLennan.
Medina.
Parker.
Rockwall.
Tarrant.
Travis.
Williamson.
Wise.
55–59 cents—
Delta.
Falls.
Henderson.
Hopkins.
Lamar.
Limestone.
Milam.
Navarro.
Rains.
Red River.
Van Zandt.
Wood.
60–64 cents—
Anderson.
Bowie.
Cass.
Cherokee.
Nacogdoches.
Rusk.
Shelby.
Smith.
UTAH:
45–49 cents—
Boxelder.
Cache.
Carbon.
Davis.
Emery.
Juab.
Morgan.
Rich.
Salt Lake.
Sanpete.
Sevier.
Summit.
Tooele.
Uinta.
Utah.
Wasatch.
Wayne.
Weber.
50–54 cents—
Beaver.
Garfield.
Iron.
Millard.
Piute.
San Juan.
VERMONT:
50–54 cents—
Addison.
Bennington.
Caledonia.
Chittenden.
Essex.
Franklin.
Grand Isle.
Lamoille.
Orange.
Orleans.
Rutland.
Washington.
Windsor.
55–59 cents—
Windham.
VIRGINIA:
50–54 cents—
Albermarle.
Alexandria.
Augusta.

AVERAGE FARM PRICES OF OATS, BY COUNTIES, 1910–1914—Continued.

VIRGINIA—Continued.
50–54 cents—Contd.
Botetourt.
Caroline.
Clarke.
Culpeper.
Essex.
Fairfax.
Fauquier.
Floyd.
Frederick.
Greene.
King George.
Lancaster.
Lee.
Loudoun.
Madison.
Montgomery.
Northumberland.
Orange.
Page.
Prince William.
Pulaski.
Rappahannock.
Richmond.
Roanoke.
Rockbridge.
Rockingham.
Scott.
Shenandoah.
Smyth.
Spotsylvania.
Stafford.
Warren.
Washington.
Westmoreland.
Wythe.

55–59 cents—
Amelia.
Amherst.
Appomattox.
Bedford.
Bland.
Buckingham.
Campbell.
Carroll.
Charles City.
Chesterfield.
Fluvanna.
Franklin.
Giles.
Gloucester.
Grayson.
Hanover.
Henrico.
James City.
King and Queen.
King William.
Louisa.
Mathews.
Middlesex.
Nelson.
New Kent.
Patrick.
Tazewell.
Warwick.
Wise.
York.
60–64 cents—
Buchanan.

VIRGINIA—Continued.
60–64 cents—Contd.
Cumberland.
Dickenson.
Dinwiddie.
Goochland.
Nottaway.
Powhatan.
Prince Edward.
Prince George.
Russell.
65–69 cents—
Brunswick.
Charlotte.
Halifax.
Henry.
Lunenburg.
Mecklenburg.
Pittsylvania.

WASHINGTON:
40–44 cents—
Adams.
Columbia.
Ferry.
Franklin.
Lincoln.
Spokane.
Stevens.
Walla Walla.
Whitman.
45–49 cents—
Chelan.
Clarke.
Cowlitz.
Douglas.
Grant.
King.
Kittitas.
Klickitat.
Lewis.
Okanogan.
Pend Oreille.
Pierce.
Skagit.
Snohomish.
Thurston.
Whatcom.
Yakima.

WEST VIRGINIA:
45–49 cents—
Brooke.
Cabell.
Hancock.
Jackson.
Marshall.
Mason.
Ohio.
Pleasants.
Tyler.
Wetzel.
Wood.
50–54 cents—
Barbour.
Berkeley.
Doddridge.
Hampshire.
Hardy.
Harrison.
Jefferson.
Kanawha.

WEST VIRGINIA—Con.
50–54 cents—Contd.
Lincoln.
Marion.
Mineral.
Monongalia.
Morgan.
Preston.
Putnam.
Ritchie.
Roane.
Taylor.
Wayne.
Wirt.
55–59 cents—
Braxton.
Calhoun.
Clay.
Fayette.
Gilmer.
Grant.
Greenbrier.
Lewis.
McDowell.
Mercer.
Monroe.
Nicholas.
Pendleton.
Pocahontas.
Raleigh.
Randolph.
Summers.
Tucker.
Upshur.
Webster.
Wyoming.

WISCONSIN:
35–39 cents—
Buffalo.
Chippewa.
Dunn.
Eau Claire.
Jackson.
Juneau.
La Crosse.
Monroe.
Pepin.
Pierce.
Polk.
St. Croix.
Trempealeau.
Vernon.
40–44 cents—
Adams.
Barron.
Brown.
Burnett.
Calumet.
Clark.
Columbia.
Crawford.
Dane.
Dodge.
Door.
Fond du Lac.
Grant.
Green.
Green Lake.
Iowa.
Jefferson.

WISCONSIN—Contd.
40–44 cents—Contd.
Kenosha.
Kewaunee.
Lafayette.
Manitowoc.
Marathon.
Marquette.
Milwaukee.
Oconto.
Outagamie.
Ozaukee.
Portage.
Racine.
Richland.
Rock.
Rusk.
Sauk.
Sawyer.
Shawano.
Sheboygan.
Taylor.
Walworth.
Washburn.
Washington.
Waukesha.
Waupaca.
Waushara.
Winnebago.
Wood.
45–49 cents—
Ashland.
Bayfield.
Douglas.
Florence.
Forest.
Iron.
Langlade.
Lincoln.
Marinette.
Oneida.
Price.
Vilas.

WYOMING:
40–44 cents—
Goshen.
Laramie.
Lincoln.
Platte.
45–49 cents—
Albany.
Bighorn.
Campbell.
Converse.
Crook.
Hot Springs.
Johnson.
Niobrara.
Park.
Sheridan.
Uinta.
Washakie.
Weston.
50–54 cents—
Carbon.
Fremont.
Natrona.
Sweetwater.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 756

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ January 29, 1919

PECAN ROSETTE IN RELATION TO SOIL DEFICIENCIES.

By S. M. McMurran,
Assistant Pathologist, Office of Fruit-Disease Investigations.

CONTENTS.

SERIOUSNESS OF THE DISEASE.

The so-called rosette is considered generally by growers to be the most serious trouble to which pecan trees are subject, and this opinion is justified by the facts. Probably 10 to 20 per cent of the pecans planted in orchards in the southeastern United States have shown this trouble in a more or less marked degree, and the resulting loss of tree growth and nut production undoubtedly has been great.

In its earliest stages the disease is indicated by a few small, wrinkled, yellow-mottled leaves at the ends of the branches. All gradations of the disease are found between that shown by these first symptoms and the condition illustrated in figure 1, where the tree is dying back. The writer has never seen a tree which has died entirely as a direct result of rosette, but affected trees become so weakened that frequently they are killed by winter injury and borer attacks. Seriously affected trees rarely bear nuts, and they make but little growth.

PREVIOUS WORK.

Investigations conducted by the United States Department of Agriculture[1] between 1902 and 1913 showed that no parasitic organ-

[1] Orton, W. A., and Rand, F. V. Pecan rosette. *In* Jour. Agr. Research, vol. 3, no. 2, p. 149–174, 1916.

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ism was associated with the diseased trees and indicated rather definitely that the cause of the trouble lay in the soil; but whether this cause was physical, chemical, biological, or a combination of the three was not indicated.

PRESENT INVESTIGATIONS.

In 1914 investigations of the disease were taken up by the writer, and an effort was made to find some common factor running through a large number of cases. Without such a common factor an infinite variety of empirical experiments was the only recourse. With this preliminary problem in mind, the examination of a large number of affected orchards was undertaken. Orchards between central Florida and eastern Louisiana were visited, and while the disease was seen to be present on a wide range of soil types and under various conditions of cultivation and fertilization, one factor seemed to stand out prominently.

FIG. 1.—A typical badly rosetted tree in one of the stable-manure plats in September, 1915. The same tree is shown in figures 2 and 3.

THE COMMON FACTOR IN PECAN ROSETTE.

A marked difference in the amount of the disease in different localities was found. On the river flood-plain soils of southern Louisiana the disease is practically unknown. Only two individual cases have ever been reported to State or Federal pathologists from that State. The soil is deep and black, of high fertility, and presumably of high water-holding capacity as compared with the typical sand, sand-clay, and clay soils of the Atlantic and Gulf coastal plains, where the disease is so widely prevalent.

Quite as striking a difference in the distribution of the disease was found within the States of Georgia and Florida. A very large proportion of the diseased trees, probably 90 per cent or more, was found on the hilltops and slopes. Occasional cases or groups of cases were on bottom lands, but all of these that have been examined have been found to be growing in deep sand or else in a clay or sand clay underlain at 2 to 3 feet by sand. It was observed also that wherever the conditions were such as to produce any quantity of rosette, the weeds or crops growing in the tree rows had a stunted, yellow, unthrifty appearance as compared with those growing among healthy trees and that large, healthy trees, 5 to 10 years old, frequently showed marked signs of the disease the first year after being transplanted. On the other hand, trees planted in low places in which humus and fertility had accumulated from year to year were uniformly vigorous, thrifty, and free from the disease.

FIG. 2.—The tree shown in figure 1 after receiving the stable-manure treatment for one and one-half seasons. July, 1917.

While apparently contradictory cases occasionally are seen, 90 per cent or more are surrounded by conditions that plainly indicate a deficiency of humus, plant-food material, and moisture. Either where the soil or topography is such that there is a deficiency of this combination, or where the tree's condition is such as to interfere with its obtaining an adequate supply of plant-food material, the result appears to be the same, i. e., a yellowing of the foliage, a shortening of the internodes, a pushing out of dormant buds, and in many cases a dying back of the twigs and branches.

The facts pointed very strongly to the rosetting of pecans being an evidence of bad soil conditions—a deficiency in humus, fertility, and moisture supply; and field experiments to determine this matter definitely were begun in the fall of 1915.

THE EXPERIMENTS.

If it were true that pecan rosette is merely an evidence of starvation, it might be supposed that liberal applications of mineral fertilizers would relieve the condition, but such is not the case. Experiments by the United States Department of Agriculture with heavy applications of mineral fertilizers in young orchards located on poor soil, as well as the experience of many growers, indicate clearly that rosetted trees generally become worse under such treatment. This point, taken in connection with the facts that the native habitat of the pecan in the United States is the flood plains of the Mississippi River, its tributaries, and other streams of the South and Southwest and that pecans make a uniformly vigorous, healthy growth on these soils, indicated that the fertility to be added should be from organic sources and that the physical condition and water-holding capacity of the soil must be improved in order to overcome the disease. Only by the annual addition to the soil of large quantities of humus-forming material could this result be obtained.

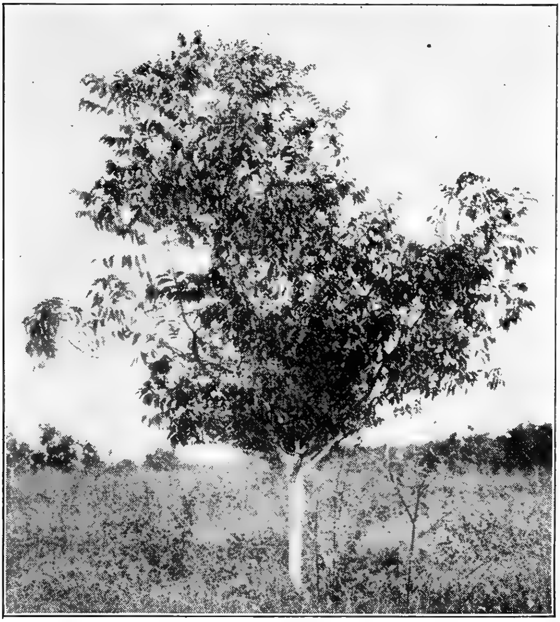

FIG. 3.—The tree shown in figures 1 and 2 after two complete seasons. There has been some normal loss of foliage, but striking improvement is evident. October, 1917.

PURPOSE OF THE EXPERIMENTS.

The experiments were designed to demonstrate the correctness or incorrectness of the view stated above. It was proposed to increase the humus content and the fertility of the soil and thereby to better its physical condition and water-holding capacity as rapidly as possible by means of heavy applications of stable manure and cottonseed meal and by the use of legumes.

In the experiments the most economical method of obtaining these results was left out of consideration for the time being. If the correctness of the principle could be established, the cheapest method of arriving at the desired results in actual orchard practice could be worked out by later experiments. Therefore, in order to secure quick results, much heavier applications of fertilizers were made than would be used in commercial practice.

Three experiments, including about 13 acres of pecans in three orchards in southern Georgia, were begun in the fall of 1915. The three tracts were divided into plats, with suitable checks. Three plats, one in each tract, received stable manure alone at the rate of 20 tons to the acre; two received stable manure at the same rate, and in addition cottonseed meal at the rate of 1 ton to the acre; and two received cottonseed meal alone at the rate of 1 ton to the acre. The stable manure was applied in the fall, and the three tracts were then plowed; the cottonseed meal, analyzing 6¾ per cent ammonia, was applied in the following April. In the fall of 1914 lime alone was applied to a separate plat in one of the tracts at the rate of 3 tons to the acre of ground limestone (unburned). From April until June clean culture was maintained with harrows in all the plats, and they were then sowed to cowpeas. These were permitted to grow until killed by frost, when they were plowed under, and then the entire program was repeated except that the cottonseed meal was omitted in the second year. The check plats received the same cultural treatment, but no fertilizer. This program has been followed without material variation for two years. The trees in two of the tracts were 6 years old and in the third 10. None had ever borne a crop. The most that had ever been obtained from the 10-year-old trees was a few scattered nuts. The soils in the three tracts were not well suited to conserve, or, when needed, give up moisture. This was largely due to the heavy clay subsoils with insufficient surface soil.

RESULTS OF THE EXPERIMENTS.

The results of the work for the past two seasons on the three experimental tracts have been compiled in Table I. The fact that the amount of rosette normally fluctuates to some extent makes this the fairest way of presenting the results. Practically no results were obtained during the first season.

In Table I the term "badly rosetted" indicates trees which are dying back and "rosetted" those which are yellow and making but little growth. Trees showing merely a trace of the disease were considered healthy, as bearing trees not infrequently show traces of the disease at the end of the growing season.

At the beginning of the experiments there were in the fertilized plats 56 badly rosetted trees, 11 rosetted, and 21 healthy. After two years the number of badly rosetted trees in the fertilized plats was reduced to 7, and 26 were in the rosetted class—i. e., partially recovered. The number of healthy trees had been increased from 21 to 53. Two trees had been killed by winter injury.

During the same period the healthy trees in the check plats had decreased from 29 to 17, the rosetted had increased from 13 to 24, and the badly rosetted had decreased from 38 to 37. Two were dead from winter injury.

TABLE I.—*Effect of the use of selected fertilizers for the control of pecan rosette in southern Georgia during the seasons of 1915 and 1917.*

Fertilizer used.	Number of trees.	Date of observation.	Badly rosetted.	Rosetted.	Healthy.	Dead.	Percentage of healthy trees.
Stable manure	46	September, 1915	29	10	7	......	15
		October, 1917	2	19	24	1	53
Stable manure and cottonseed meal	15	September, 1915	8	1	6	......	40
		October, 1917	1	2	12	......	80
Cottonseed meal	27	September, 1915	19	......	8	......	29
		October, 1917	4	5	17	1	65
Lime	46	September, 1915	27	16	3	......	6.5
		October, 1917	45	1	......	......	0
Check (not fertilized)	80	September, 1915	38	13	29	......	36
		October, 1917	37	24	17	2	21

DISCUSSION OF THE EXPERIMENTS.

The figures presented in Table I convey but an inadequate idea of the striking change that has taken place in the fertilized plats. Figure 1 shows a typical badly rosetted tree at the beginning of the experiments in September, 1915. Figures 2 and 3 show the same tree in July and October, 1917, respectively. This tree received stable manure alone, but the striking improvement shown is quite typical of that noted in all the fertilized plats. Larger leaves of dark-green color and a marked increase in the circumference of the trunks of the trees in the fertilized plats made the contrast with the unfertilized plats most striking.

Only one lot of trees in these experiments was old enough to bear nuts. Of this lot 14 received the stable-manure treatment and 33 were used as checks and received no fertilizer. These trees were 12 years old in 1917. The 14 fertilized trees produced 197 pounds of nuts the second season, and the 33 unfertilized checks produced 10 pounds.

In the last analysis the production of nuts will give the real measure of the success of these experiments and the proof of the correctness of the view that pecan rosette is due to a deficiency of humus, plant-food material, and soil moisture. Consequently, it will probably be three or four years more before definite and conclusive results can be had, but the improvement obtained during the first two years, together with the other evidence presented, makes a striking case, and it appears reasonably certain that the improvement in the fertilized plats will continue until rosette is practically eliminated and nut production established in all of the fertilized trees.

LIME AND ROSETTE.

The use of lime as a remedy for pecan rosette has been strongly urged by some growers, and there appears to be a rather widespread belief in its efficacy for this purpose. Apparently this belief is based on the assumption that the disease is due to acid soil. That there is little or no reason for making such an assumption will be evident from a consideration of the facts in the case.

The soils of the native habitat of the pecan—i. e., river flood plains—are practically all acid and yet rosette is a rarity on such soils. Practically all of the soils of the Atlantic and Gulf Coastal Plains are acid, yet as a whole the orchards planted on these soils show probably not more than 20 per cent of the trees rosetted.

Tests for acidity by the litmus method have been made of soil from around 53 trees. The samples were taken to a depth of 4 feet and each foot tested separately. Of the 30 samples from rosetted trees, 29 gave acid reactions and 1 was neutral. Of the 23 samples from healthy trees, 18 gave acid reactions and 5 were neutral.

In the lime test, the results of which are given in Table I, the trees in the plat which received lime alone at the rate of 3 tons of ground limestone to the acre not only failed to improve, but were worse at the end of the third season following its application.[1]

There appears to be no reason to suppose that lime will be of any direct benefit in the treatment of pecan rosette. That it may be of indirect benefit in improving the physical condition of certain soils and in promoting the growth of legumes is highly probable, and when lime is used in rosetted pecan orchards this relation should be kept in mind.

THE ROOT SYSTEM AND ROSETTE.

The fact that the pecan develops a long taproot probably explains the view so commonly held by growers that the tree draws largely on the subsoil for its plant-food material. The facts of the case are

[1] Similar results were obtained by Rand in experiments with lime. For details of these experiments, see Orton, W. A., and Rand, F. V., Pecan rosette, in Jour. Agr. Research, vol. 3, no. 2, p. 149–174, 1916.

that the feeding roots of the pecan are distributed through the surface soil, and in proportion as this is deep and fertile the tree does well, but where the surface soil is of insufficient depth and lacking in humus and fertility the tree is likely to become rosetted. Prolonged hot, dry weather not infrequently kills many of the feeding roots in shallow surface soils. In plowing such land large numbers of roots

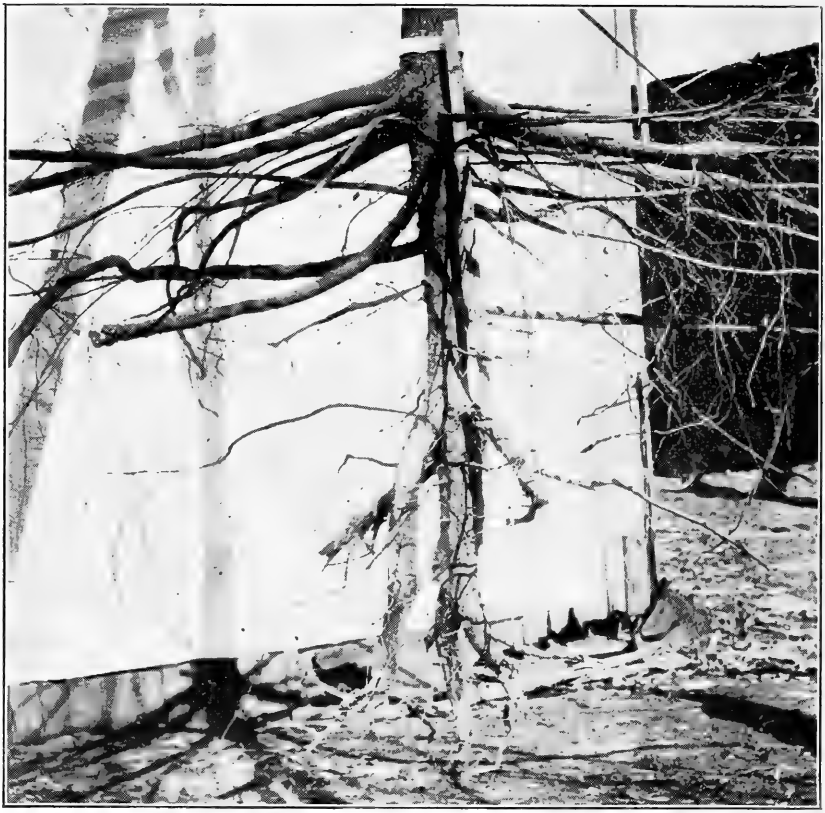

FIG. 4.—A 10-year-old pecan tree, showing taproot and main laterals intact. Practically all the laterals originated within 18 inches of the surface of the soil. Nearly all the small feeding rootlets originating on the laterals were found in the upper 6 to 8 inches of soil.

up to an inch or more in diameter are cut by the plow, and it appears that this must aggravate the disease in some degree.

It remains for experimentation to determine just how serious a matter is this drying out and cutting of the roots of rosetted trees. Meantime it would appear to be the part of good practice to develop a deeper surface soil between the rows of trees by the use of cover crops and by deepening the plow furrows from year to year until 8 to 10 inches of fertile surface soil is established and to avoid as much as possible the cutting of the roots by plowing shallow close to the trees.

Figure 4 shows a 10-year-old pecan tree which was carefully dug so that as much of the root system as possible might be obtained. This tree was growing on a stiff clay hilltop where the soil was only moderately fertile. The white band indicates the ground line. The taproot and all of the main lateral roots are shown intact. The chief point of interest is that practically all of the laterals originated within 18 inches of the ground line, and even at 12 to 15 feet from the tree they were rarely found deeper than 20 to 24 inches below the surface. The small fibrous roots originating on the main laterals may be seen plainly. Practically all of these small roots were found in the surface soil.

PREVENTION AND CONTROL.

The experimental and other evidence indicates very strongly that pecan rosette is a sign of a soil deficient in humus, fertility, and moisture supply, and certain conclusions with reference to the control of the disease in established orchards as well as its prevention in those yet to be planted may be drawn therefrom.

In setting new orchards it would be the part of sound judgment and economy to plant only on good land or land which is susceptible of rapid and permanent improvement. Deep sand, clays underlain by sand, and eroded hillsides should be avoided.

After the orchard is planted the cultural practices should be such as to increase the depth, humus content, fertility, and moisture-holding capacity of the surface soil as rapidly as possible and to conserve moisture during dry periods. Prolonged periods of dry weather during the spring are the rule rather than the exception in the southeastern United States. Consequently, the interplanting of a diseased orchard to shallow-rooted crops which require frequent cultivation, as, for example, cotton or peanuts, appears to be a desirable and economical way of obtaining this result. The constant addition of large quantities of humus-forming materials, thereby both bettering the physical condition of the soil and increasing its water-holding capacity and fertility, is absolutely necessary to produce healthy trees from those already diseased and to prevent the development of new cases of rosette.

THE USE OF COVER CROPS.

These results can be obtained in a variety of ways. Legumes, such as cowpeas, velvet beans, or soy beans, may be sown in the orchard in June and turned under in the late fall or winter. Fall and winter cover crops, either leguminous or nonleguminous, may also be used and plowed under green in the spring before the trees have started their growth. Just what procedure should be followed depends on the conditions connected with each orchard. But whatever the conditions may be, some definite and consistent soil-building policy should be adopted in the pecan orchards of the South if rosette is to be overcome and healthy productive orchards maintained. The program of work should involve the growing of one crop, preferably a legume, which may be returned to the soil. This procedure should be accompanied by the gradual deepening of the plow furrows until 8 or 10 inches of surface soil is turned over annually.

In this connection it is only necessary to add that intercrops which draw heavily on the soil moisture in the spring, such as oats, have a very undesirable effect on the trees by checking their growth, and they undoubtedly aggravate the disease. Consequently, such crops should never be allowed to mature in the orchard, but when used should be turned under about the time tree growth is starting.

THE USE OF FERTILIZERS.

Definite advice can not be given on the use of commercial fertilizers until adequate experimental data are available. Meantime, it would appear from the experiments which have been conducted and from the writer's general knowledge of the situation that the best course to follow is to use them on such intercrops as may be planted rather than to attempt to produce healthy trees by the direct use of such materials.

In these experiments, heavy applications of stable manure, cottonseed meal and stable manure, and cottonseed meal alone, in connection with legumes, have proved highly beneficial to rosetted trees. Inasmuch as the supply of stable manure is so limited, the orchardist must of necessity place his main dependence for soil improvement upon the consistent use of legumes or other crops which may be returned to the soil, together with the judicious use of commercial fertilizers to promote the growth of these crops. Legumes have the advantage of adding nitrogen to the soil as well as increasing its humus content and water-holding capacity and are for that reason to be preferred to other intercrops for improving the soil. Whether the tops of such soil-building crops are to be turned under, grazed off, or cut for hay is largely a matter of economics, and the individual grower must determine which is the best course for him to follow. While the soil will be improved and the disease overcome more rapidly by turning under the entire crop, it may be and probably would be the more profitable course in the South at the present time to utilize the tops for hay.

IMPORTANCE OF PROPER SOIL.

The newness of the pecan industry, the rapidity with which it has spread over a wide territory, and the general lack of knowledge of the tree's requirements have led to the planting of many orchards and portions of orchards in situations which are totally unsuited to the production of healthy trees. A large proportion of the cases of rosette in the Southeast are due to such plantings. While it is entirely possible to reclaim practically all of them and develop healthy trees from the diseased ones, it will probably not be profitable to do so in many cases. On deep sand, clay underlain with sand, and on badly washed hillsides the difficulty and expense of sufficiently increasing and maintaining the soil fertility will be such that it is hard to see any justification in attempting it, particularly in view of the fact that vast areas of suitable pecan lands at reasonable prices are available.

On the other hand, where the disease is present on soils which are readily susceptible of permanent improvement, it would probably be cheaper and more profitable to build up such soils and thus develop healthy bearing trees rather than to replant in a new location.

The matter is thus seen to be one of soil deficiency, and the answer to the pecan-rosette problem is very evidently "soil improvement." In proportion as the soils in the orchards are made to approach the condition of those found in the native habitat of the pecan in humus and plant-food content and in water-holding capacity, the disease may be expected to decrease and eventually to become reduced to a negligible factor, if not entirely eliminated.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 757

Office of the Secretary
Contribution from the Office of Farm Management
R. L. ADAMS, Acting Chief

Washington, D. C. ▼ March 25, 1919

FARM PRACTICES IN GRAIN FARMING IN NORTH DAKOTA.

By C. M. Hennis, *Assistant Agriculturist*, and Rex E. Willard, *Agriculturist*.

CONTENTS.

SUMMARY OF FACTS BROUGHT OUT.

This bulletin presents the results of over 350 records of grain production in 1912, 1913, and 1914, for 34 counties of North Dakota, together with information relating to dates of operations, time available for field work, farm organization, character of equipment, man labor, horse labor, use of machinery, amount of seed needed for various crops, thrashing, etc. In conclusion there are presented, in comparison, the costs of various items for five years prior to the war, and the costs of the same items for 1917, as found on a representative North Dakota farm.

Wheat occupies 39 per cent of the crop acreage of the farms studied in North Dakota, oats 17 per cent, and barley 14 per cent. Crops of less importance are flax, corn, rye, and potatoes.

The average yield of wheat on the farms visited in this investigation is 13.2 bushels per acre; for the State as a whole, 12.7 bushels.

The equivalent of one disking and two harrowings, in general, appears to give better results than either more working or less. Under certain conditions the disking may be omitted and the same results obtained by covering three times with the harrow.

Summer-fallowing is not generally profitable, except in the case of land foul with weeds. Comparatively few farmers follow this practice.

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No apparent difference in yields is seen between spring plowing and fall plowing, but fall plowing has an advantage in giving a better distribution of labor and making it possible to sow grain earlier in the spring.

"Stubbling-in" is almost invariably unprofitable. This practice of sowing grain without plowing, after merely disking the land, tends to lower yields and to encourage the spread of weeds and other pests.

About 6.4 hours of man labor and 19.4 hours of horse labor (average for all records) are required per acre in the production of wheat. Oats, barley, and flax require a little more work per acre than wheat. Different parts of the State show wide variation in this regard.

The cost of thrashing from the stack is slightly greater than the cost of thrashing from the shock, but thrashing from the stack has advantages in labor distribution and the saving of grain.

The cost of maintaining work stock was $145 per head in 1917, as compared with an average of $105 for the five years 1911–1916. The difference is attributable to the great advance in the price of feed.

The first cost of farm machinery used on North Dakota farms was 40 per cent higher in 1917 than the average for the five years 1911–1916.

Seed wheat cost $2.28 in 1917, as compared with an average of $1.23 for the preceding five years.

AGRICULTURAL DEVELOPMENT OF THE STATE.

The first agricultural enterprise to receive attention in North Dakota was the production of stock on large ranches. The location of the headquarters of the various holdings was determined largely by the availability of water for the cattle. As the tide of settlement moved westward and as the availability of underground water became known, the ranges were encroached upon by homesteaders who took up claims in units of 160 acres. A very large part of the ranges was Government land to which the ranchers could not secure title, but they nevertheless made use of the land for grazing purposes. (Fig. 1.) The ranchers, who had preceded the homesteaders, resented the presence of the farmers, because they encroached upon the ranges, and many attempts were made to force the withdrawal of the so-called "nesters." (Fig. 2.) However, the desire for ownership of the land was so strong that practically all Government land suitable for farming purposes has now been occupied by farmers, as distin-

NOTE.—The data in this bulletin were secured in cooperation with the North Dakota Agricultural College. Special acknowledgment is due Mr. W. E. Palmer for furnishing photographs.

guished from the ranchers, the latter being found at present only in the more inaccessible and less desirable lands. The discovery of artesian and other underground water made it possible for the newcomers to locate in almost any place where land was found desirable for tillage.

FIG. 1.—Headquarters of a North Dakota wheat ranch.

As settlement advanced, far-sighted pioneers in railroad development extended their lines, greatly facilitating the general settlement of the State. At present the trunk and branch lines make practically all farming land accessible to outside markets.

As the land was broken up, the four crops, wheat, oats, barley, and flax, were produced extensively, the last-mentioned crop being partic-

FIG. 2.—These "shacks" were typical homes of early homesteaders in North Dakota.

ularly adapted to freshly broken sod. Ever since farming became general in the State wheat has been the important money crop, and for many years only enough stock was kept to furnish power to till the land. However, the same experience was encountered as in other regions where a single-crop system of farming was followed, namely, the decrease in yields. This condition is very generally recognized at present and the farmers are gradually diversifying their production. The raising of stock on the farms has increased materially, indeed, in some instances enough to overcome the decrease in crop yields. It has been found, also, that certain feed and forage crops can be produced successfully, among these being corn, alfalfa, and sweet clover.

Among the early homesteaders in North Dakota were many who, unable to withstand the trials of the border line of civilization, sold their homesteads or relinquished their claims. By acquiring these lands some were able to secure title to large acreages of excellent farming land. Others secured large acreages from the railroads, to which the Government had made extensive grants as bonuses to further the construction of railroad lines. Notable examples of large holdings are to be found at present at Casselton, Amenia, and Larimore.

With the passing of the one-crop system it is found that these extensive bonanza wheat farms are not only less and less profitable, but unsuited to the new system, and they are gradually being broken up into smaller farms and sold or leased. However, the size of the average North Dakota farm will doubtless remain comparatively large for a long time to come, and some of the holdings are still much too large to be managed efficiently under systems of diversified farming.

GENERAL CONDITIONS INFLUENCING GRAIN FARMING IN NORTH DAKOTA.

In topography North Dakota varies from level to hilly, with a very large proportion of undulating to rolling land which is well adapted to grain farming.

The soils of the greater part of the State vary in texture from sand to clay loam, and in the Red River Valley very heavy clay is found. The loams and clay loams appear best adapted to grain farming, although excellent crops are produced on the clays when the moisture is not in excess.

The climate of North Dakota is extreme. Winter temperatures ordinarily range from about freezing to 30° F. below zero, with occasional extremes of from 40° to 50° below. In summer the temperature ranges from 60° to 90° above zero, with occasional cold nights when it is as low as 40°. Occasionally temperatures slightly above 100° are recorded, but these are uncommon. On account of the very low humidity of the Great Plains area, the extremes of temperature are not so keenly felt as where the air is damp.

The dates of the latest killing frosts in spring on record for the State range from May 31 to June 28 at various stations. The dates of the earliest killing frosts in the fall range from August 6 to September 12.[1]

The rainfall of North Dakota is somewhat variable, depending upon elevation and longitude. The variation is approximately 6 inches, the precipitation in the extreme eastern part of the State being slightly over 20 inches and in the extreme west slightly less than 15 inches. From 1½ to 4 feet of snow may be expected ordinarily, though occasionally there are years with scarcely any snowfall or with as much as 8 feet. However, on account of the high, northwest prevailing winds, the amount of snow that lies on the level surface during the winter is generally small, the snow being drifted into depressions and about obstructions.

The months of May and June are the critical growing months, the amount of rainfall during these months having a marked effect on the yield of crops.

The growing season varies from about 100 to approximately 160 days, averaging 135 days, but the season in which field work is done is considerably longer. Records kept in various parts of the State show that, on the average, field work begins April 18 and closes November 6, embracing a total of 202 days. The days available for field work, after deducting Sundays, holidays, and days on which the fields are too wet, amount to 144. (See p. 9.)

THE FARM AND ITS ORGANIZATION.

In general, farms in North Dakota vary in size from a quarter section (160 acres) to four sections; a few bonanza wheat farms and stock ranches have several thousand acres each, but the average farm in the State is from three-quarters to one section in extent.

INVESTMENT PER FARM.

The selling value of land varies about 100 per cent between eastern and western North Dakota, as indicated in records from over 200 farms. The average value of farm land in the Red River Valley was $50 per acre (including buildings) in 1914. The average value of land approximately in the two rows of counties west of the Red River Valley (including Towner and Cavalier, Stutsman and Barnes, Dickey and Sargent) was $40 per acre. The average value of land east of the Missouri River, not including Williams and Mountrail Counties, but west of the above-mentioned counties, was $30 per acre, while the average value of land in the western counties of the State was $22 per acre.

Difference in the amount of rainfall is the principal cause of the extreme variation in value of land, the eastern and western parts of

[1] Data from United States Weather Bureau.

the State showing a difference of approximately 6 inches in annual precipitation. While the difference in average yield per acre between different parts of the State is not wide, the difference in rainfall causes a very marked increase in risk involved in crop production, which is reflected in the price of land. A less important cause is the quality of land, as that in the Red River Valley is somewhat more fertile and, being generally heavier in texture, retains moisture better than the soils of the western part of the State.

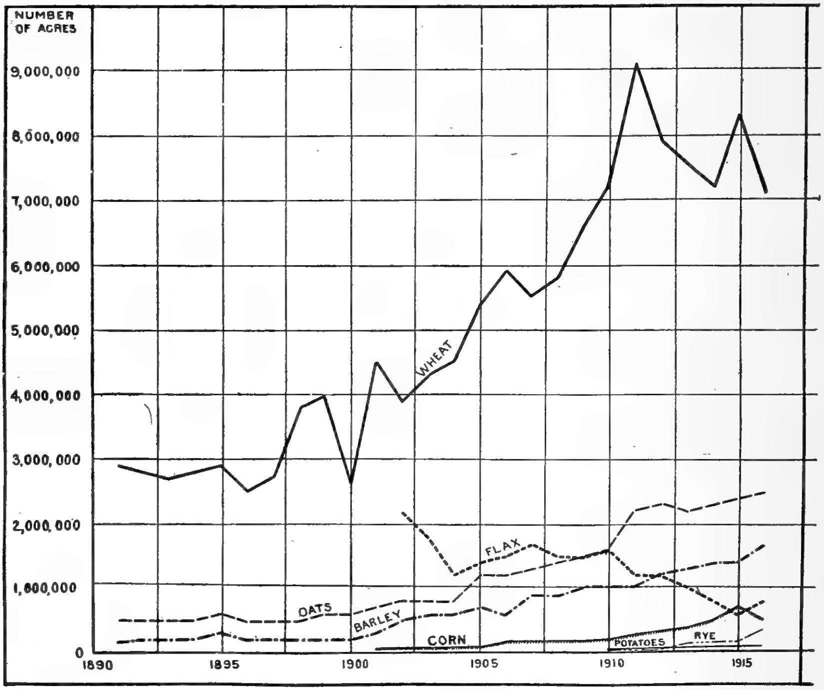

FIG. 3.—Acreage of crops (North Dakota, 1891–1916).

The value of farm buildings varies according to size of farm and decreases somewhat on farms of the same size from east to west. The latter fact is due to the earlier development of eastern North Dakota as well as to the greater certainty of production in this region. The average building investment of farms of 320 acres or under over the State is approximately $3,000. The value of buildings per farm of 321 to 640 acres averages approximately $5,000. Farms averaging 1,000 acres, and ranging from 641 to 2,560 acres, have buildings averaging $5,200 in value.

Work stock in North Dakota consists chiefly of horses, and the average value is $155 each. Farms of 640 acres utilize approximately 13 horses each. Each horse covers the equivalent of 38 acres of crops. (See page 15.)

The value of implements and machinery per farm is comparatively high. The average value of implements and machinery per farm of 640 acres, not including tractors, thrashing outfits, or automobiles, is approximately $1,800. (See p. 17.)

CROPS.

In 1917 records were obtained from representative farms in various parts of the State showing the following percentages of crop area in various crops: Wheat, 39 per cent; oats, 17 per cent; barley, 14 per cent; corn, 6 per cent; flax, 6 per cent; miscellaneous crops, 18 per cent. Tame hay and prairie hay occupied the largest areas among the miscellaneous crops; rye, millet, and alfalfa followed in order. Summer-fallow land occupied less than 3 per cent of the crop area. Pasture and waste land occupied approximately 22 per cent of the total farm area.

FIG. 4.—A field of oats on a characteristic Red River Valley farm.

The lines in figure 3 show the trend of acreage from year to year from 1891 to 1916. Wheat always occupied the first place, increasing from about 3,000,000 acres in 1891 to more than 9,000,000 in 1911. In 1891 flax occupied less than one-quarter million acres, but in 1902 occupied nearly two and one-quarter million acres; from that date it has diminished in importance to the present time. Flax reached its greatest importance at the time when a maximum amount of praric sod was being broken up, as this crop is perhaps better adapted to "breaking" than any other crop produced in the region.

Oats and barley increased in acreage from 1900 to 1916, but had remained at about the same level from 1890 to 1900. These crops are utilized locally quite largely for feed, although considerable barley is sold. A good field of oats is shown in figure 4.

Corn, potatoes, and rye received little attention until after 1900, when the corn acreage increased markedly. Varieties of hardy and quick-maturing corn were developed, so that in 1915 nearly three-quarters of a million acres were growing in the State. Rye began to receive attention in 1913, and reached 350,000 acres in 1916. Potatoes increased in acreage somewhat from 1910, there being about 75,000 acres in 1915.

LIVE STOCK.

The production of live stock, particularly cattle (fig. 5), has in general increased in the State since 1860. The broad free ranges were particularly adapted to this enterprise until about 1900. Ranching is now principally confined to isolated areas in the western part of the State.

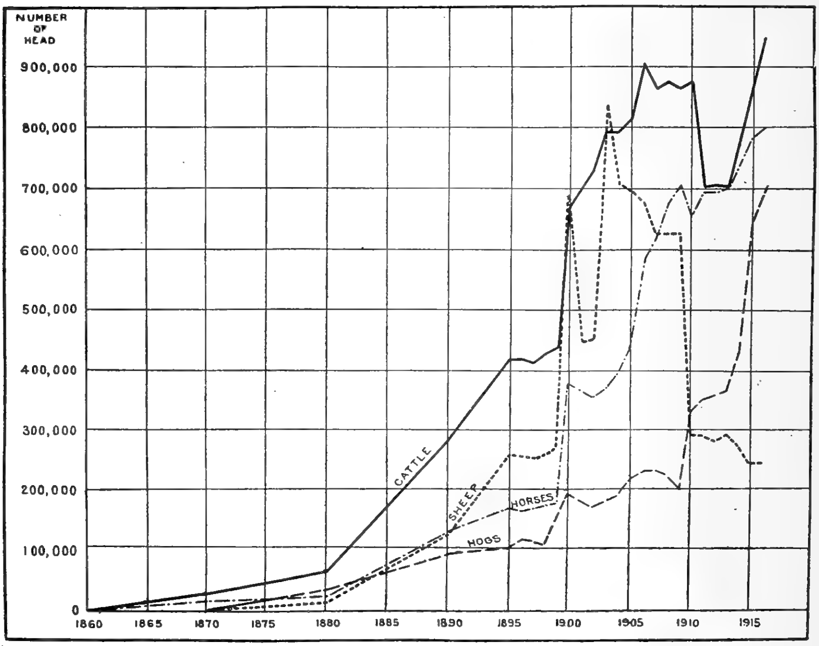

FIG. 5.—Live stock in North Dakota (1860–1915).

The years since 1899 have seen a marked increase in cattle and horses, this increase being brought about by production on farms as distinguished from that on the more extensive ranches. Sheep, being well adapted to the broader range, have decreased as the land has been developed into farms. However, sheep production on the farms of the State probably increased somewhat during 1916 and 1917.

Hogs have increased in number since 1909, amounting to more than 700,000 head in 1916.

The lines in figure 5 show that there was a decrease in horses and hogs, and particularly in sheep, following 1900, and in cattle following 1910. These decreases undoubtedly were due to scarcity of feed, which caused the sale or loss of large quantities of breeding stock. Both 1900 and 1910 were years of exceeding drought, particularly during the growing months of April, May, and June.

LABOR.

To determine the number of men required to operate a farm, representative operators were asked as to the amount of labor hired, amount of work done by members of the family other than the operator, and amount of work done by the operator himself. The average farm of 640 acres, with 480 acres in crops, requires approximately 8.5 months of time of the operator. Some farms utilize labor by other members of the family, and this was calculated on the basis of the number of months employed; other farms hire labor by the month; the total of these two items of labor average 17.3 months per farm. Extra labor was hired by the day during haying, harvesting, and thrashing, averaging 84 days per farm, or the equivalent of 2.9 months. In general, farms using family labor do not hire outside labor by the month. The 640-acre farm with 480 acres of crops requires the equivalent of approximately four men (including the operator) during the season of seven months. Each man employed under average farm organization, therefore, does the work equivalent to that required on 120 acres of crops. More men are required during harvest than during plowing and seeding, and scarcely any extra labor is needed for a period between planting and harvest.

The amount of overhead labor—that is, labor necessary to the upkeep of the farm but not applied directly to productive enterprises—is 16.2 per cent of the total labor utilized on the farm, as estimated by 40 farm operators. This overhead labor is included in the above calculations.

Labor is unevenly distributed on the grain farms of the State, inasmuch as work on the grain crops is required at about the same time for the same operations on all crops. In the case of the four leading grains—wheat, oats, barley, and flax—the work of plowing, preparation, and seeding is practically completed by May 31, and harvesting and thrashing are done between August 1 and September 30. On many farms a considerable amount of plowing is done in the fall, in which case nearly twice as much man labor is required during the critical period of late summer and fall as during preparation and planting.

While the season in North Dakota is comparatively short, not much time is lost because of unfavorable weather. On the average 144 days are available for field work, excluding Sundays, holidays, and days when it is too wet for field work. This available time is distributed as follows:

	Days.		Days.
April	14	August	22
May	22	September	20
June	21	October	22
July	21	November	2

FACTORS THAT CONTROL COST OF PRODUCTION.

Several important items enter into the cost of production of crops, each of which has a bearing on the profitableness of the various farm enterprises. In general, as each of these items increases in amount above a normal average the profits decrease. There are, however, one or two exceptions, such as the cost of twine and of thrashing, which are directly in proportion to the yield.

USE OF LAND.

The value of agricultural land, in general, is determined largely by its average productivity. Security of investment, profits from expected advances in value, and risk in production are other influencing factors. The earning value or productive value of land in North Dakota, however, is not always in proportion to its market value.

The payment to capital for the use of the land in older farming communities is usually equivalent to the current rate of cash rent for such land, less taxes and upkeep of buildings. In North Dakota scarcely any land is operated on a cash rent basis. In the rare cases, where obtainable, cash rent usually amounts to from 3.5 to 4 per cent on the investment. It was found in eastern North Dakota, where the average selling value of land is approximately $50 per acre, that, in general, when a farmer buys land, paying one-half the cost price in cash, the remaining $25 per acre is liquidated in about 15 years, interest being allowed at 6 per cent, indicating that he has made a net income of at least $2.50 per acre per year.

For purposes of calculation, if 6 per cent on the value of the land is assumed for use of land, no serious error will be made. In the Red River Valley this interest amounts to $2.97 per acre; in east-central North Dakota, $2.42; in west-central, $1.77; and in the western part, $1.34 per acre.

LABOR ON CROPS.

Man labor is one of the important factors of production. The amount required per farm was indicated on page 9. The amount required per acre for the leading crops under normal yields is shown in Table I.

TABLE I.—*Man and horse labor required per acre on various crops.*

[10-hour day.]

Crop.	Man days per acre.	Horse days per acre.	Crop.	Man days per acre.	Horse days per acre.
Wheat [a]	0.64	1.94	Flax [a]	.66	2.23
Oats [a]	.74	2.09	Corn	1.64	3.85
Barley [a]	.71	2.11	Potatoes	3.16	4.58

[a] Does not include thrashing.

The amount of man labor per acre varies somewhat with yield, since the time required for certain operations is greater if yields are heavy than if yields are light. The leading four grain crops require each approximately the same amount of man labor, since the same implements and crews are used for all of them.

Corn and potatoes require more work in cultivation and harvesting than do the small-grain crops. Most of the cultivation is done with two horses; the harvesting of corn is done by cutting with corn binder and shocking in the field. Potatoes are planted and dug by machine.

Horse labor is approximately the same on the leading four grain crops, but is considerably higher on corn and potatoes. For details of factors entering into the cost of horse labor, see page 15.

SEED PER ACRE.

The amount of seed used for planting by different farmers varies somewhat. The relation of the amount of seed for various crops to the yield of the same is shown on page 31. In seeding durum wheat, farmers generally use from one-quarter to one-half bushel more seed per acre than for other varieties.

TWINE.

Since practically all grain is harvested with the binder, large amounts of twine are required. The amount used per acre varies directly with the yield; when wheat yields 8 bushels per acre, 1.5 pounds of twine are required, and when wheat yields 20 bushels, 2 pounds. Barley and oats require slightly more twine per acre for harvesting than wheat. Where barley yields 12 bushels per acre 1.3 pounds are used, and where 30 bushels are made, 2.3 pounds. Oats require 1.5 pounds of twine when the yield is 34 bushels and 2.25 pounds when the yield is 45 bushels. Where flax yields 8 bushels of seed per acre, 1.3 pounds of twine are required. Not all flax is bound, however, it often being dropped in loose bunches by reapers or binders.

USE OF MACHINERY.

The use of machinery on North Dakota farms is costly in the aggregate, but when reduced to the acre basis the cost is comparatively small, owing to the fact that the large implements cover large acreages. The cost of operation of machinery may be classified under the three main headings: Depreciation, interest on investment, and repairs. A fourth group might be included which would cover storage, insurance, and taxes on machinery, but these amount to comparatively little.

The depreciation may be determined by estimating the life of the various implements; interest on investment in machinery is calculated on the value at the beginning of the year and not on the first cost, except during the first year; repairs cover necessary outlay for replacing broken or worn parts, paint, oil, etc. The average depreciation of farm implements in North Dakota varies considerably, depending upon the care and use of the various machines. The average life of implements is 12 years; in other words, the average annual cost for machinery depreciation is approximately 8 per cent of the new value.

FIG. 6.—Thrashing in the field from the shock.

Repairs amount to approximately 6.5 per cent of the cost value of all farm implements on the average, although there is a wide variation in the amount of repairs required for different implements. For further details concerning the use of farm machinery, see page 17.

THRASHING.

Thrashing is a comparatively large factor in the production of grain, since large amounts of both man labor and horse labor are required in a very short time, the greater part of the thrashing in the State being done in less than 30 days, after about September 10. Most of the thrashing rigs are composed of a steam traction engine and separator with self-feeder and blower.

The usual thrashing crew (fig. 6) consists of about 20 men and 22 horses as follows: Eight to 10 men with teams hauling grain from the shock to the machine, four or five field pitchers, two "spike pitchers,"[1] one man and team hauling water and fuel, an engineer, and one or two separator men, one of whom is usually foreman of the crew. The farmer usually furnishes the necessary teams to haul the grain from the machine. In some cases the crews are boarded by the farmers for whom thrashing is done, while in others "chuck-wagons" or boarding cars are maintained by the crew.

The practice is becoming very common in parts of the State for farmers to stack grain as soon as it is sufficiently cured, so that the crew for thrashing is considerably reduced and thrashing is done at a smaller cost per bushel under these conditions (fig. 7).

FIG. 7.—Many farmers now put up their grain in stacks.

Table II shows the charges per bushel in 1913 for thrashing from shock and from stack the four chief crops in eastern North Dakota, as reported by over 100 farmers.

TABLE II.—*Thrashing charge per bushel where done from shock and from stack (1913).*

[Cents per bushel.]

Thrashing method.	Wheat.	Oats.	Barley.	Flax.
From shock	10.4	6.4	6.6	25.7
From stack	6.1	3.8	4.0	11.4
Difference	4.3	2.6	2.6	14.3

Information was secured from 140 farmers regarding the amount of wheat of average yield that was stacked in an average day's work with different crews. Two men with one team stacked 10.7 acres, and three men with two teams stacked 14.3 acres. Assuming average

[1] Spike pitchers mount each loaded grain wagon as it comes to the machine and assist in pitching to the feeder of the separator.

costs of labor to be $2.50 per day for man and $1 per day for horse, which were approximately prevailing costs at that time (1913), the cost of stacking with the smaller crew was $7 per day or $0.65 per acre. With the larger crew the cost was $11.50 per day or $0.805 per acre.

With an average yield of 12 bushels of wheat per acre the saving by thrashing from the stack (from Table II) amounts to but $0.52 per acre. However, several factors taken together have an important bearing in this connection. If grain is stacked as soon as cured sufficiently, there is very little loss in quality of grain, except in rare instances. Scarcely any loss of grain from shelling occurs when thrashing is done from the stack, while considerable losses occur when the dry, ripe grain is taken from shock to machine. Also, the reduction in the size of the thrashing crew, made possible by having the grain stacked, is very important, especially during any shortage of labor. While a slightly larger total amount of labor is required when the grain is stacked, the distribution of the work over a much longer period is an advantage.

The average crew usually thrashes from 1,800 to 2,000 bushels of wheat, about 2,500 bushels of barley, and approximately 3,500 bushels of oats in a full day.

FARM UP-KEEP.

Of the total amount of man labor required on the farm, 40 operators estimated that on the average 16.2 per cent was required for overhead work not chargeable directly to any productive enterprise. This overhead labor is utilized in general repair of buildings, fences and ditches, repair of machinery, care of work stock, etc.

The amount of horse labor required in the overhead work is estimated to be about one-quarter as much as man labor.

MANAGEMENT OF FARMS.

The management of North Dakota farms is somewhat more costly than that of farms in some other sections. In determining this cost the value of the operator's time was assumed to be the value of his actual manual labor at current wages plus the estimated value of his management. The average farm operator puts in the equivalent of about eight months of actual work, averaging 21 days per month. This allows him credit for caring for productive stock in winter at the rate of about 30 hours per animal unit per year.

The average estimated value of management for 40 farms is $549. This amount is prorated to the productive enterprises in proportion to the number of days of work required on each. The total amount of man labor on crops and productive stock, together with outside labor, such as thrashing and hauling outside of the operator's own farm, is 505 days per year, so that the management charge is $1.09 per day of productive work on the average farm of 640 acres.

RISK.

As previously indicated, production is affected by several conditions over which the farmer has little or no control. Among these are rainfall, frost; hail, and market fluctuations. While failure for one year or for two successive years may be offset by high returns in seasons following for the farmer who has sufficient capital to carry him over the years of failure, many farmers lack sufficient capital or credit to carry them over even two years of failure. For some of these, one complete failure is equivalent to 100 per cent risk and for many more two crop failures mean ruin.

MAINTENANCE OF WORK STOCK.

The average cost of maintaining a work animal in North Dakota prior to 1916 was $105 per head, and in 1917, $145.

As stated previously, the average farm having 480 acres in crops requires 13 work stock, valued at $155 each. As the number of acres in crops decreases from that acreage, the number of necessary work stock decreases at the rate of about 1 horse per 38 acres, and as the size of the farm increases above 480 acres, the number of work stock increases at nearly the same rate. Large farms utilize horse labor slightly better than small ones, owing to their slightly better distribution of work.

The principal feeds for work horses in North Dakota are oats and hay, although corn and barley are occasionally fed. Straw is utilized to a large extent as a maintenance feed during the winter, oat straw being considered best. Records were obtained concerning feed for 462 horses, which show that, on the average, 142 bushels of oats and 3 tons of hay per year are fed to each horse. The amounts of each feed vary considerably, depending somewhat upon the size of the animals, but more particularly upon the combination of feed and the amount of work done by the animals.

The horses generally have free access to the straw pile, so that the amount of straw consumed can not be determined. However, this feed very often entirely replaces hay during the winter. Work stock are kept on pasture very little.

The hay utilized is generally the native prairie grass or slough grass, although tame hays are being produced to some extent. Among these are timothy, clover, and alfalfa.

The depreciation of work horses is an item of expense not usually considered by the average farmer. The number of years horses are useful for farm work varies considerably, depending upon use and care. Estimates from 100 farmers in eastern North Dakota relative to the number of years work horses are useful vary from 7 to 20 years, averaging 12 years. The average annual depreciation, therefore, is asumed to be 8.3 per cent of the prime value, which is usually considered to be the value at six years of age. As a matter of fact, very little depreciation occurs until after the animals are eight years of age. It has been shown[1] that a horse is worth 84 per cent of its prime value at 10 years of age, 70 per cent at 12 years, and 40 per cent at 16 years. The value of the average work animal changes very little between the ages of 5 and 9 years.

The shoeing of work animals is generally limited to those that are being used in hauling on hard roads or other hard surfaces. Some farmers shoe the front but not the hind feet. In ordinary field work, shoes are not necessary. Of 103 farmers, 69 had some of their horses shod, but only a small percentage had all of them shod. Of the total of 718 head on these farms the average prorated cost per horse was $0.89 per head per year.

Veterinary charges are a very small item and no data are available on this subject.

The assessed valuation of work stock in the State in 1914 was approximately $30 per head and the tax rate about 30 mills per dollar. Thus the average taxes per head amount to $0.90.

Information was secured from 48 farmers concerning the amount of barn room used for stabling. The buildings ranged in size from 16 by 22 feet for 9 animals to 38 by 80 feet for 32 animals. The average floor space utilized was 70 square feet per animal.

The time required to care for work stock varies considerably, depending upon the convenience of arrangements for feeding and for removing manure. Also, the number of animals per farm is a factor, the larger the number of animals the more total time required, but the less the time required per animal. The results of 129 records are given in Table III, the approximate time per horse being given.

TABLE III.—*Time required per day to care for work stock.*

Item.	Number of horses.									
	4		5		6		8		10	
	hrs.	*min.*	*hrs.*	*min.*	*hrs.*	*min.*	*hrs.*	*min.*	*hrs.*	*min.*
Total time per day	1	53	2	1	2	20	2	43	2	45
Minutes per horse		28		25		23		20		16

The average work horse in North Dakota is utilized for 79 days of productive labor on the farm. While 144 days are available for field work during the crop season, practically all of the work done is in planting and harvesting time, as there is very little field work to be done for a period of from six weeks to two months in June and July. Some productive work is done during the winter in hauling grain to

[1] United States Department of Agriculture Bulletin 413, page 11.

market. A small amount of work in general farm upkeep is done by horse labor.

USE OF IMPLEMENTS AND MACHINERY.

The prewar value of machinery on the average North Dakota farm visited (averaging 480 acres in cultivation), was $1,757 (cost price). This figure does not include automobiles, tractor-plow rigs, or thrashing rigs. Each acre of crop land, therefore, must bear the maintenance charges for $28 worth of machinery.

Table IV shows some of the facts relative to the utilization of the more important implements, as indicated by information secured on 40 farms in North Dakota. These figures represent prewar conditions, a marked advance having been noted in 1917. The average life of implements varies somewhat, with consequent variation in the amount of depreciation. The average life of all farm implements is 12 years, making the annual depreciation 8.3 per cent.

The annual repairs for the various implements depend upon the amount of use and care. The high repair cost of gang plows is due to the replacement and sharpening of shares. The big item of repairs of binders consists of new canvases, which are generally replaced every two to four years. The average annual cash expense for repairs amounts to 6.7 per cent of the first cost of implements.

TABLE IV.—*Average value, life, annual repair cost of various implements, and the area covered by each (prewar data).*

Implement.	Average value (new).	Average life.	Annual repair cost.	Acres covered per year (each).
		Years.		
Gang plow	$75	13	$16	174
Disk harrow	44	12	3	165
Drag harrow	23	9	1	670
Roller and packer	53	19	1	240
Grain drill	130	11	4	300
Grain binder	144	10	13	168
Mowing machine	49	12	4	54
Hay rake	30	13	1	67
Manure spreader	129	12	7	31
Corn binder	132	10	7	49
Corn planter	43	16	2	61
Sulky cultivator	36	12	1	57
Wagon gears	59	18	2	....
Grain tanks	28	11	....	....
Wagon racks	14	6	....	....
Bobsleighs	53	15	....	....
Gas engine	74	13	2	....
Harness (set)	33	11	1	....

The last column of the table shows the average number of acres each implement covers each year, in the usual farm practice. Nearly all of the larger machines cover from 150 to 300 acres each per year. This is one of the factors which determine the comparatively large size of farms in North Dakota. None but large farms can utilize these labor-saving implements efficiently.

FIG. 8.—The gang plow drawn by the five good horses turns from 5 to 6 acres in a day.

The gang plow (fig. 8) cuts two furrows of 12 to 14 inches each; the most common gang is the 28-inch. The majority of farmers use five horses on the gang plow, although a large number use only four.

FIG. 9.—The spike-tooth harrow covers from 40 to 60 acres per day, depending upon the width of the harrow and size of the team.

A very few use six horses on this implement. Usually three horses are placed abreast and two in the lead, but when four horses are used they are generally driven abreast.

The harrow (fig. 9) varies in width from 16 to 32 feet, and occasionally greater widths are used. This implement is usually constructed in 4-foot sections and may be made any width that is a multiple of 4 by the addition of more sections. Four horses are used most commonly on widths from 16 to 24 feet, but five and six horses are used on the wide harrows.

The disk harrow (fig. 10) is used generally for pulverizing cloddy soil. Sometimes it is used in place of a plow in preparing stubble land for the succeeding crop, but this practice is not common. This implement generally consists of from 16 to 24 disks on two shafts set end to end, which may be set at various angles to each other by means of

FIG. 10.—The disk harrow is an implement especially useful on packed or cloddy soil.

levers. The most common size of disk is the 16-inch, though the disks vary from 12 to 18 inches in diameter. Four horses are most commonly used on the disk harrow, with one man as driver, who usually occupies a seat on the implement.

Grain drills (fig. 11) are ordinarily from 8 to 12 feet wide, occasionally a 16-foot implement being used. Both the shoe and the disk type are in rather common use. Almost invariably four horses are used on the drill in North Dakota.

Rollers and packers are used to some extent, but are not necessary implements. They are used for pulverizing the surface and packing the soil into a firm seedbed. Figure 12 illustrates a type of subsurface packer. Four horses are normally used on either roller or packer.

The binder (fig. 13) is one of the most complicated and most expensive implements used on grain farms. Those used in North

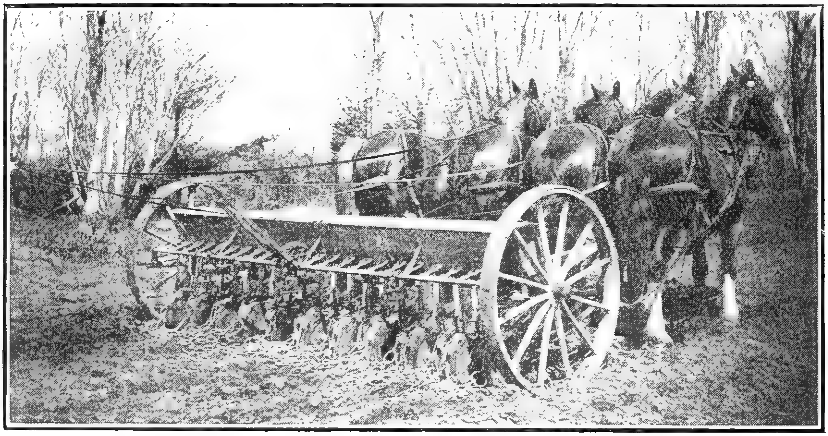

FIG. 11.—The grain drill is one of the essential large implements on the grain farm.

Dakota are usually of from 6- to 8-foot cut. In nearly all cases four horses are used on this implement, but occasionally three are used.

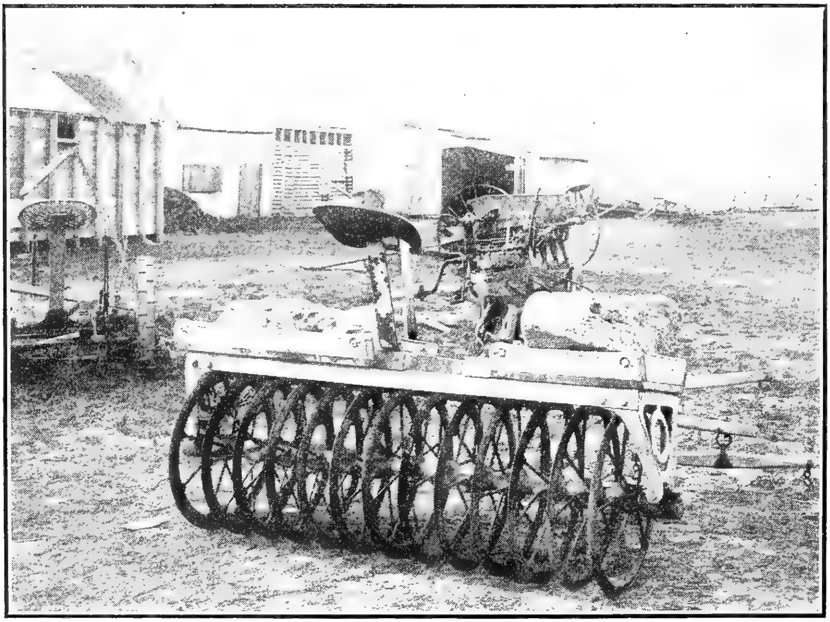

FIG. 12.—A subsurface packer that makes a firm seedbed and breaks the clods, leaving a dust mulch.

It is not uncommon for a farmer to allow the binder to stand in the open during the year, the canvases being removed and placed under cover. While this practice increases the rate of depreciation to some extent, the binder does not suffer as much from exposure to the weather as do certain other implements, notably those largely made of wood.

FIG. 13.—The self-binder is most commonly used for harvesting grain.

Mowing machines and hay rakes (generally two-horse size) are found on practically every farm (fig. 14). Each of these implements

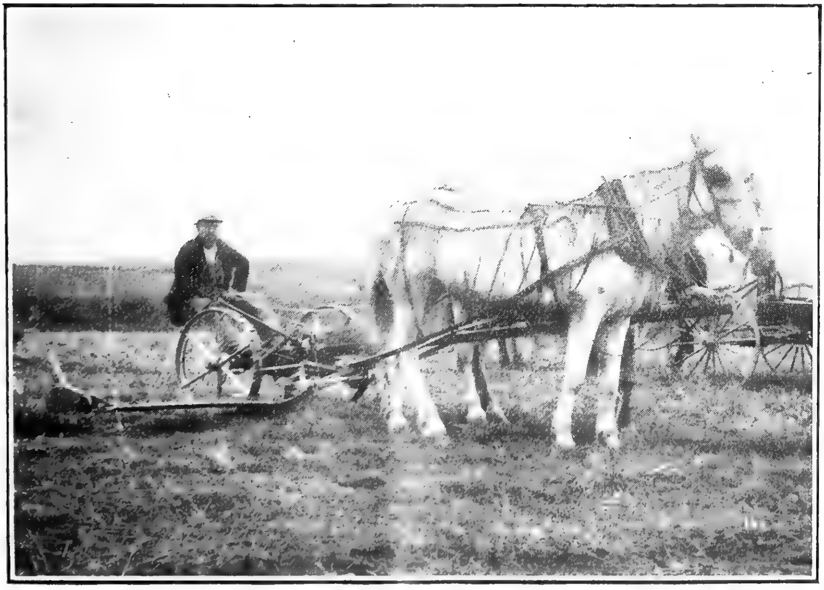

FIG. 14.—The mower. Often several acres must be cut to get a ton of prairie hay.

is nearly all of iron, and depreciation is therefore not great when they are left in the open.

The manure spreader has lately come to be a very common farm implement in certain parts of North Dakota, as the farm operators have begun to appreciate the value of manure. The increase in amount of live stock has caused an increase in the amount of manure, and this is now being utilized more efficiently. Manure spreaders vary in make and size; those of from 60 to 70 bushels capacity are common. Two, three, or four horses are used, depending on capacity. Where the barn is built with a driveway through it the spreaders are loaded directly from the gutters. In other cases overhead carriers are used, which dump into the manure spreader outside the barn.

The larger machines for corn production are now common, the two-row check planter being used as well as the corn binder. Two horses are used on the planter and four on the binder. The 2-horse riding cultivator for corn and potatoes is more common than the walking cultivator. Very little wood is used in its construction; it lasts for a dozen years with scarcely any repairs.

A farm wagon is required for approximately every 100 acres of crop land on the farm. The wide-tire wagon is most common. Grain tanks of from 60 to 125 bushels capacity are found on every farm, one to about every 270 acres. Racks for hauling hay and grain are short-lived, being almost entirely of wood construction.

Stationary gas engines are found on nearly every farm, many farms having two or even three of them. These are used for grinding feed, pumping water, elevating grain, etc. They vary in size from one to four horsepower, the one and one-half horsepower engine being very common. The prewar cost of these was approximately $30 per horsepower, with considerable variation according to make of engine. The small gas engine has now been simplified to such an extent that anyone of average intelligence can operate it, and it is now practically a necessity on the North Dakota farm.

On those farms where potatoes are raised, both planters and diggers are used. Diggers are four-horse implements, and both diggers and planters are very necessary where large acreages of the crop are raised.

Buck rakes and hay stackers (fig. 15) are not infrequently found on the larger farms where much live stock is kept and a considerable acreage of hay is harvested. It is only on such farms that these implements are profitable, inasmuch as the depreciation and repair charges on them are comparatively high.

A large amount of small tools and implements is necessary to the operation of the farm, although many farms have considerably more of these articles than are essential.

Thrashing outfits (fig. 6) are often owned and operated by farmers, although they generally do considerable outside work, except on the very large farms. Not infrequently two or more farmers in a community own a thrashing rig jointly and do their own thrashing as well as some outside work. In some cases rigs are owned and operated by men who are not farmers but who make thrashing a business. Steam engines cost from $1,500 to $3,000 (1914) and separators cost from $750 to $1,200. The cost usually depends on the size more than any other factor. An engine lasts from 12 to 20 years, according to the use and care given it. The life of a separator is not so long, being from 7 to 15 years.

It was formerly the practice to use straw for fuel, flax straw being the best for this purpose. During the last five years this practice has been almost entirely discontinued, and now coal is the fuel commonly used. An ordinary 25 to 30 horsepower engine consumes from 1,800 to 2,000 pounds of soft coal per day. It was suggested that during the shortage of coal (1918) the former practice of burning straw be revived.

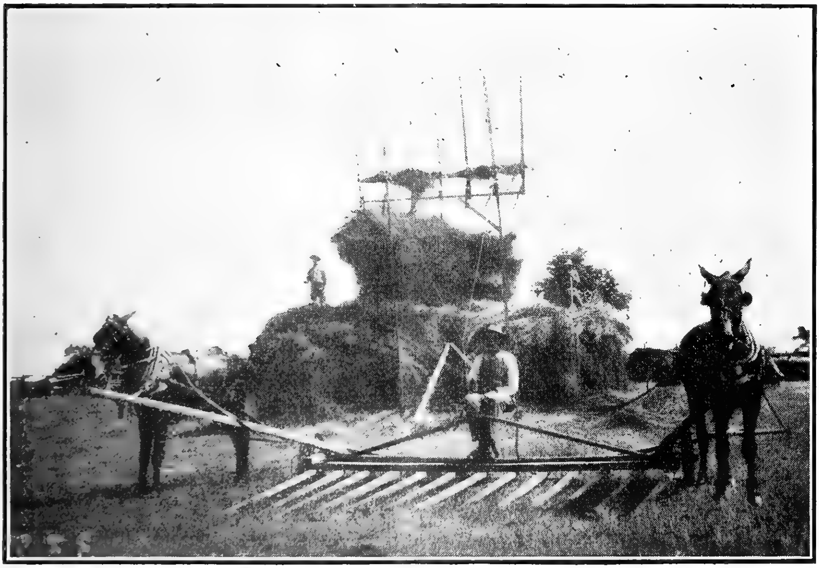

FIG. 15.—Buck-rake and hay-stacker commonly used where a considerable acreage of prairie hay is cut.

The use of straw as fuel involves the use of a larger amount of labor than where coal is used, as a fireman is required to feed the straw to the fire box almost continuously, and it is necessary to keep one man and team hauling the straw from stack to engine. Furthermore, the risk from fire is great, on account of the proximity of a load of straw to the engine and the danger from flying sparks.

Improvements and simplifications of the gas tractor have made it possible for many more farmers to use it now than formerly. No data are available as to the number of tractors on farms in North Dakota at present (1918), but among 37 representative farmers in the eastern half of the State, six owned and operated tractors for plowing and small amounts of other farm work.

The automobile now occupies an important place on North Dakota farms. Of 34 farmers, unselected, and located in the eastern half of the State, 27 operated cars of some kind, and one farmer kept two. The value of the car to the farm was determined largely by the distance from the market point.

WHAT CREWS CAN DO.

The amount of work that can be done in a normal day is important, especially in certain operations that must be done within a limited time. A very large part of the field work on North Dakota farms is done with one man and four horses. The number of acres per day covered by this crew in various operations is shown below:

	Acres per day.
Plowing	5
Harrowing	47
Disking	17
Drilling	20
Harvest wheat	16
Harvest oats	15
Harvest barley	16
Harvest flax	15

One man and five horses with a gang plow turn 5.2 acres per day and one man with six horses turns 5.5 acres per day.

A few farmers visited used three horses in harvesting wheat, and covered an average of 10.6 acres per day.

In shocking wheat one man can not quite keep up with a 4-horse binder, being able to set up 15.6 acres per day on the average. One man shocks 15.6 acres of oats or 17.8 acres of barley per day on the average.

In hauling grain to market one man and two horses haul an average of 132 bushels per day where the average length of haul is 6 miles. Two loads are hauled of approximately 65 bushels each. Where the distance is within 4 miles the average day's haul is 172 bushels (three loads) and within 2 miles, 312 bushels (five loads).

In haying, one man and two horses cut an average of 9 acres per day and rake 18 acres.

In stacking grain various crews are used, but the two most common are two men with one team and three men with two teams. The former crew stacks on the average 10.7 acres per day and the large crew stacks 14.3 acres of wheat of average yield of 12 bushels per acre.

There is a wide variation in the size of crew and proportion of men to teams in stacking hay, determined rather by the available labor than by efficiency of crews. The average amount of tame hay stacked, as reported by 15 farmers, was approximately 5 tons per day per man, and the average proportion of men to horses was approximately two men to three horses. The average yield of hay was 1.15 tons per acre and it was stacked in the field where the length of haul was short.

A very large part of the grain used for seed must be cleaned by running through a fanning mill before planting. Ordinarily this is a two-man job and in many cases the mill is run by motor. The following data relative to cleaning grain show the number of bushels per day that are cleaned:

	Bushels per day.
Wheat	108
Oats	119
Barley	92
Flax	29

DATES OF OPERATIONS.

Estimates from several hundred farmers, as well as actual records from several covering periods of from 12 to 30 years, indicate that, on the average, field work begins about April 18 and ends about November 6. These dates are subject to about 20 days' variation either way, depending upon the season. It happens not infrequently that some field work is done in March.

Any one of several operations may be the first done in spring. If plowing was done in the fall, either harrowing or disking may be done first, and seeding may follow within a day or two. Table V shows the most common dates between which the principal operations are performed. These dates are subject to some variation, depending upon the season, varieties of grains planted, etc. For example, oats are usually planted between April 26 and May 20, and are harvested generally a day or two ahead of wheat; if, however, a late variety of oats is planted the harvest may be 10 or 20 days later than the average.

TABLE V.—*Dates of operations on wheat, oats, barley, flax, corn, and potatoes.*

Crop.	Plowing (fall).	Plowing (spring).	Harrowing.
Wheat	Sept. 26–Oct. 17	Apr. 18–May 24	Apr. 18–May 28.
Oats	do	do	do.
Barley	do	do	do.
Flax	do	do	do.
Corn	do	do	do.
Potatoes	do	do	do.

Crop.	Disking.	Planting.	Harvesting.
Wheat	Apr. 18–May 19	Apr. 19–May 12	Aug. 10–Aug. 20.
Oats	do	Apr. 26–May 20	Aug. 8–Aug. 15.
Barley	do	May 12–May 28	Aug. 6–Aug. 13.
Flax	do	May 31–June 15	Sept. 1–Sept. 15.
Corn	do	May 20–June 10	Sept. 5–Sept. 25.
Potatoes	do	May 20–June 3	Sept. 20–Oct. 12.

It is scarcely possible to separate the dates of plowing and preparation of the land for the various crops, since these operations all overlap; furthermore, land that was plowed and prepared for a certain crop is often seeded to another on account of seasonal conditions, or for some other reason.

Thrashing is usually done in from one to three days on the average farm, and is generally from 25 to 35 days after the beginning of harvest. If flax is raised it sometimes happens that a separate job of thrashing is necessary because this crop is harvested much later than the others.

Farmers differ somewhat in opinion as to the latest safe seeding date in the spring for the various crops. The following dates are the averages of the estimates of over 200 farmers:

Wheat	May 12	Barley	June 3
Oats	May 21	Potatoes	June 6
Corn	May 28	Flax	June 11

Two important considerations should be taken into account in connection with these dates, namely, varieties and weather conditions. Varieties that mature quickly may be planted later than those requiring longer growing periods. When the spring season is very unfavorable, it is sometimes necessary to plant later than the above-indicated dates and take the risk of not maturing a crop.

Cultivation of corn and potatoes is usually done in June and July, the inclusive dates for corn being June 5 to July 15, and for potatoes from June 12 to July 30.

The number of days for the production of the various crops varies considerably. The following data show approximately the number of days from planting to harvest of the leading crops:

	Days to maturity.		Days to maturity.
Wheat	112	Potatoes	129
Oats	106	Flax	94
Barley	87	Millet	78
Corn	108		

The amount of time required from planting to harvest varies, depending upon the variety of grain; the above figures represent the average for the various crops produced on several farms covering periods of from 12 to 30 years. The season also has a marked effect on the length of time required. For example, the average season from seeding to harvest of wheat in 1910 was but 97 days, while the average for all years covered in the records is 112. The 1910 growing season was one of the driest on record for this area. Further, grain crops planted late in the season generally mature in a shorter time than the earlier planted crops; a difference of from 10 to 12 days is noted in the case of wheat and oats.

YIELDS.

Success in farming in North Dakota depends very largely upon yields, and the factors that affect yield are of interest to every farmer. Some of these factors are not under human control, but many of them are, and even the uncertain factors may be in some degree controlled by the prospective farmer by avoiding localities unfavorably situated.

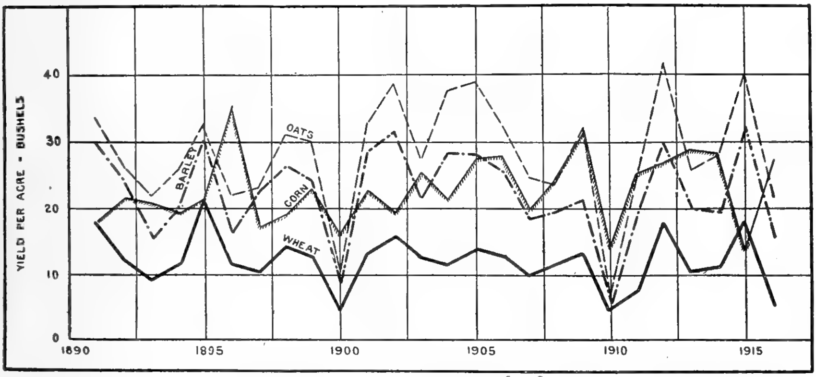

FIG. 16.—Yield per acre of wheat, oats, barley, and corn (North Dakota, 1891–1916).

Yields per acre of all crops vary from year to year for various causes. The lines in figure 16 show the average yields that have been made in the State from 1891 to 1916, inclusive. Wheat, of course, is of greatest importance. It generally happens that where low yields of this crop are made the production of other crops is also low. It is noted that there is a marked parallelism in the lines for wheat, oats, and barley; the corn line, however, does not follow the general order very closely.

Within the limits of the growing season, the yield of these crops of wheat, oats, and barley are dependent upon rainfall to a greater extent than upon any other factor. Corn is dependent upon rainfall also, but is affected very greatly by temperature. Its growing season is also different from that of the other grain crops.

The lines in figure 17 show the relation of rainfall to yield. The line at the bottom of the figure represents the combined rainfall in inches during the months of May and June for each year from 1891 to 1916, and the upper line is a crop index representing the yields of wheat, oats, and barley. It is noted that there is a marked parallelism in these lines, that is, where the rainfall is greatest the yields are uniformly largest. There are two exceptions to this order, one for 1896 and another for 1914. In both of these years there was a large amount of rainfall during May and June, in each case more than 8 inches falling in such short periods that much grain was drowned out. Three other years show rainfall during these months in excess of 8 inches, but so distributed as to cause increases rather than decreases in yields.

It should be noted that in 1900 and 1910 exceptionally low yields were made, owing to drought conditions. In 1900 the annual rainfall was about normal in the State (18.6 inches), the shortage of May and June being made up during the other months, but 1910 was very dry during the whole year, the total rainfall being but 12.4 inches.

Other data not here presented show that there is only a slight relationship between rainfall in April and yield. Neither is there any

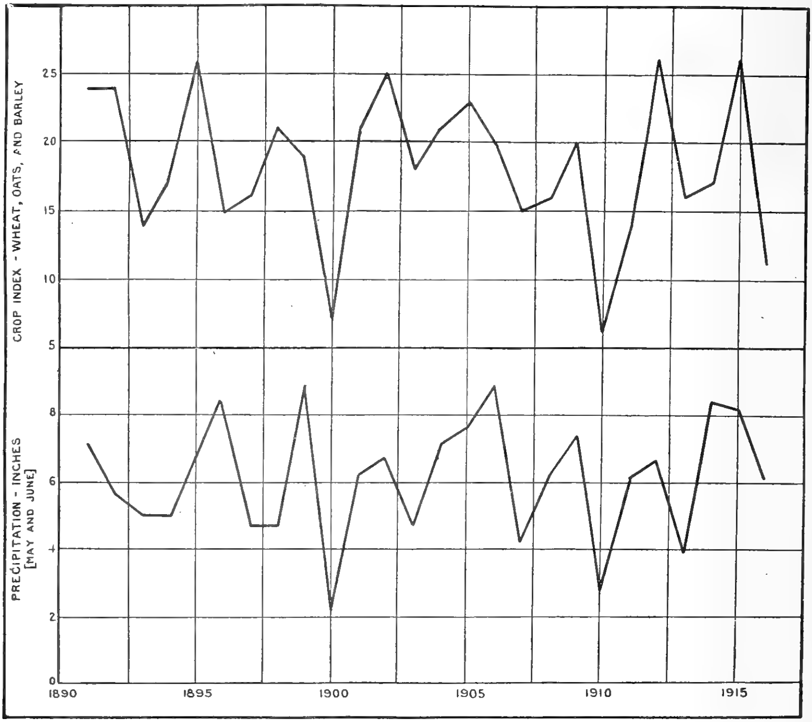

FIG. 17.—Relation of rainfall in May and June to yield per acre.

marked relation between annual rainfall and yield of these crops. May and June are the critical months. With a rainfall of 6 inches distributed over the months of May and June, at least normal crops may be expected.

TABLE VI.—*Yield per acre for various crops in North Dakota (Bureau of Crop Estimates' figures for 1891–1916, and records of actual yields obtained in this investigation for 1912–13–14).*

Source of figures.	Yield per acre (bushels).					
	Wheat.	Oats.	Barley.	Flax.	Corn.	Potatoes.
Bureau of Crop Estimates	12.3	28.1	22.4	[a] 8.6	22.8	95
This investigation	13.2	33.9	21.7	7.9	33.8	87

[a] Average 1902–1916 inclusive.

Table VI shows the average yield per acre of the leading crops of the State. There is a wide variation in yield from year to year and also between farms. The lowest yield of wheat recorded for the State is 4.9 bushels in 1900 and the next lowest 5 bushels in 1910. Other crops made their lowest yields also in these years.

RELATION OF LAND VALUE TO YIELD.

Little relation appears between the selling price of land and the yield per acre of wheat. Table VII shows the relation of land value to yield per acre for the three leading crops.

TABLE VII.—*Relation of land value to yield per acre of wheat, oats, and barley.*

[Figures are per acre.]

Wheat.		Oats.		Barley.	
Value of land.	Yield.	Value of land.	Yield.	Value of land.	Yield.
	Bushels.		*Bushels.*		*Bushels.*
$19	12	$23	28	$27	22
31	13	34	32	41	21
50	14	52	38	58	22

As previously pointed out, other factors than yield appear to determine the price of land in North Dakota. Land in the western part of the State, valued at $19 per acre, produced average yields of 12 bushels of wheat; while land in the Red River Valley, valued at $50 per acre, produced average yields of only 14 bushels. However, the risk in the western portion is many times greater than in the eastern, because of the fact that seasons of drought occur more frequently in a given period. This risk is reflected in the value of the land. Furthermore, the fact that the annual rainfall is approximately 6 inches greater in the eastern portion than in the western makes it possible to have a much wider diversification of crops and stock in the east than in the west.

RELATION OF TILLAGE TO YIELDS.

The operations in which an increase of labor may affect yield are plowing and the various operations of preparation, such as harrowing, disking, rolling, etc. The amount of labor used in seeding is practically the same on all farms, the ground being covered with a drill. The efficient plowing of the land is of prime importance. More depends upon proper plowing than upon any other operation. A few farmers were found who planted wheat without plowing, disking the seed into the stubble. These farmers made yields of 10 bushels or under per acre.

The amount of working of the soil required for best production is dependent largely upon the character of the soil and weather conditions. Under normal conditions tillage equivalent to one disking and twice over with the harrow gives better results than where greater or less amounts of labor are utilized. Frequently time is lacking for more than one harrowing, and when this is the case, yields are generally about 2 bushels of wheat per acre less than when the land is disked and harrowed twice.

The practice of going over the land with the harrow as soon as possible after each rain, conserves moisture and tends to increase yields. Where land is in a fair state of tilth after plowing, disking is omitted and care is exercised to conserve moisture by harrowing.

Leaving the land as rough as possible during the winter is advisable, as thus it catches and retains more snow than when the surface is smooth.

SUMMER-FALLOWING.

Summer-fallowing is practiced by comparatively few farmers, since experience has shown very little difference in net returns between this method and that of planting a crop each year. In some cases this method is advisable, particularly where the land is weedy, as clean cultivation for a season will eradicate many of them. In general, however, summer-fallowing does not appear as profitable for North Dakota as crop production each year.

FALL VERSUS SPRING PLOWING.

In so far as yield is concerned, it appears that, in general, it makes very little difference whether the land is plowed in fall or spring. Weather conditions may cause one method to be highly desirable in one year while in another the same practice may prove a poor one. Among nearly 100 farmers, 60 plowed for wheat in the fall and the remainder plowed in the spring. Records from a number of farms indicate on the fall-plowed land a yield of 13.1 bushels and on the spring-plowed 13.6 bushels per acre. With oats and barley slightly larger yields are made by fall than by spring plowing, a difference of from 4 to 6 bushels being noted. However, only 18 farmers out of 90 plowed in the fall for these crops.

Aside from the question of yield, there is a very great advantage in plowing in the fall where possible. The period for plowing, preparation, and sowing in the spring is short, and plowing is the operation that requires most time. Even though the weather may be disagreeable in the fall, as much plowing should be done after harvest and thrashing as possible, since it makes a much more even distribution of labor and makes it possible to seed at the earliest possible date in the spring.

SEED.

Within certain limits little difference in yield of grain is caused by sowing different amounts of seed. Much depends upon the season in this regard, small amounts of seed giving better results in dry seasons, because there may not be sufficient moisture to mature a heavy stand, while a light stand may come to full maturity. The more space allowed each plant the greater the amount of stooling, so that where grain is sown thin, more stalks of grain mature from the same individual seed than where a thick planting is made.

The amount of seed commonly sown per acre, and which produces the best yields in the average, falls between the following limits:

		Minimum.	Maximum.
Wheat	bushels	1.0	2.0
Oats	do	1.5	2.5
Barley	do	1.3	2.0
Flax	do	.4	.7

STUBBLING-IN GRAIN.

The practice of disking grain in the stubble of the previous crop without plowing is followed to some extent, and information was obtained from 136 farmers in 35 counties of North Dakota as to the profitableness of the practice. The following is a summary of the information obtained:

112 farmers reported the practice as without profit.
33 farmers reported one-fourth to one-half normal yield.
28 farmers reported a marked increase in weeds.
13 farmers reported normal yield when previous crop was properly tilled.
7 farmers reported normal yield under any previous condition.
10 farmers reported the plan satisfactory only for rye.

A few scattered farmers reported that it is more profitable to summer-follow than to stubble-in grain. Others reported that it is more profitable to let the land lie idle than to stubble-in, since stubbling-in often fails to return the equivalent of the seed sown.

Three principal arguments are used in favor of the practice: (1) A saving is made in time and cost of preparation and in consequence a larger area can be seeded; (2) stubble of the previous crop left over the winter catches and holds snow; and (3) the quality of the grain is said to be better from stubbling-in than from planting on plowed ground.

There are several serious disadvantages: (1) Low yields, from one-fourth to one-half of normal; (2) fields dry out rapidly, as less moisture is absorbed than by plowed ground; (3) the ground is harder to plow the following year; (4) a much shorter straw is made; and (5) weeds and insects are increased materially by the practice.

Ground previously planted to potatoes, corn, or flax appears to give best returns if grain is sown without previous plowing for the crop.

In general, it would seem that the practice of stubbling-in is not to be advocated except possibly in the case of winter rye. Many farmers in the eastern part of the State believe that stubbling-in rye is entirely justified.

ROTATION.

Hitherto very little consideration has been given to the subject of crop rotations by the farmers of North Dakota. Of 40 farmers interviewed on this subject, only 12 gave any information as to order of planting crops, the greater number stating that they gave little or no attention to the matter. A few said that they changed from one crop to another as often as possible. Only seven farmers, and these in widely separated counties, were found who followed a fairly uniform system of rotation. These men adhered as closely as possible to this order: Barley, 1 year; wheat, 1 year; oats, 1 year; summer fallow or intertilled crops, 1 year.

The greatest difficulty in establishing a system of rotation is the fact that the type of farm is based on a one-crop system, wheat production occupying such a large part of the farm area. However, the increase of stock production is materially remedying the situation, and tame hay and other feed crops are occupying larger and larger percentages of farm areas. Alfalfa, timothy, and clover, and corn are now of some importance, though 10 years ago these crops were scarcely known in the State.

Thus far no serious decrease in yields, due to depletion of the soil, has been noted in North Dakota. New land, that is, land that has never produced anything but prarie grass, is being brought into cultivation every year in all parts of the State, with the possible exception of some of the Red River Valley counties. As long as this condition prevails and wheat occupies so large a proportion of the crop land, rotations will hardly be given serious consideration by the farmers.

MANURE.

A decade ago scarcely any manure was applied to the land, because there was little to apply. Practically the only stock on the farms were work animals. At present, however, from 5 to 50 animal units[1] of productive stock or even more, besides the work animals, are found on every farm, so that the amount of manure now produced annually is worthy of consideration. In general, on the average farm of 640 acres, manure is applied to 30 acres or more every

[1] An animal unit is a mature horse or cow or as many smaller animals as require the feed of a horse or cow, approximately 2 young cattle, 5 hogs, 7 sheep, or 100 hens.

year. This factor is and will continue to be of great importance in maintaining yields within the State.

There has been a marked improvement in the utilization of straw within the last 10 years. Formerly, it was a common sight at night in the late summer or fall to see from 50 to 100 straw piles burning within the circle of the horizon. At present the amount of straw burned is greatly reduced, since its value as feed, and as fertilizer when rotted, is becoming better understood.

SUMMARY OF COST FACTORS.

In order that a basis may be available for determining the values of various items that enter into the cost of production of grain in North Dakota, the various cost factors for the four leading crops are summarized in Table VIII. Practice varies from farm to farm, but the figures given are based on 350 farm records, and may be taken as representative.

TABLE VIII.—*Summary of items entering into the cost of raising wheat, oats, barley, and flax in North Dakota.*

	Wheat	Oats.	Barley.	Flax.
Seed, bushels per acre	1.2	2.0	1.7	0.5
Man labor, days per acre	.64	.74	.71	.66
Horse labor, days per acre	1.94	2.09	2.11	2.33
Use of machinery, per acre	18 per cent of first cost divided by number of crop acres in farm.	Same as for wheat.	Same as for wheat.	Same as for wheat.
Twine, pounds per acre	1.78	1.88	1.75	1.33
Thrashing, cents per bushel	10 (15)	6 (9)	6 (10)	20 (35)
Management	$1.09 per man day on crop.	Same as for wheat.	Same as for wheat.	Same as for wheat.
Use of land, per acre	6 per cent of land value.	.....do......	.....do......	Do.
Manure, tons per acre	0.65	.....do......	.....do......	Do.

"Man labor, days per acre" and "Horse labor, days per acre" include all the work done upon the respective crops except thrashing, which is accounted for in the direct thrashing charge per bushel. Among the items included in the labor are plowing, disking, harrowing, planting, cutting and shocking, hauling grain from thrashing machine, and hauling grain from farm to elevator. In cases in which time was occupied in cleaning and treating grain or by any other operations in connection with the crops, this labor has been included.

Under "Use of machinery" it is found that the sum of interest on investment, depreciation cost, and repair cost amounts to 18 per cent of the new value of the equipment utilized on the farm, excluding from all calculations tractors, thrashing rigs and automobiles. Since all crops require so nearly the same use of machinery, as indicated by the amount of horse labor expended on each, the machinery cost per acre is approximately the total cost divided by the total number of acres under cultivation on the farm. If a tractor is used for any operation, a separate charge should be made for this item. The usual prices charged in custom thrashing have been used; this covers all costs for the use of machinery in this operation. The use of the automobile is of undoubted benefit to the farm business on the average farm; however, the automobile is used to a considerable extent for pleasure purposes, and although a number of farmers were found who were willing to make an estimate of the benefit that the car is to the farm business, not enough data are available to justify presenting figures in this connection.

Under the item "Thrashing, per bushel" two figures are given for each crop, the first in each case being the average charge for the period 1911–1916, and the second, the 1917 charge.

Since manure is utilized on many farms, a charge should be made against the crops for this fertilizer. It has previously been pointed out that, on the average, approximately 30 acres are covered with manure each year on the farm of 640 acres. Assuming an annual application of approximately 10 tons per acre, this application is equivalent to 0.65 tons per crop acre. This distribution of the charge is justified, inasmuch as the benefits from the manure accrue for several years after application and the object is eventually to cover the whole farm.

COSTS FOR 1917 AS COMPARED WITH PREWAR COSTS.

In Table IX are shown the relative costs of the various items entering into farm operation for the period 1911-1916 and for 1917, on a representative farm having a total acreage of approximately 640, with an organization and equipment that approaches the average very closely.

It will be noted that there is an increase in the cost of every item, the increases being particularly noticeable in the case of seed for planting and in the value of machinery. The cost of "Labor per productive day of work" is determined by ascertaining the total cost of all hired labor by the day or month, together with the labor done by the family at average rates, and dividing the sum of these by the total number of days of productive work done per farm per year. By productive work is meant that which is applied directly to an enterprise such as wheat production or stock raising, etc. All other labor, such as that necessary for the general upkeep of the farm, is considered as overhead expense, and is paid for in the labor by the day or month, or is pro-rated to the various productive enterprises. The increase noted in the cost of a productive day's work corresponds to the increase in the cost of labor by the day or month as indicated.

The increase in the value of farm machinery is 40 per cent, but additional information (1918) indicates that even greater advances have been made.

Concerning work stock, feed costs are the only costs that have advanced recently, so that depreciation in work stock may be considered as indicated on page 15. The difference in annual cost of work stock between $105 and $145 represents the increased cost of feed.

Table I.—Cost of various factors entering into cost of production of crops on a representative farm in North Dakota for 1911–1916 and for 1917.

Factors entering into cost of production.	Cost 1911-1916.	Cost 1917.	Factors entering into cost of production.	Cost 1911-1916.	Cost 1917.
Seed cost (per bushel):			New value of machinery [a]	1,757.00	2,473.00
Wheat	$1.23	$2.28	Feed for work stock:		
Oats	.47	.70	Oats, per bushel	.39	.61
Barley	.72	1.19	Hay, per ton	6.65	9.77
Flax	2.23	3.36	Manure, per ton	1.00	2.00
Hired labor:			Thrashing, (per bushel):		
Per month	35.00	45.00	Wheat	.10	.145
Per day	2.44	3.16	Oats	.06	.087
Labor per productive day of work	2.20	2.83	Barley	.06	.094
			Flax	.20	.35
Farm cost of board per month	15.70	22.80	Twine, per pound	.118	.18
Farm cost of board per productive day	.89	1.29			

[a] Does not include tractors, thrashing rigs, or automobiles.

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HENRY S. GRAVES, Forester

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PULPWOOD CONSUMPTION AND WOOD-PULP PRODUCTION IN 1917.

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CONTENTS.

INTRODUCTION.

This bulletin covering the year 1917 is the second of a series presenting detailed statistics on pulpwood consumption and wood-pulp production in the United States. The first was for 1916, and the figures for the two years are directly comparable. Similar statistics were compiled by the Forest Service for 1905 and for the period 1906–1911 in cooperation with the Bureau of the Census. The Bureau of the Census published figures for 1914 in connection with the census of manufactures.

The cooperation of the News-Print Manufacturers' Association in the collection and compilation of the statistics in 1916 was continued by the News-Print Service Bureau in 1917.

A return was made by every pulp mill solicited to make a report. The complete and cordial cooperation of the mills, particularly in view of the additional calls for information and the reduced clerical forces, is an evidence of the need of such statistics and of the convenience to the manufacturers of the form in which they are presented.

NOTE.—Acknowledgment is made for assistance in the collection and compilation of the statistics and in the review of the report to R. S. Kellogg, secretary of the News-Print Service Bureau, and Albert H. Pierson, of the Forest Service.

PULPWOOD CONSUMPTION AND WOOD-PULP PRODUCTION, 1917.

A total consumption in 1917 of 5,480,075 cords [1] of pulpwood was reported by 241 establishments, an increase of 251,517 cords, or 5 per cent, over the estimated total consumption in 1916. The imported spruce and aspen formed 14 per cent of the quantity used in 1917, in comparison with 15 per cent for the year before.

The production of wood pulp totaled 3,509,939 tons—an increase of 74,938 tons, or 2 per cent, over the 1916 reported total output. The quantity manufactured by the mechanical process was 1,535,953 tons, by the sulphite process 1,451,757 tons, by the soda process 437,430 tons, and by the sulphate process 84,799 tons. The quantity of mechanical pulp produced was 2 per cent, that of soda pulp 13 per cent, and that of sulphate pulp 15 per cent more than in 1916. The output of sulphite pulp was 1 per cent under that of the previous year.

The production of pulp was increased by the manufacturers under industrial conditions that were in reality conducive to decreased production. Not only did the cost of practically every material, inclusive of pulpwood, advance, but grave and discouraging problems were met with in securing and holding an adequate supply of labor, in procuring fuel for operation of plants, and in the transportation of both the raw and finished product. War enlarged rather than diminished the demand for pulp for ordinary purposes and at the same time developed additional uses for pulp and paper. Imports of wood pulp were practically as great as for the preceding year, despite the fact that total receipts from overseas were lighter because of war-time shipping conditions.

PULPWOOD CONSUMPTION.

In Table 1 are presented the figures on the consumption of pulpwood, by each kind of wood used, for four calendar years, 1909, 1914, 1916, and 1917. The use of both domestic and imported spruce shows a decline in 1917 from 1916, attributable perhaps to the more restricted supply available and to the possibilities attached to the cheaper species. Some of the less important species, such as balsam fir, yellow pine, tamarack, and the group of hardwoods—beech, birch, chestnut, and maple—were consumed in considerably greater quantity than during the previous year. Taken as a whole the figures for 1917 do not indicate any marked or significant changes, other than those referred to, from the statistics for 1916. While the consumption figures for the entire country are greater for 1917 than for 1916, decreases, which are mostly slight in character, are revealed (see Table 5) in individual State totals. In New York the

[1] Cord=128 cubic feet.

decrease was 3 per cent, New Hampshire 1 per cent, Pennsylvania 2 per cent, Minnesota less than 1 per cent, and West Virginia 6 per cent. On the other hand, increased consumption over the preceding year reached 9 per cent in Maine, 8 per cent in Wisconsin, less than 1 per cent in Michigan, 105 per cent in North Carolina, 7 per cent in Virginia, 25 per cent in Vermont, 102 per cent in Massachusetts, 1 per cent in California, Oregon, and Washington, and 20 per cent in all other States. (See Table 1, Appendix.)

ANNUAL WOOD CONSUMPTION AND COST.

Table 2 contains figures on the consumption of pulpwood for 1899 and for the years from 1905 to 1917 for which statistics are available. Total cost figures for 1910 and 1911 were not compiled. The consumption data reveal an almost unbroken annual increase, while the total cost figures emphasize the growing yearly expenditures made by the manufacturers. (See Table 2, Appendix.)

CONSUMPTION OF WOOD BY SPECIES AND STATES.

Pulpwood consumption by kinds of wood by the mills in the several States is detailed in Table 3. The importance and value of spruce for pulp is indicated by the fact that a greater quantity is used than of any other one wood, and that its use is reported in nearly all of the States. Spruce formed 56 per cent, hemlock 14 per cent, and poplar 7 per cent of all the pulpwood consumed. The use of certain woods, such as yellow pine, tamarack, white fir, Douglas fir, basswood, and white pine, is confined to the regions to which these species are indigenous.

As during the previous year, considerable spruce in log form that ordinarily would have gone to the sawmills was diverted to the pulp mills because of the higher prices paid by the latter.

Continued rise in wood prices will accelerate the tendency among the mills to utilize all the species available and will serve further to stimulate improvements in production to permit the use of woods of comparatively small pulp value. The 233,982 cords of slabs and other mill waste used in 1917 was 33,138 cords, or 16 per cent, in excess of the quantity reported in 1916. (See Table 3, Appendix.)

CONSUMPTION OF WOOD BY PROCESSES OF MANUFACTURE.

Table 4 shows the consumption of wood by kinds and by processes of manufacture. Of the 5,480,075 cords converted, 28 per cent went into the production of ground wood pulp, 53 per cent into sulphite, 15 per cent into soda, and 4 per cent into sulphate. The spruce, as shown by the tabulation, is about evenly reduced as between the mechanical and sulphite processes, while 89 per cent of the hemlock is reduced by the sulphite process, and 93 per cent of the poplar by the soda process. (See Table 4, Appendix.)

AVERAGE AND TOTAL COSTS OF WOOD.

Comparative figures for 1909, 1916, and 1917 are given in Table 5 on the number of establishments reporting, the quantity, average cost f. o. b. mill, and the total cost of the wood consumed, and the number of tons of wood pulp reported produced. The 1916 and 1917 figures are closely aligned, since the basis of collection and compilation was the same for each year; the 1909 statistics are reproduced to permit of the changes for the nine-year period being more readily noted.

A noteworthy advance of $2.34—from $8.76 to $11.10, or 27 per cent—took place from 1916 to 1917 in the average cost per cord of wood f. o. b. mill. The average given is secured by a weighted or statistical computation and is based upon the average cost of approximately 90 per cent of all the wood reported consumed. No figures in this publication are likely to be more commented upon or questioned as to their correctness when compared directly with actual cost data of a single operation or a group of mills. The fact is therefore emphasized that the average cost figure was determined from pulp mill costs involving long and short hauls, rail or water hauls, or a combination of both, wood purchased in the open market, cut under old and new contracts, or taken from long held lands and for which but a nominal book charge was made. All species are represented and no distinction is made for the rough, peeled, and rossed wood. The per cent of increase in average value for the several States ranged from 13 per cent for the group of "all other States" to 56 per cent in North Carolina. The advance in Minnesota was 54 per cent, in New Hampshire 41 per cent, and in New York, Pennsylvania, West Virginia, and Vermont between 30 and 40 per cent. (See Table 5, Appendix.)

RANGE OF PULPWOOD PRICES.

Table 6 is presented to show more clearly the range of prices paid by the mills for wood according to its condition—rough, peeled, and rossed, and for slabs and other mill waste. Few mills out of the total number reporting costs got their supply of pulpwood for less than $6 per cord; two mills paid between $25 and $26 per cord for their wood. The bulk of the mills paid somewhere between $10 and $20 per cord, and the average for the country as a whole was $11.10. (See Table 6, Appendix.)

QUANTITY AND COST OF WOOD BY CONDITION.

Wood as delivered to the mill is referred to as rough, or with the bark intact, or as peeled and rossed, either of the two latter adding to the cost. In Table 7 are given, by States, the quantity, average cost, and total cost for the pulpwood according to the condition in which it was reported delivered to the mill. Of the wood consumed 46 per cent was in the rough, 41 per cent peeled, 9 per cent rossed, and 4 per cent in the form of slabs and other mill waste. In 1916, 34 per cent was in the rough, 51 per cent peeled, 11 per cent rossed, and 4 per cent slabs and mill waste.

Considerable variation exists in the average cost of the wood by reason of its treatment. For rough the average was $9.67 per cord, for peeled $11.91. for rossed $17.03, and for slabs and other mill waste $6.14. (See Table 7, Appendix.)

CONDITION OF WOOD BY SPECIES.

In Table 7 is shown the condition of pulpwood as delivered to the mill, arranged by States; in Table 8 the data are presented by kinds of wood. Of the domestic spruce 57 per cent is rough, 34 per cent peeled, and 9 per cent rossed; in imported spruce 18 per cent is rough, 49 per cent peeled, and 33 per cent rossed. In hemlock 79 per cent is rough, 20 per cent peeled, and 1 per cent rossed. Spruce, hemlock, and balsam fir are the only woods which are reported rossed. All of the imported poplar, yellow poplar, gum, Douglas fir, and basswood was peeled. (See Table 8, Appendix.)

DISTANCE OF PULPWOOD HAULS.

The belief prevails in the pulp and paper industry that the distance between the source of the pulpwood supply and the place of its manufacture grows greater with each succeeding year. Figures for a number of individual plants give weight to the assumption, but proof is lacking for the industry as a whole. In order that this important phase of operation might be recorded, the schedule employed by the Forest Service in making the 1917 census carried a question as to the approximate average distance between the source of supply of pulpwood covered by the report and the mill at which it was consumed. The data are shown in Table 9 arranged according to distance zones for the five principal pulp-producing States. The figures are truly representative, since the quantity of wood referred to by distance for each State amounts to 80 per cent or more of the total quantity reported consumed in that State, an exception being noted for New Hampshire alone, where the quantity of wood included in the distance tables is but 28 per cent of all the wood reported consumed. In Maine more than 60 per cent of the quantity reported upon was transported less than 150 miles; in New York 40 per cent was hauled between 300 and 500 miles; in Wisconsin 32 per cent was shipped between 150 and 200 miles and an additional 30 per cent under 150 miles; in New Hampshire 39 per cent was moved less than 25 miles and another 54 per cent between 25 and 50 miles; in Pennsylvania 32 per cent was carried between 600 and 1,000 miles and 27 per cent between 250 and 400 miles, the remainder between 100 and 250 miles. Taking the States as a whole, approximately 54 per cent was transported under 150 miles and another 35 per cent between

150 and 400 miles. Unfortunately, no comparative data are available for preceding periods. (See Table 9, Appendix.)

WOOD-PULP PRODUCTION.

The production figures on wood pulp are given in detail in Table 10. The total output reported was 3,509,939 tons [1], of which 44 per cent was mechanical, 41 per cent sulphite, 13 per cent soda, and 2 per cent sulphate. The production of pulp in 1917 was 2 per cent more than in 1916, the mechanical pulp figures representing a 2 per cent increase, those for soda pulp a 13 per cent increase, and those for sulphate pulp a 15 per cent increase, while those for sulphite pulp are a 1 per cent decrease from the 1916 statistics. Of the mechanical pulp turned out 87 per cent was not steamed, and 13 per cent was steamed. In the production of sulphite pulp, 69 per cent was unbleached and 31 per cent bleached; in soda pulp 8 per cent was unbleached and 92 per cent bleached; in sulphate pulp, 83 per cent was unbleached and 17 per cent bleached. Maine, New York, Wisconsin, New Hampshire, Pennsylvania, and Minnesota are the leading States in pulp production in the order given and in 1917 produced collectively 79 per cent of all the pulp reported. (See Table 10, Appendix.)

The output of pulp was generally larger for all the States in 1917 than the year before, the exceptions being in New Hampshire where the decrease was 25 per cent, Pennsylvania 1 per cent, Michigan 3 per cent, and West Virginia 7 per cent. It already has been noted that less wood was used in New Hampshire, Pennsylvania, and West Virginia, which is in line with decreased pulp production even though the relation of quantity of wood consumed to pulp produced is variable.

Pulp manufacturers were asked to give the average value f. o. b. mill of all pulp sold, and the computations which have been made are based upon the reported value of approximately 90 per cent of all the pulp sold. The value of a ton of pulp is established by its quality and is further affected by competitive conditions, contractual relations, intercompany accounting methods, and other factors which make the application of an average value or sale price to any individual operation impracticable without due allowances being made. The mathematical average value for all pulp in 1917 was $43.33, an increase of $7.86 per ton, or 22 per cent, over the 1916 average. A considerable spread exists between the value of unbleached and bleached pulp, amounting to $30.27 per ton for sulphite, $6.55 for soda, and $14.85 for sulphate. The spread is much less for steamed and not steamed mechanical pulp, reaching but $2.73 per ton.

Figure 1 shows the importance of the several States in the production of pulp.

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[1] Short ton—2,000 pounds.

IMPORTS AND EXPORTS OF PULPWOOD, WOOD PULP, AND PAPER.

Tables 11 to 15, inclusive, are transcripts of statistics compiled by the Department of Commerce and are of importance in connection with this report because of their showing of the annual imports of pulpwood, and the imports and exports of wood pulp and paper. Revised classifications effected during the periods covered by the tables account for the omissions and regroupings.

IMPORTS OF PULPWOOD.

In Table 11 is shown the annual imports of pulpwood for the last eight calendar years. The figures given in the table showing importations of 1,031,934 cords in 1917 are at variance with the figures in Table 1, giving the combined consumption of imported spruce and poplar as 867,301 cords. This difference is due to the fact that the Forest Service figures are for spruce and poplar consumption alone, while the statistics in Table 11 cover all pulpwoods imported.

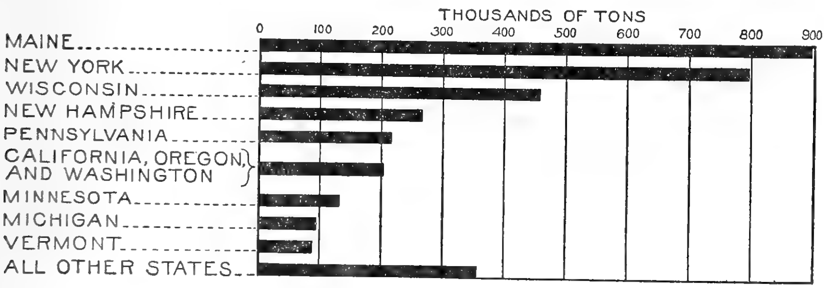

FIG. 1.—Production of pulp in the United States, by States.

Further, all of the pulpwood imported during one calendar year may not be used during the same year but stored for future consumption. The number of cords imported in 1917 was less by 65,643 cords, or 6 per cent, than in 1916. The average value of $8.30 per cord for the imported wood for 1917 is an increase of 27 per cent over the previous year. (See Table 11, Appendix.)

IMPORTS OF WOOD PULP.

The total importations of wood pulp in 1917 (Table 12) were 1 per cent less than those of 1916, but in excess of any other one of the years for which figures are given. There was a remarkable increase of 58 per cent—from $44.02 to $69.36—from 1916 in the average value per ton. The value is more than double that for 1915 or any other of the preceding years shown. In sharp contrast to this, the average value of domestically produced pulp advanced only 22 per cent. (See Table 12, Appendix.)

EXPORTS OF WOOD PULP.

Wood-pulp exports in 1917, as shown in Table 13, total 34,695 tons and were 3 per cent under those in 1916. Shipments were largely to Canada, England, Japan, and Argentina. There has been a decided acceleration in exports since the beginning of hostilities in Europe in 1914. A jump was made in the average value per ton of export pulp even greater than that in the value of imported pulp. The value rose from $59.37 in 1916 to a flat $100 in 1917, an advance of 68 per cent. (See Table 13, Appendix.)

IMPORTS OF NEWS PRINT AND OTHER PAPER.

A material increase in the imports of news print paper in 1917 over the imports of the previous year is shown in Table 14. The total quantity imported was 1,118,225,912 pounds, an increase of 19 per cent over 1916. The mathematical average value of the imported news print in 1916 was 1.98 cents per pound; in 1917 it was 2.76 cents per pound, an increase for the year of 39 per cent. While news print imports increased in 1917, the imports of all other printing paper fell off 67 per cent from the year before, and the imports of wrapping paper 6 per cent. (See Table 14, Appendix.)

EXPORTS OF NEWS PRINT AND OTHER PAPER.

Exports of news print paper in 1917 amounted to 187,780,747 pounds and were 22 per cent more than those recorded for 1916. The exports were equal to 27 per cent of the total imports of news print, showing that 83 per cent, or 930,445,165 pounds, of the total imports went into domestic consumption. Exports of all other printing paper declined 24 per cent in comparison with 1916, and exports for wrapping paper 37 per cent. Export figures are shown in Table 15, Appendix.

APPENDIX.

TABLE 1.—*Pulpwood consumption: Quantity of wood consumed by kinds, with per cent of distribution, 1909, 1914, 1916, and 1917.*

Kind of wood.	1917		1916		1914		1909	
	Quantity (cords).	Per cent distribution	Quantity (cords).	Per cent distribution	Quantity (cords).	Per cent distribution	Quantity (cords).	Per cent distribution
Total	5,480,075	100.0	5,228,558	100.0	4,470,763	100.0	4,001,607	100.0
Spruce:								
Domestic	2,385,966	43.5	2,399,993	45.9	1,892,739	42.3	1,653,249	41.3
Imported	681,450	12.4	701,667	13.4	768,056	17.2	768,332	19.2
Hemlock	775,003	14.1	760,226	14.6	602,754	13.5	559,657	14.0
Poplar:								
Domestic	313,955	5.7	329,370	6.3	328,513	7.3	302,876	7.6
Imported	92,298	1.7	82,326	1.6	61,644	1.4	25,622	.6
Balsam fir	382,036	7.0	301,032	5.8	125,296	2.8	95,366	2.4
Yellow pine	142,094	2.6	90,310	1.7	141,350	3.2	90,885	2.3
Jack pine	75,382	1.4	80,068	1.5	(1)	......	(1)	......
Tamarack	58,732	1.1	33,271	.6	15,320	.3	(2)	......
Yellow poplar	41,155	.7	37,974	.7	(3)	......	(3)	......
White fir	33,181	.6	49,425	1.0	39,648	.9	37,176	.9
Cottonwood (poplar)	32,993	.6	22,211	.4	18,176	.4	36,898	.9
Gum	32,513	.6	37,391	.7	11,935	.3	(2)	......
Basswood	3,807	.1	11,481	.2	(2)	......	(2)	......
White pine	3,562	.1	2,545	(5)	(2)	......	(2)	......
Beech, birch, chestnut, and maple [6]	183,317	3.3	[4] 77,762	1.5	(2)	......	(2)	......
All other species	8,649	.2	10,662	.2	211,436	4.7	182,569	4.6
Slabs and other mill waste	233,982	4.3	200,844	3.9	253,887	5.7	248,977	6.2

[1] Included in "yellow pine."
[2] Included in "all other species."
[3] Included in "domestic poplar" previous to 1916.
[4] Not including "chestnut."
[5] Less than one-tenth of 1 per cent.
[6] Mills keep no separate record of species.
[7] 1909 figures=Bureau of the Census and Forest Service.
[8] 1914 figures=Bureau of the Census.
[9] 1916 figures=Forest Service.
[10] 1917 figures=Forest Service.

TABLE 2.—*Annual consumption of pulpwood and total cost for specified years.*

Year.	Consumption (cords).	Total cost.
1899	1,986,310	$9,837,516
1905	3,192,123	17,735,665
1906	3,661,176	26,411,887
1907	3,962,660	32,360,276
1908	3,346,953	28,047,473
1909	4,001,607	34,477,540
1910	4,094,306	....
1911	4,328,052	....
1914	4,470,763	39,408,453
1916	5,228,558	[1] 45,785,682
1917	5,480,075	60,815,057

[1] Not including cost of slabs and other mill waste in Louisiana, Massachusetts, North Carolina, and Virginia.

TABLE 3.—*Pulpwood consumption: Quantity of wood consumed, by kinds and States, 1917.*

	Number of establishments.	Total.	Spruce.		Hemlock.	Poplar.		Balsam fir.	Yellow pine.	Jack pine.	Tamarack.	Yellow poplar.	White fir.	Cottonwood (poplar).	Gum.	Basswood.	White pine.	Beech, birch, chestnut and maple.	All other.	Slabs and other mill waste.
			Domestic.	Imported.		Domestic.	Imported.													
		Cords.	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords*	*Cords.*
United States	241	5,480,075	2,385,966	681,450	775,003	313,955	92,298	382,036	42,094	75,382	58,732	41,155	33,181	32,993	32,513	3,807	3,562	183,317	8,649	233,982
Maine	33	1,309,239	920,357	85,496	8,098	190,871	19,007	60,934		45										24,431
New York	79	1,056,556	465,880	355,977	35,944	48,950	61,236	75,395								3,698				9,476
Wisconsin	38	805,490	197,976	33,628	443,666	3,767		63,097		7,708	48,641			65			212			6,730
New Hampshire	11	416,553	198,545	79,293	230	1,199		137,129												157
Pennsylvania	14	415,776	20,000	93,424	10,985	8,914	12,029	6,000	7,574	64,698		3,580			21,357	109	753	98,690		67,663
Minnesota	6	205,026	204,623					403												
Michigan	11	187,117	58,485	10,046	50,373	1,583		25,702		2,931	10,091						2,597			25,309
Virginia	7	141,579	66,200		18,400				18,935			36,844								1,200
West Virginia	5	119,918	70,704		23,774	1,832														23,608
Vermont	10	109,616	86,247	8,360	1,341	1,201	26	12,441												
California, Oregon, and Washington [1]	8	262,294	58,490		148,444								33,181	14,742					7,437	
All other States [1]	19	450,911	38,459	15,226	33,748	55,638		935	115,585			731		18,186	11,156			84,627	1,212	75,408

[1] Includes Delaware, District of Columbia, Georgia, Louisiana, Maryland, Massachusetts, North Carolina, Ohio, South Carolina, Tennessee, Texas, and Vermont.

TABLE 4.—*Pulpwood consumption: Quantity of wood consumed, by kinds and processes of manufacture, 1917.*

	Aggregate quantity.	Reduced by—			
		Mechanical process.	Sulphite process.	Soda process.	Sulphate process.
	Cords.	*Cords.*	*Cords.*	*Cords.*	*Cords.*
Total	5.480,075	1,553,633	2,892,322	843,048	191,072
Spruce:					
Domestic	2,385,966	1,076,027	1,290,817	4,890	14,232
Imported	681,450	264,570	415,870	1,010	
Hemlock	775,003	55,628	689,703	11,069	18,603
Poplar:					
Domestic	313,955	21,009	1,748	291,198	
Imported	92,298	508	3,522	88,268	
Balsam fir	382,036	98,225	262,478	924	20,409
Yellow pine	142,094	11,477	5,724	50,816	74,077
Jack pine	75,382	6,001		64,698	4,683
Tamarack	58,732	12,393	4,784		41,555
Yellow poplar	41,155			41,155	
White fir	33,181	2,646	30,535		
Cottonwood (poplar)	32,993	131	58	32,804	
Gum	32,513			32,513	
Douglas fir	7,421			7,421	
Basswood	3,807			3,807	
White pine	3,562	212		753	2,597
Sycamore	1,212			1,212	
Cedar	16		16		
Beech, birch, chestnut, and maple	183,317			183,317	
Slabs and other mill waste	233,982	4,806	187,067	27,193	14,916

TABLE 5.—*Pulpwood consumption: Number of mills, quantity and cost of wood consumed, with average cost per cord and quantity of wood pulp produced by States, 1909, 1916, and 1917.*

State.	Year.	Wood consumed.				Wood pulp produced (tons).
		Establishment (number).	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	
United States	1917	241	5,480,075	$11.10	$60,815,057	3,509,939
	1916	230	5,228,558	8.76	[1] 45,785,682	3,435,001
	1909	253	4,001,607	8.62	34,477,540	2,491,406
Maine	1917	33	1,309,239	11.31	14,813,387	898,798
	1916	32	1,198,753	9.09	10,891,247	852,276
	1909	37	903,962	9.15	8,267,958	603,852
New York	1917	79	1,056,556	14.45	15,270,142	798,616
	1916	95	1,094,513	11.05	12,098,608	787,397
	1909	90	921,882	10.45	9,630,575	686,323
Wisconsin	1917	38	805,490	8.79	7,083,173	456,129
	1916	38	743,595	7.70	5,729,044	451,651
	1909	37	576,019	7.46	4,294,229	324,509
New Hampshire	1917	11	416,553	13.78	5,738,883	257,645
	1916	11	471,041	9.81	4,623,146	341,365
	1909	11	349,997	9.36	3,276,620	212,599
Pennsylvania	1917	14	415,776	11.23	4,669,165	215,060
	1916	13	423,843	8.74	3,706,081	216,964
	1909	15	295,038	7.25	2,139,087	135,525
Minnesota	1917	6	205,026	11.31	2,319,833	140,353
	1916	5	205,433	7.34	1,507,233	138,799
	1909	7	47,373	7.02	332,548	37,295
Michigan	1917	11	187,117	9.30	1,740,580	96,623
	1916	10	186,993	7.50	1,402,245	99,601
	1909	8	132,846	6.29	835,861	64,369

[1] Not including cost of "Slabs and other mill waste" in Louisiana, Massachusetts, North Carolina, and Virginia.

TABLE 5.—*Pulpwood consumption: Number of mills, quantity and cost of wood consumed, with average cost per cord and quantity of wood pulp produced by States, 1909, 1916, and 1917*—Continued.

State.	Wood consumed.					Wood pulp produced (tons).
	Year.	Establishment (number).	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	
North Carolina	1917	3	175,433	$8.05	1,412,940	64,548
	1916	3	85,709	5.16	[1] 266,207	35,348
	1909	4	145,090	6.34	919,733	53,926
Virginia	1917	7	141,579	10.31	1,459,061	75,972
	1916	6	132,736	8.46	[1] 1,036,116	68,595
	1909	6	92,039	8.40	772,963	48,641
West Virginia	1917	5	119,918	8.61	1,032,045	54,813
	1916	5	127,478	6.42	818,983	58,913
	1909	5	109,166	5.43	582,985	48,797
Vermont	1917	10	109,616	12.33	1,351,825	94,975
	1916	10	87,675	9.43	826,904	73,813
	1909	11	70,977	10.18	722,777	59,356
Massachusetts	1917	4	55,897	12.58	703,369	30,802
	1916	3	27,640	9.91	[1] 271,978	19,247
	1909	5	45,899	8.80	403,778	25,804
California, Oregon, and Washington	1917	8	262,294	6.43	1,687,670	213,813
	1916	8	259,544	5.67	1,472,736	188,782
	1909	8	155,843	7.52	1,172,556	110,371
All other States	[2] 1917	12	219,581	6.98	1,532,984	102,792
	[3] 1916	11	183,605	6.18	[4] 1,135,154	102,250
	[5] 1909	9	155,476	6.86	1,125,870	80,039

[1] Not including cost of "Slabs and other mill waste.
[2] Includes Delaware, District of Columbia, Georgia, Louisiana, Maryland, Mississippi, Ohio, South Carolina, Tennessee, and Texas.
[3] Includes Delaware, Georgia, Louisiana, Maryland, Mississippi, Ohio, South Carolina, and Texas.
[4] Not including cost of "Slabs and other mill waste" in Louisiana.
[5] Includes Delaware, Maryland, Ohio, South Carolina, and Texas.

TABLE 6.—*Prices paid for pulpwood, number of mills, and form in which purchased.*

Range of price per cord (f. o. b. mill).	Number of mills.			
	Rough.	Peeled.	Rossed.	Slabs and other mill waste.
$1.00–$1.99				1
2.00– 2.99	2			
3.00– 3.99	1			4
4.00– 4.99	1	1		3
5.00– 5.99	4	4		6
6.00– 6.99	13	3		6
7.00– 7.99	10	5		3
8.00– 8.99	14	10	1	3
9.00– 9.99	21	5		
10.00–10.99	10	12		
11.00–11.99	26	15		
12.00–12.99	13	15	2	
13.00–13.99	9	17	2	3
14.00–14.99	5	13	1	
15.00–15.99	5	10	5	
16.00–16.99	2	13	4	
17.00–17.99		5	7	
18.00–18.99	1	8	4	
19.00–19.99		7	7	
20.00–20.99		1	3	
21.00–21.99		1	3	
22.00–22.99			2	
23.00–23.99			1	
24.00–24.99				
25.00–26.00		1	1	

TABLE 7.—*Pulpwood consumption: Quantity, average cost per cord, and total cost of wood consumed according to condition, by States, 1917.*

State.	Total.			Rough.			Peeled.			Rossed.			Slabs and other mill waste.		
	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	Quantity (cords.)	Average cost per cord (f. o. b. mill).	Total cost.
United States	5,480,075	$11.10	$60,815,057	2,500,827	$9.67	$24,180,745	2,258,169	$11.91	$26,905,102	487,097	$17.03	$8,293,074	233,982	$6.14	$1,436,136
Maine	1,309,239	11.31	14,813,387	602,533	10.79	6,502,120	522,659	11.38	7,085,847	59,616	18.46	1,100,721	24,431	5.10	124,699
New York	1,056,556	14.45	15,270,142	195,764	11.50	2,251,658	651,220	14.45	9,411,261	200,096	17.56	3,513,132	9,476	9.93	94,091
Wisconsin	805,490	8.79	7,083,173	721,606	8.78	6,333,378	77,057	9.27	714,043	97	16.49	1,600	6,730	5.07	34,152
New Hampshire	416,553	13.78	5,738,883	82,488	10.30	849,582	143,609	13.34	1,915,047	190,299	15.62	2,972,174	157	13.25	2,080
Pennsylvania	415,776	11.23	4,669,165	46,400	16.00	742,400	274,532	10.63	2,918,451	27,181	19.60	532,841	67,663	7.03	475,473
Minnesota	205,026	11.31	2,319,833	205,026	11.31	2,319,833	...	...	...	...	...	...	...	...	...
Michigan	187,117	9.30	1,740,580	149,002	9.79	1,457,996	12,806	9.77	125,161	...	...	...	25,309	6.22	157,423
Virginia	141,579	10.31	1,459,061	18,935	6.00	113,610	121,444	11.04	1,341,251	...	...	...	1,200	3.50	4,200
West Virginia	119,918	8.61	1,032,045	53,874	6.94	373,963	42,436	11.93	506,326	...	...	...	23,608	6.43	151,756
Vermont	109,616	12.33	1,351,825	54,272	10.28	557,845	51,877	14.17	735,241	3,467	16.94	58,739	...	...	...
California, Oregon, and Washington	262,294	6.34	1,687,670	191,772	6.84	1,311,667	70,522	5.33	376,003	...	...	...	...	...	...
All other states [1]	450,911	8.09	3,649,293	179,155	7.63	1,366,693	190,007	9.35	1,776,471	6,341	17.96	113,867	75,408	5.20	392,262

[1] Includes Delaware, District of Columbia, Georgia, Louisiana, Maryland, Massachusetts, North Carolina, Tennessee, Texas, and Vermont.

TABLE 8.—*Pulpwood consumption: Quantity, average cost per cord, and total cost of wood consumed, according to condition, by kinds of wood, 1917.*

Kind of wood.	Total.			Rough.			Peeled.			Rossed.		
	Quantity (cords).	Average cost per cord (f. o. b. mill).	Total cost.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Cost.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Cost.	Quantity (cords).	Average cost per cord (f. o. b. mill).	Cost.
Total	5,480,075	$11.10	$60,815,057	2,559,184	$9.55	$24,429,306	2,427,448	$11.54	$28,008,234	493,443	$16.98	$8,377,517
Spruce, domestic	2,385,966	11.98	28,575,146	1,357,006	10.91	14,800,934	821,475	12.85	10,552,978	207,485	15.53	3,221,234
Spruce, imported	681,450	16.52	11,258,917	122,621	13.82	1,695,214	336,300	16.28	5,476,240	222,529	18.37	4,087,463
Hemlock	775,003	7.96	6,167,635	617,196	7.69	4,747,549	152,140	8.76	1,332,247	5,667	15.50	87,839
Poplar, domestic	313,955	9.69	3,041,923	15,239	7.50	114,389	298,716	9.80	2,927,534			
Poplar, imported	92,298	11.03	1,018,315				92,298	11.03	1,018,315			
Balsam fir	382,036	12.16	4,645,957	152,177	9.07	1,379,911	178,443	13.28	2,369,508	51,416	17.44	896,538
Yellow pine	142,094	5.26	748,007	66,392	4.40	292,100	75,702	6.02	455,907			
Jack pine	75,382	10.45	787,660	9,145	7.03	64,311	66,237	10.92	723,349			
Tamarack	58,732	6.35	372,882	57,226	6.27	358,575	1,506	9.50	14,307			
Yellow poplar	41,155	8.97	369,088				41,155	8.97	369,088			
White fir	33,181	5.43	180,190	26,951	5.30	142,810	6,230	6.00	37,380			
Cottonwood	32,993	8.94	295,171	189	5.75	1,086	32,804	8.96	294,085			
Gum	32,513	11.44	371,972				32,513	11.44	371,972			
Douglas fir	7,421	5.50	40,816				7,421	5.50	40,816			
Basswood	3,807	8.95	34,090				3,807	8.95	34,090			
White pine	3,562	9.36	33,333	1,303	8.41	10,954	2,259	9.91	22,379			
Sycamore	1,212	11.73	14,219				1,212	11.73	14,219			
Cedar	16	8.10	130	16	8.10	130						
Beech, birch, maple, and chestnut	183,317	7.77	1,423,470	75,366	7.60	572,782	107,951	7.88	850,688			
Slabs and other mill waste	233,982	6.14	1,436,136	58,357	4.26	248,561	169,279	6.52	1,103,132	6,346	13.31	84,443

TABLE 9.—*Reported length of pulpwood haul, by States.*

Distance zones.	Total quantity.	Per cent distribution.	Maine.		New York.		Wisconsin.		New Hampshire.		Pennsylvania.		All other States.	
			Quantity.	Per cent distribution.	Quantity.	Per cent distribution.	Quantity.	Per cent distribution.	Quantity.	Per cent distribution.	Quantity.	Per cent distribution.	Quantity.	Per cent distribution.
	Cords.		*Cords.*		*Cords.*		*Cords.*		*Cords.*		*Cords.*		*Cords.*	
Total	4,378,789	100.0	1,082,713	100.0	931,566	100.0	707,194	100.0	115,823	100.0	366,604	100.0	1,174,889	100.0
1- 24 miles	253,755	5.8	62,982	5.8	55,172	5.9	6,452	0.9	45,097	38.9	...	...	84,052	7.2
25- 49 miles	381,594	8.7	119,662	11.1	49,355	5.3	27,897	3.9	62,726	54.2	...	...	121,954	10.4
50- 74 miles	293,552	6.7	62,395	5.8	61,467	6.6	75,293	10.6	8,000	6.9	...	...	86,397	7.4
75- 99 miles	492,968	11.3	300,427	27.7	88,436	9.5	7,017	1.0	...	...	61,612	16.8	35,476	3.0
100-149 miles	952,363	21.7	131,153	12.1	96,660	10.4	94,899	13.4	...	...	34,948	9.5	594,703	50.6
150-199 miles	392,063	9.0	3,837	.4	15,167	1.6	226,627	32.1	...	...	24,237	6.6	122,195	10.4
200-249 miles	293,941	6.7	114,020	10.5	52,278	5.6	83,579	11.8	...	...	30,485	8.3	13,579	1.1
250-299 miles	428,928	9.8	254,868	23.5	63,635	6.8	34,304	4.9	...	...	62,221	17.0	13,900	1.2
300-399 miles	415,876	9.5	33,369	3.1	212,199	22.8	108,292	15.3	...	...	36,291	9.9	25,725	2.2
400-499 miles	204,978	4.7	...	...	166,217	17.9	1,899	0.3	...	...	...	...	36,862	3.1
500-599 miles	89,073	2.0	...	...	18,138	1.9	40,935	5.8	...	...	...	...	30,000	2.6
600-699 miles	30,662	.7	...	...	20,616	2.2	...	...	...	...	...	...	10,046	.8
700-799 miles	72,552	1.7	...	...	16,742	1.8	...	...	...	...	55,810	15.2	...	...
800-899 miles	15,484	.3	...	...	15,484	1.7	...	...	...	...	...	...	...	...
900-999 miles	61,000	1.4	...	...	...	...	...	...	...	...	61,000	16.7	...	...
Total reported consumption	5,480,075	...	1,309,239	...	1,056,556	...	805,490	...	416,553	...	415,776	...	1,476,461	...

TABLE 10.—*Production of unbleached and not steamed and bleached and steamed wood pulp, with average value per ton and total value, by States and processes, 1917.*

State.	Total.			Mechanical.			Sulphite.			Soda.			Sulphate.		
	Quantity (tons).	Average value per ton f. o. b. mill.	Total value.	Quantity (tons).	Average value per ton f. o. b. mill.	Total value.	Quantity (tons).	Average value per ton f. o. b. mill.	Total value.	Quantity (tons).	Average value per ton f. o. b. mill.	Total value.	Quantity (tons).	Average value per ton f. o. b. mill.	Total value.
United States	3,509,939	$43.33	$150,902,280	1,535,953	$21.98	$33,762,755	1,451,757	$58.12	$84,380,253	437,430	$65.14	$28,494,433	84,799	$50.29	$4,264,888
				Not steamed.			Unbleached.								
	2,440,684	34.04	83,069,111	1,336,268	$21.63	$28,898,169	999,909	$48.70	$48,697,382	34,509	$61.85	$2,134,553	69,998	$47.70	$3,339,007
Maine	659,497	26.87	17,721,964	422,195	16.07	6,783,842	228,905	44.50	10,185,712	(1)	100.00	(1)	(1)	65.00	(1)
Michigan	77,789	55.67	4,330,282	13,052	21.09	275,217	57,413	63.94	3,670,994				(1)	52.44	(1)
Minnesota	131,843	29.77	3,924,665	83,401	20.69	1,725,363	(1)	45.40	(1)						
New Hampshire	128,635	35.00	4,501,654	59,933	27.72	1,421,678	68,702	44.83	3,079,976						
New York	641,828	36.62	23,501,382	410,664	24.73	10,156,716	231,164	57.73	13,344,666						
Pennsylvania	64,161	50.25	3,224,109	(1)	20.59	(1)	36,815	50.62	1,863,476	(1)	54.30	(1)			
Vermont	87,815	29.07	2,553,173	70,027	22.78	1,595,246	(1)	48.89	(1)				(1)	63.00	(1)
Wisconsin	363,340	40.72	14,794,528	150,743	29.96	4,515,615	181,133	48.08	8,708,518				31,464	49.91	1,570,395
California, Oregon, and Washington	203,333	25.90	5,266,316	103,828	17.90	1,858,221	99,505	34.25	3,408,095						
All other States[2]	82,443	39.43	3,251,038	22,425	25.25	566,271	96,272	46.08	4,435,945	34,509	61.85	2,134,553	38,534	45.90	1,768,612
				Steamed.			Bleached.								
	1,069,255	63.44	67,833,169	199,685	$24.36	$4,864,587	451,848	$78.97	$35,682,871	402,921	$68.40	$26,359,880	14,801	$62.55	$925,831
Maine	239,301	53.68	12,846,152	48,482	20.81	1,009,110	75,742	70.70	5,354,839	115,077	56.33	6,482,203			
Michigan	18,834	56.55	1,065,156	(3)	30.00	(3)	10,970	75.06	823,379				(3)	52.44	(3)
New Hampshire	138,010	80.76	11,145,665				138,010	80.76	11,145,665						
New York	156,788	58.52	9,175,465	65,870	27.60	1,817,763	(3)	92.48	(3)	62,826	75.76	4,759,754			
Pennsylvania	150,899	68.37	10,316,900				(3)	69.86	(3)	99,571	67.60	6,731,131			
Wisconsin	92,789	48.31	4,482,287	53,547	24.00	1,285,061	36,642	83.35	3,054,226				(3)	55.00	(3)
All other States[4]	272,634	68.96	18,801,544	31,786	23.68	752,653	190,484	80.35	15,304,762	125,447	66.86	8,386,792	14,801	62.55	925,831

[1] Included in "All other States," unbleached and not steamed.
[2] Includes District of Columbia, Georgia, Massachusetts, Mississippi, North Carolina, Ohio, South Carolina, Texas, Virginia, and West Virginia.
[3] Included in "All other States," bleached and steamed.
[4] Includes Delaware, District of Columbia, Louisiana, Maryland, Massachusetts, Minnesota, North Carolina, Ohio, Tennessee, Vermont, Virginia, Washington, and West Virginia.

NOTE.—Short ton=2,000 pounds.

TABLE 11.—*Imports of pulpwood, calendar years, 1910 to 1917.*

Year.	Quantity.				Value (see note).		
	By form.	Cords.	Per cent of form.	Total cords.	Per cord.	Average.	Total.
Total (8 years)				7,894,572		$6.82	$53,845,160
1917			100.0	1,031,934		8.30	8,563,458
	Rough	206,081	20.0		$7.29		
	Peeled	673,235	65.2		8.07		
	Rossed	152,618	14.8		10.73		
1916			100.0	1,097,577		6.56	7,202,570
	Rough	190,921	17.4		5.93		
	Peeled	742,337	67.6		6.43		
	Rossed	164,319	15.0		7.90		
1915			100.0	975,974		6.43	6,278,948
	Rough	258,620	26.5		5.82		
	Peeled	544,139	55.8		6.28		
	Rossed	173,215	17.7		7.83		
1914			100.0	999,649		6.78	6,773,198
	Rough	198,414	19.8		6.04		
	Peeled	599,299	60.0		6.40		
	Rossed	201,936	20.2		8.61		
1913			100.0	1,034,885		6.77	7,007,350
	Rough	195,906	18.9		5.66		
	Peeled	581,756	56.2		6.47		
	Rossed	257,223	24.9		8.30		
1912			100.0	933,565		6.67	6,227,346
	Rough	139,002	14.9		6.03		
	Peeled	528,900	56.7		6.06		
	Rossed	265,663	28.4		8.23		
1911			100.0	889,257		6.39	5,682,716
	Rough	191,062	21.5		5.44		
	Peeled	473,116	5.32		5.98		
	Rossed	225,079	25.3		8.06		
1910			100.0	931,731		6.56	6,109,574
	Rough	229,691	24.7		5.83		
	Peeled	459,681	49.3		6.28		
	Rossed	242,359	26.0		7.77		

NOTE.—The value of merchandise imported is the actual market value or wholesale price thereof at the time of exportation to the United States in the principal markets of the country from whence exported.

TABLE 12.—*Imports of wood pulp, calendar years 1907 to 1917.*

	Total.			Mechanically ground.		Chemical—unbleached.						Chemical—bleached.					
						Unclassified.		Sulphite.		Sulphate.		Unclassified.		Sulphite.		Sulphate.	
	Quantity (long tons).	Average value per ton.	Total value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Total (11 years)..	5,063,631	$37.55	$190,129,114	1,774,702	$35,450,637	1,786,427	$65,578,721	375,469	$30,113,666	150,749	$13,143,590	562,323	$28,653,439	53,649	$5,760,344	5,569	$497,923
1917........	605,215	69.36	41,979,330	249,172	7,991,368	....	....	221,583	19,291,410	96,369	9,993,170	....	....	36,640	4,508,368	1,451	195,014
1916........	610,504	44.02	26,935,693	234,390	4,696,801	[1] 120,575	[1] 5,255,297	[2] 153,886	[2] 10,822,256	[2] 54,380	[2] 3,150,420	[2] 26,146	[2] 1,506,034	[2] 17,009	[2] 1,251,976	[2] 4,118	[2] 302,909
1915........	507,481	33.36	16,907,026	155,407	2,588,846	287,232	10,954,182	....	....	....	....	64,842	3,363,998	....	....	....	....
1914........	603,183	33.84	20,411,225	193,979	3,246,933	294,884	11,180,232	....	....	....	....	114,320	5,984,060	....	....	....	....
1913........	483,442	32.96	15,935,517	149,901	2,670,781	264,513	9,676,380	....	....	....	....	69,028	3,588,356	....	....	....	....
1912........	482,277	30.90	14,903,218	165,896	3,051,381	247,501	8,477,766	....	....	....	....	68,880	3,374,071	....	....	....	....
1911........	502,165	28.66	14,394,253	234,537	4,221,948	190,394	6,482,360	....	....	....	....	77,234	3,689,945	....	....	....	....
1910........	452,478	29.38	13,296,500	200,164	3,578,316	183,701	6,374,762	....	....	....	....	68,613	3,343,422	....	....	....	....
1909........	328,259	31.42	10,315,089	127,669	2,266,668	144,350	5,189,794	....	....	....	....	56,240	2,858,627	....	....	....	....
1908........	223,647	31.19	6,976,311	[2] 63,587	[2] 1,137,595	[2] 53,277	[2] 1,987,948	....	....	....	....	[2] 17,020	[2] 944,926	....	....	....	....
1907........	264,980	30.29	8,024,952	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[1] Jan. 1 to June 30 only.
[2] July 1 to Dec. 31.—In 1908 an additional quantity of wood pulp, not classified as to kind, was imported up to June 30, amounting to 89,763 tons, valued at $2,905,842.

TABLE 13.—*Exports of wood pulp, calendar years 1908 to 1917.*

Year.	Quantity (long tons).	Value.	
		Average per ton.	Total.
Total (10 years)	163,914	$59.73	$9,791,089
1917	34,695	100.00	3,469,549
1916	35,735	59.37	2,121,745
1915	18,120	45.26	820,134
1914	11,015	43.98	484,477
1913	17,657	41,82	738,451
1912	[1] 12,669	42.86	542,949
1911	[1] 8,477	45.62	386,711
1910	[1] 7,465	46.12	344,251
1909	[1] 7,994	46.13	368,738
1908	[1] 10,087	50.97	514,084

[1] Quantity shown in pounds and is reduced in this table to the nearest long ton.

TABLE 14.—*Imports of paper, calendar years 1910 to 1917.*

Year.	Total.	News-print paper.		All other printing paper.		Wrapping paper.		All other paper.
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
		Pounds.		*Pounds.*		*Pounds.*		
Total (8 years)	$201,779,996	4,258,310,682	$91,876,005	31,532,503	$1,944,558	77,054,050	$4,503,848	$103,455,585
1917	41,734,084	1,118,225,912	30,929,628	412,091	67,931	6,661,518	456,752	10,279,773
1916	28,189,998	936,460,899	18,527,748	1,259,761	119,802	7,103,661	280,952	9,261,496
1915	24,465,694	736,817,721	14,138,651	2,395,755	161,703	22,208,212	626,661	9,538,679
1914	27,604,771	630,950,295	12,189,792	5,752,447	261,616	41,080,659	1,156,591	13,996,772
1913	24,359,827	439,687,195	8,549,062	6,758,490	371,328	....	735,857	14,703,580
1912	18,723,877	171,186,402	3,262,778	5,597,094	292,242	....	846,500	14,322,357
1911	18,112,859	111,660,615	2,096,105	7,376,598	534,250	....	400,535	15,081,969
1910	18,588,886	113,321,643	2,182,241	[1] 1,980,267	[1] 135,686	....	....	16,270,959

[1] July 1 to Dec. 31.

TABLE 15.—*Exports of paper, calendar years 1910 to 1917.*

Year.	Total.	News-print paper.		All other printing paper.		Wrapping paper.		All other paper.
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
		Pounds.		*Pounds.*		*Pounds.*		
Total (8 years)	$207,525,606	918,231,527	$25,767,653	430,324,115	$26,222,250	208,756,641	$11,048,494	$144,487,209
1917	46,566,671	187,780,747	7,597,509	94,423,954	8,168,277	52,519,392	3,988,727	26,812,158
1916	39,576,879	153,472,663	4,126,617	124,145,837	8,069,812	83,673,411	4,025,388	23,355,062
1915	22,264,371	110,322,513	2,707,626	44,657,646	2,169,067	36,991,079	1,667,387	15,720,291
1914	20,113,942	121,578,332	2,983,344	30,259,588	1,568,960	14,815,496	522,951	15,038,687
1913	21,174,217	86,602,057	2,105,984	28,117,371	1,617,285	13,722,414	560,535	16,890,413
1912	21,166,566	111,135,997	2,690,225	26,904,552	1,440,992	[1] 7,034,849	[1] 283,506	16,751,843
1911	18,702,151	97,841,361	2,357,455	26,429,186	1,278,796	....	....	15,065,900
1910	17,960,809	[1] 49,497,857	[1] 1,198,893	55,385,981	1,909,061	....	....	14,852,855

[1] Figures for period July 1 to Dec. 31.

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WM. A. TAYLOR, Chief

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THE LEAF-SPOT DISEASES OF ALFALFA AND RED CLOVER CAUSED BY THE FUNGI PSEUDOPEZIZA MEDICAGINIS AND PSUEDOPEZIZA TRIFOLII, RESPECTIVELY.

By Fred Reuel Jones, *Pathologist,*
Cotton, Truck, and Forage Crop Disease Investigations.

CONTENTS.

SCOPE OF THE INVESTIGATION.

Among the diseases of the foliage of the alfalfa plant, the one which is most widely known and is reported to cause the greatest loss is the leaf-spot caused by the fungus *Pseudopeziza medicaginis.* The disease is commonly called the alfalfa leaf-spot. This name is not distinctive, and its continued use is open to the objection that it promotes the present tendency to apply it inclusively to all the several leaf diseases that may be present with the true leaf-spot. However, the usage is so prevalent that it appears likely to persist.

Although the importance of the disease has caused it to be mentioned widely and frequently, little careful study has been devoted to it. A great number of scattered and conflicting observations have left the life cycle of the fungus causing the disease in doubt; the

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method of overwintering of the fungus has not been conclusively demonstrated; and the oft-considered question whether this fungus is identical with or merely similar to one which causes a corresponding leaf-spot on red clover has never been decisively answered. It is because of the last consideration that the two diseases have been studied together. The leaf-spot of red clover caused by the fungus *Pseudopeziza trifolii* occurs over a wide range of territory, but usually not so abundantly as that on alfalfa. Mention of it occurs frequently in literature. No distinctive common name has been applied to it. Much of the later interest in this disease is in connection with the question whether or not red clover is a source of infection, producing destructive outbreaks of leaf-spot on neighboring alfalfa when this plant has been introduced into new localities.

Leaf-spots of a nature very similar to the two already mentioned and commonly reported to be caused by the same fungi are known on a long list of clovers, alfalfas, and closely related plants. All of these diseases should be studied together and the relationship of the causal organisms determined. However, most of them do not occur in America or only in restricted localities, and none of them causes great damage to the host plants. The only one of these of which any living material has been available for study is that caused by *Pseudopeziza medicaginis* on *Medicago lupulina*. The incomplete notes on this disease have been included.

THE DISEASES.

ECONOMIC IMPORTANCE.

As has already been stated, the assertion has been made again and again that leaf-spot is the most common and destructive of the foliage diseases of alfalfa. That it is the most common is beyond question. But in the estimates of the loss which it has caused it appears highly probable that damage from other causes than the conspicuous leaf-spot has been included. Nevertheless, even if proper deductions for these inclusions could be made it might still be true that leaf-spot causes greater loss than any other foliage disease.

The highest estimate of loss from this disease is that of Pammel (1891)[1] from Iowa. In 1890 he attributes to this cause a loss of half the crop. Stewart and others (1908, pp. 384–387) report from New York that young stands are often ruined and that old stands are killed outright. Chester (1891) reports that some plats at the Delaware station in 1889 were attacked severely before the plants were large, and some of them were completely destroyed. Voges (1909) in Germany and Ivy Massee (1914) in England note the sickly appearance of diseased fields.

[1] The dates in parentheses refer to "Literature cited" at the end of this bulletin.

The amount of damage which the fungus may cause appears to depend on several circumstances relating to the development of the crop and the weather. Under ordinary conditions the incubation period of the disease is more than a week. If for any reason the plant is growing slowly, the stand is thick, and the weather is frequently wet, only a few of the upper leaves reach full development before they are covered with the disease. Thus young stands which grow slowly before becoming firmly rooted and old stands which are retarded for any reason are likely to show bad attacks, while stands which are growing rapidly keep most of the upper leaves well above the rising invasion of the fungus and show little harm. Thus, in most cases where the fungus is found in great abundance, apparently defoliating plants, it will be found that some condition has reduced the normal rate of growth of the plants and is in part responsible for the resulting damage. When plants are vigorous, infection must be heavy indeed to cause extensive yellowing and falling of leaves, though this may occasionally occur.

Nevertheless, the fungus is present in almost every alfalfa field, if not in all fields, taking a small toll of the foliage under even dry conditions and a large toll under more humid conditions. Since it rarely produces great loss at one time it has come to be regarded as one of the unavoidable evils to which the alfalfa plant is subject.

The leaf-spot of red clover caused by the fungus *Pseudopeziza trifolii* has not frequently been reported as occasioning great loss. In Russia Jaczewski (1912, p. 98) speaks of it as causing appreciable damage. Blasdale (1902, p. 75) states that it injures nearly all the clovers of the stock ranges of northwestern California. Freeman (1905, p. 309–310) notes that it causes local epidemics in clover fields in Minnesota. In fields in northern Wisconsin and in Maine in the summer of 1915 it was observed by the writer to be so abundant as to cause appreciable loss of foliage. From the evidence at hand it appears that the disease is not of great significance to clover and that this significance is only in northern regions. However, the destroyed foliage is so much less conspicuous than that on alfalfa that the amount of damage is more likely to be underestimated than overestimated.

DESCRIPTION OF THE DISEASE ON ALFALFA.

There are two characteristics of the leaf-spot caused by *Pseudopeziza medicaginis* which usually serve to distinguish it from spots caused by other parasitic fungi. The first of these is the circular shape and limited size of the spot. (Pl. I, *A*.) The second is the presence of a small raised disk (Pl. II, *B*) that appears in the center of the spot when it has reached full development. The edge of the spot may be smooth and definite, especially if the leaf has been much exposed to the sun, or it may be more or less dendritic, with a fringe of olive-colored rays. No marked killing or sinking of the leaf tissue occurs. In size, the spot rarely exceeds 2 or 3 millimeters in diameter.

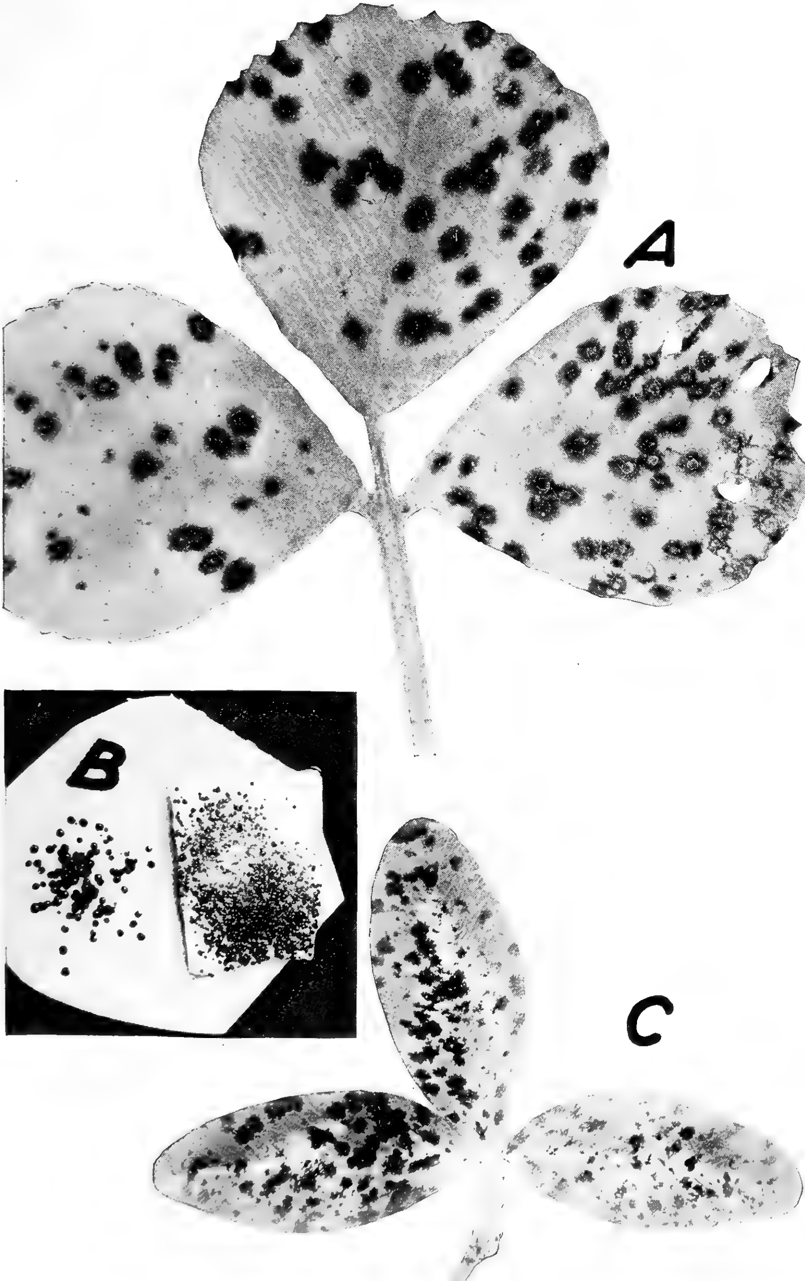
The disk at the center of the spot is the fruiting structure of the fungus and consists of a mass of asci which discharge large numbers of spores when sufficient moisture is present. These disks usually occur on the upper side of the leaf, sometimes on the lower side, and rarely on both sides from the same spot. Typically they are 1 to 1½ millimeters in diameter, slightly raised, and when fully developed surrounded by the torn edges of the epidermis of the leaf. Rarely the central disk is found surrounded with several smaller disks at its margin. Under very moist conditions the disk may appear as a jellylike drop of exudate at the center of the spot. Under arid conditions it becomes very dark in color, often almost black.

There is not usually a striking difference in color between the diseased tissue and the disk at the center. This color varies from dark brown to almost black. If the leaf has begun to yellow, the green color is sometimes retained longest around the diseased area.

The disease often occurs on succulent stems, where it has an appearance so characteristic that it can hardly be confused with injury from any other cause. The spot is elliptical in shape, with perfectly smooth edges. In size it is about 1½ by 3 mm. It is not abundant, and rarely bears a fruiting disk.

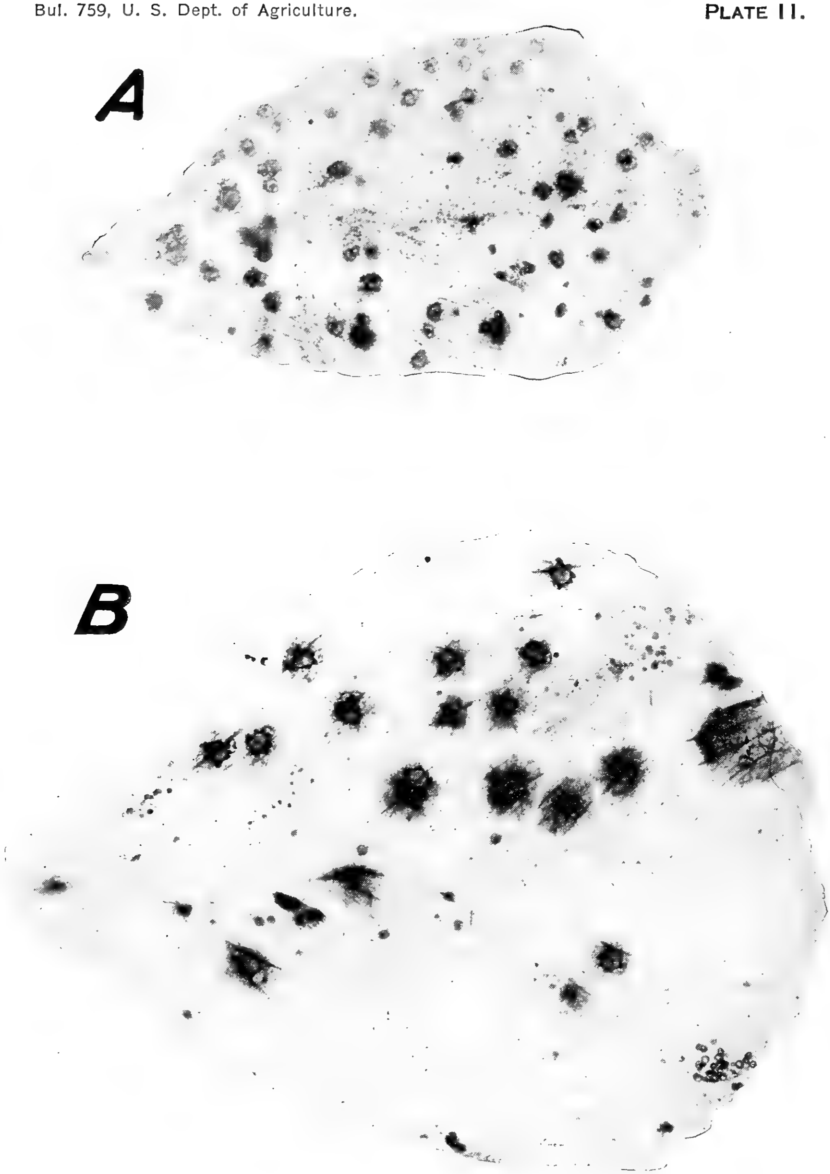
DESCRIPTION OF THE DISEASE ON RED CLOVER.

The leaf-spot on red clover caused by Pseudopeziza bears a very close resemblance to the similar disease on alfalfa. The spots are limited in size, usually slightly larger than on alfalfa, in early stages tending to be angular (Pl. I, *C*). The border of the spot is more frequently dendritic in outline. In early stages the color is dark olive, becoming brown or almost black in later stages. After the death of the entire leaf, the spot usually becomes almost indistinguishable. Fruiting disks are not as frequently found abundantly on the spots while the leaf is still alive as in the case of the leaf-spot of alfalfa, but they may develop abundantly after the death of the leaf. In early stages they are brownish or dirty yellow, but later they become almost black. They are more frequently found on the under side of the leaf than on the upper side, and occasionally occur on both sides from the same spot. On dead leaves they appear as amber drops of jelly in wet weather, but when dried they shrink to bodies so small and inconspicuous that it is practically impossible to find them. The disease has not been noted on any other part of the plant than the leaves.



PSEUDOPEZIZA ON HOST PLANTS AND PURE CULTURES.

A, Leaf-spot of *Medicago lupulina* caused by *Pseudopeziza medicaginis* (Lib.) Sacc. *B*, *Pseudopeziza medicaginis* developing in pure culture from spores discharged on plaster of Paris (right) and filter paper (left). *C*, Leaf-spot of red clover caused by *Pseudopeziza trifolii* (Biv.-Bern.) Fckl. at an early stage of development. Apothecia have not yet appeared.



PSEUDOPEZIZA ON ALFALFA.

A, Apothecia of Pseudopeziza developing on old leaf-spots on overwintered leaves. In many cases the apothecia are clustered. × 3, approximately. *B*, Apothecia of Pseudopeziza on an alfalfa leaflet. The leaf has been decolorized to show the fungus more clearly. The small dark circles near the lower right-hand edge of the leaf are early stages of apothecia of *Pyrenopeziza medicaginis*. × 5, approximately.

HOST PLANTS.

Although these fungi occur extensively in America on alfalfa and clover only, each of them has been reported in mycological literature on a number of related plants.

The names of these host plants are shown in Table I.[1]

TABLE I.—*List of host plants of Pseudopeziza trifolii and Pseudopeziza medicaginis.*

Hosts of Pseudopeziza trifolii.		Hosts of Pseudopeziza medicaginis.	
Name of host plant.	Authority cited.	Name of host plant.	Authority cited.
Trifolium:		Medicago:	
alpestre L	Saccardo, D., 1903, no. 526, 1319.	carstiensis Jacq	Saccardo, D., 1903, no. 526, 1319.
arvense L	Krieger, 1892, no. 781, 794.	fulcata L	Cavara, 1892, p. 243.
cyathiferum Lindl	Blasdale, 1902.	hispida denticulata (Wild.) Urban.	Massee, 1914.
fragiferum L	Massee, 1914.	lupulina L	
hybridum L	Bivona-Bernardi, 1816, man. 4, p. 27, pl. 6, fig. 5.	lupulina wildenowii (Boenn.) Aschers.	Libert, 1832, fasc. 2, no. 176.
incarnatum L	Saccardo, P. A., 1889, pp. 723–724.	minima Link	Fuckel, 1870, p. 290, 236.
medium L	Lambotte, 1880, p. 264.	prostrata Jacq	Jaap, 1916.
macrodon Hook and Arn.	Blasdale, 1902, p. 75.	sativa L	Desmazieres, 1847, pp. 182–183.
nigrescens Viv	Briosi, 1888.	Melilotus alba Desv	Tracy and Earle, 1895, p. 106.
pallescens Schreb	Massee, 1914.		
pratense L	Saccardo, P. A., 1889, pp. 723–724.	Onobrychis sativa Link.	Berthault, 1913.
		Trigonella:	
pallidum W. and K.	Maire, 1913, no. 119.	coerulea (L.) Ser	Mazerius, 1875, fasc. 33, no. 1645.
repens L	Briosi, 1888.		
resupinatum L	Massee, 1914.	corniculata L	Jaap, 1916.
spadiceum L	Saccardo, P. A., 1897, p. 623.	foenum-graecum L	Massee, 1914.
		Vicia villosa Roth	Tracy and Earle, 1895, p. 106.

THE FUNGI.

SYNONOMY OF PSEUDOPEZIZA TRIFOLII.

Pseudopeziza trifolii was first described by Antonio Bivona-Bernardi (1816, Mar. 4, p. 27, pl. 6, fig. 5) on *Trifolium hybridum* from Sicily under the name of *Ascobolus trifolii.* When Boudier (1869) revised the genus Ascobolus he listed this species among those which he believed should be excluded, and suggested that it be placed in the genus Phacidium. The following year Fuckel (1870) made this species the type of his new genus Pseudopeziza.

Other early synonyms as given by Rehm (1892, p. 597–598) are as follows: *Peziza trifoliorum* Libert, *Trochilia trifolii* DeNot., *Molliscia trifolii* Phill., *Phyllachora trifolii* Sacc.

The following three names have been included in the synonomy by Ivy Massee: *Pseudopeziza* (*Phacidium*) *divergens* (Desmaz.) Sacc.; *Peziza dehnii* Rab., a common parasite of Potentilla; *Pyrenopeziza medicaginis* Fckl. The last of these three species has already been shown by the writer (Jones, 1918) to be the ascigerous stage of

[1] In compiling this host list, the fungus found on species of the genus Trifolium is regarded as *Pseudopeziza trifolii* (Biv.-Bern.) Fckl., while the fungus on species of the genus Medicago or closely related genera is regarded as *P. medicaginis* (Lib.) Sacc. Owing to the fact that the two fungi have frequently been regarded as one, the fungus on Medicago and its relatives has often been reported as *P. trifolii.*

Sporonema phacidioides Desmaz. The writer has not been able to discover any adequate reason for the inclusion of the other two names.

SYNONOMY OF PSEUDOPEZIZA MEDICAGINIS.

The first collection and description of Pseudopeziza upon a species of the genus Medicago were made by Madam Libert (1832, fasc. 2, no. 176) under the name of *Phacidium medicaginis.* The host was *Medicago wildenowii,* now known as *Medicago lupulina wildenowii.* Later, when Desmazieres (1841) found Pseudopeziza upon alfalfa he assumed that it was identical with the species described on *Medicago wildenowii.* His assumption has not been seriously questioned.

In 1883 Saccardo (1883, no. 1390, 1391) transferred this species to the genus Pseudopeziza which Fuckel (1870) had established with *Pseudopeziza trifolii* as the type species. As soon as the two fungi were brought together in the same genus their similarity raised the question whether they were not identical. Briosi (1888) compared the fungi as they occurred on several species of Trifolium and Medicago and failing to find sufficient morphological difference between them to justify retaining them as distinct species advised that Pseudopeziza on alfalfa be called *Pseudopeziza trifolii* forma *medicaginis.* This usage has been followed by Rehm (1892, p. 597–598) and appears to have been generally accepted by mycologists, many of whom drop the form name altogether. Plant pathologists, on the other hand, have found it more convenient to retain the two names, though in most texts it is noted that possibly or even probably the two species are identical. The writer believes that the following pages present adequate evidence that the fungi on the two hosts are separate and distinct species.

COMPARATIVE MORPHOLOGY OF THE FUNGI.

The apothecia of both these species of Pseudopeziza arise in a delicate stroma beneath the epidermal layer of the leaf. The apothecia on alfalfa are usually solitary, except on overwintered leaves, where several clustered apothecia may develop on a stroma. On red-clover apothecia are sometimes clustered. The hymenial layer when first developed is covered with a thin stromatic stratum of small rounded cells, the outer layer of which may develop thick dark-colored walls. This stroma usually remains adherent to the epidermis when this is ruptured by the developing asci.

As the hymenial layer develops, the stroma from which it arises becomes thicker, forming in and among the collapsing leaf cells. The epidermis is ruptured, the hymenium is raised above the surface of the leaf, and after the spores have been largely discharged and the hymenium has shrunken the recurved flaps of the torn epidermis become conspicuous around the apothecium.

Under favorable conditions apothecia may reach 1½ mm. in diameter, but are usually 1 mm. or less. Asci are 60 to 70 microns long, and about 10 microns in diameter. Paraphyses are slightly longer than the asci, nonseptate, and swollen at the ends.

Ascospores of the two species (figs. 1 and 2) show slight differences in size, those of *Pseudopeziza trifolii* being larger. The spores of each species have shown small variations in measurement when they were obtained under different conditions affecting their discharge. The most important of these variations has occurred when spores are obtained from apothecia which are drying rapidly. Under these conditions discharge is greatly accelerated, and the number of spores of smaller size is increased. Therefore, in order to obtain comparable measurements certain precautions were always taken to obtain spores of the same degree of maturity. Fruiting cultures of the fungus or leaves bearing apothecia were placed in the cover of a Petri dish over a layer of clear agar. After about 10 hours, when the discharge of spores was apparently proceeding at a uniform rate, the cover of the dish was turned about so that the spores now fell on a new portion of the agar surface.

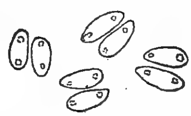


FIG. 1.—Ascospores of *Pseudopeziza trifolii.* × 600.

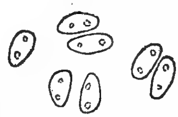


FIG. 2.—Ascospores of *Pseudopeziza medicaginis.* × 600.

After half an hour a considerable number of spores were usually found on the agar. The cover was then removed from the dish, a small drop of water and a cover glass were placed on the area on which the spores were scattered,. and measurement was made as rapidly as possible.

When a large number of spores have been measured to the nearest micron and the spore lengths arranged, as shown in Table II, it has always been found that the number of spores of *Pseudopeziza medicaginis* which measure 10 microns and less constitute more than half the total, while in the case of *P. trifolii* the number of spores which are 11 microns and longer constitute more than half the total. Table II presents a typical comparison of the measurement of 100 spores of each species.

TABLE II.—*Comparison of the lengths of 100 spores each of Pseudopeziza medicaginis and Pseudopeziza trifolii, measured to the nearest micron.*

Spores of—	Length (microns).						
	8	9	10	11	12	13	14
Pseudopeziza medicaginis...........number..	7	26	33	24	10	....	......
Pseudopeziza trifolii....................do....	....	3	26	46	18	6	1

By careful comparison in this manner it has been found possible to distinguish between the two species on the basis of spore measurement alone.

In addition to the difference in size, there is a difference in shape that is discoverable by the examination of many spores—a difference that does not significantly appear in measurement. Some of the spores of *Pseudopeziza trifolii* are slightly flattened on one side. When the flattened side is seen in profile the spore has a somewhat pointed appearance. The occurrence of occasional pointed spores (fig. 1) is a distinguishing feature of this species.

Spores from dried specimens have not been found satisfactory for comparative measurement. Unless the collection is made just before the apothecium is completely mature, nearly all of the spores are unavoidably discharged during drying. The few remaining are likely to be found much shrunken.

MORPHOLOGICAL CHARACTERS IN CULTURE.

MYCELIUM.

In culture these fungi preserve the same general characteristics that they show on the host plant. The mycelium radiating from the germinating spore or group of spores soon produces a stroma at the center. Thereafter this stroma is surrounded with a narrow fringe of hyphæ, which never advance far beyond the stroma. When the fungi are grown from spores on the same nutrient substratum, differences in the character of the mycelium can be noted. That from *Pseudopeziza medicaginis* branches earlier than that of *P. trifolii;* most of its branches come off at an acute angle, while those of *P. trifolii* come off somewhat regularly at a right angle, or occasionally at an obtuse angle.

CONIDIUMLIKE STRUCTURES.

Although no conidia have been found in nature, conidiumlike structures occur regularly in culture and are a feature by which cultures of the two species can be most easily distinguished. They arise from the ends of branches or from the distal ends of somewhat swollen cells. They measure 5 to 8 by 3 to 5 microns. They occur most abundantly when the ascospores are germinated on clear agar to which no nutrient has been added, appearing in about three days in the case of *Pseudopeziza medicaginis* and somewhat later on mycelium of *P. trifolii.* On mycelium of the first fungus they are produced in great abundance before the end of the first week, though the mycelium from different spores or groups of spores produces them in varying amount. (Fig. 3.) The mycelium may grow but little, becoming thickly covered with the conidia, or it may grow more freely with but a few conidia at the ends of short branches. Rarely are they absent. In striking contrast is the scarcity of these spores on mycelium from spores of *P. trifolii.* (Fig. 4.) Never are they produced in great numbers, and frequently they are entirely absent from all but a few fungous colonies. Thus, the striking abundance of these structures on mycelium of *P. medicaginis* and their scarcity on

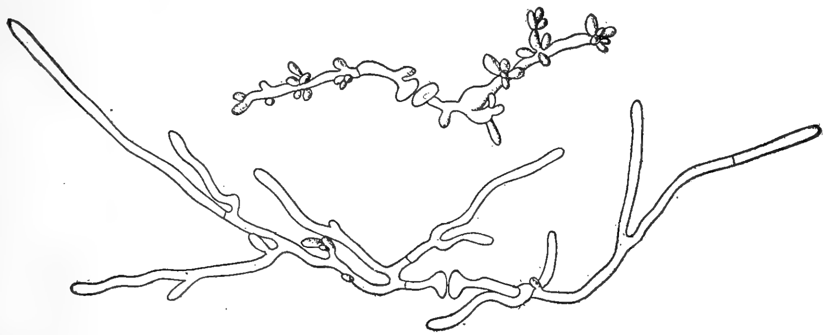


FIG. 3.—Mycelium and conidiumlike structures developing from ascospores of *Pseudopeziza medicaginis* on agar agar. × 400.

mycelium of *P. trifolii* furnish an easy morphological distinction between the two species.

REPORTED CONIDIAL STAGES OF THESE FUNGI.

It is a matter of some interest to note that all the studies of Pseudopeziza on alfalfa and clover which have been made by European mycologists and pathologists with but a single exception (Briosi, 1888) have contained a discussion of an associated conidial stage. Thus at least three, perhaps four, imperfect fungi have been assigned to this rôle in addition to the conidiumlike structures which are produced in culture. A summary of the evidence on the basis of which the association of these conidial stages has been made is here given.

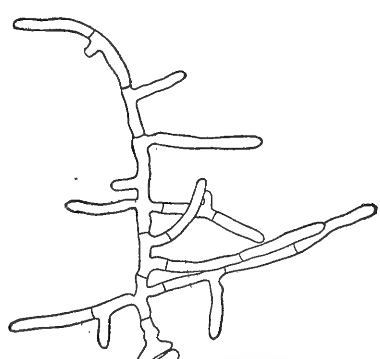


FIG. 4.—Mycelium developing from an ascospore of *Pseudopeziza trifolii* on agar-agar. × 400.

The first of these fungi to be regarded as a conidial stage of *Pseudopeziza medicaginis* was *Sporonema phacidioides* Desm. Since the writer has a previous article (Jones, 1918) traced the development of the purely observational evidence on which this association was based and has shown that this Sporonema is the conidial stage of *Pyrenopeziza medicaginis* Fckl., no further discussion is necessary here.

The second suggestion that Pseudopeziza produces conidia comes from the work of Brefeld (1891, p. 325). In the course of his study of Pseudopeziza on both clover and alfalfa he germinated the ascospores. The cultures thus obtained of these fungi behaved alike. Very little mycelium was produced. After about 14 days conidia were cut off laterally from certain threads and from the ends of side branches. These conidia were not observed to germinate. After describing them, Brefeld refers them to the conidia described by Tulasne (probably referring to the conidia of *Sporonema phacidioides*), but he does not state whether he regards his conidia identical with those described by Tulasne or not. The structures which Brefeld describes and figures as conidia appear to be identical with those already described as occurring in culture.

The third and most extended reference to a conidial stage of *Pseudopeziza medicaginis* is that of Voges (1909). In the course of a study of an outbreak of the disease in fields under his observation in Germany, he reports that he finds closely associated with the fruiting disks of Pseudopeziza on living leaves the pycnidia of a Phyllosticta which does not appear to him to belong to a previously described species. Unfortunately, his own description of this Phyllosticta is so meager that it does not serve to identify it. He states that the spores are differentiated into two forms—a smaller 1-celled spore and a larger, often 2-celled spore. No mention is made of any attempt to determine whether or not the two types really belong to the same fungus or not, nor does he explain why such a fungus should not be called Ascochyta rather than Phyllosticta.

Voges next attempts to identify the Phyllosticta with Pseudopeziza by cultural methods. He places fragments of Pseudopeziza fruit disks on a nutrient substratum. When this is done in March and October, no results are obtained; but in June he gets a fungus on his plates which first produces aerial conidia and later pycnidia like those previously found on the leaves. Inoculations made on alfalfa leaves with these leaf-spot cultures produced typical Phyllosticta spots. Inoculation of alfalfa leaves with fragments of Pseudopeziza fruiting disks gave like results. Consequently he concludes that the Phyllosticta and Pseudopeziza are identical and that Pseudopeziza has three spore forms—aerial conidia, conidia in pycnidia, and ascospores. Finally he inoculates clover leaves with fragments of his Phyllosticta culture and finds that typical spots bearing Phyllosticta spores are produced. Hence he concludes that the Pseudopeziza on alfalfa must be identical with that on clover.

Even if these results of the few experiments which he performed are accepted at their full value, the conclusions which he draws are manifestly not justified. In the first place, the fact that he was unable to get cultures of his Phyllosticta from Pseudopeziza spots except at a certain period in the summer is not adequately explained by his extraordinary theory of a periodicity in the vegetative vigor of the fungus. In the second place, inoculations with this Phyllosticta whether upon alfalfa or upon clover produced lesions which bore only the pycnidia of the Phyllosticta, never the apothecia of the Pseudopeziza. These cultures obtained under doubtful conditions produced ascospores neither in culture nor as a result of inoculation. Thus, the evidence which Voges presents, judged entirely by itself, does not prove or even clearly indicate that he ever had Pseudopeziza in culture. It does not appear, however, that the work of Voges has been widely accepted, at least not in America, even though the report of his work as presented in the Experiment Station Record [1] is incorrect or misleading in almost every detail, causing his conclusions to appear much more justifiable than when they are read in the original article.

In the same year that the article by Voges was published Voglino (1909, pp. 226–228) in Italy presented evidence which he believed indicates that *Gloeosporium caulivorum* Kirch. or *G. trifolii* Pk., which in his opinion may be identical with it, is the conidial stage of Pseudopeziza on *Trifolium pratense*. His evidence was obtained both from observation and from cultures. In a certain field considerably injured by Gloeosporium he finds apothecia of *Pseudopeziza trifolii* developing in close association with the acervuli of the Gloeosporium. Later he makes cultures from conidia obtained from stems on a clover decoction with gelatin, and in a single culture he found after 30 days three apothecia of a fungus which he assumes to be a Pseudopeziza. On the basis of this evidence he decides that the Gloeosporium must be the conidial stage of Pseudopeziza.

The account which Voglino gives of his work is very brief and bare of details. No mention of inoculations is made. No description of the Pseudopeziza which he regards as *Pseudopeziza trifolii* is given. It is not clear from his account that he obtained a pure culture. Therefore his results can hardly be regarded as having more than a suggestive value.

This review of European literature brings us to the conclusion that, with the possible exception of the description by Brefeld of conidia in culture, there is no conclusive observational or experimental evidence that either of these Pseudopezizas has an associated condidial stage.

PHYSIOLOGY OF THE FUNGI.

ISOLATION OF THE FUNGI.

Efforts to isolate these fungi by ordinary methods were continued for a long time without avail. The first success was obtained by

[1] Experiment Station Record, v. 22, no. 7, p. 648.

taking advantage of the fact that when the ascospores are discharged from the ascus they are thrown several millimeters vertically. Repeated trials showed that if fresh leaves were used, spores could sometimes be obtained in considerable numbers on an agar surface placed over the apothecia without bacterial or fungous contamination. This work of collecting spores was best carried out in a Petri dish in which a layer of very clear agar had been poured. The dish was inverted and the leaf bearing the apothecia supported 2 or 3 millimeters below the agar. After a short period the area over the apothecia was marked, the dish turned, and examination made with the low power of the microscope to determine whether the requisite number of spores were present. The difficulty would have been lessened had a few spores been sufficient for the development of a culture, but experience soon showed that a large number of fungous colonies crowded together developed better than a few. When several areas on the plate had been scattered with spores, the leaf bearing the apothecia was transferred to another plate. By using the utmost care and exposing a large number of plates a few could be obtained without contamination or with so small a number of foreign organisms that they could be cut out with a sterile needle. After a plate had been observed until it appeared certain that no foreign organism was present, it was found advisable in order to prevent drying to cut out the area bearing the developing fungous colonies and transfer them to agar slopes in test tubes.

In the course of experiments with cultures made in this way the first culture of Pseudopeziza from alfalfa to produce apothecia was obtained. The spores were discharged on an alfalfa-agar plate on October 5, and the agar was transferred to a water-agar slope on October 22. The ascospores were being produced on November 6. At first it was assumed that the fungus had been starved into fruiting by this process, but later work does not indicate that this was the case. Fruiting cultures can be obtained most readily by transferring the developing fungous colonies as soon as they become macroscopic from the water-agar plates to oatmeal-agar slopes. In this way the fungus was isolated six times in the autumn of 1914 and once in the autumn of 1916.

Pseudopeziza was isolated from red clover in the same way as from alfalfa. Two isolations were made of this fungus in 1915, one from clover leaves collected by Prof. H. H. Whetzel at Ithaca, N. Y., and one from clover collected in Door County, Wis.

A later successful reisolation of this fungus from plants inoculated in the greenhouse suggests that it may not always be necessary to employ this tedious process. In the instance referred to, diseased leaf fragments were cut from clover leaves two weeks after inoculation. The fragments, each bearing from one to three infections, were dipped in 50 per cent alcohol and placed in a solution of 1 part of bichlorid of mercury in 1,000 parts of water for 1 to 1½ minutes. After washing, the fragments were placed separately on slopes of 2 per cent water agar. After these cultures had been kept three weeks at 17° to 19° C., small tufts of mycelium emerged from the fragments which had remained free from contamination. The fragments were then transferred to oat agar. Apothecia appeared two weeks later, and cultures were started. Success in this instance seems to be due to the relative freedom of these greenhouse plants from fungi which quickly enter the host tissue that has been killed by the parasite.

CULTURAL CHARACTERS OF SPECIAL MEDIA.

Only a few of the more common media on which the fungi grow most readily and show the most striking differences are selected. In connection with these descriptions the following facts regarding the method of making cultures and their habit of development should be kept in mind:

(1) New cultures are started by placing near the top of an agar slope a fragment of a culture which is producing and discharging ascospores abundantly. The position of the slope should be changed from time to time to insure a somewhat uniform distribution of the spores over its entire length. After from one to four days the original transfer may be removed to another slope and thus serve to start a number of cultures successively.

(2) The small fungous colonies which arise fruit better and earlier when closely crowded together. Yet excessive crowding may delay fruiting.

(3) Apothecia appear in three to five weeks at favorable temperatures. After a period of active spore production lasting from one to two weeks, further spore production takes place only occasionally. Transfer of the stroma to new media increases the likelihood of its occurrence but does not insure it. The stroma itself continues to grow very slowly.

Oatmeal agar.—As a culture medium oatmeal agar has proved to be the most useful for general culture work, because upon it ascospores are produced in greatest abundance. The following description applies to cultures kept at 20° to 22° C.

Pseudopeziza medicaginis: The first evidence of growth appears about one week after spores are discharged upon the medium. At this time the surface of the substrate appears roughened as though pushed up into a multitude of minute flat cones. In about two weeks the cones are increased in size and show a rusty brown color at the center. The color becomes darker at the center of the cone, surrounded by a rusty rim. Soon the dark-brown color covers the entire slope. If the colonies are not sufficiently close to touch each other in three weeks, the color is darker than if the colonies merge. At the end of three or four weeks apothecia appear at the center of the stromata as small grayish white, often glistening gelatinous masses, very small at first, but often extending until they merge. The apothecium is merely a rounded, sometimes flattened, firm mass of asci and paraphyses which crumbles when crushed (Pl. III, *B*). The gray color of the mass becomes darker with the increased age of the culture, and finally is dark brown or almost black. The rusty brown color that is seen early in the development of the culture is usually found to have permeated the agar slightly by the time the fruiting stage is reached. A greater amount of color is usually found in cultures which have relatively few colonies and which fruit but little. Retardation of the growth of the cultures by low temperature appears to allow the color to diffuse farther through the agar. In cultures which grow rapidly, the yellow color may be diffused only in the upper part of the slope where the layer of agar is thin.

Pseudopeziza trifolii: The development of *Pseudopeziza trifolii* on this culture medium differs from that described for *P. medicaginis* only in the details here stated. The color which develops in the stromata as they develop is dark gray, becoming black, with no trace of brown. The fungous colonies appear a little more vigorous and coalesce into a more solid crust on the surface of the medium than those of *P. medicaginis.* The fruiting structures appear more typical (Pl. III, *A*), being flat on top, but are not surrounded by a wall. The substrate never becomes discolored.

Potato-dextrose agar.—Cultures of both fungi grow very rapidly on potato-dextrose agar. When the colonies are much crowded the leathery surface growth becomes crumpled.

Pseudopeziza medicaginis: Color at the end of four weeks brown, sprinkled with a few black stromata; substrate decidedly colored; apothecia produced in small numbers.

Pseudopeziza: Culture coal black, with slight amount of frosty mycelium. There is a slight staining of the substrate.

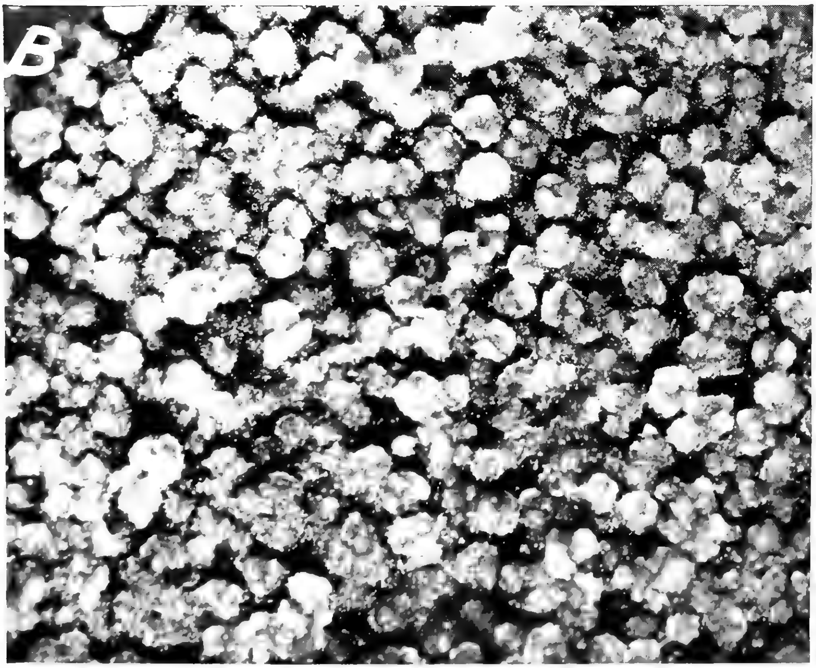
Lima-bean agar.—Pseudopeziza medicaginis: Growth yellowish in varying degree; no fruiting observed; substrate shows discoloration.

Pseudopeziza trifolii: The growth is a rough black mat with a little white mycelium. The substrate shows slight discoloration.

Corn-meal agar.—Pseudopeziza medicaginis: Growth not vigorous; colonies scattered, black, and distinctly raised from the surface, which appears as though sprinkled with coarse black pepper; apothecia minute and scattered.

Pseudopeziza trifolii: Growth black, almost submerged in the substrate; colonies tend to remain separate, though the slope appears a solid black color; scattered minute apothecia occur.

Liquefaction of gelatin.—Both fungi cause rapid liquefaction of gelatin.



FRUITING CULTURES OF PSEUDOPEZIZA.

A, Fruiting culture of *Pseudopeziza trifolii*. × 15, approximately. *B*, Fruiting culture of *Pseudopeziza medicaginis* from alfalfa. × 15, approximately.

SPORE DISCHARGE.

The discharge of ascospores has been observed frequently under the microscope when apothecia have been crushed in water. The ascus slowly becomes longer and of greater diameter, forcing the spores forward in a more or less oblique biseriate position. The increase in diameter of the ascus of *Pseudopeziza medicaginis* appears to be somewhat greater than in the case of *P. trifolii*, thus allowing the spores to come more nearly into a biseriate position. When the limit of resistance of the ascus wall has been reached, the end ruptures, allowing the spores to be expelled in a column. When discharge takes place under water the spores show no tendency to remain together, but when they are discharged in air they show a tendency to remain in pairs. This pairing of the spores is probably due to the adhesive quality of the spore wall, a quality which is also shown by the tenacity with which the spores adhere to the cuticle of a leaf.

It is interesting to note that the tendency to remain in pairs is not shown equally by spores of the two species of Pseudopeziza. It is somewhat more marked in the case of *Pseudopeziza medicaginis*. This may be due to the fact already cited that the spores of this species are brought more clearly into biseriate position before discharge takes place. In order to determine this difference, spores were collected on water agar as though for measurement. The spores in each group in selected miscroscopic fields were counted until the grouping of 1,000 spores had been determined. The results obtained at various times are shown in Table III.

TABLE III.—*Grouping of ascospores of Pseudopeziza medicaginis and Pseudopeziza trifolii when caught on an agar surface after being discharged normally from cultures.*

Spores of—	Spores in group—							
	1	2	3	4	5	6	7	8
Pseudopeziza medicaginis:								
First lot....number..	60	238	19	43	7	19	2	9
Second lot....do....	66	342	8	30	4	9	......	4
Third lot....do....	58	356	6	33	6	4	......	1
Total....	184	936	33	106	17	32	2	14
Pseudopeziza trifolii:								
First lot....number..	133	215	39	28	16	11	2	6
Second....do....	272	189	48	22	7	4	5	3
Third lot....do....	242	185	54	19	10	9	2	4
Total....	647	589	141	69	33	24	9	13

It will thus be seen that while in the case of *Pseudopeziza medicaginis* each spore group containing an even number of spores is greater than the preceding or following group, in the case of *P.*

trifolii there is almost a regular decrease of the number of groups from those containing one to those containing eight. Sufficient evidence has not been collected to determine whether the same clean-cut difference in the behavior of the two species appears when the spores are discharged from apothecia on living leaves.

SPORE GERMINATION.

In all the more obvious features of germination, the ascospores of the two fungi behave alike. They germinate readily when they have been discharged naturally upon a suitable moist surface; but germination is infrequent if the spores have been crushed out of the asci or if they are submerged in water. A single germ tube emerges from any point in the circumference of the spore, except that germination from the end has been observed only in the case of a few spores of *Pseudopeziza trifolii.* Under the best conditions that have been found, the proportion of germination is usually from 30 to 50 per cent. The vigor of germination varies greatly. Many of the spores which push out short germ tubes cease growth promptly, while a few develop vigorous germ tubes.

TABLE IV.—*Time required for the germination of ascospores of Pseudopeziza medicaginis and Pseudopeziza trifolii and rate of growth of the germ tube for three days at constant temperatures.*

[A plus sign indicates that the germ tube could be seen emerging from the spore, but that it did not reach a length equal to half the length of the spore. The figures in the body of the table represent the estimated length of the germ tube in terms of the length of the spores.]

Temperature (°C.).	Pseudopeziza medicaginis.						Pseudopeziza trifolii.					
	4 hours.	8 hours.	12 hours.	24 hours.	48 hours.	72 hours.	4 hours.	8 hours.	12 hours.	24 hours.	48 hours.	72 hours.
2.5 to 3	......	......	......	0.5	1	2	......	......	......	+	1	2
6 to 7	......	......	+	.75	1.5	2	......	......	+	0.75	1.5	2
9 to 10	......	+	+	.75	1.5	2	......	+	+	.5	1.5	2
12	......	+	0.5	1.5	3	4	......	+	0.5	1.5	3	4
16	+	0.5	1	1.5	3	4	+	0.5	1	1.5	3.5	5
21 to 22	+	.5	1	1.5	5	......	+	.5	1	2	5	......
24 to 25	+	.5	1	2.5	5	......	+	.5	1	2.5	5	......
27 to 28	......	+	.5	2.5	4	......	......	......	+	1	[1]	[1]
29	......	......	+	1	2	[1]	......	......	......	+	......	......
30	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]

[1] Spores disintegrate. [2] No germination.

The one significant difference that they show is found in the fact that the spores of *Pseudopeziza medicaginis* will continue to germinate at a slightly higher temperature than those of *P. trifolii.* In order to test this relation of temperature to germination, spores were discharged naturally upon an agar surface with all the precautions necessary to secure mature spores previously described in obtaining spores for measurement. The agar used in all cases consisted of 2 per cent of agar-agar in water carefully cleared and filtered. In order to insure identical conditions for the two species in each test, transfers of both were made to the cover of the Petri dish containing the agar. The spores were discharged simultaneously for 1 to 1½ hours. If at the end of this time sufficient spores were present, the cover containing the cultures was transferred to another dish and the spores placed at the desired temperature. Petri dishes to the number of 72, nearly all of them containing spores of the two fungi, were incubated in this way. The results are given in Table IV.

This table shows that the two species germinate with almost exactly the same degree of vigor at each temperature, except that the spores of *Pseudopeziza trifolii* cease to germinate, or, perhaps more exactly, to make growth after the initial stages of germination, at a slightly lower temperature than those of *P. medicaginis.* Although the difference here may seem slight—almost within the limit of experimental error—it has been found constant and definite in repeated tests. The possible significance of this fact in connection with the difference in geographic range of the two fungi will be considered later.

EFFECTS OF TEMPERATURE ON SPORE PRODUCTION.

When cultures of the two fungi are placed at a series of constant temperatures they appear to show constant differences in the time required for spore production and in the abundance of spore production at each temperature. At the outset it must be stated that limitations inherent in the method of starting cultures cause wide variation in the behavior of the cultures of each species. This difficulty is partly overcome by using several cultures and by repeating the work. Even then the results must be regarded as being suggestive rather than accurate. The time required for the production of ascopores as obtained in two trials is given in Table V. Three cultures of each fungus were used, and the earliest time at which the discharge of ascospores could be demonstrated in any of the three cultures was recorded. The three highest and the lowest temperature rarely varied more than one degree, and the remaining temperatures varied only half a degree.

TABLE V.—*Time required for the production of ascospores of Pseudopeziza medicaginis and Pseudopeziza trifolii at constant temperatures.*

Ascospores of—	Temperatures (°C.).											
	8	9	11	12.5	13	14	15	16	18.5	20	21.5	24
Pseudopeziza trifolii..........days..	82	53	52	30	43	30	36	30	20	16	16	21
Pseudopeziza medicaginis.....do....	82	.....	.....	58	.....	52	49	36	16	14	14	20

Table V shows that below 14° C. the behavior of *Pseudopeziza medicaginis* was erratic, rarely fruiting at all. Only one culture fruited at 8° C. in one of the trials. At and below 16° *P. trifolii* requires a shorter time for the production of spores than *P. medicaginis*, while above this temperature the condition appears to be reversed. But the most striking differences in the behavior of the two fungi are not shown in the table. These differences lie in the length of the spore-producing period and in the abundance of the spores produced. Although *P. trifolii* is under most circumstances the more prolific spore producer, this preponderance is greatly increased at and below 18° C. Here abundant fruiting may occur for two weeks and longer, while cultures of *P. medicaginis* fruit very meagerly and only for a short period at these temperatures. Above 16° *P. medicaginis* begins to fruit more abundantly, reaching its maximum at temperatures a little above 20° C. Thus, the optimum temperatures for the fruiting of these fungi may be judged roughly as about 13° to 22° C. for *P. trifolii* and 16° to 24° for *P. medicaginis*.

RESISTANCE OF THE SPORES TO DESICCATION.

In order to determine whether ascospores discharged from the ascus might be able to live over winter on seed or débris carried with the seed, it was desirable to test the resistance of discharged ascospores to periods of drying of such duration as they would be obliged to endure on the seed. Owing to the slow growth of the fungus after germination and the limitations of conditions under which spores will germinate at all, it is obvious that the spores must be dried and germinated under such conditions that all other organisms will be excluded; that is to say, the entire process must be carried out under conditions of pure culture.

Obviously, the preferable method would be to dry the spores on the seed itself. In order to do this, sterile seeds were necessary. The difficulty of obtaining such seeds which were certainly free from any residual effect of the sterilizing agent on the seed coat was so great that it was finally abandoned.

Preliminary tests with plaster of Paris blocks as the conveyor for the spores during desiccation were so satisfactory that they were used exclusively. Thin blocks small enough to slip into a test tube easily, were sterilized by heat and placed beneath cultures which were discharging spores actively. After a period of 8 to 12 hours the blocks were placed in sterilized test tubes. These were stored, some in a glass case in the laboratory and some outside a north window.

From time to time one or more of these blocks were placed on water agar to which a small amount of alfalfa-leaf decoction had been added. The amount of the decoction appeared to make no material difference up to any amount that could be added to 3 per cent agar without causing it to lose its ability to solidify upon cooling. Other culture media were tried, but none gave as prompt a result as this. The red-brown color of the Pseudopeziza stroma produced by this medium on these white blocks (Pl. I, *B*) could be recognized at an earlier date than the pale-colored growth which developed when other media were tried.

Spores of *Pseudopeziza trifolii* were tested in the same way with those of *P. medicaginis*, though not as extensively. The results are given in Table VI.

TABLE VI.—*Viability test of ascospores of Pseudopeziza medicaginis and Pseudopeziza trifolii viable when dried on plaster of Paris blocks in the laboratory and out of doors.*

Place and date of ending desiccation.	Time (days).	Results.
PSEUDOPEZIZA MEDICAGINIS.		
In laboratory:		
Feb. 1, 1915	32	+
Jan. 23, 1915	36	+
Dec. 3, 1915	37	+
Feb. 1, 1915	38	+
Dec. 9, 1916	39	+
Dec. 16, 1915	48	+
Feb. 20, 1915	49	+
Mar. 26, 1915	63	+
Jan. 5, 1916	66	0
Jan. 12, 1916	72	+
Jan. 17, 1916	76	+
Jan. 23, 1915	76	+
Jan. 22, 1915	79	+
Jan. 1, 1915	85	0
Aug. 26, 1915	93	0
Do	94	0
Apr. 11, 1915	100	0
Feb. 12, 1916	104	+
Sept. 1, 1916	210	0
Jan. 15, 1916	357	0
Out of doors:		
Dec. 9, 1915	27	+
Dec. 16, 1915	34	+
Dec. 22, 1915	52	0
Jan. 17, 1916	77	+
Jan. 13, 1916	78	+
Feb. 15, 1916	106	+
PSEUDOPEZIZA MEDICAGINIS—continued.		
Out of doors—Continued.		
May 20, 1916	120	+
Feb. 15, 1916	108	+
Apr. 7, 1916	159	+
May 20, 1915	212	0
Sept. 1, 1916	303	+
Do	329	0
PSEUDOPEZIZA TRIFOLII.		
In laboratory:		
Jan. 17, 1916	36	+
Mar. 7, 1916	63	+
Feb. 15, 1915	64	+
Apr. 6, 1916	112	0
May 15, 1916	113	+
Apr. 20, 1916	120	0
Sept. 1, 1916	258	0
Do	256	0
Out of doors:		
Jan. 17, 1916	28	+
Do	25	+
May 4, 1916	104	+
Apr. 7, 1916	107	0
Sept. 2, 1916	265	0
Sept. 1, 1916	265	0

From these results it appears that drying alone can not be depended upon to kill all the spores of either Pseudopeziza in less than one year. Severe freezing during drying had no apparent effect. If conditions for survival are as favorable on the seed as on plaster of Paris blocks, the spores should be able to live from one season to the next on the seed. But unless conditions on the seed are more favorable than on the block, they should not be able to survive and germinate during a second year.

PATHOGENICITY OF THE FUNGI.

METHOD OF MAKING INOCULATIONS.

In all inoculations that have been made, ascospores alone have been used as the inoculum. The conidiumlike structures which have been described are produced almost wholly in the substrate, and since only rarely will one of them separate from the mycelium, no practicable method for using them has been developed. Since no evidence has been found indicating that they occur in nature or that they germinate, no great importance attaches to them.

In the first inoculations an attempt was made to obtain the ascospores in water suspension, but when the apothecia were crushed in water usually only a few spores became separated from the ascus. The few attempts to make inoculations with such meager spore suspensions failed. The method finally adopted and used with minor modifications in all inoculations reported takes advantage of the natural discharge of spores from cultures. If a Pseudopeziza culture is removed from the test tube carefully it may be cut into fragments and placed on a support, where it will continue to discharge spores for several days provided it is not exposed to direct sunlight or high temperatures. A culture may thus be removed from a test tube and placed over a plant upon which the spores will fall. If the whole plant is to be inoculated, the culture may be placed in the top of a bell jar which is set over the plant and turned from time to time to insure a uniform distribution of the spores.

If single leaves are to be inoculated, the culture or fragments of the culture may be placed for a short time over these leaves in succession. A more uniform discharge of spores for long periods is obtained in a dark room at 16° to 20° C. If inoculations are made in the field, they should be made at night or on a cloudy day. The plants may be wet with a fine spray before the spores are discharged, or if time permits this may be deferred until the spores are on the leaf. In the latter case, a larger number of infections are usually secured, due apparently to the fact that spores falling on large drops of water are held from sinking by surface tension and germinate too far from the leaf surface to effect penetration. After the inoculated plants are sprayed, they should be kept in a moist chamber for at least 12 hours.

This method has been employed in all inoculations made, unless otherwise stated.

CONDITIONS UNDER WHICH INOCULATIONS WERE MADE.

If inoculations are to be entirely conclusive in result, the control plants must remain free from the disease. It has been found impossible to keep plants free from leaf-spot for infection experiments during the summer at Madison, Wis., where the work was done. This has been due to the fact that alfalfa fields are located so close to the greenhouse that spores are easily blown in through the ventilators. But it has been found that if all diseased alfalfa foliage was removed from the greenhouses in the autumn after the ground outside froze, it was possible to keep alfalfa plants free from infection with leaf-spot during the winter and spring. Therefore all inoculations have been made or at least repeated during the winter months. This precaution has not been necessary in the case of inoculations with *Pseudopeziza trifolii*, since the Pseudopeziza leaf-spot has not occurred on any species of Trifolium about Madison during the time this work was in progress. The following host plants have been inoculated with pure cultures of both species of Pseudopeziza.

HOST PLANTS INOCULATED.

Medicago sativa with Pseudopeziza medicaginis.—In seven or eight days, under greenhouse conditions, infections begin to show as minute brown spots scattered over the foliage. If infection is very abundant these leaves quickly die. If only four or five infections are scattered over each leaflet, apothecia begin to appear in about two weeks. For instance, one inoculation made on December 2, 1915, produced abundant apothecia on the spots by December 15. On December 20 spores discharged from apothecia on one of the leaves of this plant were cultured, and the fungus was recovered. An inoculation made on April 17, 1915, on plants in the field before the natural infection developed showed abundant spotting 11 days later. The weather turned cold after this date and no fruiting was observed.

Leaves of all ages are attacked. Leaves which have grown to full size appear to develop more abundant infections than leaves which are not full grown, but leaves which are yellow and weak do not seem to become infected as easily as those which are more vigorous.

None of the infection experiments performed during three winters has failed to develop a greater or less amount of typical leaf-spot.

Medicago sativa with Pseudopeziza trifolii.—Inoculation experiments have been repeatedly conducted parallel with those already cited on alfalfa, using plants of different ages. No infections visible to the naked eye have been produced.

Medicago lupulina with Pseudopeziza medicaginis.—Plants of this host have never been very thrifty under greenhouse conditions, and therefore not a large number have beeen available for inoculation. In no case has any infection been obtained. Attempts to secure infection by setting *Medicago lupulina* plants in the garden among alfalfa plants which were heavily infected with *Pseudopeziza medicaginis* also failed to produce infection.

Medicago lupulina with Pseudopeziza trifolii.—Only two inoculations have been tried. No infections resulted.

Melilotus alba with Pseudopeziza medicaginis.—On March 28, 1915, several leaves of a vigorous sweet-clover plant were placed beneath fragments of a culture of *Pseudopeziza medicaginis* which was discharging spores. At the end of 24 hours the culture was placed over the entire plant, which was kept in a moist chamber 48 hours longer. After four days the leaves first inoculated showed minute brownish spots. These did not increase in size. After two weeks the portions of the leaves bearing the minute spots were embedded in paraffin and sectioned. In these sections the brown spots were found to consist of dead shrunken cells in which traces of mycelium could be found. But this mycelium appeared to be shrunken and dead and not advancing into the living cells of the host. From this, it appears possible that under favorable conditions *P. medicaginis* may be able to cause a very slight spotting of sweet-clover leaves.

Trifolium pratense with Pseudopeziza medicaginis.—Inoculations of red-clover plants in the greenhouse with pure cultures failed to produce any infection. Red-clover plants grown in the garden in close proximity to badly diseased alfalfa plants have never shown a trace of this leaf-spot during the two years that these diseases have been under observation.

Trifolium pratense with Pseudopeziza trifolii.—Infection from inoculation with spores from pure cultures has been at all times easy under greenhouse conditions. Frequently such abundant infection has been obtained that the leaves are killed before the spots develop to a fruiting stage. The incubation period of the disease appears to be slightly longer than that of *Pseudopeziza medicaginis*, varying somewhat with the abundance of the infection. If a leaf is heavily infected, the individual infections appear to develop more rapidly and produce small characteristic killed areas earlier than if infections are few. Numerous infections appear in 11 or 12 days, and in the greenhouse the leaf frequently dies a few days later. Fruiting bodies have not been observed on such leaves, but a reisolation has been made from infections two weeks after inoculation.

Less numerous infections may not show for two weeks or even longer, but at the end of three weeks or more they may produce typical apothecia if the air of the greenhouse is sufficiently moist. These apothecia have been found on leaves nearly or quite dead. In this respect the fungus behaves differently than does *Pseudopeziza medicaginis*. Apothecia on dead leaves are very difficult to discover unless the leaf has been in a moist atmosphere for some time, when they appear as dark-amber gelatinous masses on the leaf surface. The exposure of these gelatinous masses of asci to dry air for even a few minutes causes them to discharge the larger part of the spores present and to shrink to a minute mass only a little darker in color than the leaf and therefore difficult to identify. The best development of apothecia has been obtained by placing infected plants outside the greenhouse during protracted periods of rainy weather.

Trifolium hybridum with Pseudopeziza medicaginis.—No success in obtaining visible infections has been attained.

Trifolium hybridum with Pseudopeziza trifolii.—Of the several plants inoculated only one survived in a vigorous condition for a sufficient period to show infection. This showed an abundant spotting, which was in every way characteristic of the Pseudopeziza spot on red clover except that the spot appeared to be somewhat limited in development by the veins, thus showing a slight tendency to become angular. No fruiting bodies were produced. Apparently infection takes place only under the most favorable circumstances. This plant appears to be a much less congenial host than red clover.

GERMINATION OF THE SPORES ON THE LEAF.

While study was being made of the leaf-spot fungus in the host tissue it was found that the mode of penetration could be observed very readily by decolorizing the leaf soon after inoculation was made. This method of study was used, not only to determine the normal penetration of these fungi into their own hosts, but to determine the relation of these parasites to other closely related plants reputed to be hosts of these fungi but upon which infection had not been obtained. In case preliminary inoculations failed to give visible results it was more simple and rapid to determine whether the spores of that fungus could penetrate the host in question and develop after penetration had taken place than to conduct other extensive inoculations. Thus, a study of penetration has formed a part of all inoculation trials. The results of the two methods of attacking host relationships should be considered together.

METHOD OF STUDY.

The most of the data given here have been obtained by the following simple procedure: Leaves which have just reached full development are selected for inoculation. A culture of Pseudopeziza known to be discharging spores abundantly is supported over the leaf or one of the leaflets so that the spores as they are discharged will all fall upon it. The leaf may be removed from the plant for studies which do not involve a period of more than two days, since results obtained from such leaves have always been found by comparison to agree with results obtained from leaves attached to the plant. The leaf may be sprayed with very fine spray before the spores are discharged upon it, but more abundant penetrations are usually obtained if the spores are allowed to stick to the leaf before it is wet. When the leaf has been kept moistened for at least 12 hours, usually longer, it is removed, dropped into a mixture of equal parts of acetic acid and alcohol and promptly heated to the boiling point. Leaves which are killed promptly in this fashion decolorize in better condition than when slower killing takes place in cold acetic alcohol. The acetic alcohol is changed until all color has been removed from the leaf.

The leaf may then be mounted in this liquid on a slide under a cover glass and examined under the microscope. The epidermal cells should be perfectly clear, and the entire structure of the leaf to its very center should be visible. The spores remain attached to the leaf during the treatment, and the method of entry and the mycelium within the leaf can be clearly seen. No method of staining has been found to improve the visibility of the fungus.

Although this method works best in the case of alfalfa leaves, it works well enough with the various clovers to give entirely satisfactory results.

METHOD OF PENETRATION.

In all of the hundreds of penetrations observed the method of entry has invariably been as here stated. The spore is found stuck fast to the leaf. The germ tube emerges from the spore either within or at the margin of the area of contact of the spore with the leaf and passes directly through the cuticle into the epidermal cell. Occasionally a spore sends out its germ tube along the surface of the leaf, but such a germ tube has never been observed to enter the leaf. Apparently the germ tube must enter the leaf at the moment of emergence from the spore, if at all. Ordinarily there is no perceptible thickening or alteration of the wall in consequence of this penetration. The actual opening appears to be extremely minute.

After passing through the wall, the germ tube quickly expands to normal size. When it reaches the center of the cell it usually divides (fig. 5) into two or three branches, which pass into the adjoining epidermal cells or down into the palisade layer. Cell walls do not appear to offer any obstruction to advancing hyphæ. No marked disorganization of the cell contents appears to result from this invasion until hyphæ become very numerous.

The actual time required for a spore to germinate and transfer its contents to the germ tube inside the leaf has not been determined accurately, but in most cases it must be less than 12 hours at 18° to 22° C.

This description applies to the method of penetration of *Pseudopeziza medicaginis* and *P. trifolii* in their respective hosts. The following notes have been made of the penetration of germinating spores of these fungi in other reported hosts that have been available:

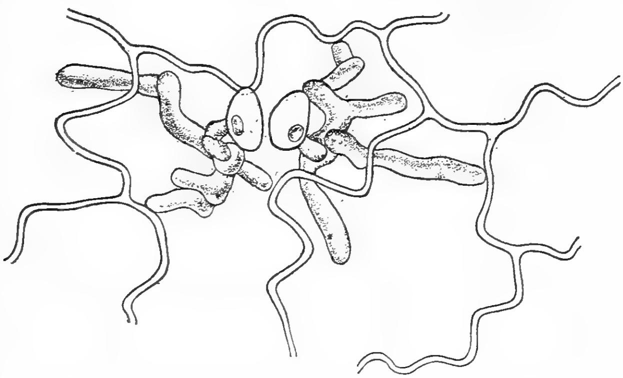


Fig. 5.—Penetration of the epidermis of an alfalfa leaf by the germinating ascospores of *Pseudopeziza medicaginis*. × 800.

Trifolium pratense by Pseudopeziza medicaginis.—Inoculated leaves were decolorized in two, three and five days after inoculation. After three days the host cells beneath many of the germinated spores had yellow granular contents. The yellow color made the exact relation of the germ tube to the cell impossible to determine. In five days it could be observed that in the case of at least a part of these yellowed cells the germ tube had passed through the epidermal cell wall, but had not advanced far into the cell.

Medicago sativa by Pseudopeziza trifolii.—A leaf inoculated on the plant on March 28, 1915, appeared to show penetration in 60 hours. Five leaves inoculated on December 4, 1916, and decolorized four days later showed many yellowed cells beneath germinated spores. Suitable fragments were embedded and penetrations found in sections. The germ tube had not advanced beyond the first cell which it entered.

Medicago lupulina by Pseudopeziza medicaginis.—Four series of leaves removed from the plant were tried. Penetrations were noted in 23 hours at 22° C. Penetrated cells always show yellow granular contents. Even after 75 hours it was doubtful whether the germ tube had advanced beyond the first cell penetrated.

Medicago lupulina by Pseudopeziza trifolii.—One series of leaves was removed from the plant. Penetrations were abundant and the penetrated cells yellowed, but even after 52 hours the germ tubes had not advanced beyond the cell first penetrated.

Melilotus alba by Pseudopeziza trifolii.—Three days from inoculation a few germ tubes were found distinctly inside epidermal cells, but they had advanced but slightly. Penetrated cells were not yellowed.

Melilotus alba by Pseudopeziza medicaginis.—The cultures used for inoculation in this series did not produce many spores. Nevertheless, after four days two penerations were found. The penetrated cells were very slightly yellowed.

Trifolium hybridum by Pseudopeziza trifolii.—No examination was made until two days after inoculation. At this time penetrations were abundant and easily seen. In a few cases germ tubes had advanced into cells adjoining those first penetrated. No yellowing of penetrated cells was observed.

Trifolium hybridum by Pseudopeziza medicaginis.—In 24 hours penetrations were abundant, but the germ tubes had not advanced far into penetrated cells. Penetrated cells showed no yellowing.

It appears that the results which are shown above are exactly parallel to the results obtained from inoculations. In every case where infection in varying degree has been attained, penetration has occurred abundantly and the growth of the hyphæ within the host cells has been rapid without causing discoloration of the cell contents. In cases where visible infection has not been obtained, the relative number of penetrations is usually reduced, but in any case growth of the germ tube ceases promptly upon entering the epidermal cell. Thus, the resistance which the plants that can not be infected offer appears to be due not to any mechanical obstruction to entry, but to something within the epidermal cell which prohibits growth.

These infection experiments supported by penetration studies have failed to produce a completely successful infection of any of the hosts tried except those from which the fungi were isolated. This result is very different from that which was anticipated from a consideration of the host lists. Have we here a group of closely similar fungi highly specialized in their host relationships?

It is noteworthy that in both host lists only two or three of the species of Trifolium are native to America. All the rest have been introduced if they occur here at all. Moreover, some of these introduced hosts which are widely distributed do not appear to be attacked by this parasite except in certain limited areas. For example, *Pseudopeziza medicaginis* has been found on *Medicago lupulina* only in New York; *P. trifolii* has been reported on *Trifolium repens* only by McClatchie (1895) on the Pacific coast[1] and not at all on *T. hybridum.* It is not likely that these fungi have been overlooked on these hosts in other localities, and therefore the conclusion that they do not always pass to these hosts can hardly be escaped. Thus, there is reason to suspect that these two species, as now re-

[1] An excellent collection of Pseudopeziza on *Trifolium repens* now in the possession of the writer was made by Mr. C. W. Hungerford at Olga, Wash., on Sept. 3, 1916.

garded, are made up either of several closely similar species or of a group of specialized races.

Especially in the case of the Pseudopeziza on *Medicago lupulina* the fragmentary evidence indicates a species distinct from that on alfalfa. In addition to the evidence already given, the measurements of 113 ascospores collected under standard conditions is adduced. (Table VII.)

TABLE VII.—*Lengths of 113 ascospores of Pseudopeziza medicaginis on Medicago lupulina, measured to the nearest micron.*

Ascospores of —	Length (microns).				
	9	10	11	12	13
Pseudopeziza medicaginis........number..	1	14	59	31	8

When Table VII is compared with Table II, it will be noted that these spores are even larger than those of *Pseudopeziza trifolii*. Unfortunately, the cultures which were made of this fungus were destroyed, and complete evidence of the relationship of these fungi was not obtained.[1] Of the other hosts of *P. medicaginis*, less can be said. Field observation indicates that the fungus in *Medicago falcata* and *M. hispida denticulata* occurs by infection from Pseudopeziza in alfalfa. A collection of the fungus has been found in only one instance each on *Melilotus alba* and *Vicia villosa*. An examination of a portion of the collection on *Melilotus alba* reveals a lesion that is in all respects similar to that which the fungus causes on other hosts, but no asci and spores by which the fungus could be identified were found. Certainly the occurrence of the fungus on these hosts is not common or of economic importance. No material of Pseudopeziza on *Onobrychis sativa* or any species of Trigonella has been available for study.

Of the host list of *Pseudopeziza trifolii* only a few species have been available for study. The fungus from *Trifolium pratense* has not infected any other species to produce fruiting of the fungus on that host. Furthermore, it has not been found fruiting on any other host in America except in the one instance already mentioned. Yet reports well supported by herbarium specimens indicate that *Trifolium repens* and *T. hybridum* are abundantly infected in Italy. Whether this infection is by the same species of the fungus or not can not be determined at present.

[1] It is of interest to note that *Pseudopeziza medicaginis* was first described on what is now known as the variety *wildenowii* of *Medicago lupulina*. If it should be shown that Pseudopeziza on *Medicago lupulina wildenowii* is a distinct species from that on *Medicago sativa* the name *Pseudopeziza medicaginis* will be restricted to the fungus on the original host, and a new species name will be required for the fungus on alfalfa.

LIFE HISTORY OF THE CAUSAL ORGANISM IN RELATION TO THE HOST PLANTS.

AMERICAN STUDIES BEARING ON LIFE HISTORY.

The great economic importance of the alfalfa crop in America has inspired the small amount of work which has been done upon this disease with a point of view quite different from that shown in the European studies already reviewed. Life history has been studied with a view to the possible control of the disease.

The first work was done by Chester (1891) at the Delaware Agricultural Experiment Station. In 1889 twenty plats of alfalfa were seeded in different parts of Delaware, with seed from the same source. The disease appeared on all of these plats at about the sixth week after planting. The plat under closest observation at Newark showed a yellowing of the leaves accompanied by black spots before Pseudopeziza was found fruiting on some of the dark spots. Evidently some other disease was associated with Pseudopeziza. Chester concludes from this experiment that the disease is carried by the seed and next tries a method of disinfecting the seed in order to prevent such conveyance. Seed was treated with copper sulphate and planted in heat-sterilized soil in cans. The diseases appeared on all the plants from these cans. Therefore, Chester concludes that the source of the disease must be a general atmospheric infection. Unfortunately, in none of his experiments does he give any details regarding the proximity of his plats or plants in cans of sterile soil to alfalfa which was infected with the leaf-spot and which might have been a source of wind-borne spores.

The only other attempt to study the disease which has been reported was made by Coombs (1897a) in Iowa. On August 20 alfalfa seedlings 3 weeks old grown under bell jars were treated as follows: One was left as control, one sprayed with germinating Pseudopeziza spores, and one sprinkled with powdered diseased leaves showing disease. Next, plants growing in the field were cut back, and after the débris was removed, the roots were protected by large bell jars. In the next six weeks the plants outside the bell jars became diseased, while those inside were healthy. However, when the jars were removed the plants immediately became diseased. As a result of this work Coombs concludes that two things are established: (1) That plants are infected by spores from the air and (2) that the disease is strictly local and not systemic.

It will be seen at once that these conclusions are based on a very small amount of experimental evidence. Such important factors as the high temperature and absence of dew or rainfall inside the bell jars do not appear to have been considered as possible conditions which might have prevented infection even had the spores been present.

At this point, it is convenient to mention an English discussion of this disease by Ivy Massee (1914) in which an effort is made to throw light on the method by which the fungus is conveyed from one locality to another. In this article Miss Massee states that so far as England is concerned the dissemination of the disease is due to diseased seed which is badly cleaned. She says, "I have recently examined a sample of commercial seed and found the fungus present in abundance on minute fragments of leaves and calyces, and rarely on the seed itself." Unfortunately, Miss Massee does not state the methods by which she was able to make the identification of the fungus with such certainty on this single sample of commercial seed. Even if she was correct in this observation, it still remains to be proved that the fungus which she found was alive and capable of infecting the plants grown from this seed.

The many scattered observations of the disease merely contribute data regarding distribution, seasonal occurrence, and environmental factors. Most of these reports indicate that the disease is worse on plants during the first summer of their growth than later, but Coombs (1897) speaks of attacks as being worse after the first year. Most reports indicate that the disease usually gains headway slowly in the spring and becomes worse later in the season, but this is not always the case. Stewart, French, and Wilson (1908, p. 384–387) speak of the disease as being worse in dry years while most reports, especially from drier regions, indicate that the disease is worse in wet seasons.

The facts bearing upon the overwintering of the fungus in the field are surprisingly meager. The only definite bit of observational evidence is that of Chester (1891), who states that he found live asci on leaves in midwinter. Voges (1909) suggests in addition that the fungus survives the winter in living leaves.

After surveying these scattered references in American literature we find that there is a general belief that *Pseudopeziza medicaginis* is distributed with the seed and survives the winter on dead leaves. This opinion has been reached, not so much as the result of careful experimental evidence, which in fact is meager, but more as the cumulative effect of the expressed opinions of competent observers who have watched its development during a series of years.

METHOD OF OVERWINTERING.

The first evidence of the method of overwintering of the leaf-spot fungus in the field was obtained in the spring of 1916. On April 11 overwintered alfalfa leaves showing abundant Pseudopeziza spotting were brought into the laboratory and placed in a moist chamber.

Two days later, when one of the apothecia was crushed out in water, asci containing spores apparently mature were found. The leaf was then supported over an agar surface. In two hours a large number of spores were discharged, which germinated promptly. At this time the young alfalfa shoots had hardly emerged from the mulch of the débris of the previous season's growth.

On May 6 spots began to appear on the alfalfa foliage of some of the plats under observation. When the spotted leaves were decolorized, characteristic Pseudopeziza spores with germ tubes penetrating the epidermal cells were found in nearly all the spots.

A search of the overwintered foliage discovered a large number of fresh-appearing apothecia developed on leaf areas that had been diseased the previous year. When the overwintered leaves were placed over agar plates, a large number of viable ascospores were caught.

Fragments of overwintered leaves bearing apothecia were placed over ten marked leaves of a healthy alfalfa plant in the greenhouse, and the plant was kept in a moist chamber for 24 hours. On May 17 seven of the ten marked leaves showed more or less of the characteristic Pseudopeziza spotting.

Five or six of these overwintered leaves bearing apothecia were placed on the ground under a rank growth of alfalfa plants in the greenhouse. The plants were then sprayed, but not covered to prevent evaporation of water from the foliage. On May 21 the alfalfa foliage in the vicinity of these overwintered leaves was found infected with leaf-spot.

On March 31, 1917, overwintered alfalfa leaves bearing leaf-spot lesions were collected in an alfalfa plat. At this time no spores could be found in the apothecia. These leaves were kept in a moist chamber for a week, care being taken to soak them in water twice a day to remove the products of decomposition. At the end of the week asci with mature spores had developed in the old apothecia.

Thus, it appears evident that *Pseudopeziza medicaginis* survives the winter on diseased foliage which escapes decay. When the weather becomes sufficiently warm in the spring and moisture is provided by protracted rains or the shelter offered by the young growing foliage, new asci develop apparently in the old apothecia and, in addition, new apothecia are produced around the old one (Pl. II, *A*). The spores thus produced furnish the primary infection in the spring.

Apothecia producing spores indistinguishable from those of *Pseudopeziza trifolii* were found on overwintered clover leaves in the spring of 1916 in northern Wisconsin, but since no inoculations were made with these spores, their identity was not determined. However, it does not seem unlikely that this fungus winters in the same way that has been demonstrated for its close relative on alfalfa.[1]

METHOD OF DISTRIBUTION.

SUGGESTIONS FOUND IN THE LITERATURE.

Since the method of overwintering of these fungi has been traced, it is now possible to see their entire annual cycle in a field in which they have once been introduced. But thus far no information has been gained which serves to indicate how they are conveyed into new localities in which the host plants are grown for the first time. This phase of the problem is of special importance in connection with the alfalfa leaf-spot. A large amount of recorded experience indicates that this disease appears wherever alfalfa is grown, regardless of environment. A knowledge of the source of infection in these new localities might suggest feasible control measures.

Scattered through the various discussions of the alfalfa leaf-spot are found four suggestions that have been put forth to explain the constant appearance of Pseudopeziza on alfalfa in newly seeded fields: It is suggested (1) that the fungus is carried with the seed, (2) that it is conveyed in soil that is used to inoculate the new field with the bacteria producing nodules on the roots, (3) that the fungus spores are generally distributed in the air, and (4) that other host plants near by furnish the source of infection. Since none of these suggestions are supported by carefully controlled experimental evidence, they must be subjected to examination before they are used as working hypotheses in experimental work.

The first suggestion, that the fungus is carried with the seed, deserves careful attention. This might happen in three ways. Spores might adhere to the seed coat, spores or fragments of the fungus might accompany the seed, and living mycelium of the fungus might occur within the seed. When the conditions under which seed is produced are examined it is found that the fungus spores are practically all discharged and blown away before the seed is thrashed, thus making it highly improbable that spores are attached to the seed except as a rare occurrence. Commercial seed is so well cleaned that there appears to be small chance that fragments of the fungus are often conveyed with the seed.

The possibility that fragments of the fungus as well as the spores may be carried with the seed appears unlikely in the case of most commercial seed. Débris consisting of plant parts is so light in comparison with the seed that it is easily removed. Nevertheless, Ivy Massee (1914) states that she has examined commercial seed and

[1] On April 6, 1919, apothecia of *Pseudopeziza trifolii* were found abundantly on living overwintered clover leaves at Madison, Wis., showing clearly that young leaves infected late in the autumn under favorable conditions may carry the fungus over winter.

found the fungus present. This can hardly be a common occurrence in America.

The possibility that the fungus may be present in the seed as mycelium is open to the objection that this involves a larger or smaller amount of systemic infection, both of the plant producing the seed and of the seedling. No evidence of such a relation of these fungi to their host plants has been found, and therefore this method appears highly improbable.

The second suggestion, that the fungus is conveyed with plant débris that accompanies soil which is transported to new fields, may and probably does account for a small amount of the distribution of the fungus. But owing to the restricted extent of this practice, this method must be of minor importance.

The third hypothesis, that spores of Pseudopeziza are generally distributed in the air, has been advanced several times in a vague way either in a discussion of conditions where large areas of diseased alfalfa were growing at no great distance or with an implied belief that some other host plant in the vicinity was the source from which this general infection arose. In the vicinity of areas of diseased alfalfa it is highly probable that spores are borne to a considerable distance by wind, but it is not often that the spores are produced so abundantly that they are likely to be conveyed great distances in large numbers.

The final hypothesis, that other hosts provide the source of infection, has been rendered less probable by results already presented. The only common hosts that can be considered are red clover and yellow trefoil (*Medicago lupulina*). Pseudopeziza on red clover appears to be a distinct species from that on alfalfa, and no evidence has been obtained indicating that the fungus on yellow trefoil can cross to that host.

Thus, a summary of the available evidence does not point clearly to any of these suggestions as the one most likely to contain the truth. However, the suggestion that the fungus is carried with the seed affords most opportunity for experimental study and, if found true, affords the greatest opportunity for the application of control measures. The following experiments in seed sterilization were carried out.

EXPERIMENTAL METHODS AND RESULTS.

Laboratory experiments.—If the fungus spores are carried adherent to the seed they must inevitably germinate upon the seed coat and produce apothecia there, if at all. In order to determine to what extent the fungus is capable of developing upon the seed coat, spores were discharged upon seeds sterilized with formaldehyde. The seeds were then germinated upon agar in test tubes. After a time minute fungous colonies were found developing upon the seed coats, whether they remained attached to the cotyledon leaves or fell to the agar. In no case were the cotyledon leaves attacked. Subsequent attempts to infect cotyledon leaves of seedlings did not produce macroscopic lesions. The seed coats bearing the minute fungous colonies were subsequently transferred to fresh agar slopes to keep them moist, and finally they developed minute apothecia. This development was so slow, however, that it is doubtful whether it could proceed so far under field conditions, where periods of drying would occur and competition with other fungi would be encountered.

Efforts to grow the fungus on soil sterilized or unsterilized have been entirely unsuccessful.

If the fungus occurs on the outside of the seed or in débris it can easily be destroyed by the surface sterilization of the seed. If such treated seed can then be grown under conditions which will exclude other sources of infection and which will also be favorable for the development of the fungus, the occurrence of the disease will indicate that the fungus is carried within the seed.

A satisfactory method of seed sterilization has been worked out by Mr. A. H. Gilbert (in an unpublished manuscript). He found that treatment with a solution of 1 part of bichlorid of mercury in 1,000 parts of water for five minutes rendered the seed sterile, while treatment for 10 minutes injured the seed. These treatments were repeated, and it was found that treatment for eight minutes was more than sufficient to render the seeds sterile without injury, provided they were washed promptly after treatment. All sterilized seed mentioned in the experiments here described were treated in this way.

Suitable conditions for growing the treated seed were difficult to obtain. Two places were tried—in the greenhouse during the winter months and in the open field in localities as remote as possible from other alfalfa. Experience in the greenhouse in the winter of 1915 showed that unless great care was taken with infected plants, the fungus was likely to occur occasionally on other alfalfa plants in the same house. During the following two winters all inoculated plants were cared for so thoroughly that in not a single instance did the leaf-spot develop upon any other plant in the houses until the disease appeared in the fields outside in the spring. Alfalfa plants grown close to red clover infested with *Pseudopeziza trifolii* remained free from leaf-spot. The following greenhouse-plat trials were made:

(1) Four grams of sterilized alfalfa seed were exposed to a discharge of ascospores of *Pseudopeziza medicaginis* for three days before sowing in the garden greenhouse on March 3, 1916. Thousands of viable spores must have been attached to the seeds at the time they were sown. By April 15 the plants were 6 inches tall and very vigorous. When the experiment was discontinued

on May 10 no trace of Pseudopeziza had appeared. The plants were then 10 to 12 inches tall, very vigorous, and in a dense mat apparently favorable for the development of the fungus. At the end of this experiment the plat was inoculated with Pseudopeziza from overwintered leaves and was quickly overrun with the disease, showing that the greenhouse conditions were favorable for its development.

(2) On January 27, 1917, a plat about 4 feet square was sown in the garden greenhouse with unsterilized Kansas-grown alfalfa seed. This plat developed normally without leaf-spot until May 5, when the disease was present in the field outside.

(3) On February 16, 1917, a plat 2 by 3 feet was sown in a garden greenhouse with sterilized alfalfa seed 3 years old. This plat likewise developed normally with no leaf-spot until May 10, at which date leaf-spot was abundant outside the greenhouse.

Several other plats were started and developed in the greenhouse without leaf-spot, like those referred to above, but owing to insect injury the conditions were not as favorable for the development of the disease as those described. In fact, all greenhouse plats started from seed, whether sterilized, unsterilized, or even treated with spores before sowing, have developed without the appearance of leaf-spot until the disease occurred abundantly in an alfalfa field close outside the greenhouse.

Field plats.—In the selection of locations for plats three conditions were sought: (1) Remoteness from large areas of growing alfalfa; (2) the greatest possible distance from farms where alfalfa has been grown; and (3) accessibility, so that a visit to the plat would be possible. The second condition was very difficult to secure. Small plats of alfalfa are surprisingly abundant even in localities where it is not grown as a farm crop. In consequence of this fact, only one of the eight plats started in 1915 was found upon examination to be sufficiently remote to give results of value.

In 1915 the assistance of the States Relations Service secured the cooperation of several agricultural county agents whose intimate knowledge of local conditions made possible the selection of a larger number of suitable locations. To these men the writer is indebted for any degree of success that was attained in these experiments.

The seed which had been sterilized superficially was furnished to the agricultural county agents, who allotted it to the men on whose farms the plats were to be located. In the autumn all the plats were visited except the one at Bruce, S. Dak., which was under the observation of Dr. A. G. Johnson, and the presence or absence of leaf-spot was determined. In a number of cases alfalfa was found growing nearer the plat than was previously supposed. The results noted on such plats—always an abundance of leaf-spot—are excluded from the summary in Table VIII. However, if, as sometimes occurred, the near-by plants were very few in number and no other plants were known to exist within a 5-mile radius the results have been included.

TABLE VIII.—*Summary of data of plat tests to determine whether leaf-spot can be prevented on alfalfa sown in isolated localities by the superficial sterilization of alfalfa seed.*

State and town.	Date sown.	Date visited.	Area (square rods).	Distance to nearest alfalfa (miles).	Leaf-spot.
Maine:	1915.	1916.			
Mercer	June 28	June 14	1	6	Present.
	1916.				
Albion	May 6	Sept. 12	20	3½	Do.
Fairfield	June	...do	40	5	Do.
Gorham	May 20	Sept. 5	1	½	Do.
Harrison	June 1	...do	2	3½	Doubtful.
Vassalboro	May	Sept. 6	40	5	Present.
Windsor	June	Sept. 12	40	5	Do.
South Dakota:					
Bruce	May 20	Aug. 11	40	5	Do.
Wisconsin:					
Doering	June	Oct. 2	40	10	Doubtful.
McConnor	May	Oct. 4	10	½	Present.
Radisson	June	...do	40	½	Do.
Merrill	...do	Oct. 2	40	5	Do.
Do	...do	...do	40	8	Do.
Do	...do	...do	40	12½	Do.
Tomahawk	...do	...do	40	10	Do.
Do	...do	...do	40	10	Do.
Weirgor	...do	Oct. 5	40	5	Do.

From Table VIII it appears that the one small well-isolated plat started in 1915 did not develop leaf-spot until the following year. Of the 16 plats started in 1916 only 2 failed to show an abundance of leaf-spot in the autumn of the same year. One of these plats, located at Harrison, Me., was in very poor condition, only a few scattering spindling plants about 4 inches high being found. However, other plats in almost as poor condition showed leaf-spot. The second doubtful plat, at Doering, Wis., was in very vigorous condition, but it had been cut just previous to inspection, leaving very little foliage. Unfortunately, it was not feasible to revisit the plat the following year.

These results are in accord with previous experiments and experience. Surface sterilization of seed apparently accomplishes nothing in excluding leaf-spot from alfalfa fields. But these results do point very clearly to one conclusion, that the leaf-spot fungus is not carried on or in débris mixed with the seed. The greenhouse experiments, which are only suggestive because of their limited extent, indicate that the fungus is not carried within the seed.

Thus, in conclusion, it is necessary to say that no positive evidence pointing toward the method by which this disease gains access to remote alfalfa fields has been found. Evidence has been obtained which apparently eliminates other plants previously under suspicion as host plants of the fungus from consideration as sources. A limited amount of evidence indicates that the fungus is not carried with the seed. Yet the fact of the almost universal occurrence of the disease in remote localities is well established. The explanation of this fact still furnishes a very interesting and apparently very difficult problem.

SUMMARY.

(1) One of the most important diseases, if not the most important foliage disease, of alfalfa is the leaf-spot caused by the fungus *Pseudopeziza medicaginis* (Lib.) Sacc. A similar but less important leaf-spot of red clover is caused by the fungus *Pseudopeziza trifolii* (Biv.-Bern.) Fckl. The morphological differences between these fungi are so slight that doubt has frequently been expressed whether they are not identical. Several conflicting opinions as to the life histories of these fungi are found in mycological literature. This study attempts to determine the relationship of the two fungi here mentioned and to trace as far as possible their life histories in relation to their host plants.

(2) *Pseudopeziza medicaginis* on alfalfa and *Pseudopeziza trifolii* on red clover have been obtained and studied in pure culture. Efforts to cross these fungi from one host to the other have not been successful. Morphological as well as physiological differences have been found which in the opinion of the writer justify retaining the fungi as distinct species.

(3) None of the imperfect fungi which have been regarded as a stage in the development of these fungi have been found to be related. Apparently no other spore form than the ascospore occurs in nature.

(4) Infection is produced by the direct penetration of the germinating ascopores through the cuticle and epidermal cell wall of the leaf. The mycelium developing into a small stroma about the point of entry produces in about two weeks an apothecium.

(5) The fungus lives over winter on dead leaves which escape decay, and ascopores produced in the spring furnish the source of new infection.

(6) Efforts to exclude the disease from alfalfa fields sown in localities remote from other alfalfa by the surface sterilization of the seed have given no degree of success. Evidently, in these experiments at least, the fungus was not carried on the surface of the seed—probably not with the seed at all. The demonstration of the source of infection in such fields still furnishes an interesting problem.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 760

Office of the Secretary
Joint Contribution from the Office of Farm Management
R. L. ADAMS, Acting Chief
and
Bureau of Plant Industry
W. A. TAYLOR, Chief

Washington, D. C. | March 14, 1919

FARM PRACTICE IN GROWING SUGAR BEETS IN THREE CALIFORNIA DISTRICTS.

By T. H. Summers, *Scientific Assistant*, L. A. Moorhouse, *Agriculturist*, and R. S. Washburn, *Scientific Assistant, Office of Farm Management*, and C. O. Townsend, *Pathologist in Charge of Sugar-Plant Investigations, Bureau of Plant Industry.*

CONTENTS.

The data presented in the following pages are based upon 165 farm records obtained in three typical sugar-beet regions of California. (See fig. 1.) The first part of the bulletin deals with farm practice in the production of the sugar beet. The second part discusses the requirements of the beet crop in terms of the values that prevailed during 1915 and 1916. If such requirements are known, that is, the amount of labor, seed, water, etc., used, the cost of producing sugar beets can be ascertained for any given crop year by substituting current rates for those used in this study. Actual costs for 1915–1916 are presented solely for purposes of comparison.

Eighty-one records were obtained south of Los Angeles, in Los Angeles and Orange Counties; 45 were taken at Oxnard, in Ventura

Note.—This bulletin is the fourth of a series of publications which have been prepared to give the results of an investigation dealing with the farm practice involved in growing sugar beets in four of the more important sugar-beet areas in the United States. The first bulletin dealt with this study in Utah and Idaho, the second took up the work in Colorado, and the third gave the results obtained in Michigan and Ohio.

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County; and 39 records were obtained at Salinas, in Monterey County. The Salinas records apply to the 1916 crop, while records obtained in the two other areas are for the 1915 and 1916 crops.

While the suggestions that have been made as a result of this sur-

FIG. 1.—Map of California showing the districts in which records were obtained and indicating the beet-sugar factory areas of this State. It will be seen that the southern part of the State possesses a majority of the factories now in operation.

vey are directly applicable to the districts in which the records were taken, it is believed that certain features relating to increased production will be of very great value to men who are growing this crop in other regions.

ERRATUM.

In the explanation of the symbols in figure 1, designating factories operating and factories idle, 1915-1916, the symbols should be reversed. Only two factories, Hamilton City and Corcoran, were idle in 1915-1916.

SUMMARY OF RESULTS.

Briefly, these are the more important facts brought out in this study of 165 California sugar-beet farms:

Tillable area in sugar beets: Los Angeles district, 68 per cent; Oxnard, 34 per cent; Salinas, 52 per cent.

No definite cropping system is followed. Sugar beets are sometimes grown on the same land for as many as 10 successive years. Other important crops are beans and barley.

All available farm manure is spread upon beet land, but so little manure is available that only a small fraction of the beet acreage is manured each year.

Average yields (1915–1916): Los Angeles, 14.52 tons per acre; Oxnard, 9.53 tons; Salinas, 15.59 tons.

Cost per acre (1915–1916): Los Angeles, $67.11; Oxnard, $54.88; Salinas, $66.45. In general, as acreage increases cost per acre decreases, while as yield increases cost per acre increases though cost per ton decreases.

Labor constitutes 50 per cent of total cost of production; use of land, 35 per cent.

Beet tops were fed on the majority of the farms in the Los Angeles and Oxnard areas. At Salinas 56 per cent of the growers plowed under the tops. The value of this by-product depends on the method of utilization. The highest value was put on the tops when used as feed.

METHOD OF INVESTIGATION.

Experienced enumerators visited the growers and obtained information as to the number of times the beet land was plowed, disked, harrowed, rolled, etc., the size and kind of implements used, the size of the crew worked, and the time required to perform these operations, the season of the year when the work was done, and the materials used, such as manure, fertilizer, seed, and irrigation water. Each grower was also asked to outline his cropping system. In short, a complete record of the sugar-beet crop was obtained, and sufficient data on other farm crops and live stock to make possible a study of the entire farm business. Enough of these records were obtained so that variations in individual estimates were more or less equalized in the averages. A comparison of farmers' estimates with actual figures taken from the books of the beet-sugar factories in two districts indicates the reliability of the results obtained by this method. (Table I.) Figures for the Los Angeles district are omitted, as a number of growers contracted a part of the acreage to one factory and the remainder to another. For similar reasons several growers in the other districts are not included in this table. It will be noted that there was a slight tendency on the part of the grower to overestimate.[1]

TABLE I.—*Comparison of farmers' estimates with factory records (crop year 1916).*

District.	Number of farms.	Number of acres in beets.		Tons per acre.		Total receipts.	
		Farmers'.	*Factory.*	*Farmers'.*	*Factory.*	*Farmers'.*	*Factory.*
Oxnard	11	122.21	124.52	10.94	10.88	$10,731.26	$10,102.78
Salinas	31	92.13	90.16	15.42	15.73	8,044.71	7,556.48

HISTORY AND DEVELOPMENT OF THE SUGAR-BEET INDUSTRY IN CALIFORNIA.

As early as 1856 a small beet-sugar factory was built at Ocean View near San Francisco, which failed in a few years. In 1869 and

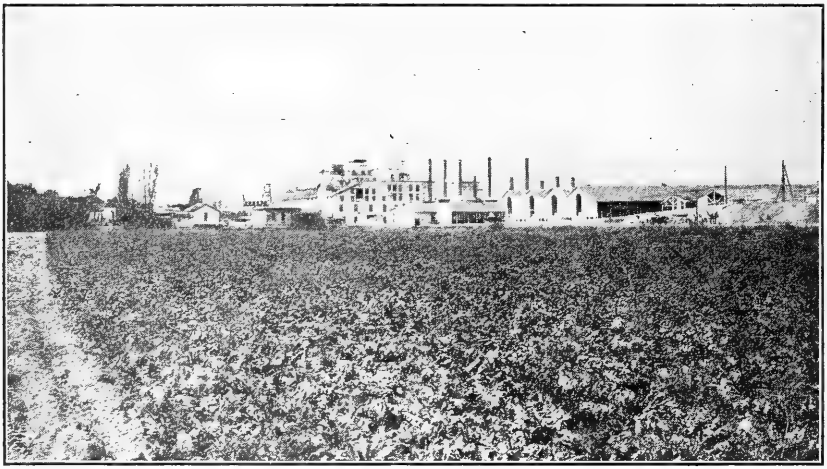

FIG. 2.—Beet-sugar factory at Alvarado, Cal. It was on this site that the beet-sugar industry had its beginning on the Pacific Coast.

1870 a beet-sugar factory having a capacity of 50 tons was erected at Alvarado and was operated under the name of the California Beet Sugar Manufacturing Co. After operating four years it was sold to a concern in Santa Cruz County, which failed in 1876. The

[1] The Office of Farm Management and the Office of Sugar-Plant Investigations worked in cooperation in securing the records. The former office was primarily interested in the labor requirements of the crop and farm organization in the sugar-beet areas. The latter office was concerned with the methods of growing the crop, as well as with the study of the effect of certain pests and diseases upon production.

Acknowledgment is due to the many farmers through whose liberal contribution of time and information this publication has been made possible, and to the sugar-factory officials who furnished the figures from the company books for comparison with the farm estimates.

Acknowledgment is also due S. B. Nuckols and James W. Jones, Agriculturists, Office of Sugar-Plant Investigations, who assisted in obtaining the field records from the growers.

factory opened again for one year in 1880. About this time a new company was formed, which increased the capacity to 100 tons daily, but in 1886 the factory was partially destroyed by fire and the enterprise failed. In 1887 and 1888 the factory was rebuilt and sold to the Alameda Sugar Co. The plant was subsequently enlarged in 1890. This factory in 1916 had a daily slicing capacity of 800 tons. (See fig. 2.)

Other attempts to establish the beet-sugar industry were made at Brighton and Isleton, but these met with no success. In 1888 a plant was built at Watsonville with a 300-ton capacity. This was soon enlarged to 1,000 tons, but was later dismantled. In 1898 the Spreckels plant was erected at Spreckels, Cal., with a 3,000-ton capacity. This

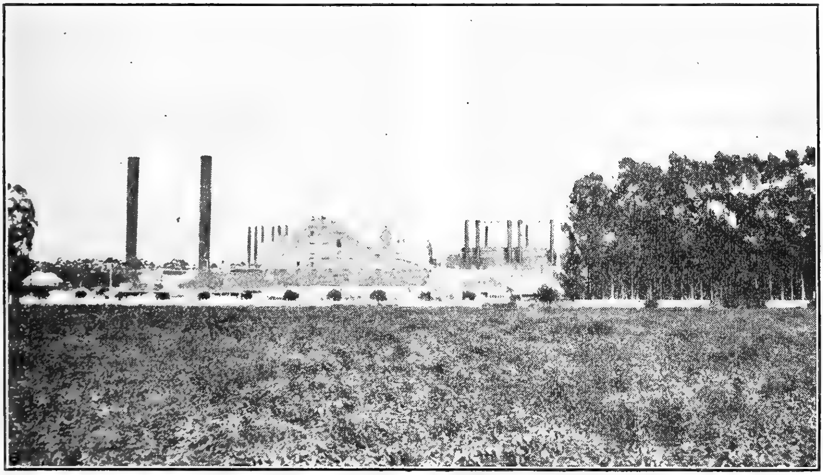

FIG. 3.—A modern beet-sugar factory in the Oxnard area. This factory has a daily slicing capacity of 3,000 tons of sugar beets.

factory has become the largest in the United States, and in 1916 sliced an average of 4,500 tons daily.

At the close of the 1890 slicing season there were only three factories in the United States, two in California and one in Nebraska. Following is a list of the beet-sugar factories now in California:

Location.	Date erected.	Capacity.	Location.	Date erected.	Capacity.
		Tons.			*Tons.*
Alvarado	1870	800	Visalia	1906	400
Chino	1891	1,100	Santa Ana	1908	600
Los Alamitos	1897	800	Corcoran	1908	600
Oxnard	1898	3,000	Huntington Beach	1911	1,200
Spreckels	1899	4,500	Anaheim	1911	850
Betteravia	1899	1,000	Dyer	1912	1,200
Hamilton City	1906	700			

During 1915–1916 two of these plants (Corcoran and Hamilton City) were not operating.

The industry has grown rapidly. During the 5-year period from 1913 to 1917 over 20 per cent of the entire acreage of sugar beets in the United States was grown in California. In 10 years, 1899–1909 (see Table II) the acreage almost doubled, while the tonnage increased more than 100 per cent. The yield per acre was also increased 2.1 tons, or about 24 per cent. In the same period the total acreage in the United States had increased about three times, while the total yield had become five times as great as in 1899.

TABLE II.—*California sugar-beet acreage and yield.*

Census.	Year.	Acres in beets.	Total production (tons).	Yield per acre (tons).	Beet acreage in United States.	Total production in United States (tons).
Twelfth	1899	41,242	356,535	8.6	110,170	793,353
Thirteenth	1909	78,957	845,191	10.7	364,093	3,932,857

The following data from the Crop Reporter of the United States Department of Agriculture show the acreage and yield of sugar beets in California from 1910 to 1917. (Table III.)

TABLE III.—*Acreage and yield of sugar beets in California.*

Year.	Acres harvested.	Total production.	Yield per acre.	Sugar made.
		Short tons.	*Short tons.*	*Short tons.*
1910	90,500	923,100	10.20	139,890
1911	99,545	1,037,283	10.42	161,300
1912	111,416	1,004,328	9.01	158,904
1913	127,610	1,138,003	8.92	171,208
1914	104,000	1,126,700	10.83	169,004
1915	122,737	1,249,111	10.20	195,343
1916	141,097	1,462,895	10.36	236,322
1917	154,700	1,318,400	8.53	200,100

AGRICULTURE OF AREAS STUDIED.

CLIMATE.

The climate of the region studied is characterized by two seasons, one wet and the other dry. Practically all of the precipitation occurs during the period from November to March. The average annual rainfall for the three areas is fairly uniform, ranging from 14.06 to 15.73 inches. However, in 1915 and 1916 the rainfall was in excess of the average. Records were obtained covering both the 1915 and 1916 crop years at Los Angeles and Oxnard. In this way the effect of the fluctuation in the annual precipitation has been considered. (See Table IV.)

TABLE IV.—*The annual average rainfall by months for three sugar-beet districts in California.*

	Los Angeles. 1877–1909. Elevation 293 ft.	Oxnard. 1892–1912. Elevation 150 ft.	Salinas. 1873–1912. Elevation 40 ft.
January	3.03	3.96	3.02
February	3.00	2.44	2.21
March	3.05	3.09	2.50
April	1.02	0.44	1.18
May	0.48	0.43	0.49
June	0.08	T[1]	0.13
July	0.01	0.01	T[1]
August	0.03	T[1]	0.01
September	0.10	0.48	0.19
October	0.75	0.79	0.68
November	1.33	1.03	1.33
December	2.85	2.08	2.32
Total	15.73	14.75	14.06
Total:			
1915	16.67	19.38	18.24
1916	23.29	28.01	18.81

[1] A trace of moisture only.

In the Los Angeles area the normal monthly temperature ranges from 53° to 70°, at Oxnard from 52° to 64°, and at Salinas from 47° to 62°. Generally speaking, no irrigation is practiced at Oxnard; at Salinas it is frequently advisable to irrigate the land before it is plowed for beets (see fig. 4), and at Los Angeles it is often necessary to irrigate at least once during the growing season. The prevalence of fogs during the dry season plays an important part in the conservation of moisture. In all areas the average temperature during the growing season approaches 70°, the temperature recognized as being necessary for sugar-beet production.

SOIL.

Several soil types are found in the three areas studied. A brief reference to these types will undoubtedly assist the reader in his interpretation of the cultural methods which are described in this bulletin. The amount of work that may be required in the preparation of a good seed bed is governed to a certain extent by the character of the soil. Very heavy land must be cultivated at the proper time if the minimum labor requirement is to be attained.[1]

Most of the records in the Los Angeles district were taken on two types of soil, Fresno fine sandy loam and Fresno sand. By far the

[1] In 1901 the Bureau of Soils, United States Department of Agriculture, made a survey of the Salinas Valley and the Ventura area, the latter including the Oxnard district. In 1903 the Los Angeles area was surveyed, so that all three areas have been mapped by the Bureau of Soils. (Soil Survey of the Los Angeles Area, California, by Louis Mesmer, 1903. Soil Survey of the Ventura Area, California, by J. Garnett Holmes and Louis Mesmer, 1901. Soil Survey of the Lower Salinas Valley, California, by Macy H. Lapham and W. H. Heileman, 1901.)

most of the sugar beets were grown on the former. In the Oxnard district there are two soil types, Oxnard sandy loam and Oxnard sand. As is suggested by the name, the Oxnard sand is the coarser and more open of the two and contains less organic matter. The sandy loam is probably better adapted to sugar-beet production than is the sand. In the Salinas district the records were obtained on three types of soil, Salinas gray adobe, San Joaquin black adobe and Fresno fine sandy loam. Salinas gray adobe is very sticky when wet, becoming hard when dry. It holds moisture well. At certain seasons of the year it is very heavy to work. San Joaquin

FIG. 4.—A field which has received an application of waste water from the beet-sugar factory. This water contains considerable lime, which is deposited on the surface of the field. The whitened portions of the ground indicate that the surplus water flowed into these areas and the lime was left after the water had passed into the soil.

black adobe is similar to Salinas gray adobe, and is probably a little better adapted to sugar-beet production. Sugar beets are grown also on Fresno fine sandy loam, but they probably do best on the adobe soils.

SIZE OF FARMS.

The relation of the sugar-beet enterprise to size of farm may be seen in part by comparing the Thirteenth Census figures with the distribution of the records obtained in this investigation (see Table V).

TABLE V.—*Distribution of farms by size in Los Angeles, Ventura, and Monterey counties, and in the groups in which the records obtained appear (1915–1916).*

Size.	Los Angeles County.		Ventura County.		Monterey County.	
	Thirteenth Census.	Farm records.	Thirteenth Census.	Farm records.	Thirteenth Census.	Farm records.
9 acres and under	3,122	....	100	....	80	....
10 to 49 acres	5,374	9	319	1	253	1
50 to 99 acres	1,049	37	214	8	185	9
100 to 174 acres	706	14	207	14	263	12
175 to 259 acres	252	10	142	16	127	10
260 to 999 acres	459	10	245	6	507	7
1,000 acres and above	122	1	66	....	243	....

In Los Angeles and Ventura Counties, according to the Census figures, the largest group of farms is that of from 10 to 49 acres, while in Monterey County there are more farms in the 260 to 999 acre group than in any other class, and 243 of 1,000 acres and above.

The numbers of farm records obtained in these groups are not quite in proportion to the Census figures. In Los Angeles County there are many small farms in the suburbs of the city of Los Angeles, over 75 per cent of the farms in the county having an acreage of 49 acres or less. Many of these small farms grow beets, but have such small acreages that they are not comparable with the larger sugar-beet farms. No records were used from farms with less than 5 acres of beets. The largest number of records was obtained in the 50 to 99 acre group.[1]

The beet farms visited in the other two areas are, as a rule, larger, most of them being in the 100 to 259 acre groups.[2]

CROPS GROWN.

The number of major crops in each district was rather small. (See Table VI.) In the Los Angeles district sugar beets, alfalfa, and barley hay were the principal crops; in the Oxnard district sugar beets, beans, and barley; at Salinas, sugar beets, barley hay, and beans.

[1] It is the practice in this region for a grower owning a small farm to rent additional land. The total acreage farmed in such cases is considered the farm unit. This accounts for the apparent inconsistency in the table.

[2] One peculiarity in these districts is the lack of uniformity in size. Instead of being 40, 80, 120, or 160 acre farms as in other Western States, the farms are of many different sizes. This is probably due to the breaking up of the land grants and the selling of the land in small irregular acreages.

TABLE VI.—*Crop acreages per farm and average yields per acre.*

District and crop.	Number of farms.	Per cent of total farms.	Acres per farm.	Yield per acre.
Los Angeles (average tillable area, 140 acres):				
Sugar beets	81	100	95.2	14.52 tons.
Alfalfa	27	33	14.11	6.82 tons.
Barley hay	24	30	61.4	1.28 tons.
Corn	17	21	35.49	
Beans	12	15	45.5	12.37 cwt.
Barley grain	2	2	140	30.84 cwt.
Potatoes	2	2	8	83 cwt.
Oxnard (average tillable area, 183 acres):				
Sugar beets	45	100	62.47	9.53 tons.
Beans	42	93	87.57	13.43 cwt.
Barley hay	23	51	27.65	1.48 tons
Alfalfa	9	20	9.33	4.88 tons
Wheat hay	6	13	61.33	1.74 tons.
Barley grain	2	4	11	26.54 cwt.
Potatoes	2	4	.75	94.4 cwt.
Corn	2	4	3	
Salinas (average tillable area, 178 acres):				
Sugar beets	39	100	92.72	15.59 tons.
Barley hay	30	77	35.93	2.42 tons.
Beans	15	38	27	10.28 cwt.
Barley grain	15	38	59.13	36.95 cwt.
Potatoes	14	36	22.82	70.85 cwt.
Alfalfa	7	18	16.57	4.74 tons.
Peas	4	10	43.25	22.98 cwt.

On all farms where records were obtained sugar beets and beans were the principal cash crops. In the Oxnard district, beans were grown on 93 per cent of the farms visited. Barley hay was produced on 77 per cent of the Salinas farms. In all districts the major portion of the barley crop was grown for hay. On 38 per cent of these farms barley was grown for grain.

Twenty-one per cent of the farmers reporting in the Los Angeles area grew corn. As a part was husked and the remainder fed as fodder, no attempt was made to determine the yield per acre.

Alfalfa was grown on 33 per cent of the Los Angeles farms studied in this investigation and was cut an average of six times during the season. On Oxnard farms five cuttings were made, in the Salinas district three. Peas for seed were grown on 10 per cent of the Salinas farms.

In addition to the crops shown in the table a small acreage in each district was devoted to fruit, and in the Los Angeles district a small amount of cauliflower and other vegetables was grown.

No attempt has been made in any case to establish a definite crop rotation, nor is the acreage grown from year to year at all uniform. On 78 per cent of the farms in the Los Angeles district beets followed beets, and on a few farms the sugar beet had been grown continuously on the same land for as many as 10 years. Beets followed beans on only five farms.

In the Oxnard district beets were grown immediately after beets on 51 per cent of the farms. It is a common practice in this area to grow beets continuously on land that is slightly alkaline, while beans are grown continuously on the better-drained and more valuable land. The fact that the beet is grown on the less productive land may explain in part the relatively low yield in this district. A few of these men occasionally grow a crop of barley on the beet land, while others sometimes let it lie fallow for a season.

In the Salinas area beets were grown after beets on 64 per cent of the farms. The tendency to rotate occasionally with barley was more in evidence here than in the other districts visited.

Considering the benefits that are usually obtained through following a well-planned cropping system, it would seem that the crop land in these areas is not as well managed as would seem to be advisable.

RELATION OF BEET ACREAGE TO TILLABLE AREA.

The total acreage per farm averages about 200 acres at Salinas, 195 at Oxnard, and 150 at Los Angeles. About 93 per cent of the farm land in the Los Angeles area is tillable and in the Oxnard district 94 per cent is tillable. At Salinas the figure drops to 89 per cent.

At Los Angeles and Salinas more than 50 per cent of the tillable land is utilized by the beet crop, while at Oxnard over one-third of the tillable area is devoted to beets.

FARM PRACTICES.

SCATTERING BEET TOPS.

Beet tops are usually plowed under in the Salinas area. Tops are of considerable value for fertilizing the land, the best results being obtained when they are evenly distributed over the field. The beet tops when cut are usually left in rows, with occasional small piles in the row. Before the land is plowed for the succeeding crop of beets the tops are sometimes scattered over the field with a harrow. This operation is known as "scattering tops." One harrowing is sufficient to do the work. Fifty per cent of the Salinas growers scattered the beet tops before plowing. An average crew of one man and six horses was used, with a 16-foot harrow. The time required per acre was 0.42 man hours and 2.47 horse hours, the labor cost per acre being 34 cents.[1]

MANURING.

In the California areas farm manure is exceedingly scarce. Although it is the general practice to spread all available manure upon the beet land, in the Oxnard area only about 9 per cent of the beet

[1] In computing the cost of labor a uniform rate of 10 cents per hour was used for horse labor. The man-labor rate at Oxnard and Salinas was 21 cents per hour, while at Los Angeles a man-labor rate of 20 cents per hour was used.

acreage was manured, at Los Angeles only 6 per cent, and at Salinas $2\frac{1}{4}$ per cent.

Sixty-nine per cent of the Los Angeles growers applied manure to the beet land, 62 per cent of the Oxnard growers, and 54 per cent of the Salinas growers. (See Table VII.)

TABLE VII.—*Manuring.*

District.	Number of records.	Acres manured per farm.	Tons applied per acre.	Hours of labor per acre.		Labor cost per acre.
				Man.	Horse.	
Los Angeles	56	8.33	13.70	15.81	24.22	$5.58
Oxnard	28	8.93	10.83	13.29	28.02	5.59
Salinas	21	3.90	11.82	13.21	19.94	4.76

A crew of 1 man and 2 horses was used in hauling manure on 39 farms. On 27 farms the crew was 2 men and 2 horses. Twelve operators hauled with a crew of 1 man and 3 horses, while 13 growers with the same number of horses provided an additional man to assist with the loading, etc. Two men and four horses were used on nine farms. Approximately two-thirds of these growers hauled manure with wagons; slightly more than one-third used spreaders.

Twenty-six operators applied manure during the fall, 20 did this work throughout the winter months, a few at odd times during the fall, winter, and spring, and in one case the work was done in summer.

There was little variation in labor cost for the first two areas ($5.58 and $5.59), but at Salinas the total labor cost was considerably less ($4.76).

PLOWING.

For the successful production of an intensive crop like the sugar beet, it is necessary to have a deep, well-prepared seed bed. In regions where rainfall is limited and occurs mainly during the winter, as in California, it is especially desirable to practice deep fall plowing. This enables the soil to store a large quantity of water during the rainy period and increases the yield by facilitating the development of a beet with a long tap root. On the farms included in this study the depth of plowing ranged from an average of 9.5 inches in the Salinas district to 11.5 inches in the Oxnard district.

Most of the plowing on the farms in question was done from October 1 to February 1. A small number of growers practiced spring plowing, but all customarily had finished this operation by May 1.

Eighteen men replowed all or a portion of their beet acreage during March and April to an average depth of 5 inches. The average number of times plowed for all sections was 1.1. Replowing was necessary mainly because weeds had not been kept in control during the winter.

Ninety-one per cent of the men in the Los Angeles and Oxnard districts and 86 per cent in the Salinas district used horsepower. (See Table VIII.) In the Los Angeles area a 1-man-4-horse crew was reported on 15 farms and a 1-man-6-horse crew on 28 farms. In the Oxnard area a larger crew size predominated, a 1-man-8-horse crew being reported on 20 farms and a 1-man-10-horse crew on 10 farms. In the Salinas area a 1-man-6-horse crew was reported on 15 farms and the 1-man-8-horse crew on 15 farms.

Table VIII.—*Plowing with horses.*

District.	Number of records.	Per cent of total records.	Acres per farm plowed for beets.	Hours of labor per acre.		Labor cost per acre.
				Man.	Horse.	
Los Angeles	74	91	80.24	4.66	24.83	$3.41
Oxnard	41	91	45.80	3.95	26.72	3.50
Salinas	35	86	79.51	3.13	21.72	2.83

For all districts considered together 11 per cent used a 1-man-4-horse crew, 31 per cent a 1-man-6-horse crew, 27 per cent a 1-man-8-horse crew, and 7 per cent a 1-man-10-horse crew. In addition to the above a few other crew sizes appeared in the three districts, such as the 1-man-3-horse, 1-man-5-horse, 1-man-7-horse, and 1-man-9-horse crews.

The average depth of plowing ranged from 10.75 inches for the 1-man-4-horse crew, to 12.8 inches for the 1-man-10-horse crew. The labor requirements varied from an average of 5.2 man hours and 20.8 horse hours per acre for the 1-man-4-horse crew, to 2.8 man hours and 28 horse hours per acre for the 1-man-10-horse crew. From the above it will be seen that there was a distinct saving in the man labor requirements through the use of the larger crew. However, the additional horse-labor requirements for the larger crew made the total labor cost 23 cents more for the 1-man-10-horse, than for the 1-man-4-horse crew.

In the Los Angeles district 14- to 16-inch sulky plows were most in evidence, 56 of this size being reported. In the Oxnard and Salinas districts, however, the 2-gang, 24- to 28-inch plow was the popular size, 28 being reported in the former and 27 in the latter area. (See fig. 5.)

For all districts 11 men were found who had all or a portion of their beet acreage plowed on contract with tractor power, at a rate ranging from $3 to $4 per acre. Twelve men plowed the beet acreage with their own tractors. Two- to 4-gang 14- to 16-inch plows were used, and the ground was plowed to an average depth of 12 inches. The man-labor requirement averaged 1.77 hours per acre, involving a labor cost of 37 cents per acre. (See fig. 6.)

CHISELING.

The field chisel or deep cultivator, as it is often called, has two staggered rows of rigid, narrow teeth, firmly attached to an iron frame which is supported on wheels at either end. (See Table IX.) Hand levers which are attached to the frame insure an accurate adjustment of the depth of cultivation. On loose, spring-plowed land, the deep cultivator is used to firm and compact the

FIG. 5.—Plowing with an ordinary sulky. The crew in this case consisted of one man and six mules.

soil for the entire depth of the seed bed. When the chisel is used for this purpose it should be followed soon after by a spike-tooth harrow to create a dust mulch to lessen evaporation. On the heavier soil types, such as are found in the Salinas area, the deep cultivator serves to loosen up the surface soil which has become compact, and at the same time to subdue weeds.

TABLE IX.—*Chiseling.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times chiseled.	Hours of labor per acre.		Labor cost per acre.
			Total.	Chiseled.		Man.	Horse.	
Los Angeles	7	9	119.29	97.86	1.43	2.07	14.40	$1.85
Oxnard	5	11	93.20	53.20	1.20	1.90	12.76	1.68
Salinas	34	87	88.85	88.12	1.28	1.69	12.93	1.64

Of a total of 46 farms where chiseling was reported, 61 per cent used a 1-man-8-horse crew, and 24 per cent a 1-man-6-horse crew. The width of the implement ranged from 5 feet to 8 feet, with an average of about 5½ feet. This work was performed mainly during the months of March and April.

In the Salinas area where the majority of the growers used this implement, practically the entire beet acreage was covered with the chisel in each case (Table IX), while in the Los Angeles and Oxnard districts 82 per cent and 57 per cent, respectively, of the beet acreage was covered on the few farms using this implement. However, 22 men at Los Angeles and 25 at Oxnard used the spring tooth, which serves much the same purpose as the chisel.

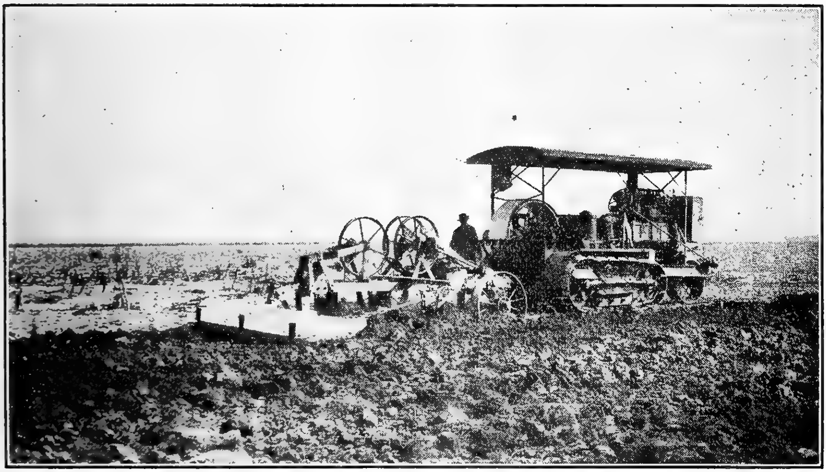

FIG. 6.—Dry plowing with a tractor. It will be observed that a float or planker is being operated simultaneously with the plow.

In addition to those included in the table, three men in the Salinas district did the work of chiseling with tractor power. One of these had an 8-foot double disk and an 8-foot spike-tooth harrow attached behind the chisel. Another had a 10-foot spike-tooth harrow attached. The average man-labor requirement for tractor chiseling was 1½ hours per acre.

DISKING.

The disk harrow was used on a relatively small number of farms. (See Table X.) Disking breaks up surface clods, kills the weeds, and firms the seed bed. Occasionally, where the harvesting of a preceding crop has left the surface of the field rough, this condition is corrected by disking the ground prior to plowing.

TABLE X.—*Disking.*

District.	Number of records.	Per cent of total records.	Acres disked per farm.	Times disked.	Hours of labor per acre.		Labor cost per acre.
					Man.	Horse.	
Los Angeles	25	31	63.44	1.15	1.18	6.47	$0.89
Oxnard	8	18	62.88	1.88	1.25	8.28	1.09
Salinas	8	20	78.38	1.38	1.05	7.30	.95

Two types of disk were used, the single action and the double action. The latter type has two sets of disks, one set in front of the other and so adjusted that the front set throws the soil out while the rear set throws it in, thus leaving the ground smooth.

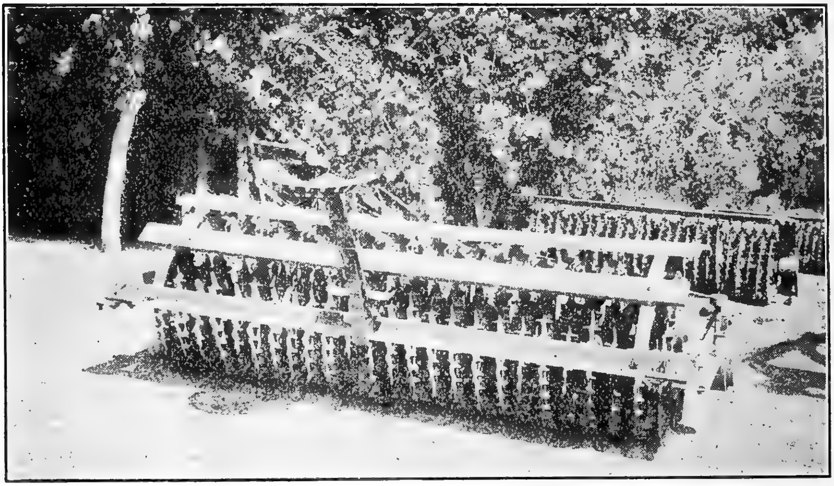

FIG. 7.—A cross-kill roller. The method of construction not only permits this implement to break clods, but it is also well fitted to firm the loose surface and secure the proper texture for a first-class seed bed.

The width of implements used varied from 8 to 12 feet. Four men in the Los Angeles and one each in the Oxnard and Salinas districts did this work with a tractor.

ROLLING.

BEFORE PLANTING.

The type of roller employed in preparing the seed bed ranged from the smooth-drum roller, either wood or steel, to the clod crusher or "cross-kill" (see fig. 7), as it is commonly called. The cross-kill consists essentially of a series of narrow, toothed rings, attached to a shaft or axle. This implement not only breaks up clods and pulverizes the soil, but also serves to pack loose soil. (See Table XI.)

TABLE XI.—*Rolling.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times rolled.	Hours of labor per acre.		Labor cost per acre.
			Total.	Rolled.		Man.	Horse.	
Before planting:								
Los Angeles	30	37	115.22	96.38	1.24	0.90	3.75	$0.56
Oxnard	11	24	117.36	80.55	1.09	1.01	5.53	.76
Salinas	35	90	93.46	93.46	1.41	1.14	5.51	.79
After planting:								
Los Angeles	78	96	93.16	91.42	1.69	.97	1.95	.39
Oxnard	39	87	66.72	61.59	1.52	.80	1.60	.33

The cross-kill was used exclusively in the Salinas district and on 50 per cent and 72 per cent, respectively, of the farms in the Los Angeles and Oxnard areas. The smooth wood and steel rollers were also used to some extent in preparing the seed bed. The season for rolling extended from October to May. The width of implement ranged from 6 to 12 feet. The labor cost per acre was about the same at Oxnard and Salinas, but considerably lower at Los Angeles.

AFTER PLANTING.

At Los Angeles and Oxnard 96 per cent and 87 per cent, respectively, of the growers rolled after seeding. This work was done when the seedlings were about to push through the ground, and again after thinning. If the rain causes a crust to form before the beets are up, it is customary to break this crust with a roller. Again after thinning it is customary to use a roller to firm the surface soil around the plants.

With the exception of 12 bar rollers in the Los Angeles district, smooth iron and wood rollers were used for this purpose. These rollers were drawn by two-horse teams, and ranged in width from 8 to 16 feet.

HARROWING.

SPIKE-TOOTH HARROW AND SMUDGE.

In addition to the common spike-tooth harrow, the "smudge" harrow was found on many farms in the Los Angeles district. The most common type of smudge consists of two square timbers, usually 4 by 4 inches, and ranging in length from 10 to 12 feet, set parallel about 4 feet apart and securely fastened together by means of cross-pieces, with usually a small platform in the center, on which the operator stands to give the implement additional weight. At regular intervals of about 6 inches steel teeth are driven through the two main timbers. These teeth are shorter than those of the spike-tooth harrow, and are set at an angle of about 45 degrees by placing the timbers on edge. (See fig. 8.) In passing over the surface of the soil this implement has a grinding, pulverizing action, fills in depressions, and serves to make a smooth, even surface. (See Table XII.)

TABLE XII.—*Harrowing (spike tooth and smudge).*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times harrowed.	Hours per acre.		Labor cost per acre.
			Total.	Harrowed.		Man.	Horse.	
Los Angeles	80	99	95.66	95.66	3.77	3.01	12.80	$1.88
Oxnard	41	91	57.73	55.05	2.49	1.14	7.26	.97
Salinas	39	100	92.72	92.72	4.74	2.00	12.45	1.67

FIG. 8.—Harrowing with a smudge.

The spike-tooth harrow was in almost universal use in the Oxnard and Salinas districts. Smudging was common in the Los Angeles district. On 95 per cent of the farms in the Oxnard and Salinas districts the spike-tooth was used while 95 per cent of the men in the Los Angeles district reported the use of the smudge.

The 1-man-4-horse crew was most in evidence in the Los Angeles district. Sixty-five per cent reported a crew of that size, while 14 per cent, 33 per cent, and 74 per cent in the Los Angeles, Oxnard and Salinas districts, respectively, reported the use of the 1-man-6-horse crew (see figs. 9 and 10). The 1-man-8-horse crew was reported on 42 per cent of the farms in the Oxnard district.

The spike-tooth used consisted of from two to four sections and varied in width from 10 to 20 feet.

THE CYCLONE HARROW.

The cyclone harrow was found on five farms in the Los Angeles area and on four at Oxnard. This implement consists of a heavy

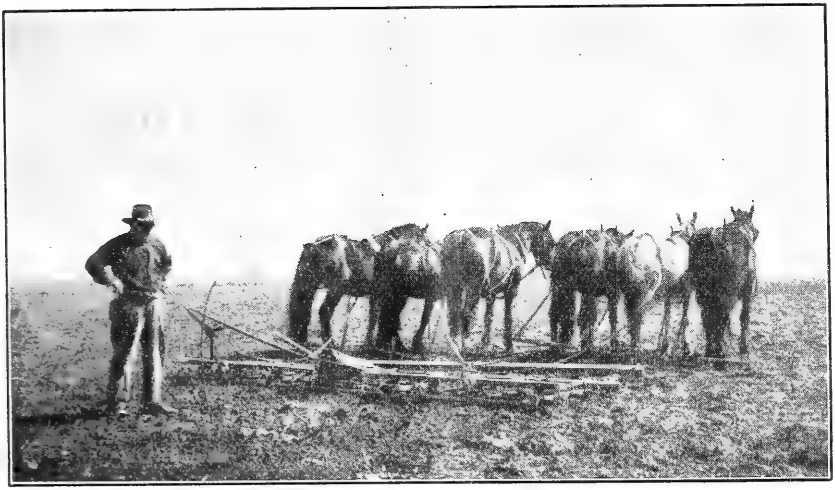

FIG. 9.—Typical crew harrowing with a spike-tooth.

plank armed with steel knives which extend to the rear and downward. These knives are bent toward the center of the implement

FIG. 10.—Spike-tooth harrowing with a crew of one man and six horses. Two horses are hitched directly to the harrow, while four horses are worked abreast in front of them.

from either side, and they run just below the surface and cut off weeds. This implement pulverizes the soil quite effectively and creates a dust mulch on the surface.

The cyclone harrows ranged in width from 8 to 10 feet, and were used for a period extending from December to April. In the Oxnard area the total beet acreage was covered on the farms using this implement, while in the Los Angeles area only 32 per cent of the acreage per farm was covered.

SPRING-TOOTH HARROW.

This implement was found only in the Los Angeles and Oxnard areas, its purpose being served by the chisel in the Salinas area. The spring-tooth harrow stirs the soil to a greater depth than does the cyclone or spike-tooth, brings clods to the surface and pulverizes the soil. Like the cyclone, the spring-tooth, where operated, was used on the total beet acreage per farm in the Oxnard district (see Table XIII) but on only 80 per cent of the Los Angeles acreage per farm.

TABLE XIII.—*Harrowing (spring-tooth).*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times harrowed.	Hours of labor per acre.		Labor cost per acre.
			Total.	Harrowed.		Man.	Horse.	
Los Angeles	22	27	99.86	79.73	1.2	1.51	8.01	$1.10
Oxnard	25	56	44.36	44.36	1.6	1.25	8.48	1.11

The spring-tooth harrows used consisted of from 2 to 4 sections and ranged in width from 6 to 12 feet. Its use extended over a period of from December to April. Four-horse outfits were used on 32 per cent of the farms in the Los Angeles district. On 72 per cent of the Oxnard farms 8-horse outfits were used.

FLOATING AND LEVELING.

The float or plank drag was used on a relatively small number of farms, ranging from 11 per cent in the Los Angeles to 46 per cent in the Salinas district. (See Table XIV.) This implement is an excellent tool to break up small clods and create a smooth, even surface. It is generally one of the last implements to be used in preparing the seed bed and is usually run over the ground a few days before planting.

TABLE XIV.—*Floating and leveling.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times over.	Hours of labor per acre.		Labor cost per acre.
			Total.	Floated.		Man.	Horse.	
Los Angeles	9	11	122.11	122.11	1.6	1.58	10.69	$1.39
Oxnard	16	36	71.88	47.19	1.1	.90	6.09	.80
Salinas	18	46	95.00	81.39	1.4	.97	5.73	.77

The width of the floats used varied from 8 to 14 feet. The size of implements depends somewhat upon the horse power available. For all districts studied 43 per cent used a 1-man-8-horse crew, 35 per cent a 1-man-6-horse crew, and 16 per cent a 1-man-4-horse crew.

On fields where irrigation is necessary a homemade implement, known as a level, is used to make the surface of the ground level and to facilitate an even distribution of water over the land. (See fig. 11.)

PLANTING.

The seeding was done from December 1 to June 1, the time varying somewhat according to locality. The records for the Los Angeles district do not indicate any definite planting period. There the seeding extended from December to May, with 39 per cent of the men

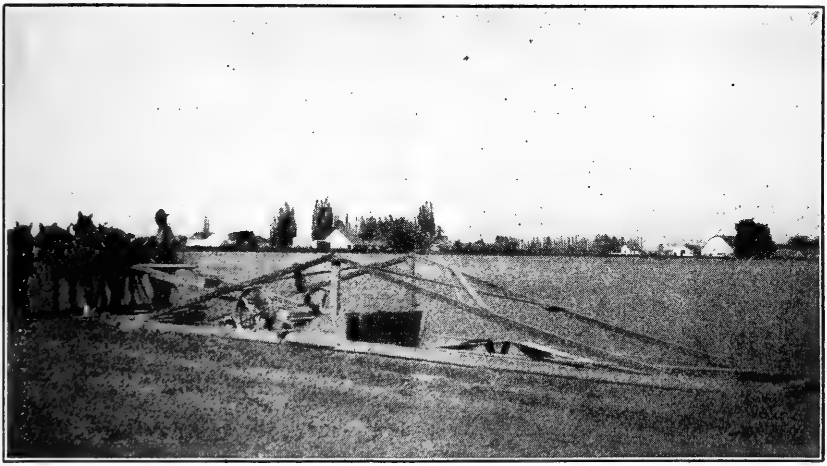

Fig. 11.—Leveling. This operation is especially important on fields that are to receive irrigation.

reporting the work as being performed in March or April. In the Oxnard area 44 per cent planted in December or January and in the Salinas area 80 per cent seeded in April or May. (See Table XV.)

Table XV.—*Planting.*

District.	Number of records.	Acres in beets per farm.	Times planted.	Hours of labor per acre.		Labor cost per acre.
				Man.	Horse.	
Los Angeles	81	95.14	1.25	1.15	2.34	$0.46
Oxnard	45	62.47	1.05	.93	2.12	.41
Salinas	39	92.72	1.13	1.12	2.24	.46

In every district some replanting was necessary. Forty-eight men in the Los Angeles district and seven and sixteen, respectively, in the Oxnard and Salinas districts, replanted a portion of their acreage. In most cases reseeding is made necessary by rains causing the surface of the soil to cake so that the young beet seedlings are unable to push through. Sometimes, on sandy soil, wind storms blow the seed out, and sometimes excessive alkali prevents good germination.

The average rate of seeding for the several districts showed some variation. Approximately an average of 18½ pounds per acre was required in the Los Angeles district, while an average of 16 pounds and 14 pounds, respectively, was used in the Oxnard and Salinas districts.

The seed is planted in solid rows to insure a good stand. Later, after the young plants have pushed through to the surface, they are thinned out to a suitable distance. This operation will be discussed under a separate heading.

Special beet drills were used. These were of two sizes, the 4-row and the 8-row, and they were usually equipped with press wheels, which exert a uniform pressure on the drill row, firming the soil and aiding in retention of sufficient moisture to insure quick germination of the seed. The 8-row drill was not very common, only two being reported in the Los Angeles district and eleven in the Oxnard district. None were reported in the Salinas district. The 8-row outfit requires four horses to operate, while 4-row drills are operated with 2-horse teams. On farms in the Oxnard area, when no replanting was done, the average labor cost of planting with an 8-row drill was 18 cents per acre less than on farms where 4-row drills were used.

In the Los Angeles area the seed was planted in rows 18 inches apart on 38 farms and 16 inches apart on 43 farms. All of the Oxnard growers planted in 18-inch rows, while in the Salinas district 20-inch rows were reported on all farms except four, where the 18-inch row was used.

CULTIVATING.

The cultivating period in the Los Angeles and Oxnard districts extended from about February 15 to July 15. On Salinas farms the work was done mainly in May, June, and July. The first cultivation precedes blocking and thinning. The cultivator is usually equipped with knives or "duck feet" for killing weeds, and a shallow cultivation is given. Subsequent cultivations are usually deeper. It is customary to run the cultivator at frequent intervals until the beets are so large that it is impossible to follow the row.

On the Los Angeles and Oxnard farms the ground was cultivated from three to seven times (Table XVI), while in the Salinas district it was covered from one to three times. Twelve other men in the Salinas district, whose records do not figure in the table, had cultivating done under contract by Japanese, the horses and implements being provided by the grower.

TABLE XVI.—*Cultivating.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Times culti-vated.	Hours of labor per acre.		Labor cost per acre.
			Total.	Cultivated.		Man.	Horse.	
Los Angeles	81	100	95.20	95.20	4.72	4.54	9.08	$1.82
Oxnard	45	100	62.47	62.47	3.73	3.78	7.56	1.55
Salinas	26	67	85.62	85.62	1.50	1.47	2.94	.60

There is no apparent reason for the relatively few cultivations given on the Salinas farms. It would seem that somewhat more intensive cultivation throughout the growing period would be necessary to control weed growth effectively.

In all districts special 4-row riding cultivators and 2-horse teams were used.

HAND LABOR.

The hand labor includes such work as thinning, weeding, hoeing, pulling, topping, and loading. These operations are done on a contract basis. In some cases all of the hand labor is handled under one contract. Some growers use two contracts, the first taking care of the thinning, weeding, and hoeing and the second dealing with the pulling, topping, and loading.[1]

---

[1] A contract embracing all hand labor is given herewith for the purpose of illustration:

This agreement, made and entered into between ———, party of the first part, and ———, party of the second part,

Witnesseth: That, for and in consideration of the covenants hereinafter contained on the part of the first party, the party of the second part agrees, at different times and in the manner prescribed by the party of the first part to thin out, hoe, clean between the beets in the row and keep said beets free from weeds until they are harvested, and top and load said beets into wagons, a portion or portions, to be assigned hereafter, of sugar beets planted by party of the first part on land described as follows:———

The party of the second part further agrees as follows:

1. To commence thinning beets within 24 hours after verbal notice given by the party of the first part, and to complete the thinning before the said beets shall have four leaves well developed.

2. To thin out beets to ——— inches apart in the rows and to leave no more than one beet to each ——— inches in the row. While thinning to hoe, with hand hoe, two inches on each side of the beet row as well as between the beets in the row so that the soil will be thoroughly cultivated and all the weeds totally destroyed.

3. To do the thinning and weeding above mentioned in proper and farmerlike manner and to the satisfaction of the party of the first part.

4. Within 24 hours after verbal notice given by the party of the first part to pull, shake free from adhering earth, top and load beets into wagons; beets to be topped cleanly and squarely with one blow of the knife at base of bottom or last leaves. Beets will be carefully plowed out by party of the first part, but any beets not loosened by the plow shall be dug out by party of the second part.

5. When beets are plowed, party of the second part shall top and load into wagons as many tons of beets each day as party of the first part shall be required to deliver to the sugar factory.

6. Party of the second part agrees to personally superintend all the work above described and to have it done to the satisfaction of the party of the first part.

It is further agreed that if the party of the second part shall neglect or refuse to perform any of the above operations at the time set, or in the manner prescribed by the party of the first part, then the party of the first part shall have the right and option to cancel this contract, and any money that may have become due to the party of the second part on account of thinning, hoeing, topping, or loading done shall be forfeited to the party of the first part, or it shall be optional with the party of the first part to

IRRIGATION.

In the Los Angeles and Salinas areas irrigation is frequently necessary in the production of sugar beets. Usually one irrigation is required.

Different methods are employed in applying the water. In the Los Angeles area the water is pumped from wells and forced through portable galvanized iron pipes (see figs. 12 and 13). These pipes, 10 to 12 feet long, with a diameter of 8 to 10 inches, are fitted together and stretched across the beet field. The entire field is covered by moving them from one place to another, the land adjacent to the pumping plant being watered last. In a number of cases underground concrete pipes are used to carry the water from the well out into the field, where a number of outlets are provided for attaching the galvanized surface pipe. This method requires less surface pipe than the first, and less work in moving pipes from one place to another. It is a comparatively expensive method, however, requiring a large investment in equipment.

This system of irrigation is known as the flood system and the water is applied to the growing crop usually during the latter part of July or the first part of August.

In the Salinas area winter irrigation is usually practiced. In most instances the water, as well as the labor for applying it to the land, is furnished by the sugar company at a flat rate of $3.75 an acre. The water used is the factory waste water, and it is applied in October

put in other men to complete any work unfinished or neglected by the party of the second part and charge the cost of such labor to the party of the second part.

In consideration whereof the party of the first part agrees to pay to the party of the second part for thinning, hoeing, weeding, topping, and loading beets, as follows:

Tons per acre.	Price per acre.	Price per ton.	Tons per acre.	Price per acre.	Price per ton.
20	$16.50	$0.825	11	$14.25	$1.295
19	16.25	.855	10	14.00	1.400
18	16.00	.890	9	13.75	1.528
17	15.75	.926	8	13.50	1.687
16	15.50	.969	7	13.25	1.893
15	15.25	1.017	6	13.00	2.167
14	15.00	1.071	5	12.75	2.550
13	14.75	1.135	4 or under	12.50	3.125
12	14.50	1.208			

Fractions of tons per acre in proportion.

The tonnage per acre to be determined for each field upon the net weight of the beets received by the sugar factory.

During the course of the work the first party agrees to pay the second party a sum not exceeding 80 per cent of the amount covering work already done, the balance to be paid when the work specified in this contract shall have been completed to the satisfaction of the first party.

The sum not to exceed 80 per cent of the amount covering the work already done is to be based on $——— per acre for thinning, $——— per acre for the first hoeing, and $——— per acre for the second hoeing, and the balance for topping and loading, according to schedule of prices stated in this contract.

Witness our hands and seals this ——— day of ——— 19—.

Witness:

——————————— ——————————— [SEAL.]

——————————— ——————————— [SEAL.]

and November. The irrigation may come before the land is plowed, or after the plowing, depending on the condition of the soil. It is

FIG. 12.—Pipes used for irrigating. They have been distributed across the field, but have not been connected in a continuous line.

frequently advisable to put the water on the land before plowing, since this practice greatly facilitates that operation.

Occasionally it is necessary to irrigate the beets after they are up. When this is done river water is used, being pumped through the same system as is used for the factory waste water, at the same

FIG. 13.—Irrigating sugar beets.

charge per acre. At this time the flood system is used without the use of surface pipe.

A few growers have their own water systems and pump the water from wells on the farm. In these cases also the land is flooded, but no surface pipe is used.

CHECKING LAND.

Where winter irrigation is practiced, considerable labor is required in preparing the land for the water. The land is checked—that is, a network of small levees is thrown up which serves to hold the water on the land until it has time to soak in. A strip several furrows wide is plowed across the field where each levee is to be made and the loose earth is ridged by a special implement called a "V." (See fig. 14.) When a "V" is not available a Fresno, or a small scraper, is used to ridge the earth.

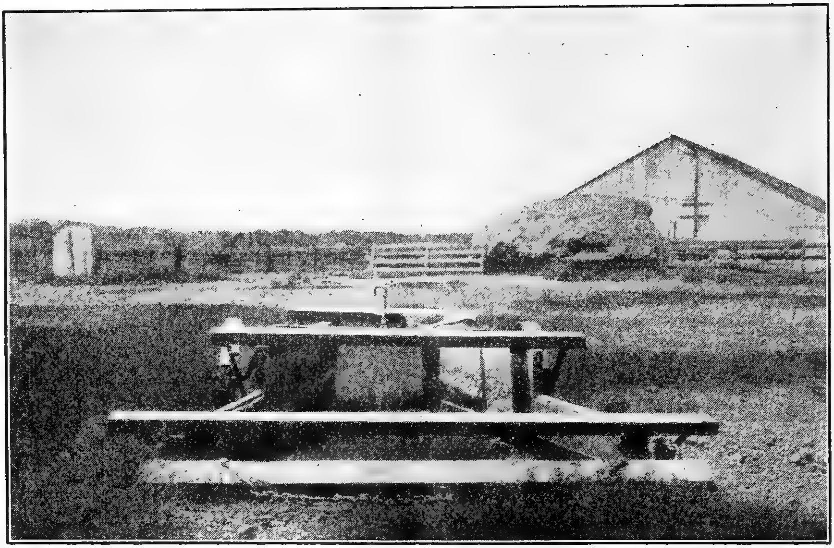

FIG. 14.—A "V." This implement is used to check the land for winter irrigation.

About 62 per cent of the growers at Salinas checked the land for irrigation. There were only two instances where the land was rechecked. This was done to irrigate for replanting. This operation occurred from September to June. An average crew of 1.5 men and 7.2 horses was used and 0.93 man hours and 3.96 horse hours were required per acre at an average cost of 40 cents per acre.

Frequently these levees are permanent and require only a small amount of labor each year to keep them in repair. Sometimes, however, the levees are harrowed down after the irrigation and new ones are constructed annually.

About 30 per cent of the growers who checked the land for irrigating made it the practice to break up or level the levees before the beets were planted. A plow, harrow, and roller were used in this operation. An average crew of 1.1 men and 5.4 horses consumed 0.33 man hours and 1.56 horse hours per acre at an average cost of 23 cents per acre.

TABLE XVII.—*Irrigating.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Man hours per acre.	Labor cost per acre.
			Total.	Irrigated.		
Los Angeles	53	65	104.67	87.26	6.57	$1.31
Salinas	9	23	97.67	73.44	5.04	1.06

Irrigation was not practiced at Oxnard, and only nine growers at Salinas reported labor on this operation. (Table XVII.) However, this number represents only the growers who practiced irrigation, and not those who had it done on contract. In all, 24 growers, or 62 per cent, irrigated, 56 per cent of which paid a contract rate of $3.75 per acre. The percentage of total number of records in both areas where irrigation was practiced is fairly uniform. On the farms where irrigation was practiced, 83 per cent of the beet land was irrigated in the Los Angeles area, while at Salinas 92 per cent of the beet land received an application of water.

At Los Angeles the beets were irrigated from March to August. At Salinas three growers irrigated the beets from June to August, two men irrigated only for replanting beets, fourteen growers irrigated before plowing, while five made the application after the land was plowed.

The time required per acre, as well as the cost, does not vary greatly in the two regions. At Salinas the estimates are slightly lower than in the Los Angeles area. The average crew at Salinas was 2.7 men, while at Los Angeles the crew was only 1.6 men.

A twofold benefit is derived from the factory waste water. In addition to furnishing moisture that is usually sufficient to bring the crop to maturity, the water returns to the soil some of the mineral constituents of the sugar beet. It has been found that for every 100,000 parts of water there are 80 parts residue. This plant food is in an available form and can be readily taken up by the sugar beet.

LIFTING.

The degree of maturity of the crop determines the time to start the work of lifting or plowing out the sugar beet in these areas. The time that the beet reaches the proper stage varies according to weather conditions, time of planting, etc., and is generally determined for the grower by a sugar test made by the sugar-factory representative.

In the Los Angeles area this period extended from July 20 to December 1, in the Oxnard district from July 15 to November 10, and on Salinas farms from September 1 to November 25. (Table XVIII.)

TABLE XVIII.—*Lifting.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Hours of labor per acre.		Labor cost per acre.
			Total.	Lifted.	Man.	Horse.	
Los Angeles	66	81	91.92	89.52	4.19	16.72	$2.51
Oxnard	37	82	46.68	46.68	3.63	23.77	3.14
Salinas	39	100	92.72	92.72	4.45	26.37	3.57

FIG. 15.—Harvesting sugar beets with a crotch lifter that is operated by a crew of one man and four horses.

There are two general types of implement used in doing this work, viz, the crotch lifter and the side lifter. (See fig. 15.) The crotch lifter has double prongs which run on both sides of the row, while the side lifter has single points on the ends of long, thin, cutting blades, the most common size being the one-row implement with but one point. This is called a "side lifter" because the point runs at the side of the row. The crotch type lifts only one row, while side lifters are made to lift from one to four rows at a time. Side lifters are universally used when tractor power is employed. (See fig. 16.) The size of the lifter used depends on the horsepower of the tractor. Both side and crotch lifters were used in the Los Angeles district. On Salinas farms crotch lifters were used exclusively, while on farms in the Oxnard district the side lifter was the universal type.

In the Los Angeles district 4-horse outfits were employed on 48 per cent of the farms and 3-horse outfits on 19 per cent. Six-horse outfits were found on 44 per cent of the farms in the Oxnard and on 95 per cent in the Salinas area.

In addition to the work shown in the table, 13 men in the Los Angeles and 5 in the Oxnard area contracted the lifting at a rate of $3 to $3.50 per acre. In some cases this work was done by steam power. (See fig. 17.)

Four men at Los Angeles and four at Oxnard did the work of lifting with their own tractors. The amount of work accomplished per day varied from 4 to 10 acres.

FIG. 16.—A 4-row beet harvester (side lifter) that is operated by a gasoline tractor.

TOPPING.

Topping is classified as contract labor, and has been considered under the heading "Hand labor." (See fig. 18.)

HAULING.

The sugar beet is loaded by the contract beet workers into strong, well-built beet boxes, either with forks or by hand. (See figs. 19 and 20.) From the field they are hauled either to a loading station where they are loaded into cars, or directly to the sugar factory beet dump. Upon arrival at the loading station or factory, as the

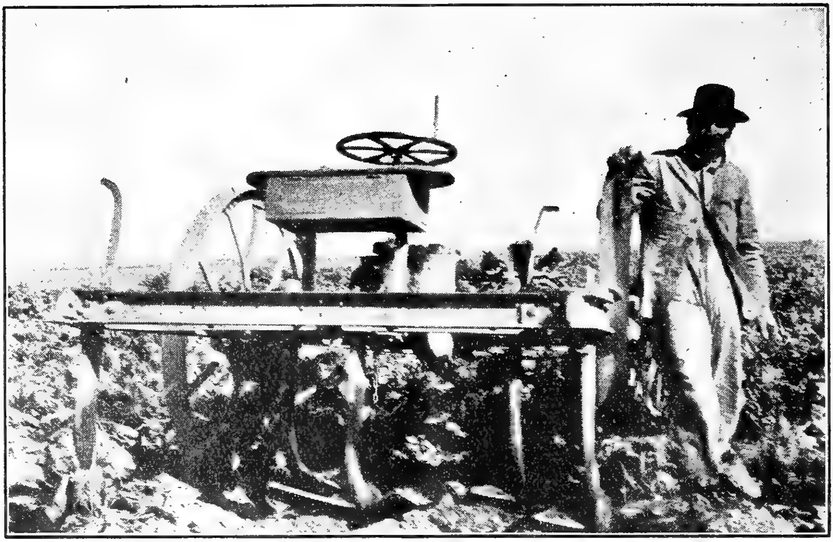

FIG. 17.—A beet harvester that is operated by steam power through the use of a steel cable. Two engines are required in this case, one at each end of the field.

FIG. 18.—Topping sugar beets. A small hook attached to the end of the knife enables the worker to lift the loosened beet out of the soil. He then takes hold of the root with his left hand and cuts off the top.

FIG. 19.—Loading by hand and hauling sugar beets from the field. Observe the net that is used on the wagon rack. At the dump the wagon is unloaded in a single operation by lifting this net.

FIG. 20.—Loading sugar beets with forks.

case may be, a representative sample is taken and weighed as it comes from the load. Then all dirt is removed, the sample is retopped when necessary, and the clean beets are weighed a second time. The difference in weight between the beets before and after cleaning determines the percentage of tare.

Eighteen men in the Los Angeles and five in the Oxnard district hired all of the hauling done at a contract rate of from 35 to 55 cents per ton, depending on the distance hauled. (See Table XIX.) In the Salinas area the hauling was all done by the farmers themselves. The number of tons of beets hauled at one trip ranged from 3 to 6

FIG. 21.—Hauling sugar beets with wagon and trailer. The crew consists of one man and eight horses. This is a common practice in the beet-producing districts of California.

tons for the single wagon to 7 to 10 tons where a trailer wagon was used.

TABLE XIX.—*Hauling.*

District.	Number of records.	Per cent of total records.	Acres in beets per farm.		Distance hauled.	Hours of labor per acre.		Labor cost per acre.
			Total.	Sold.		Man.	Horse.	
					Miles			
Los Angeles	63	78	109.29	108.90	1.20	5.80	31.36	$4.30
Oxnard	40	89	63.30	63.30	1.76	4.66	31.00	4.08
Salinas	39	100	92.72	90.15	1.06	4.99	30.74	4.12

The season for hauling extended from July to December. The 1-man-6-horse and 1-man-8-horse crews were the ones most in evidence, 50 per cent of the former and 24 per cent of the latter being reported. (See figs. 21 and 22.)

The average distance to the loading station was 1.33 miles. The shortest average distance hauled, 1.02 miles, was found in the Salinas district, and the longest, 1.76 miles, in the Oxnard area. (Table XX.) One hundred and forty-two men reported hauling with horsepower, and of this number 47 per cent hauled less than 1 mile and 13 per cent more than 2 miles. Forty per cent hauled an average of 1.56 miles. Those who hauled an average distance of 0.67 of a mile did so at an average cost of 14 cents per ton less than the men who hauled over 2 miles, or an average of 2.83 miles. (See figs. 23 and 24.)

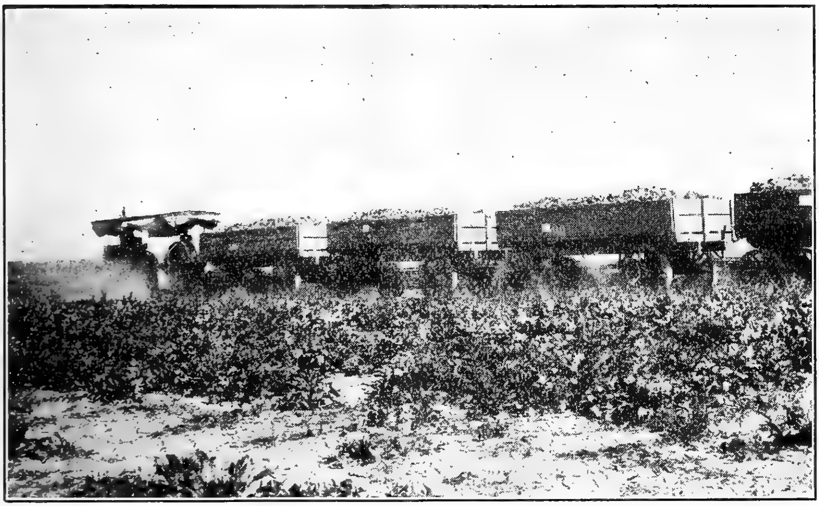

FIG. 22.—Hauling sugar beets from field to factory with a tractor and a train of four wagons.

TABLE XX.—*Cost of hauling as influenced by the distance hauled.*

Distance.	Average distance.	Number of records.	Per cent of total records.	Labor cost per ton.
	Miles			
1 mile and under	0.67	66	47	$0.26
1 to 2 miles, inclusive	1.56	57	40	.32
Over 2 miles	2.83	19	13	.40

VARIATIONS IN FIELD PRACTICE.

While standard methods of handling a crop may be followed quite closely by many growers in a given district, certain variations are inevitable because of differences in soil, or in the previous treatment of the field, or in the time when the work of preparation is begun.

Factory methods can not always be followed in producing a crop of sugar beets or any other crop. In districts where the weather conditions do not interfere seriously with field operations, the plowing,

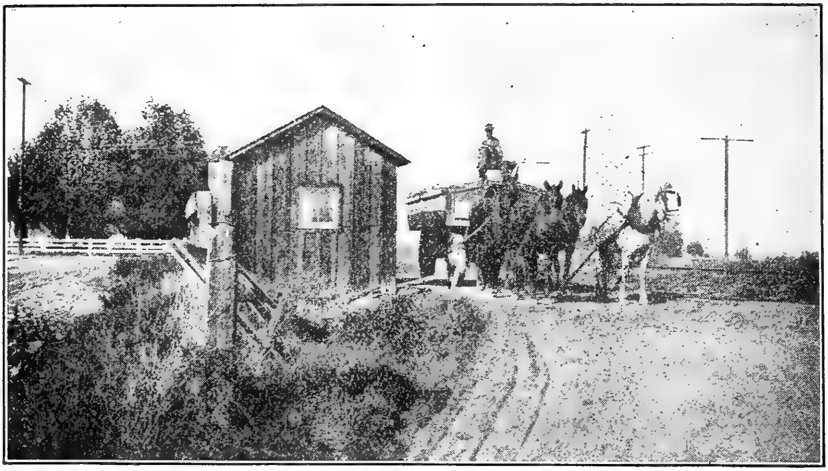

FIG. 23.—Weighing sugar beets at point of delivery.

harrowing, etc., may be done according to a previously planned schedule, but even in such cases variations in field practice are bound to exist. Some of these features are illustrated in Tables XXI, XXII,

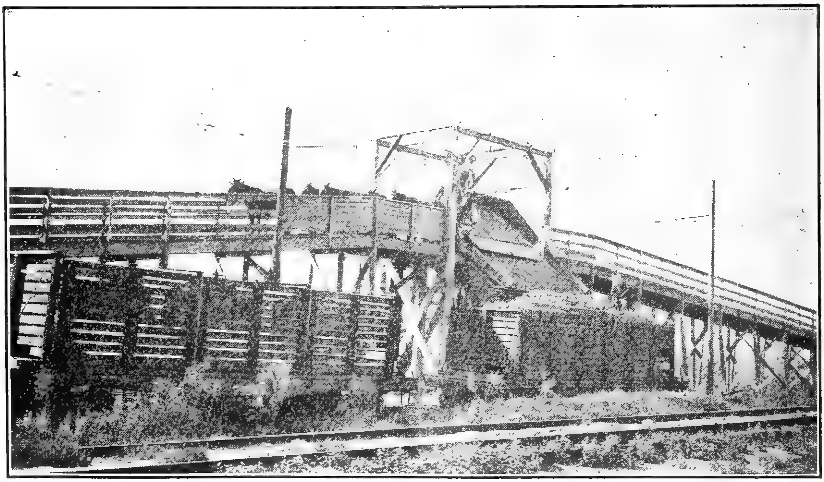

FIG. 24.—Delivering sugar beets to cars at a typical loading station.

and XXIII, tabulated from the records of 10 selected farms from each district.

TABLE XXI.—*Variations in farm practice (Los Angeles district).*

Operation.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.									
Plowing	1.2	1	1	1	1	1	1		1	1
Disking						.4		1		
Chiseling								1		
Harrowing:										
Cyclone			.6							
Spike	4	6	3	3	3	4	3	2	6.6	3
Spring	.2				1		1			1
Rolling	.2	3	1	2		1				2
Planting	1.2	1	1.2	1	1.1	1	1	2	1.8	1.5
Rolling beets	.3	1	1	2	3	2			.5	1.
Cultivating	4	4	4	5	5	3	4.5	4	4	7
Irrigating	1	.7	1	1	1.8	1			1	
Blocking and thinning	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Hoeing:										
First	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Second	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Topping and loading	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Lifting	Con.	1	1	1	1	1	1	1	1	Con.
Hauling	1	1	1	1	Con.	1	1	Con.	1	1
Scraping		1								
Manuring[1]	.4		.1	.2		.1	.1		.2	.04
Hours per acre:										
Man	25	26	33	43	24	28	17	17	42	25
Horse	72	98	100	136	63	105	94	58	130	109
Yield per acre	15.3	22.0	15.8	16.1	13.3	17.2	13.9	12.0	18.6	19.2
Cost per acre	$74.55	$68.85	$76.77	$74.28	$67.13	$69.48	$64.92	$65.41	$76.11	$74.69

Average cost per acre for the district........ $67.11

[1] It will be seen that fractional numbers are used under the operation manuring. These numbers indicate that only a part of the beet land was manured. For instance, Farm No. 1 in the Los Angeles district applied manure to four-tenths of the sugar-beet acreage. No. 3 treated one-tenth of the beet acreage with manure, while No. 4 covered two-tenths. Fractions occurring under other operations should be interpreted in the same manner.

TABLE XXII.—*Variations in Farm Practice (Oxnard District).*

Operation.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.									
Plowing	1	2	1	1	2	1	2	1	1	1
Disking		1		2				2		
Chiseling										
Floating	1		1	1	1					2
Harrowing:										
Cyclone									1	
Spike	1	2	4	2	4	3	2	2	4	4
Spring	3	2	1				1	1		3
Rolling:										
Crosskill		1			1					
Ring									1	
Fertilizing										
Planting	1.03	1	1	1	1	1	1	1	1	1
Rolling beets	1	2	2	1	1				2	3
Cultivating	4	4	4	4	5	5	3	4	3	3
Blocking and thinning	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Hoeing	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Topping and loading	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	Con.	1	1	1	1	1	1	1	1
Manuring	.1			.2	.1	.2	.3	.2	.6	
Hours per acre:										
Man	12	29	19	16	19	25	20	19	30	22
Horse	79	86	122	107	117	109	121	102	100	119
Yield per acre	10	6.5	8	9	8.25	11	8	12	12	16.3
Cost per acre	$53.34	$51.41	$52.37	$55.92	$54.88	$55.54	$59.00	$56.34	$57.83	$60.01

Average cost per acre for the district........ $54.88

TABLE XXIII.—*Variations in Farm Practice (Salinas District).*

Operation.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.									
Plowing	1	1	1.7	1	......	1	1	1	1	1
Disking	......	......	......	......	......	2	......	......	1	......
Floating	......	2	......	......	1	2	......	......	......	1
Chiseling	1.5	1	1	1	1	2	.5	1.3	1	1
Harrowing (spike)	3.5	6	6	3	2	5	3	10	5	5
Rolling	1	1	2	1	1	2	1.5	1.3	1	2
Planting	1.5	1.1	1	1	1	1	1.5	1.3	1	2
Cultivating	......	1	1	1	1	2	3	2	1	1
Checking land	.5	1	......	1	......	.5	......	......	1	1
Irrigating	Con.	Con.	......	1	......	.5	......	......	Con.	1
Leveling levees	......	......	......	......	......	......	......	......	1	1
Blocking and thinning	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Hoeing:										
First	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Second	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Topping and loading	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.	Con.
Lifting	1	1	1	1	1	1	1	1	1	1
Net man	......	......	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Scattering tops	1	......	......	......	......	1	1	......	......	......
Manuring	.1	......	......	.03	......	.01	......	.1	.02	.1
Hours per acre:										
Man	14	24	24	22	17	32	20	25	19	30
Horse	80	142	107	85	85	149	122	132	93	122
Yield per acre	16.50	17.70	15.00	18.50	14.00	9.00	20.50	18.00	14.80	13.00
Cost per acre	$56.56	$67.48	$60.78	$67.81	$54.88	$63.86	$74.21	$69.72	$63.00	$73.96

Average cost per acre for the district $66.45

Some of the operations that are mentioned in these three tables were not common to all districts. On many farms it was customary to give the land one plowing. However, in several cases the early fall plowing was followed by winter plowing. The chisel was used on only one of the ten Los Angeles farms, on none in the Oxnard group, and on all farms in the Salinas group. There was considerable variation in the number of times the fields were covered with the spike-tooth harrow. This was also true with cultivation.

COST OF PRODUCING SUGAR BEETS.

The more important factors which enter into the cost of producing sugar beets are labor, interest on land or rental, seed, water, taxes and insurance. In terms of money these factors are variable. As the supply of farm labor decreases the labor cost increases. There is a corresponding increase in the cost of farm implements. Increased labor costs result also in an increase in the cost of materials. If the land valuation advances or the rate of interest increases, so also does the interest on the land investment become greater. However, such fundamental factors as hours of man labor, hours of horse labor, pounds of seed, hours use of equipment and tons of manure do not fluctuate appreciably. Comparisons of amounts of labor and materials required in each area give the true relationship of farm practices. Thus, though the values of the several items in dollars and cents have increased since these records were obtained, the amounts of labor and material used have not changed, and the actual cost of production for a given region in a given season can be ascertained by substituting current prices for those that prevailed when this study was made. It should be borne in mind that the cost figures given herewith are presented solely for the purpose of comparison.

The computations are made to apply to the entire beet acreage. Thus all averages are weighted, and the cost per acre in the respective areas represents the cost per acre of producing 7,711.5 acres of beets in the Los Angeles district, 2,811 acres in the Oxnard area, and 3,616 acres at Salinas.

LABOR.

As has been previously stated, the production of sugar beets necessitates a great amount of both man labor and horse labor. A considerable portion of the man labor is crowded into two distinct periods. The first period covers blocking and thinning, and hoeing, while the other comes at the harvest time, when the pulling, topping, loading, and hauling are done. So much labor is necessary during these periods that extra laborers must be hired to do the work.

It is the general practice to hire most of this labor on a contract basis, paying a stipulated sum per acre or per ton. Such labor is frequently called "contract labor." Sometimes the same group of laborers will contract for all the hand work. This is the general practice in the Salinas area. In other sections there are sometimes two groups of workers. The first contracts the blocking and thinning, and hoeing, while the second takes care of the pulling, topping, and loading.

The number of acres of beets that can be grown on the farm depends on the available supply of labor to do the contract work. In years when farm labor is scarce, considerable difficulty has been encountered in getting the crop harvested.

There is very little difference in the labor cost per acre between the Los Angeles district and the Oxnard district (Table XXIV). The labor cost at Salinas exceeds the labor cost in the other regions, but when reduced to the basis of cost per ton, the labor cost at Oxnard is the largest. The difference is due entirely to the factor of yield. The smallest yield per acre, 9.53 tons, was realized in the Oxnard district. The labor cost alone ranged from \$2.13 to \$3.02 per ton, or \$28.73 to \$35.64 per acre. (See Table XXIV.)

TABLE XXIV.—*Labor costs.*

District.	Number of farm records.	Total acres in beets.	Labor cost per acre.	Labor cost per ton.
Los Angeles	81	7,711.5	$30.93	$2.13
Oxnard	45	2,811.0	28.73	3.02
Salinas	39	3,616.0	35.64	2.29

MATERIALS.

Under materials come the items of seed, manure, and water. The cash paid out for materials as well as the estimated values of materials produced on the farm were used in computing the costs.

SEED.

Beet seed is furnished by the sugar companies and advanced to the farmer. The seed is paid for out of the first delivery of beets to the factory. No interest is charged to the farmer on the money invested in the seed during this period.

In the Los Angeles and Oxnard districts, the beet seed cost 12 cents per pound, while in the Salinas area the farmer was charged 16 cents a pound. The rate of seeding also affects the cost per acre. At Los Angeles the average rate of seeding was 20.7 pounds per acre, at Oxnard 16.6 pounds, and at Salinas 14.6 pounds.[1] It will be seen that the low cost at Oxnard is due to the lower rate of seeding (Table XXV), while the high cost at Los Angeles results from a high rate of seeding. In the Salinas district the high cost per acre is due to the higher cost per pound of beet seed.

TABLE XXV—*Cost of materials.*

District.	Number of farm records.	Cost per acre.			Total cost of materials per acre.	Cost of materials per ton.
		Seed.	Manure.	Water.		
Los Angeles	81	$2.48	$0.67	$0.55	$3.70	$0.25
Oxnard	45	1.99	.89		2.88	.30
Salinas	39	2.34	.27	1.50	4.11	.26

MANURE.

The manure charge deals only with the manure produced by the stock kept on the farm. Neither commercial fertilizer nor green manures are used to any extent in any of the areas studied.

An estimate of the value per ton of the manure in the barnyard was obtained from the grower. By multiplying this figure by the

[1] This includes seed for replanting if charged to the grower.

number of tons of manure applied per acre the actual cost per acre covered was computed.

Comparatively speaking, very little manure was used. At Los Angeles about 6 per cent of the beet land was manured, in the Oxnard district 9 per cent, and at Salinas only $2\frac{1}{4}$ per cent. The cost of manure per acre of beets grown is found by dividing the total value of the manure applied by the entire beet acreage. Thus the extremely low costs per acre are shown, since but a small percentage of the sugar beet acreage received an application of manure.

WATER.

In the Los Angeles area and in the Salinas district the sugar beet is frequently grown under irrigation. At Oxnard only one man was interviewed who followed this practice. No favorable report was obtained regarding irrigation in this area.

At Los Angeles the beets are irrigated by pumping water from wells. Here the principal charge, exclusive of equipment, is for fuel and lubricating oil. The equipment charge is included under the machinery cost. About 62 per cent of the beet land was irrigated in this district.

At Salinas the greater portion of the irrigation is done by the sugar company. A flat rate of $3.75 per acre is charged. A few growers who own the land they farm have pumping plants and irrigate by pumping the water from wells. About 50 per cent of the growers either irrigated their beet land or hired it done. Since the cost of labor required to irrigate is included in most of the records for Salinas, the cost per acre for this district is considerably greater than for Los Angeles.

The highest cost per acre for materials was reported at Salinas, the lowest at Oxnard. As has been indicated, much of the difference in the cost in favor of Oxnard is due to the fact that the farmers of that district did not irrigate their beet land. Figured on the ton basis, the low yield per acre gives the highest cost per ton to Oxnard. The costs in the other two areas are approximately the same.

OTHER COST ITEMS.

In considering the cost of producing any farm crop, there are a number of items of expense which apply to more than one enterprise on the farm and some that have to deal with the whole farm as a unit. Such items as insurance, taxes, interest on the land investment, machinery, and miscellaneous expense come in this group of costs. Table XXVI shows the average cost per acre of these different items, the total cost per acre of the group, and the cost per ton for the three areas.

INSURANCE AND TAXES.

The sugar beet must stand a share of the farm insurance and taxes. This charge is greater on farms owned by the operator than on rented land, since the owner pays taxes on the assessed valuation of the land, while the tenant pay taxes only on his personal property.

TABLE XXVI.—*Other costs.*

District.	Number of farm records.	Total beet acreage.	Cost per acre.				Total cost per acre.	Cost per ton.
			Insurance and taxes.	Interest and rent.	Machinery.	Miscellaneous expense.		
Los Angeles	81	7,711.5	$1.98	$26.66	$2.80	$1.04	$32.48	$2.24
Oxnard	45	2,811.0	1.97	17.85	2.50	.95	23.27	2.44
Salinas	39	3,616.0	1.04	21.22	3.25	1.19	26.70	1.71

On owned farms taxes and insurance were charged against the beet crop according to the percentage the investment in the beet land was of the total farm real-estate investment. (See Table XXVI.) On tenant farms the proportion of this expense chargeable to the sugar beet was determined by the relative importance of the sugar-beet enterprise. In the latter case the charge per acre was always small.

Several factors affect the average charge for these two items, namely, percentage of tenant farmers in a given group, the relative importance of the beet crop compared with other farm enterprises, and the valuation of the beet land. At Los Angeles the tenure was about evenly divided between tenants and owners; at Oxnard only 20 per cent of the growers were tenants, at Salinas 64 per cent. On some farms practically all the tillable area is in beets. In such instances all the insurance and taxes are chargeable against this crop. At Los Angeles and Oxnard taxes were higher than in the Salinas area. As a result of the influence of these several factors the cost per acre for insurance and taxes in the Los Angeles and Oxnard districts averaged about $2, while at Salinas it was only about half that figure.

INTEREST AND RENT.

Interest on the land investment, where the owner is the operator, and rent where the operator is a tenant, are probably the most variable factors.

The current rate of 7 per cent on first-mortgage notes was used in computing interest. The cash paid out for rent of land or the value of the part of the crop given to the landlord as rent was used in figuring the rental charge. Some of the factors affecting these charges are value of land, amount of cash paid as rent, proportion of the crop given as rent, the yield of beets, and the price received per ton.

In the areas studied the value of the share given for the use of the land exceeds the cash paid for this same privilege. However, the element of risk enters into the consideration. A share renter runs less risk of failing to meet his rent than the cash renter. In poor crop years the cash renter usually has to pay the same rent as in seasons of good crop yields, while the smaller the yield the less the actual number of tons of beets the tenant must give to the landlord. In sections where $6 a ton is received for beets, the value of one-fourth of the crop is greater than where $4.50 a ton is received for the crop.

At Los Angeles sugar beets brought an average of $5.79 a ton; at Oxnard, $6.88 a ton; at Salinas, $5.58.

The land values were highest at Los Angeles, where the average value of sugar-beet land was $494 per acre. At Oxnard and Salinas the values were $294 and $328 per acre, respectively. In the Los Angeles and Salinas districts about one-fourth of the land in beets was farmed by the owners; at Oxnard about 60 per cent. At Los Angeles about one-third of the beet land was cash rented, at Oxnard 22 per cent, and at Salinas 18 per cent. The highest average cash rent was paid at Los Angeles ($26.33 an acre), the lowest at Oxnard ($12). At Salinas the cash rent averaged $15.06 an acre. Of the share renters the major portion gave one-fourth of the crop to the landlord. A little over one-third of the beet land in the Los Angeles area was share rented, about one-fifth was share rented at Oxnard, while over one-half was share rented at Salinas. The highest share rent was paid in the Los Angeles district ($22.13), and the lowest in the Oxnard region ($15.82). At Salinas the share rent was $20.12 per acre.

MACHINERY.

Interest on investment, depreciation, and annual repairs, taken together, make the total annual machinery charge. This total charge was used in the case of implements used exclusively on the beet crop, and a fair proportion of this charge for implements used in common with other crops or farm enterprises.

The machinery charge was fairly uniform at Los Angeles and Oxnard, but was considerably higher at Salinas. This difference is due in a measure to the type of tillage implements used. At Salinas very deep tillage is practiced, and heavy and expensive implements are necessary to do the work. The cost per acre for machinery was $2.50 at Oxnard, $2.80 at Los Angeles, and $3.25 in the Salinas district.

MISCELLANEOUS EXPENSE.

All expenses not hitherto provided for have been grouped as "miscellaneous." It has been found that a rough approximation of this item can be reached by taking 3 per cent of the cost of labor and materials combined. The figures for miscellaneous expense are fairly uniform for the three districts.

SUMMARY AND DISTRIBUTION OF COSTS.

In making plans for greater efficiency in the production of sugar beets, it is necessary to know something of the relative importance of the different items of cost. To improve methods which reduce the cost of an item that constitutes only 1 per cent of the total cost may be merely a waste of time. However, if an item representing 50 per cent of the total cost can be reduced one-half, then something worth while has been accomplished.

Labor is the largest item of expense, constituting about 50 per cent of the total cost of production. (See Table XXVII.) The cost of materials is about 5 per cent of the total cost, while the remainder is taken up by other costs.

TABLE XXVII.—*Summary and distribution of costs.*

District.	Cost per acre.	Cost per ton.	Distribution of costs.		
			Labor.	Materials.	Other costs.
			Per cent.	*Per cent.*	*Per cent.*
Los Angeles	$67.11	$4.62	46	6	48
Oxnard	54.88	5.76	52	5	43
Salinas	66.45	4.26	54	6	40

The largest item in the labor cost is man labor, exclusive of contract labor. This constitutes about 55 per cent of the total labor cost. The cost of seed is about 65 per cent of the cost of materials, while the interest and rent make up the greater part of the other costs.

DISTRIBUTION OF RECORDS ACCORDING TO COST PER TON.

All of the records were sorted in reference to the cost per ton of producing sugar beets. The growers producing beets for $3 a ton, or under, made up one group; those producing for an average of $3.50 were put in another class and so on. A frequency curve was then constructed which shows the number of growers in each group and also the average yield per acre for each class. (See fig. 25.)

The $5 class is the largest, containing about 22 per cent of the growers. In the three larger groups 45 per cent of the farmers are represented. The cost per ton in these groups ranges from $4 to $5.50. The growers for the three areas studied received an average of $5.88 a ton for their beets, which means a profit of 38 cents a ton for the $5.50 group and a loss of 12 cents a ton for the $6 group. At this rate, 19 per cent of the farmers, producing about 11 per cent of the total tonnage, are not making any profit growing sugar beets. They are living on the interest on their investment.

It will be noticed that, generally speaking, those producing high yields per acre had low costs per ton and those who produced low yields per acre had high costs per ton. In the case of the $6 and the $6.50 groups, an analysis shows that the farms in the former class grew an average of 146 acres of beets per farm, while those in the latter grew only 49 acres of beets per farm. It is usually found that the larger the acreage in beets the more efficiently certain opera-

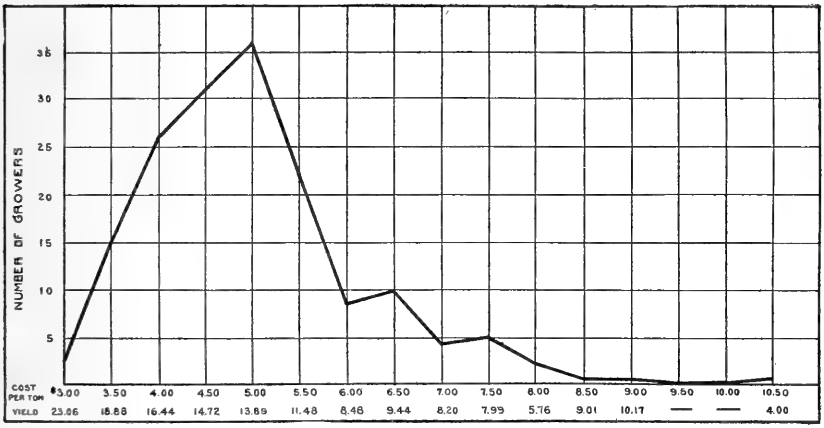

FIG. 25.—Curve showing the distribution of operators and the relationship of yield per acre to cost per ton.

tions can be performed and the lower the cost will be per ton. The yield undoubtedly is a very important factor affecting the cost per ton.

AVERAGE RETURNS AND MARGIN ABOVE COST.

In all the areas studied beets are bought on contract by the sugar factories. At Los Angeles beets were paid for on the sugar test. Beets testing 11 per cent sugar and under brought $3.50 per ton, with an increase of 25 cents per ton for each additional 1 per cent above 11 per cent until 15 per cent was reached. Above 15 per cent an increase of 30 cents a ton was paid for each additional 1 per cent. A bonus of 50 cents a ton was added to this amount for the 1916 crop. When the wholesale price of sugar was raised beyond expectation during the crop year an additional bonus of 50 cents a ton was given to the grower, making a total bonus of $1 per ton.

The same scale of prices was in force in the Oxnard area for the 1916 crop, including the bonus of 50 cents a ton for the beets.

In the Salinas area certain records were obtained from tenants who rented beet land from the sugar company. In 1916 these tenants received from $4.50 to $5 a ton for beets. The scale for the growers who did not rent sugar-company land started at $5.25 for beets testing 15 per cent sugar, with an addition of 25 cents per ton for each 1 per cent above 15 per cent.

It can be plainly seen that on account of the difference in amounts received per ton for the beets and the variation in yield that the receipts per acre would not be uniform for the three regions. The largest average price, $6.88 a ton, was received at Oxnard, the Salinas and Los Angeles growers getting a slightly lower price. By subtracting the cost of production from the receipts there is left a margin of from slightly more than $10 to almost $21 an acre. (See Table XXVIII.) Figured on the ton basis, the net returns per ton from beets alone ranged from $1.12 at Oxnard to $1.32 at Salinas. In addition to this amount there is a benefit received from the beet tops, whether sold, fed, or plowed under, which brings the average net return up to from $12.99 to $23.41 per acre.

TABLE XXVIII.—*Average returns and margin above cost.*

District.	Yield per acre.	Beet receipts per acre.	Cost per acre of beets.	Net returns per acre for beets alone.	Net returns per acre including beet tops.
	Tons.				
Los Angeles	14.52	$84.04	$67.11	$16.93	$19.68
Oxnard	9.53	65.56	54.88	10.68	12.99
Salinas	15.59	87.06	66.45	20.61	23.41

THE EFFECT OF SIZE OF BEET ACREAGE AND YIELD PER ACRE ON THE COST OF PRODUCTION.

It has already been indicated that the yield of beets is one of the most important factors affecting the unit cost of production. There is also another factor which materially affects the cost of production, namely, the size of the beet acreage.

To bring out the effect of these two factors, all the records were classified according to acreage in beets. The first group contained the farms producing 40 acres and under, the second those growing 41 to 70 acres, and the third, those producing 71 acres and over. Each group was then subdivided into three classes according to whether the yield per acre was 10 tons or less, 11 to 15 tons, or 16 tons or over. (See Table XXIX.)

TABLE XXIX.—*Relation of acreage and yield to cost of producing beets.*

Acres in beets.	10 tons or less per acre.			11 to 15 tons per acre.			16 tons or over per acre.		
	Number of farms.	Cost per acre.	Cost per ton.	Number of farms.	Cost per acre.	Cost per ton.	Number of farms.	Cost per acre.	Cost per ton.
40 and under	15	$54.04	$6.63	16	$66.93	$5.29	18	$80.77	$4.50
41 to 70	14	57.46	6.03	18	67.54	4.83	15	79.31	4.22
71 and over	16	50.84	5.97	25	62.05	4.60	28	73.85	4.05

It will be noticed that the group growing 40 acres and under had a higher acre cost than the growers producing 71 acres and over, but that the group growing 41 to 70 acres had a higher acre cost than the first group except in the case of farms with a yield of 16 tons or over per acre. An analysis of the records in this group shows that the major portion of these records was obtained in the Los Angeles and Salinas areas, where the acre costs were uniformly higher than in the Oxnard area. Generally speaking, however, the larger the acreage devoted to sugar beets, the smaller is the cost of production per acre.

The effect of both acreage and yield can be plainly seen in the cost per ton. The higher average yields in the group which produced 41 to 70 acres throw this group into its logical place in relative unit cost. As the acreage and yield increase there is a uniform decrease in the cost per ton.

VALUE OF THE SUGAR-BEET TOPS.

The sugar-beet tops are a valuable by-product of the sugar beet, and their value depends on the use made of them. The tops may be fed to stock or plowed under. They may be sold as pasture on the farm (see fig. 26) or sold and hauled away from the farm. Some growers may combine two or more of these practices, especially if the beet acreage is very large. (See Table XXX.)

TABLE XXX.—*Disposition and estimated acre value of sugar-beet tops.*

District.	Number of farm records.	Per cent feeding.	Value when fed.	Per cent selling.	Value when sold.	Per cent plowing under.	Value when plowed under.
Los Angeles	81	10	$3.04	42	$2.82	9	$2.67
Oxnard	45	11	2.82	51	2.37	29	2.08
Salinas	39	....	....	18	3.25	56	3.61

Among the Los Angeles and Oxnard growers the general practice was to sell the tops as pasture. Forty-two per cent of the former and 51 per cent of the latter handled the tops in this manner. About 10 per cent in each of these areas fed tops to stock kept on the farm. In the Los Angeles district 39 per cent of the growers combined two or three methods of handling. It will be noticed that in these areas the highest valuation was placed on the tops when fed to stock on the farm, the next highest on tops sold and the lowest when the tops were turned under for manure. Where combinations of methods were employed, the results show that the acre value depends on the percentage of tops handled in a given manner, a higher valuation resulting when the greater percentage of tops was fed or sold, than when plowed under.

In Salinas it is not the common practice to pasture the tops with stock on the farm since very little stock other than work stock is kept. Then, too, the scarcity of farm manure makes it advisable to plow under the tops. Fifty-six per cent of the growers followed this practice, 18 per cent sold the tops to be pastured on the field, and

FIG. 26.—Dairy cattle feeding on beet tops. A temporary fence separates the cattle from the part of the field not yet harvested.

the remainder combined these methods of handling. A higher valuation was placed on the tops when plowed under than when sold. However, the highest acre value ($4) was reported where part of the tops were fed to stock on the farm and the remainder plowed under.

Generally speaking, beet tops are of the greatest value when fed to farm stock by the operator and of least value when plowed under, and of more value when sold as pasture on the field than when sold and hauled away from the farm. (See fig. 27.)

BEET RECEIPTS IN COMPARISON WITH OTHER FARM RECEIPTS.

Table XXXI shows how beet receipts compare with other farm receipts on these farms. It will be seen that 92 per cent to 98 per cent of the farm receipts came from the sale of crops. Considerably more than 50 per cent of the farm receipts in the Los Angeles and

Salinas areas were derived from the sale of sugar beets alone, while at Oxnard about 43 per cent came from sugar beets. In this last section the bean is a competing crop, about 46 per cent of the receipts resulting from the sale of beans. Beans and beets combined furnished 89 per cent of the total farm receipts.

TABLE XXXI.—*Beet receipts in comparison with other farm receipts.*

District.	Number of farm records.	Average total receipts per farm.	Per cent of farm receipts from—			Per cent of farm receipts from beets.	Per cent of crop receipts from beets.
			Crops.	Live stock.	Miscellaneous.		
Los Angeles	81	$8,159.60	92	7	1	84	91
Oxnard	45	4,192.16	98	1	1	43	44
Salinas	39	8,197.56	97	2	1	66	68

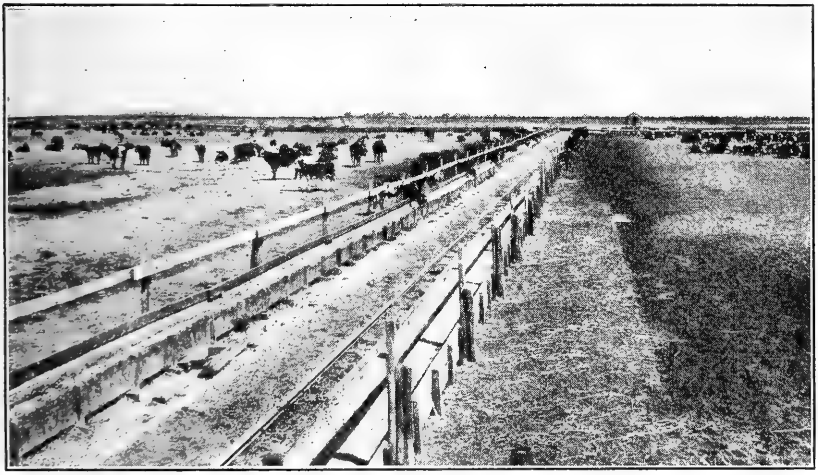

FIG. 27.—Feeding yards at Betteravia, Cal., where beet pulp constitutes an important part of the ration.

The receipts from live stock and live-stock products are second in importance, while not more than 1 per cent of the receipts in any of the three sections came from sales other than crops or live stock.

It can be stated that in Los Angeles and Salinas the farms are specialized and can be properly classed as beet farms, while at Oxnard the type can be designated as bean and beet farms.

There is certainly a field for more diversified farming in these areas. Since crops like barley, alfalfa, potatoes, and beans can be grown successfully, there is no good reason for depending on a single crop. In sugar-beet areas of Michigan, Ohio, Colorado, Utah, and Idaho, live stock fits in with the general farm scheme and utilizes to good advantage the beet tops, alfalfa, and other roughage produced on the farm. More live stock in the California beet region would mean more manure to keep up the soil fertility and a better distribution of profitable labor throughout the year. The development of a sound cropping system at the same time would increase yields by adding humus to the soil.

LABOR REQUIREMENTS.

It has already been pointed out that the sugar beet is an intensive crop and requires a great amount of labor, some of which is hired and paid on a contract basis. In discussing labor requirement, the cash amount paid out for contract labor has been converted to man-hours, using a rate of 25 cents per hour. It is generally conceded that the expert labor that contracts this work receives a higher wage per hour than the regular farm labor. (See Table XXXII.)

TABLE XXXII.—*Labor requirements in producing an acre of sugar beets.*

District.	Acres grown.	Hours of man labor.			Total hours per acre.	
		Farmers' labor.	Contract.			
		Machine operations.	Contract price.	Equivalent hours.	Man labor.	Horse labor.
Los Angeles	7,711.5	27.7	$15.01	60.0	87.7	109.3
Oxnard	2,811.0	20.2	14.82	59.3	79.5	111.5
Salinas	3,616.0	25.7	18.87	75.5	101.2	124.3

In these three districts all of the hand labor was done on a contract basis. The machine operations are given separately so that the reader may see the relation between this part and the total man labor. The number of man hours per acre expended at Oxnard is considerably less than for the other two areas, since the yield at Oxnard is the lowest and irrigation was not practiced in this area.

The horse labor necessary to produce an acre of sugar beets was fairly uniform at Los Angeles and Oxnard, but slightly greater at Salinas, where, on account of the character of the soil, the work is heavier, and larger teams are used, than in the other areas.

The cash paid out for contract labor was almost $3 per acre more at Salinas than anywhere else. For the most part the contract labor at Salinas includes not only the cost of irrigation water but also the man labor necessary to do this work. When the cost of irrigation is deducted from the contract labor cost, there is no very wide variation in the amount paid out for contract labor in the three areas.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 761

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ April 7, 1919

A COMPARISON OF CONCENTRATES FOR FATTENING STEERS IN THE SOUTH.

By W. F. WARD and S. S. JERDAN, *Animal Husbandry Division, Bureau of Animal Industry*, and E. R. LLOYD, *Director of Mississippi Experiment Station.*[1]

I. The Comparative Value of Cottonseed Meal, Cold-Pressed Cottonseed Cake, and a Mixture of Cottonseed Meal and Corn for Fattening Steers.

II. A Comparison of Cottonseed Meal, Cottonseed Meal and Broken-Ear Corn, and Cottonseed Meal and Shelled Corn for Fattening Steers.

I. THE COMPARATIVE VALUE OF COTTONSEED MEAL, COLD-PRESSED COTTONSEED CAKE, AND A MIXTURE OF COTTONSEED MEAL AND CORN FOR FATTENING STEERS.

INTRODUCTION.

During recent years there has been much interest manifested in the manufacture of cottonseed oil from cotton seed without cooking it. The oil is extracted by severe pressure without hulling the seed, thus securing a better quality of oil and leaving a residue called cold-pressed cake, which is made up of the entire seed less the oil. With the increased output of cold-pressed cottonseed cake has arisen a demand for definite information concerning its feeding value.

Several years ago a cooperative experiment was conducted by the Bureau of Animal Industry and the Alabama experiment station testing the value of cold-pressed cottonseed cake for fattening steers on grass.[2] Now, however, most of the up-to-date farmers of the South who fatten beef cattle for the market have silos and use silage for the roughage in fattening the stock. No work had been done by the bureau to test the feeding value of cold-pressed cake when

[1] Acknowledgment is due G. A. Scott and S. W. Greene, of the Animal Husbandry Division, United States Department of Agriculture, for assistance in compiling this bulletin.

[2] See Bureau of Animal Industry Bulletin 131.

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fed with silage during the winter months. To get information on this subject the experiment hereinafter described was planned and executed.

OBJECT AND PLAN OF WORK.

The objects of this experiment were to make a comparison between the feeding values of cottonseed meal and cold-pressed cottonseed cake, when each was fed to steers with a roughage ration of corn silage, and to study the effects of the addition of corn-and-cob meal to a ration of cottonseed meal and corn silage.

The steers used in this work were bought during the fall months after having been on pasture during the summer without other feed. They were placed in the cotton and cornstalk fields until the feeding was begun and were given a small allowance of cold-pressed cottonseed cake. Nearly all the 75 steers used in the test were horned when purchased. They were dehorned two weeks prior to the beginning of the experiment.

Individual weights of the steers were obtained on November 30 and December 1. After weighing on the second day the steers were divided into three lots of 25 each and started on feed. The division was made so as to have the three lots as nearly equal in weight and quality as possible.

CATTLE USED.

The steers used in the test were grade Shorthorns, Herefords, Aberdeen-Angus, and Red Polls. Their breeding was from one-half to seven-eighths pure bred. They were all raised in Madison County, Miss., and were somewhat better than the average of steers found in the State. They had been run on good grass pastures during the previous summer, and averaged 860 pounds the day they were placed in the feed lots. After they were brought to the farm they were given a small allowance of cottonseed cake and most of them were in fair condition at the beginning of the experiment. At that time the steers were all about three years of age.

CHARACTER AND PRICES OF FEED.

The cottonseed meal used in the experiment was of very good quality; the analysis showed a protein content of about 40 per cent. The cold-pressed cottonseed cake likewise was of good quality and showed a protein content of about 27.5 per cent.

The silage used was mixed; about one-half of it was made of corn, and the other half of corn and sorghum. Some of the corn used for silage would have averaged about 35 bushels an acre in production of grain. Some of it, however, was rather poor, but the silage on the whole was considered excellent by the feeders.

During the second and third 28-day periods a small amount of cowpea hay was fed to each of the three lots. During this time the steers were given what silage they would eat and as much hay as they would consume in addition. The hay was fed in racks and less than 3½ pounds was eaten by each steer daily. It was of fair quality and contained a considerable quantity of peas.

The various feeds used were charged as follows:

Cottonseed meal	per ton	$22.50
Cold-pressed cottonseed cake	do	16.50
Corn	per bushel	.70
Cowpea hay	per ton	10.00
Silage	do	3.00

METHOD OF FEEDING AND HANDLING CATTLE.

The steers were divided into three similar lots, 25 in each, on December 1. They were weighed individually on this and the day previous and the average of the two weights was used as the initial weight. At the end of the experiment they were again weighed individually, and in the meantime they were weighed by lots at the end of each 28-day period. Each steer was provided with a numbered metal tag, which was placed on a strap and attached around the neck for identification.

Each lot of steers had the run of a shed, which was about 24 by 30 feet in size and opened on a yard about 30 by 150 feet. All lots and sheds were kept well bedded at all times. Inferior hay, oat straw, and broom sedge were used for this purpose. The yards never became boggy, but at times were somewhat sloppy.

Stationary troughs under the sheds were used for feeding. The cowpea hay that was used during the last two months was fed in racks with a trough underneath. These racks were in the yards. The steers were fed at 7 in the morning and at 5 in the afternoon. All lots were given as much silage as they would clean up. The cowpea hay was fed once each day. Salt was given the steers in their feed troughs and over their feed once each week. Fresh water from a deep well was furnished in galvanized-iron troughs placed in the feed lots. Feed which was not cleaned up was weighed back as often as necessary, and credit for same was given the steers. The feeding period lasted 123 days.

AVERAGE DAILY RATIONS.

The amounts of silage and hay consumed by Lots 1 and 3 were practically the same; that consumed by Lot 2 was considerably less. This same condition has been found in other experiments and seems to be due principally to a considerable quantity of hulls contained in the cold-pressed cake, and as the latter can not be as thoroughly mixed with the silage as cottonseed meal, the silage may be slightly less appetizing than when cottonseed meal is fed with it. Lot 1, in addition to the roughage mentioned, received cottonseed meal; Lot 2, cold-pressed cottonseed cake; and Lot 3 a mixture of cottonseed meal and corn-and-cob meal. The ratio used in mixing the two feeds was two parts by weight of cottonseed meal and one part corn-and-cob meal.

TABLE 1.—*Average daily rations by 28-day periods.*

Lot No.	Number of steers.	Ration.	First period.	Second period.	Third period.	Fourth period.	Fifth period (11 days).	Entire period (123 days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	25	Cottonseed meal	5.0	6.8	7.04	7.3	7.4	6.62
		Silage	39.4	41.2	37.0	41.9	41.8	40.2
		Cowpea hay		3.4	2.7			1.46
2	25	Cold-pressed cottonseed cake	8.6	10.3	10.6	10.7	11.0	10.0
		Silage	32.2	32.5	27.6	31.2	31.5	30.96
		Cowpea hay		3.5	3.1			1.48
3	25	Cottonseed meal	3.7	5.1	5.3	5.9	6.0	5.1
		Corn-and-cob meal	1.8	2.5	2.6	3.0	3.0	2.55
		Silage	39.8	40.7	37.4	41.8	37.0	39.54
		Cowpea hay		3.5	3.3			1.55

Lot 1 was started on a ration of 2 pounds of cottonseed meal. This was gradually increased until at the end of the first 28-day period they were receiving 6 pounds. The amount of meal received by each steer in this lot at the end of each period thereafter was, second period, 6 pounds; third period, 7 pounds; fourth period, 7.3 pounds. During the last week of the experiment they were receiving 7.4 pounds.

Lot 2 was started on a ration of 3.4 pounds of cold-pressed cake, which was gradually increased to 10 pounds at the end of the first month. They were kept on this amount until near the end of the fourth period, when the cake was increased to 11 pounds.

Lot 3 was started on a ration of 1.44 pounds of cottonseed meal and 0.72 pound of corn-and-cob meal. This was increased to about 4 pounds of cottonseed meal and 2 pounds of corn-and-cob meal at the end of the first 28-day period. During the second, third, and fourth periods they received an average of about 5½ pounds of cottonseed meal and 2¾ pounds of corn-and-cob meal. At the end of the experiment they were receiving 6 pounds of cottonseed meal and 3 pounds of corn-and-cob meal.

WEIGHTS AND GAINS.

The following table shows the initial and final weights and the total and average gains for each of the lots.

TABLE 2.—*Weights and gains (Dec. 1, 1914, to Apr. 3, 1915—123 days).*

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gain per steer.	Average daily gain per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal, silage, and cowpea hay	863	1,114	251	2.04
2	Cold-pressed cake, silage, and cowpea hay	860	1,108	248	2.01
3	Two-thirds cottonseed meal, one-third corn-and-cob meal, silage, and cowpea hay	865	1,117	252	2.05

There was very little difference in the average daily gains per steer. These gains are very satisfactory for a feeding period of 123 days with steers such as those used.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

Table 3 shows the amount and costs of feed required to make 100 pounds of gain.

TABLE 3.—*Quantity and cost of feed required to make 100 pounds of gain—December 1, 1914, to April 3, 1915, 123 days.*

Lot No.	Ration.	Quantity of feed to make 100 pounds of gain.	Cost of 100 pounds of gain.
		Pounds.	
1	Cottonseed meal	325	$6.96
	Silage	1,971	
	Cowpea hay	71	
2	Cold-pressed cake	502	6.80
	Silage	1,535	
	Cowpea hay	73	
3	⅔ cottonseed meal	249	7.82
	⅓ corn-and-cob meal	125	
	Silage	1,931	
	Cowpea hay	75	

Lot 1 consumed 325 pounds of cottonseed meal for each 100 pounds of gain made. Lot 2 consumed 502 pounds of cold-pressed cottonseed cake per 100 pounds gain. Lot 3 consumed 249 pounds of cottonseed meal and 125 pounds of corn-and-cob meal for 100 pounds of gain.

Lot 2 consumed much less silage per hundred pounds of gain than either of the other two lots. Lots 1, 2, and 3 consumed 1,971 pounds, 1,535 pounds, and 1,931 pounds, respectively, for each 100 pounds of gain.

Lot 2, which received cold-pressed cake, made the cheapest gains, each 100 pounds of gain costing $6.80. The gains made by Lot 3 were the most expensive, costing $7.82 per 100 pounds. The gains on Lot 1 were made at a cost of $6.96 per 100 pounds.

The cost of gains made by the steers of all lots was very satisfactory and was much smaller than usually obtained with steers fed in the ordinary manner.

FINANCIAL STATEMENT.

The steers of each lot were charged in the experiment at $5.50 per 100 pounds, which was the actual average purchase price. They were marketed at St. Louis, and sold for $7.35 per hundredweight.

The steers were driven about 3 miles from the feeding station to the railroad at Canton, Miss. They were loaded at Canton on

April 5, and arrived at the National Stock Yards on April 7, after being in transit 47 hours.

The following statement shows the financial results for each of the three lots:

Financial statement.

Lot 1, cottonseed meal, silage, and cowpea hay:	
To 25 steers, 21,580 pounds, at $5.50 per hundredweight	$1,186.90
To 20,368 pounds cottonseed meal at $22.50 per ton	229.14
To 123,668 pounds silage at $3 per ton	185.50
To 4,499 pounds cowpea hay at $10 per ton	22.49
To freight on car of 25 steers	89.60
To commission, yardage, feed, insurance, etc	26.85
Total expenditure	1,740.48
By sale of 25 steers, 25,590 pounds, at $7.35 per hundredweight	1,880.86
Total profit	136.38
Average profit per steer	5.45
Lot 2, cold-pressed cottonseed cake, silage, and cowpea hay:	
To 25 steers, 21,507 pounds, at $5.50 per hundredweight	1,187.88
To 31,183 pounds cold-pressed cake at $16.50 per ton	257.25
To 95,235 pounds silage at $3 per ton	152.85
To 4,570 pounds cowpea hay, at $10 per ton	22.85
To freight on car of 25 steers	89.60
To commission, yardage, feed, insurance, etc	26.85
Total expenditure	1,737.28
By sale of 25 steers, 25,510 pounds, at $7.35 per hundredweight	1,874.98
Total profit	137.70
Average profit per steer	5.50
Lot 3, $\frac{2}{3}$ cottonseed meal, $\frac{1}{3}$ corn-and-cob meal, silage, and cowpea hay:	
To 25 steers, 21,646 pounds, at $5.50 per hundredweight	$1,190.53
To 15,709 pounds cottonseed meal at $22.50 per ton	176.72
To 7,854 pounds corn-and-cob meal, at 70 cents per bushel	78.54
To 121,599 pounds silage at $3 per ton	182.40
To 4,778 pounds cowpea hay, at $10 per ton	23.89
To freight on car of 25 steers	89.60
To commission, yardage, feed, insurance, etc	26.85
Total expenditure	1,768.50
By sale of 25 steers, 25,620 pounds, at $7.35 per hundredweight	1,883.07
Total profit	114.57
Average profit per steer	4.58

The steers of Lots 1 and 2 made practically the same average profit per head, $5.45 and $5.50 per head, respectively. Lot 3, which was fed cottonseed meal and corn-and-cob meal, made a profit per steer of $4.58, being nearly a dollar per head less than Lots 1 and 2.

The steers of Lot 3 made slightly greater daily gains than either of the other two lots, but the cost per 100 pounds of gain was about

$1 greater, which reduced the profit per steer. The financial outcome of the feeding test was satisfactory, as the farm-grown feeds were marketed by means of the steers at a good price, a large amount of manure was produced for the farm, and in addition an average cash profit of more than $5 per steer was realized.

SLAUGHTER DATA.

The following table shows the shipping and slaughter data for each of the three lots:

TABLE 4.—*Slaughter data.*

Lot No.	Ration.	Average farm weight per steer.	Average market weight per steer.	Average shrinkage in transit.	Average weight of carcass.	Per cent dressed.	
						By farm weights.	By market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Cottonseed meal, silage, and cowpea hay	1,092	1,024	68	608	55.67	59.37
2	Cold-pressed cake, silage, and cowpea hay	1,092	1,020	72	603	55.22	59.12
3	⅔ cottonseed meal, ⅓ corn-and-cob meal, silage, and cowpea hay	1,101	1,029	72	600	54.40	58.79

The shrinkage of the steers of all lots was very uniform and was considered about normal for that distance and time in transit. The dressing percentages were exceedingly satisfactory and show clearly that the steers of all lots were well finished. The carcasses were very desirable, showing a good covering of fat and a nice marbling of the meat.

SUMMARY OF THE EXPERIMENT.

1. The object of this experiment was to make a comparison of the feeding value of cottonseed meal, cold-pressed cottonseed cake, and a combination of cottonseed meal and corn-and-cob meal for fattening steers. As this was a study of the feeding value of various concentrates, the same kinds of roughage were fed to all three lots.

2. The 75 steers used were grade steers of medium-to-good quality, raised in Mississippi, 2 to 3 years of age, and averaging 860 pounds at the beginning of the experiment.

3. Each lot contained 25 head of steers evenly divided. When on full feed each steer was eating the following ration:

Lot 1.	Cottonseed meal	7.4 pounds.
	Corn silage	41.8 pounds.
Lot 2.	Cold-pressed cottonseed cake	11.0 pounds.
	Corn silage	31.5 pounds.
Lot 3.	Cottonseed meal	6.0 pounds.
	Corn-and-cob meal	3.0 pounds.
	Corn silage	37.0 pounds.

The steers of Lot 2, which received cold-pressed cottonseed cake, consumed much less silage per day than the other steers, because of the large amount of dry matter in the grain ration.

4. The average daily gain for each steer of Lots 1, 2, and 3, was 2.04, 2.01, and 2.05 pounds, respectively, or practically the same for each lot. The greatest variation in the total gain was 4 pounds per head for a feeding period of 123 days.

5. The cost of 100 pounds of gain for Lots 1 and 2 was very uniform, being $6.96 and $6.80. The cost for Lot 3 was $7.82.

6. After paying for all feeds at market prices each steer of the three lots made a net profit of $5.45, $5.50, and $4.58 per head, respectively.

7. Cold-pressed cottonseed cake at $16.50 per ton is as economical as cottonseed meal at $22.50 per ton, or 3 pounds of cottonseed meal proved to be equal in feeding value to 4 pounds of cold-pressed cottonseed cake; as the price of these feeds advance the same proportion should be maintained. The cottonseed meal analyzed 40.4 per cent protein and the cold-pressed cottonseed cake 27.6 per cent protein.

8. The cold-pressed cake was relished by the steers and all of them ate it readily from the first.

9. It did not pay to feed a one-third ration of corn-and-cob meal with the cottonseed meal.

10. There was no difference in the finish of the three lots and each sold for the same price, viz, $7.35 per hundred pounds.

11. The shrinkage in transit to the St. Louis market was heavier than for the steers shipped from Abbott, Miss. The steers shrank 68, 72, and 72 pounds per head, respectively, for Lots 1, 2, and 3.

12. By market weights the steers dressed out as follows: Lot 1, 59.4 per cent; Lot 2, 59.1 per cent; and Lot 3, 58.8 per cent; which indicates a uniformly high finish.

II. A COMPARISON OF COTTONSEED MEAL; COTTONSEED MEAL AND BROKEN-EAR CORN; AND COTTONSEED MEAL AND SHELLED CORN FOR FATTENING STEERS.

INTRODUCTION.

Since the boll weevil has done such damage in Mississippi the farmers have been turning very strongly to raising more live stock and more feeds for stock, such as corn and various kinds of hay. This has resulted in a greater interest in cattle feeding and a greatly increased corn crop. In many parts of the prairie and brown-loam section of Mississippi there has been quite a large amount of corn and hay produce, which has been very hard to dispose of satisfactorily because of poor roads, long distances from shipping points, and lack of knowledge regarding the marketing of such products. Under these conditions any definite information regarding the feeding of corn to beef cattle to be fattened for the market is of prime importance. The farmers and plantation owners desire to know whether it is possible to market the corn at a good price through the cattle.

To get definite information on this subject the Bureau of Animal Industry, cooperating with the Mississippi experiment station, conducted the feeding experiment described herein, using three carloads of grade Mississippi steers for the experiment.

OBJECT AND PLAN OF WORK.

The object of this experiment was to study the relative feeding value of cottonseed meal when fed alone, when supplemented with shelled corn, and when supplemented with broken-ear corn, as the concentrated part of the ration for fattening steers for the market.

The steers arrived on the farm during late October and early November. From this time until November 24 they were run in good cornstalk pasture. The experiment involved no preliminary feeding period. About one-fourth of the steers had to be dehorned, which was done two weeks previously to the date on which the experiment began. On November 23 the steers were brought to the feeding pens and 75 of the best animals were selected from a total of 127 and divided into three lots of 25 each. The different lots were practically equal in size and quality. The general plan of the feeding work was the same as that outlined in previous experiments. Mr. N. F. Hanson, under the direction of Mr. S. S. Jerdan, did the feeding and kept complete records of the work throughout the experiment.

CATTLE USED.

The steers used in the experiment were mostly grade Shorthorns, with a few Angus, Red Polls, and Herefords. The cattle were all natives, being raised in the county where fed, but as a whole were much better than the average of steers in Mississippi. They ranged in age from 2 to 3½ years. All were raised in the neighborhood of Abbott, Miss., and were free from ticks.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed meal used in the experiment contained from 39 to 41 per cent protein; the corn used was clean and sound. Most of the corn silage was very good; it kept well and showed considerable grain. The oat straw was bright and the steers ate it with relish. The following prices were paid for feeds: Cottonseed meal, $27 per ton; corn, 70 cents per bushel. The corn silage and oat straw were valued at $3 and $5 per ton, respectively. The cottonseed meal was purchased early in the fall and was then cheaper than it was later in the year. While corn could be bought on neighboring farms at about 50 cents per bushel early in the fall, it is charged at 70 cents, which was about the average market price in that section for the winter of 1915–16.

METHOD OF FEEDING AND HANDLING THE CATTLE.

All the steers in each of the lots were numbered by means of a tag on a leather neck strap. They were weighed individually on November 24, 25, and 26, respectively, and the average of these three weights used as the initial weight. After that the steers were weighed at the end of each 28-day period. The steers of each lot were well housed at all times and did not have the run of open lots until after March 29, when they had the run of open lots both night and day. Each pen used previously to March 29 was 38 by 98 feet in size and each had troughs which were kept full of running water at all times. The steers were supplied with plenty of fresh water while in the open lots.

Mixed shavings, cornstalks, and oat straw were used for bedding in all the lots during the first half of the feeding period. After that the roads became so bad that bedding could not be hauled and the pens became somewhat sloppy. The pens had been concreted around the watering troughs during the summer and they did not become so muddy as they did the previous year.

The steers were given their feed at 7 in the morning and 3.30 in the afternoon. The cottonseed meal and corn were thoroughly mixed with the corn silage at each feeding and the feeds placed in stationary troughs. Rock salt was kept before the steers at all times.

AVERAGE DAILY RATIONS.

Table 5 shows the average daily rations by 28-day periods for each lot. As a comparison was to be made of the concentrated portion of the rations, each lot was fed as nearly the same amounts of roughage as possible. During the first 28-day period the amount of corn silage and oat straw consumed by each lot was the same. After that the steers were given what feed they would clean up within 1 hour after feeding. The silage ration was kept practically the same for all lots, so that the variations occurred chiefly in the amounts of oat straw consumed. The cattle were permitted to eat as much oat straw as they desired after being fed the silage.

TABLE 5.—*Average daily ration by 28-day periods.*

Lot No.	Number of steers.	Ration.	1st period.	2d period.	3d period.	4th period.	5th period (29 days).	Entire period (141 days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	25	Cottonseed meal	3.1	5.0	6.6	7.0	7.0	5.7
		Corn silage	38.8	40.0	39.5	37.0	40.0	39.1
		Oat straw[1]	4.9	4.5	4.8	5.0	5.0	4.9
2	25	Cottonseed meal	1.9	2.8	3.3	3.5	3.5	3.0
		Ear corn	4.4	7.0	8.5	8.7	8.7	7.6
		Corn silage	38.8	37.4	39.4	35.1	36.0	37.4
		Oat straw[1]	4.9	3.3	2.2	2.0	2.0	2.9
3	25	Cottonseed meal	1.9	2.8	3.3	3.5	3.5	3.0
		Shelled corn	3.9	5.6	6.5	7.0	7.0	6.0
		Corn silage	38.8	40.0	39.5	35.7	38.5	38.5
		Oat straw[1]	4.9	3.5	4.0	2.6	2.4	3.5

[1] Johnson grass hay fed instead of oat straw during last 17½ days.

The steers of Lot 1 in this experiment, which received cottonseed meal as the sole concentrate, were fed as much of it as was deemed advisable for a feeding period of 141 days. Lots 2 and 3, which received broken-ear corn and shelled corn, respectively, were given an allowance of cottonseed meal which was about one-half that received by Lot 1. Lots 2 and 3 received exactly the same amounts of cottonseed meal and practically the same amount of corn without considering the cob.

The difference in the amounts of roughage consumed by each lot would be expected, since lots 2 and 3, which were getting broken-ear corn and shelled corn, were getting slightly larger amounts of roughage material in their grain allowance than Lot 1, which received cottonseed meal only.

WEIGHTS AND GAINS.

The following table shows the initial and final weights, the total and average daily gain per steer for each of the three lots:

TABLE 6.—*Weights and gains (Nov. 26, 1915, to Apr. 15, 1916—141 days).*

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gain per steer.	Average daily gain per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal, corn silage, and oat straw	824	1,044	220	1.56
2	Cottonseed meal, broken-ear corn, corn silage, and oat straw	824	1,059	235	1.66
3	Cottonseed meal, shelled corn, corn silage, and oat straw	826	1,066	240	1.70

The gains made by the steers, while fairly uniform, were not so good as they should have been considering the quality of the steers that were used. This may have been due somewhat to the lack of bedding during the latter part of the experiment, and to the fact that the steers were kept in pens under a barn without access to open yards during most of the experiment. As soon as the steers were transferred to open yards the daily gains increased.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

The following table shows the quantity and cost of feed required to make 100 pounds of gain:

TABLE 7.—*Quantity and cost of feed required to make 100 pounds of gain (Nov. 26, 1915, to Apr. 15, 1916—141 days).*

Lot No.	Ration.	Pounds of feed to make 100 pounds of gain.	Cost of 100 pounds of gain.
1	Cottonseed meal	366	
	Corn silage	2,497	$9.53
	Oat straw	310	
2	Cottonseed meal	181	
	Broken-ear corn	457	
	Corn silage	2,244	10.82
	Oat straw	173	
3	Cottonseed meal	177	
	Shelled corn	355	
	Corn silage	2,260	10.75
	Oat straw	205	

The steers of Lots 2 and 3, receiving broken-ear corn and shelled corn, respectively, made better average daily gains, but the gains made by Lot 1, which received cottonseed meal only as a concentrate, were made at much less cost per 100 pounds. While Lot 2, which received broken-ear corn, made fairly good average daily gains, the cost per 100 pounds gain in this lot was greater than that of the other two lots.

The prices used in computing the cost of the feeds were as follows:

Cottonseed meal	per ton	$27.00
Corn	per bushel	.70
Corn silage	per ton	3.00
Oat straw	do	5.00

The cottonseed meal used in the test was contracted for early and hence was obtained somewhat more cheaply than the same meal could have been purchased at a later date. It cost, however, about $5 per ton more than was paid for meal at the same station the previous year.

FINANCIAL STATEMENT.

The steers used in this experiment were delivered on the farm at a cost of 5½ cents per pound. This figure was used in making up the financial statements for each lot. The prices of feeds have already been given.

Financial statement.

Lot 1, cottonseed meal, corn silage, oat straw, and Johnson grass:	
To 25 steers, 20,593 pounds, at $5.50 per hundredweight	$1,132.63
To 20,217½ pounds cottonseed meal, at $27 per ton	272.94
To 137,773 pounds corn silage, at $3 per ton	206.66
To 14,929 pounds oat straw, at $5 per ton	37.32
To 2,187½ pounds Johnson grass, at $8 per ton	8.75
To freight charges to market	63.00
To commission, yardage, hay, etc	23.85
Total expenditure	1,745.15
By sale of 25 steers, 24,760 pounds, at $8.58 per hundredweight	2,124.80
Total net profit	379.65
Average profit per steer	15.19
Lot 2, cottonseed meal, broken-ear corn, corn silage, oat straw, and Johnson grass:	
To 25 steers, 20,167 pounds, at $5.50 per hundredweight	1,133.91
To 10,633 pounds cottonseed meal, at $27 per ton	143.55
To 26,796½ pounds (382.8 bushels) broken-ear corn, at 70 cents per bushel	267.96
To 131,672 pounds corn silage, at $3 per ton	197.51
To 9,291 pounds oat straw, at $5 per ton	23.23
To 875 pounds Johnson grass, at $8 per ton	3.50
To freight charges to market	63.00
To commission, yardage, hay, etc	23.85
Total expenditure	1,856.51
By sale of 25 steers, 25,040 pounds, at $8.60 per hundredweight	2,153.44
Total net profit	296.93
Average profit per steer	11.87
Lot 3, cottonseed meal, shelled corn, corn silage, oat straw, and Johnson grass:	
To 25 steers, 20,660 pounds, at $5.50 per hundredweight	1,136.30
To 10,633 pounds cottonseed meal, at $27 per ton	143.55
To 21,306 pounds (380.46 bushels) shelled corn, at 70 cents per bushel	266.32
To 135,796 pounds corn silage, at $3 per ton	203.69

To 11,257 pounds oat straw, at $5 per ton	$28.14
To 1,050 pounds Johnson grass, at $8 per ton	4.20
To freight charges to market	63.00
To commission, yardage, hay, etc	23.85
Total expenditure	1,869.05
By sale of 25 steers, 25,070 pounds, at $8.60 per hundredweight	2,156.02
Total net profit	286.97
Average profit per steer	11.48

It will be noted from the foregoing statement that Lot 1 made a profit per steer of $15.19; Lot 2 a profit of $11.87, and Lot 3 made a profit of $11.48 per head. It will be remembered that lot 1 made lower gains than either of the other lots; Lot 2 was second in rate of gains; while Lot 3, which made the lowest profit, had the highest average daily gains. The cost of the gains made by the different lots is responsible, more than any other factor, for these differences. The gains made by Lot 1, while smaller than the others, were made at so much less per pound that a greater profit resulted.

The two corn-fed lots brought 2 cents per 100 pounds more than Lot 1, which received cottonseed meal only. This difference in sale price was due to one steer in Lot 1, which brought only $8 per hundredweight.

The degree of finish and quality of the steers of all lots was about the same. When weighed at market there was a difference of only 30 pounds in weight between Lots 2 and 3, they weighing 25,040 and 25,070 pounds, respectively. The relation of the weights of the cattle changed very little throughout the test.

In this experiment the steers fed on cottonseed meal showed a greater profit than either the lot receiving cottonseed meal and broken-ear corn or the lot receiving cottonseed meal and shelled corn. The differences in profits were due chiefly to differences in cost of gains. With more expensive cottonseed meal or with cheaper corn the differences, of course, would have been less.

Twenty-five shotes followed the steers of Lots 2 and 3, but as an outbreak of cholera occurred on the place and the shotes got out several times, they were disposed of, and accurate records were not secured on the amount of pork produced from the refuse corn in the droppings.

Under ordinary conditions, with hogs worth 10 cents a pound, the pork credit for each steer for the 141-day period would undoubtedly have amounted to over $3 per steer. A credit of $3 per steer on Lots 2 and 3 would have made the profits on these lots about the same as for Lot 1.

Unless hogs are used to utilize the waste corn it would undoubtedly be less profitable to use corn for fattening steers than to use cottonseed meal alone at the current prices of these feeds.

SLAUGHTER DATA.

Table 8 shows the slaughter data for each of the three lots:

TABLE 8.—*Slaughter data.*

Lot No.	Ration.	Average farm weight per steer.	Average market weight per steer.	Average shrinkage in transit.		Average weight of carcass.	Per cent dressed.	
							By farm weights.	By market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Cottonseed meal, corn silage, and oat straw	1,044	990	54	5.13	576	55.2	58.2
2	Cottonseed meal, corn silage, broken-ear corn, and oat straw	1,059	1,001	58	5.46	579	54.7	57.8
3	Cottonseed meal, shelled corn, corn silage, and oat straw	1,067	1,003	64	6.00	576	53.9	57.4

The steers were driven from the farm to West Point, Miss., a distance of 12 miles, from which point they were shipped to St. Louis. Before being loaded at West Point they were given hay and water. They had a very good run to market and made it within the 36-hour limit.

The steers of Lot 1, which were fattened on cottonseed meal, showed the least shrinkage in transit from farm to market. They shrank 54 pounds per head; the other two lots shrank 58 and 64 pounds, respectively. This was very satisfactory, being only a medium shrinkage for a 12-mile drive and a long run to market.

The carcass weights for the three lots were almost identical, and there was very little difference between the dressing percentages of the different lots. The carcasses of the steers of all lots were nice, being well covered with fat. The uniformity of the shrinkage in transit and of the dressing percentages of the steers is rather unusual and shows that there was little difference between the various lots as regards quality and finish.

SUMMARY OF THE EXPERIMENT.

1. The object of this experiment was to study the relative feeding value of (*a*) cottonseed meal alone, (*b*) a combination of one-third cottonseed meal and two-thirds broken-ear corn, and (*c*) one-third cottonseed meal and two-thirds shelled corn as the concentrates used for fattening steers for the market.

2. The steers were grades of the beef breeds of medium to good quality, raised in Mississippi, and averaging about 825 pounds at the beginning of the experiment. They were 2 and 3 year olds.

3. The steers were divided into three lots of 25 head each, and fed for 141 days. When on full feed they were fed the following rations daily:

Lot 1.

Cottonseed meal ... pounds..	7
Corn silage ... do....	40
Oat straw ... do....	5

Lot 2.

Cottonseed meal ... pounds..	3.5
Ear corn ... do....	8.7
Corn silage ... do....	36
Oat straw ... do....	2

Lot 3.

Cottonseed meal ... pounds..	3.5
Shelled corn ... do....	7
Corn silage ... do....	38.5
Oat straw ... do....	2.4

4. The steers of Lots 1, 2, and 3 gained 1.56, 1.66, and 1.70 pounds per head per day for the entire period of 141 days. The final average weights of the three lots were 1,044, 1,059, and 1,066 pounds, respectively.

5. The cost of making 100 pounds of gain on each lot was $9.53, $10.82, and $10.75, when no pork credit is given the steers.

6. The conditions under which the cattle were kept possibly influenced the rate and consequently the cost of gains.

7. Each steer in Lots 1, 2, and 3 made a net profit of $15.19, $11.87, and $11.48, respectively, when no credit is given the steers of Lots 2 and 3 for the pork produced. The pork credit probably amounted to about $3.00 per steer.

8. When the pork made is credited to the steers of Lots 2 and 3, they paid for corn at 70 cents a bushel and then made over $14 a head profit, or almost as much as was made on the cottonseed meal-fed steers. Without hogs following the steers, the feeding of corn would have been considerably less profitable than feeding cottonseed meal alone.

9. The shrinkage in transit to market, a 34-hour run, average 54, 58, and 64 pounds per head for Lots 1, 2, and 3.

10. By market weights the steers of each lot dressed out 58.2, 57.8, and 57.4 per cent of marketable meat. The carcasses were well covered with fat and were very satisfactory.

11. The steers of all lots were well finished and very uniform. All sold for $8.60 per 100 pounds except one steer of Lot 1 which sold for $8 per hundredweight.

12. This test clearly establishes the fact that the farmer having a surplus of corn and farm roughages can market them at a handsome price through steers of good quality, when properly purchased, and at the same time retain the fertilizing elements of the feeds on the farm in the form of manure. In this work it is assumed that the cost of labor was offset by the value of the manure produced.

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JOHN R. MOHLER, Chief

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A COMPARISON OF ROUGHAGES FOR FATTENING STEERS IN THE SOUTH.

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INTRODUCTION.

The investigations reported in this bulletin are a continuation of the cooperative work started in 1904 between the Bureau of Animal Industry and the Alabama State experiment station. Previous results will be found in Bureau of Animal Industry Bulletins 103, 131, 147, and 159, and Department of Agriculture Bulletins 73 and 110.

The map (fig. 1) shows the general location of the farms in Alabama and Mississippi where the experiments were conducted and the location of the markets most convenient to the southern farmer and cattleman. The shaded area shows the portion of the South to which the results of this feeding work are directly applicable. In this area the climatic conditions, pasture grasses, and forage crops are very similar to those of western Alabama and central Mississippi.

Since such a large portion of the South has eradicated the cattle tick, there has been quite a change in the movement of cattle to market. Formerly most of the cattle from Alabama and Mississippi were marketed at New Orleans and Mobile. Now practically all

[1] Acknowledgment is due G. A. Scott and S. W. Greene, of the Animal Husbandry Division, United States Department of Agriculture, for assistance in compiling this bulletin.

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the cattle from the tick-free sections of these States go to the St. Louis market, where they are sold in the free pens in direct competition with the cattle from the corn belt. The cattle from the tick-infested sections of these States go largely to New Orleans, the Louisiana cattle go to New Orleans, Fort Worth, and St. Louis, and the cattle from Georgia, South Carolina, and North Carolina are shipped to the Richmond, Baltimore, Jersey City, and Jacksonville, Fla., markets. The new stockyards and packing plant at Jacksonville, Fla., will receive many of the Florida and some southern Georgia cattle, while a few may still be exported to Cuba from Tampa.

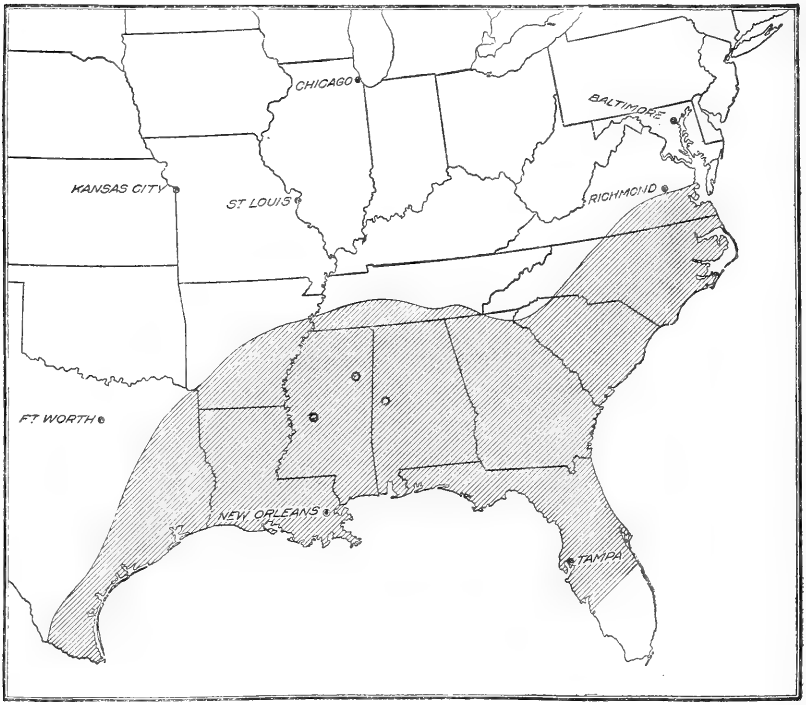

FIG. 1.—The shaded area represents the portion of the United States to which the results obtained in the feeding experiment are applicable. The circles in Alabama and Mississppi show the approxmate location of the test farms. The location of the various cattle markets to which southern cattle are shipped is shown also.

Packing plants at Natchez, Miss., Birmingham, Ala., Moultrie, Ga., and Jacksonville, Fla., are having a stimulating effect on the live-stock industries in those sections, and this influence will grow in proportion to the prices paid for live stock. If prices are paid which compare favorably with those the farmer can get at other available markets less the cost of shipping, then, and only then, will the establishment of such plants exert a permanent influence for good upon the live-stock industry of those sections.

Since the cooperative cattle-feeding work was started between the Bureau and the Alabama experiment station, there has been a growing demand for more definite information concerning the cost of growing or raising cattle and fattening them for the market. In many cases the cooperative experimental work has been the absolute foundation for building up the cattle industry in certain sections.

Many of the cooperative experiments were conducted to determine what concentrates and combinations of concentrates were most desirable to use for fattening steers and calves for the market. The tests reported herein were conducted to determine the comparative value of some of the more common farm-grown and commercial roughages for fattening steers. Cottonseed meal was the sole concentrate used in each of the experiments.

In times gone by cottonseed hulls were the principal and the cheapest roughage used by farmers of the South, but the price of hulls has advanced to such a degree that few farmers can afford to feed them. Then, too, where diversified farming has been taken up more forage is produced upon the farms, and many of the progressive live-stock farmers of the South have one or more silos and are producing much corn silage, corn stover, and leguminous hays upon the farm.

The importation of pure-bred beef bulls in large numbers in every State of the South emphasizes the importance of the growing beef-cattle industry, and with the prevailing high prices of meat animals there has never been a time when studies of various methods of fattening beef cattle were of more importance to the farmers of the South.

The first experiment reported in this bulletin was conducted in cooperation with the Alabama experiment station in western Alabama; the others were conducted in Mississippi in cooperation with the State experment station.

I. A COMPARISON OF COTTONSEED HULLS, CORN SILAGE, AND A COMBINATION OF COTTONSEED HULLS AND CORN SILAGE FOR FATTENING STEERS DURING A SHORT FEEDING PERIOD (ALABAMA EXPERIMENT).

This is the last of a series of cooperative cattle-feeding experiments conducted in western Alabama by the Bureau of Animal Industry and the Alabama experiment station for the purpose of testing various concentrates and roughages for fattening steers for the market. The results of the previous work have been reported in Bureau of Animal Industry Bulletins 103, 131, and 159, and Department Bulletin 110.

OBJECTS AND PLAN OF THE WORK.

A comparison was to be made of the value of cottonseed hulls, corn silage, and a combination of these two roughages for fattening steers economically and substantially. As this test was to compare roughages, the same amount of cottonseed meal was fed per head to the steers of all lots. No other concentrate was used.

The same general plan was followed as had been used in former experiments. The cattle were bought in the fall and put on a preliminary feed of cottonseed hulls and meal, and some silage, while confined on a 15-acre pasture until they became thoroughly accustomed to the feeds. They were dehorned during this time and on November 19, 1913, all were tagged, divided into three lots of the same quality and about the same size, weighed individually, and started on their regular experimental rations. They were weighed individually again on the following day, an average taken of the two weights as the initial weight, and the experiment started on the afternoon of November 20.

STEERS USED.

The steers were mostly half and three-quarter breds of Aberdeen-Angus, Shorthorn, Hereford, and Red Polled breeding. They represented one or two crosses of pure-bred beef bulls on the native cows of Alabama. Some of them showed a small amount of Jersey blood also. They averaged about 3 years of age and were of a fair feeder type. They were far superior to the scrub steers of the State, but about the same grade as the steers produced in the prairie section of Alabama and Mississippi.

CHARACTER AND PRICES OF FEEDS USED.

The feeds were all of good quality. The cottonseed meal analyzed 8 per cent ammonia, or about 41 per cent crude protein, and was bright in color. The corn silage was excellent and was made from corn which would have yielded about 35 to 40 bushels of corn per acre.

The feeds were charged at the following prices:

Cottonseed meal	per ton	$27.50
Cottonseed hulls	per ton	9.50
Corn silage	per ton	3.25

The price of cottonseed meal and hulls was the cost delivered to the barn. The cost of the silage was the estimated cost of production and ensiling, including the estimated waste which would occur in making and feeding it.

METHODS OF FEEDING AND HANDLING THE STEERS.

The steers of each of the three lots had an open, unpaved lot for exercise and were fed in troughs under sheds which were planked up on the north and west sides, but open on the other sides. They were furnished water from a 1,300-foot well, and concrete troughs equipped with float valves were located in the lots so that the steers had access to fresh water all the time.

The steers were fed at 7 o'clock in the morning and 5 o'clock in the afternoon. The cottonseed meal was mixed with the roughage in the feed troughs at the time of feeding. The steers were given all the feed they would eat up clean within an hour after feeding.

AVERAGE DAILY RATIONS.

The steers of all three lots were fed the same amount of cottonseed meal each day, as this experiment was conducted for comparing roughages. The cottonseed meal was thoroughly mixed with the roughage at the time of feeding.

Table 1 shows the average daily ration per steer by 28-day periods during the experiment:

TABLE 1.—*Average daily ration per head, by 28-day periods.*

Lot No.	Number of steers.	Ration.	First period.	Second period.	Third period.	Entire period (84 days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	20	Cottonseed meal	5.0	6.6	7.2	6.25
		Cottonseed hulls	28.1	29.8	27.7	28.46
2	20	Cottonseed meal	5.0	6.6	7.2	6.25
		Corn silage	39.4	45.3	44.8	43.10
3	20	Cottonseed meal	5.0	6.6	7.2	6.25
		Cottonseed hulls	18.3	19.3	18.6	18.76
		Corn silage	17.4	18.3	17.7	17.77

WEIGHTS AND GAINS OF STEERS.

The following table shows the initial weight of the steers of all lots, the final weights, the total gain per head, and the average daily gain:

TABLE 2.—*Weights and gains of steers (Nov. 20, 1913, to Feb. 12, 1914—84 days).*

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gains per steer.	Average daily gains per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal and cottonseed hulls	837	1,046	209	2.48
2	Cottonseed meal and corn silage	847	1,058	211	2.51
3	Cottonseed meal, cottonseed hulls, and corn silage	819	1,036	217	2.58

The gains made by the steers of all lots were exceedingly satisfactory and indicate that the steers relished their rations and made good use of their feed. The silage-fed steers gained slightly more for the short period than those fed cottonseed hulls. The steers receiving the mixed ration of cottonseed hulls and silage made the greatest gains.

It is a well-known fact that for a short feeding period a ration of cottonseed meal and hulls is a superior feed for fattening steers that are not to be fed over 90 days. The results of this experiment indicate, however, that corn silage as the sole roughage is fully equal to cottonseed hulls for making large daily gains, and it is known that it would have proved much superior for a long feeding period.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

The economy of gains must be considered as well as the size of the gains before drawing any conclusions concerning the value of the two roughages. Knowing the price of feeds and the amount of feed required to make 100 pounds of gain, this can be determined easily. The following table shows the amount of feed required to make 100 pounds of gain and the cost of 100 pounds of gain for each lot of steers:

TABLE 3.—*Quantity and cost of feed required to make 100 pounds of gain. (Nov. 12, 1913, to Feb. 12, 1914—84 days).*

Lot No.	Ration.	Pounds of feed to make 100 pounds of gain.	Cost of 100 pounds of gain.
1	Cottonseed meal	251	$8.88
	Cottonseed hulls	1,142	
2	Cottonseed meal	248	6.19
	Corn silage	1,711	
3	Cottonseed meal	242	7.89
	One-half cottonseed hulls	727	
	Corn silage	689	

The amount of cottonseed meal required to make 100 pounds of gain varied very little for each of the three lots, ranging from 242 to 251 pounds. The cost of the gain varied greatly, however, there being a difference of $2.69 per 100 pounds between the cost for Lots 1 and 2. The use of cottonseed hulls at $9.50 per ton is usually of very questionable economy and at times is quite unprofitable. Corn silage proved much more economical as a feed at $3.25 per ton.

As 1,711 pounds of corn silage (the amount required to make 100 pounds of gain) proved equal to 1,142 pounds of hulls and three pounds of cottonseed meal, then each ton of silage proved to be worth $6.38 when cottonseed hulls cost $9.50 per ton. This is a very strong argument for using corn silage on the farm, for in Alabama it can usually be grown and put up for about $3 per ton.

FINANCIAL STATEMENT.

The silage was almost exhausted at the end of the third period and it was decided to terminate the experiment, but as the steers were not finished their valuation on the farm was appraised and they were continued on a feed of cottonseed hulls and cottonseed meal for a while longer.

All lots were appraised at the same value, viz, $6.75 per 100 pounds on the farm less 3 per cent shrinkage. The following financial statement has therefore been made for the 84-day feeding experiment:

Financial statement.

Lot 1, cottonseed meal and cottonseed hulls:	
To 20 steers, 16,747 pounds, at $5.25 per hundredweight	$879.21
To 10,510 pounds cottonseed meal at $27.50 per ton	144.51
To 47,823 pounds cottonseed hulls at $9.50 per ton	227.16
Total expenditure	1,250.88
By sale of 20 steers, 20,306 pounds, at $6.75 per hundredweight	1,370.65
Total profit	119.77
Average profit on each steer	5.99
Lot 2, cottonseed meal and corn silage:	
To 20 steers, 16,931 pounds, at $5.25 per hundredweight	888.87
To 10,510 pounds cottonseed meal at $27.50 per ton	144.51
To 72,521 pounds silage at $3.25 per ton	117.85
Total expenditure	1,151.23
By sale of 20 steers, 20,535 pounds, at $6.75 per hundredweight	1,386.11
Total profit	234.88
Average profit per steer	11.74
Lot 3, cottonseed meal, one-half cottonseed hulls, one-half corn silage:	
To 20 steers, 16,390 pounds, at $5.25 per hundredweight	860.47
To 10,510 pounds cottonseed meal at $27.50 per ton	144.51
To 31,520 pounds cottonseed hulls at $9.50 per ton	149.72
To 27,861 pounds silage at $3.25 per ton	48.52
Total expenditure	1,203.22
By sale of 20 steers, 20,103 pounds, at $6.75 hundredweight	1,356.95
Total profit	153.73
Average profit per steer	7.69

The steers of all lots cost $5.25 per hundredweight in the fall. At the end of the feeding period they were appraised at $6.75 per 100 pounds, or a margin of $1.50 per hundredweight was received for all. No charge is made for labor and no credit is given for the manure produced.

The silage-fed steers were by far the most profitable. The steers of Lot 1, which received cottonseed hulls as the sole roughage, made the smallest profits. When the prices of feeds are considered the steers of all lots made exceedingly satisfactory profits.

SUMMARY OF THE EXPERIMENT.

1. The object of this experiment was to study the relative efficiency of cottonseed hulls, corn silage, and a combination of these two roughages when fed with cottonseed meal for finishing steers during a short feeding period.
2. The steers used were mostly 3-year-olds showing a predominance of blood of the various beef breeds, and averaged 834 pounds per head at the beginning of the test. They were divided into three lots of 20 each and fed 84 days during the winter.
3. The steers of Lot 1 were fed a ration of cottonseed meal and cottonseed hulls; those of Lot 2 received a ration of cottonseed meal and corn silage; while those of Lot 3 were given cottonseed meal, cottonseed hulls, and corn silage.
4. During the 84-day feeding period the average daily gain per head was 2.48 pounds, 2.51 pounds, and 2.58 pounds, respectively, for the steers of Lots 1, 2, and 3.
5. It cost $8.88 to produce 100 pounds of gain in Lot 1, $6.19 in Lot 2, and $7.89 in Lot 3.
6. The net profits per head amounted to $5.99, $11.74, and $7.69 for the steers of Lots 1, 2, and 3, respectively.
7. The experiment shows very clearly the superiority of corn silage over cottonseed hulls as a roughage for fattening steers.

II. A COMPARISON OF THE VALUE OF COTTONSEED HULLS, CORN SILAGE, AND A COMBINATION OF COTTONSEED HULLS AND CORN SILAGE FOR FATTENING STEERS (MISSISSIPPI EXPERIMENT).

INTRODUCTION.

The results of the cooperative experiment between the Bureau of Animal Industry and the Alabama Experiment Station, reported in Part I of this bulletin, were very satisfactory in every way, but following the policy of the bureau in all experimental work it was decided to duplicate the experiment before publishing the results, as conditions under which a feeding test is conducted vary greatly from year to year, due to climatic conditions, variations in the feed used, conditions of feed lots, fluctuations in the buying and selling prices of cattle, feed, etc. As the cooperative cattle-feeding work was transferred from Alabama to Mississippi before the test could be duplicated, it was decided to conduct another test in Mississippi under conditions as nearly similar as possible.

There are a few points which should be borne in mind in comparing the results of the two tests in order to do the work justice in each case, namely, (1) The steers used in each test were of almost the same grade and breeding, but the Alabama steers were a little better in quality. (2) Good bright cottonseed meal and cottonseed hulls of the same grade were used for both experiments and were therefore similar. (3) The corn silage used in the Alabama test was excellent, having a large amount of grain in it and keeping splendidly, but owing to a bad season for corn the silage used in the Mississippi experiment was much below the average, as it had very little grain in it and did not keep so well as it should. (4) The feeding pens became muddy each winter, but the sheds used in the Alabama experiment were kept well bedded, while in the Mississippi test after the sixth week bedding was very scarce and the feeding pens became very deep in mud, the steers having no choice but to lie in the deep mud. (5) The Alabama test covered a period of 84 days, while the steers in this experiment were fed 143 days.

OBJECT AND PLAN OF THE WORK.

This test was to be a duplication of the feeding experiment reported in Part I of this bulletin, namely, a study of the comparative value of cottonseed hulls, corn silage, and a combination of cottonseed hulls and corn silage for fattening steers, with cottonseed meal as the sole concentrate.

The steers were bought in the fall and started on a preliminary feed of cottonseed meal and cottonseed hulls on October 8, 1914. On October 25 corn silage was introduced in the ration and the feeding continued until November 12, when the steers were divided into three lots and started in the regular feeding experiment on November 13.

The work was conducted upon the farm of Mr. Ben Walker, of Abbott, Miss. Mr. Walker furnished the cattle, the feeds, and all equipment except such things as feed baskets, small scales, etc., which were furnished by the Mississippi experiment station. The bureau placed Mr. N. F. Hanson upon the farm to conduct the experiment, and his entire time was devoted to the work.

CATTLE USED.

The steers were grades of the various beef breeds and ranged from one-half to three-quarters pure. They were from 2½ to 3½ years of age, but were fairly uniform in size. They were not quite so good in quality as the Alabama steers. The steers were such as may be found anywhere in the South where one or two crosses of pure-bred beef bulls have been made on the native cows. All of them were raised in the neighborhood of Abbott, Miss. All were tick free and had been so for more than a year.

CHARACTER AND PRICE OF FEEDS.

The cottonseed meal was bright, and analysis showed a crude protein content of about 38 per cent. The hulls were of average quality. The corn silage was below the average in quality, as it contained very little grain and was somewhat dry when put into the silo. The cottonseed meal and hulls were contracted for in the early summer and purchased cheap. The cottonseed meal cost $23.50 per ton and the hulls $6.50 per ton. They are charged at actual cost in this test. Corn silage was charged at $3 per ton.

METHODS OF FEEDING AND HANDLING THE CATTLE.

The steers which had horns were dehorned during the preliminary feeding period, and each was numbered by means of a tag on a leather neckstrap. The steers were divided into three similar lots and weighed individually on November 12 and 13, and an average of the two weights taken as the initial weight. The steers were weighed each 28 days and were again weighed individually at the end of the experiment.

All three lots were fed in a large barn, but the feeding pens were so arranged as to give the cattle the run of lots outside the barn. Water troughs were in each pen, and a deep well furnished fresh water at all times. The feeds were placed in stationary feed troughs, the cottonseed meal being thoroughly mixed with the roughage at the time of feeding. The steers were fed all the roughage they would eat up clean within one hour after feeding. The feeding was done at 7 a. m. and 3.30 p. m. each day. Rock salt was kept in the feed troughs at all times.

Enough bedding, consisting of shavings, waste straw, and cornstalks, was used during the first six weeks to keep the animals very comfortable. After that time bedding was scarce, and the prairie roads were in such condition that it could not be obtained; as a result the pens became very muddy. Some rotten limerock was placed around the feed and water troughs to make a firm standing place but the urine caused the rock to disintegrate in a few days, leaving the pens in worse condition than before. Although some manure was taken out, all the pens remained deep in mud until the close of the experiment. The relatively small daily gains made by all the steers can be attributed largely to the condition of the pens and the absence of open lots. There were 25 steers in Lot 1 and 26 in each of the other two lots.

AVERAGE DAILY RATIONS.

The object of the work being to compare the roughage rations, the steers of all three lots were fed the same amount of cottonseed meal per head per day throughout the experiment. Table 4 shows the average daily ration of the steers of each lot by 28-day periods.

TABLE 4.—*Average daily ration per head by 28-day periods. (Nov. 13, 1914 to April 5, 1915—143 days.)*

Lot No.	Number of steers.	Ration.	First period.	Second period.	Third period.	Fourth period.	Fifth period (31 days).	Entire period (143 days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	25	Cottonseed meal	4.7	5.5	5.9	6.5	6.7	5.90
		Cottonseed hulls	25.2	22.2	25.6	24.9	23.2	24.12
2	26	Cottonseed meal	4.7	5.5	5.9	6.5	6.7	5.90
		Corn silage	38.1	42.2	45.2	43.5	43.5	42.89
3	26	Cottonseed meal	4.8	5.5	5.9	6.5	6.7	5.90
		Cottonseed hulls	10.7	11.4	12.6	11.7	11.9	11.68
		Corn silage	26.4	26.6	29.4	27.6	29.2	27.98

Each steer was fed an average of about 4¾ pounds of cottonseed meal per day during the first 28-day period. The amount was gradually increased until the last period, when each steer consumed practically 6¾ pounds of meal a day. All the roughage was fed which the steers would clean up within one hour after feeding. The amount consumed by Lots 2 and 3 remained fairly constant for the entire experiment. The steers of Lot 1 did not consume quite as much cottonseed hulls the last two months as they did before that time. For the entire period of 143 days each steer of Lot 1 consumed on the average 24.12 pounds of cottonseed hulls daily; each steer in Lot 2 ate 42.89 pounds of corn silage; and each steer of Lot 3 was fed an average of 11.68 pounds of cottonseed hulls and practically 28 pounds of corn silage per day.

WEIGHTS AND GAINS.

The following table shows the initial weight, the final weight, the total gain, and the average daily gain per steer for all three lots:

TABLE 5.—*Weights and gains.* (*Nov. 13, 1914, to Apr. 5, 1915—143 days.*)

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gain per steer.	Average daily gain per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal and cottonseed hulls	814	1,012	198	1.38
2	Cottonseed meal and corn silage	812	976	164	1.15
3	Cottonseed meal, cottonseed hulls, and corn silage	814	1,054	240	1.67

The average initial weight of the steers in each lot was very uniform, being 814, 812, and 814 pounds, respectively, for the steers of Lots 1, 2, and 3. The steers did not gain as much as they should during the experiment. The fact that the pens were deep in mud during most of the time had considerable to do with the amount of gains made and emphasizes the importance of having dry and comfortable beds for fattening steers. In the black-prairie section of Mississippi and Alabama, where the ground tramps into deep mud very easily, it is essential that the steers have either dry beds under shelter, or paved lots, or a combination of both.

The fact that the silage was of poor quality this year was reflected in the average daily gains made by the steers. The silage was practically of the same character as that which would be made by pulling all the ears from the corn and running the stalks alone into the silo. During the previous year the steers which were fed a ration of good silage and had comfortable beds made an average daily gain of 2.51 pounds per head per day for 84 days, while the steers in this test made less than 1¼ pounds per day for 143 days.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

The following table shows the amount and cost of feed required to make 100 pounds of gain for each lot:

TABLE 6.—*Quantity and cost of feed required to make 100 pounds of gain (Nov. 13, 1914, to Apr. 5, 1915—143 days).*

Lot No.	Ration.	Pounds of feed to make 100 pounds of gain.	Cost of 100 pounds of gain.
1	Cottonseed meal	427	$10.70
	Cottonseed hulls	1,749	
2	Cottonseed meal	515	11.26
	Corn silage	3,745	
3	Cottonseed meal	352	8.90
	Cottonseed hulls	697	
	Corn silage	1,668	

The steers which received a combination of cottonseed hulls and corn silage for their roughage utilized their feed better than the steers in either of the other lots, as a considerably smaller amount of cottonseed meal was required to make 100 pounds of gain.

The following prices were charged for feeds in this test:

Cottonseed meal, per ton	$23.50
Cottonseed hulls, per ton	6.50
Corn silage, per ton	3.00

The price of cottonseed meal was less than normal, as the meal was contracted for in the summer, when the price was low. The price of cottonseed hulls was relatively cheap for that year, while the price charged for corn silage was about as much as it was worth. It probably cost about $3 per ton to grow and prepare this silage for feeding. With a reasonably good season the silage would have been much higher in quality and probably would have cost somewhat less per ton, due to the increased tonnage per acre. With feeds at these prices the cost of 100 pounds of gain for the entire period was $10.70, $11.26, and $8.90 for Lots 1, 2, and 3, respectively.

FINANCIAL STATEMENT.

The steers which were used in this experiment had been bought in the fall, and put on a preliminary feed from October 8 to November 12, at which time the experiment was started. The original cost of the steers, plus the cost of feed during the preliminary period, was divided by the initial weight of the steers to get the price per 100 pounds. This amounted to an average price of $5.47 per hundredweight for the entire bunch of steers. They are charged at that price. The price of feeds has already been stated. The steers were shipped from Abbott, Miss., to the St. Louis market. The freight on the cattle to market was $63 per car or per lot, and the charges for commission, yardage, feed, insurance, etc. totaled $24 per lot.

Financial statement.

Lot 1, cottonseed meal and cottonseed hulls:	
To 25 steers, 20,345 pounds, at $5.47 per hundredweight	$1,112.87
To 21,098 pounds cottonseed meal, at $23.50 per ton	247.90
To 86,508 pounds cottonseed hulls, at $6.50 per ton	281.35
To freight on one car of 25 steers	63.00
To commission, yardage, feed, insurance, etc	24.00
Total expenditure	1,729.12
By sale of 23 steers, 21,800 pounds, at $7.45 per hundredweight	1,729.12
By sale of 1 steer, 800 pounds, at $6.50 per hundredweight	52.00
By sale of 1 steer, 930 pounds, at $5.40 per hundredweight	50.22
Total sale of Lot 1	1,688.52
Total loss	40.60
Average loss per head	1.62
Lot 2, cottonseed meal and corn silage:	
To 26 steers, 21,125 pounds, at $5.47 per hundredweight	1,155.54
To 21,952 pounds cottonseed meal, at $23.50 per ton	257.94
To 159,494 pounds corn silage, at $3 per ton	239.24
To freight on car of 26 steers	63.00
To commission, yardage, feed, insurance, etc	24.00
Total expenditure	1,739.72
By sale of 26 steers, 24,810 pounds, at $7.25 per hundredweight	1,798.72
Total profit	59.00
Average profit per steer	2.27
Lot 3, cottonseed meal, cottonseed hulls, and corn silage:	
To 26 steers, 21,172 pounds, at $5.47 per hundredweight	1,158.11
To 21,952 pounds cottonseed meal, at $23.50 per ton	257.94
To 43,451 pounds cottonseed hulls, at $6.50 per ton	141.21
To 104,059 pounds corn silage, at $3 per ton	156.09
To freight on car of 26 steers	63.00
To commission, yardage, feed, insurance, etc	24.00
Total expenditure	1,800.35
By sale of 26 steers, 25,420 pounds, at $7.30 per hundredweight	1,855.66
Total profit	55.31
Average profit per steer	2.13

The total expenditure for Lot 1 was $1,729.12, while the selling price of the cattle was $1,688.52, showing a loss of $40.60 on the lot or an average loss of $1.62 per head. The steers of Lot 2, which received cottonseed meal and corn silage, made a net profit of $59 for the lot, or an average profit of $2.27 per steer. It is seen that although the silage-fed steers did not make as big daily gains as the steers fed on cottonseed hulls, they sold for a higher price on the market. This was due to finishing more uniformly and having better coats than the cattle fed on cottonseed hulls and meal. The steers of Lot 3, which made the largest gains of all the lots, sold for 5 cents more per hundredweight than the steers of Lot 2, and made a profit of $55.31 on the lot, or an average profit of $2.13 per head.

The feeding of cottonseed hulls and meal in this experiment was unprofitable, whereas the feeding of corn silage or a combination of corn silage and cottonseed hulls with cottonseed meal as a concentrate was profitable. The steers of both Lots 2 and 3, as a whole, showed more uniformity of finish than the steers of Lot 1, although some of the latter had gained exceedingly well and had finished out well. This is frequently the case when cottonseed hulls and meal are fed. Cattle fed on these feeds seldom finish out as uniformly as cattle which receive silage as a roughage. The steers were sold on a rather poor market, and if they could have been held three weeks longer they would have brought considerably more money and showed quite a nice profit. When all things are considered, the results of the test were satisfactory and tend to emphasize the importance of corn silage as a roughage for finishing steers for the market.

SLAUGHTER DATA.

In Table 7 are shown the results of the shipping and slaughtering of the steers in this experiment:

TABLE 7.—*Slaughter data.*

Lot No.	Ration.	Average farm weight per steer.[1]	Average market weight per steer.	Average shrinkage in transit.	Average weight of carcass.	Per cent dressed.	
						By farm weights.	By market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Cottonseed meal and cottonseed hulls	996	944	52	531.6	53.40	56.27
2	Cottonseed meal and corn silage	1,017	954	63	557.4	54.81	58.41
3	Cottonseed meal, cottonseed hulls, and corn silage	1,033	978	55	566.8	54.85	57.97

[1] The final farm weights were taken April 11, six days after conclusion of the experiment; the market weights were taken three days later, April 14.

The steers were driven from the feed lots to West Point, Miss., a distance of 12 miles, to be loaded on the cars. As they had to travel over a gravel road, some of them began getting tender footed before reaching the pens. They arrived at the loading pens in the afternoon, where they were given hay and had access to water, and were loaded the following morning. They were in transit 24 hours, and were sold and slaughtered the same day that they reached the market.

The dressing percentages show that the steers of both Lots 2 and 3 were finished somewhat better than the steers of Lot 1. The percentages are all satisfactory, and th e purchaser reports that the steers of all lots showed extra nice carcasses and that he was well pleased with the way they dressed out.

SUMMARY OF THE EXPERIMENT.

1. This experiment was a duplication of the Alabama test reported in Part I of this bulletin as to the relative efficiency of cottonseed hulls, corn silage, and a combination of the two when fed with cottonseed meal for fattening steers.

2. The steers used were grades of the various beef breeds, averaging 813 pounds per head at the beginning of the experiment. The 77 steers were divided into three lots and fed 143 days during the winter of 1914-15.

3. Cottonseed meal was fed in equal quantities to all the steers. In addition to this the steers in Lot 1 were fed cottonseed hulls, those in Lot 2 corn silage, and those in Lot 3 both cottonseed hulls and corn silage.

4. For the entire feeding period of 143 days the steers of Lots 1, 2, and 3 made an average daily gain per head of 1.38, 1.15, and 1.67 pounds, respectively. These daily gains are noticeably smaller than those made in the Alabama test the previous winter. This is due chiefly to slightly inferior steers, poor silage, less desirable feeding conditions, and a longer feeding period in the 1914–15 trial.

5. The cost to make 100 pounds of gain was $10.70 for Lot 1; $11.26 for Lot 2, and $8.90 for Lot 3.

6. The steers of Lot 1 were marketed at an average loss of $1.62 per head, but those of Lots 2 and 3 returned an average net profit of $2.27 and $2.13 per head, respectively. Notwithstanding the fact that the prices of feeds were less and the steers were sold at a greater margin in the 1914–15 trials, the three lots of steers fed the previous year in Alabama made considerably more profit. The high cost of gains in 1914–15 had offset the advantages of cheap feeds and more favorable marketing.

7. The shrinkage per head in transit to market was 51 pounds for Lot 1, 63 pounds for Lot 2, and 56 pounds for Lot 3. The silage-fed steers shrank a little more in transit than the steers of Lot 1.

8. The dressing percentages were 56.27, 58.41, and 57.97 for Lots 1, 2, and 3, respectively.

9. While the steers of Lot 1, which were fed cottonseed hulls as roughage, made slightly larger daily gains and less expensive gains than the steers of Lot 2, which received a poor grade of silage, the steers of Lot 2 made a greater profit and dressed out a higher percentage of marketable meat.

III. A COMPARISON OF SOME COMMON FARM-GROWN ROUGHAGES FOR FATTENING STEERS (EXPERIMENT OF 1915–16.)

INTRODUCTION.

This experiment was conducted on the Canton Stock Farm, located in the "Brown loam" section of Mississippi, near the town of Canton, in Madison County. The work was conducted during the winter of 1915–16 under the same general plan under which the other cooperative work was conducted and does not need explaining here. Mr. S. S. Jerdan, who had been employed for three years previously in conducting such experiments, was located on the farm and closely supervised the weighing of all feeds and the feeding. His entire time was devoted to this and some other experimental work being done on the farm.

OBJECT AND PLAN OF THE WORK.

Many feeders have claimed that when silage is fed to steers they should have a small amount of dry roughage in addition, and that it would be more economical and satisfactory to feed a small amount of roughage with the silage than to feed silage alone. It has been claimed also that this is especially desirable when no other concentrate than cottonseed meal is fed.

This experiment was planned and conducted to determine whether these statements were true. Three lots of steers were used for this comparison, and a fourth lot was fed to see what such common southern feeds as cowpea hay, oat straw, and corn stover would give satisfactory returns if they were fed in equal parts to fattening steers.

CATTLE USED.

The 80 steers used in this experiment were grades ranging from one-half to seven-eighths pure-bred of the various beef breeds—Shorthorn, Hereford, Aberdeen-Angus, Red Poll, and Devon. In age they ranged from 2 to 4 years.

All the steers were bought in Madison County, Miss., and were better than the average steers found in that section. They averaged 787 pounds in weight when placed in the experiment.

CHARACTER AND PRICES OF FEEDS USED.

The steers were divided into 4 lots of 20 each. Lot 1 was fed cottonseed meal and sorghum silage. Lot 2 received cottonseed meal, sorghum silage, and corn stover. Lot 3 received cottonseed meal, sorghum silage, and oat straw. Lot 4 received cottonseed cake, cowpea hay, oat straw, and corn stover.

The meal and cake used in the test had a crude-protein analysis of 41 per cent. Both were bright and of good quality. The cake was cracked to nut size. The silage was made of a rank-growth sorghum and was very good. The cowpea hay was of good quality; most of it carried lots of peas, and it was nicely cured. The corn stover was fairly bright and as good as the average stover found in the South. Oat straw that had been baled immediately after thrashing was used; it was clean and bright.

The prices used in charging the different feeds were as follows:

Cottonseed meal	per ton	$32
Sorghum silage	do	3
Cowpea hay	do	10
Corn stover	do	5
Oat straw	do	5

METHOD OF FEEDING AND HANDLING THE CATTLE.

The lots in which the steers were fed varied somewhat in size. Lots 1, 2, and 3 were fed in stationary troughs which were located under sheds, which opened on the south and west sides. Lot 4 was fed from a trough which was in the open.

Water was furnished to each lot in large galvanized-iron troughs kept filled from a deep well.

The steers were fed at 7 a. m. and 5 p. m. Each of the first three lots were fed cottonseed meal and silage twice a day. The hay and stover were fed once a day. The silage was limited to the amount they would clean up in one hour.

All the steers were dehorned about two weeks before going into the experiment. About this time they were placed on a preliminary feed of cottonseed meal and sorghum silage. The cattle were tagged and on November 26 and 27 were weighed individually, the average of the two weights being used as the initial weight.

During the progress of the experiment the steers were weighed by lots at the end of each 28-day period. At the end of the experiment the steers were weighed individually on three successive days, and the average of these weights was used as the final weight.

AVERAGE DAILY RATIONS.

The average daily ration per steer by 28-day periods and the average ration for the entire period of 127 days is shown in the following table:

TABLE 8.—*Average daily ration per head by 28-day periods.*

Lot No.	Number of steers.	Feeds.	First period.	Second period.	Third period.	Fourth period.	Fifth period. (15 days).	Entire period (127 days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	20	Cottonseed meal	4.1	5.8	6.9	7.0	7.0	6.1
		Sorghum silage	40.5	46.0	41.0	42.7	40.8	42.4
2	20	Cottonsead meal	4.1	5.8	6.9	7.0	7.0	6.1
		Sorghum silage	36.0	41.1	37.7	38.7	39.5	38.6
		Corn stover	3.7	3.0	2.4	1.5	0.8	2.5
3	20	Cottonseed meal	4.1	5.8	6.9	7.0	7.0	6.1
		Sorghum silage	36.3	41.0	37.8	38.8	39.0	38.6
		Oat straw	3.5	1.7	2.3	0.9	0.8	1.9
4	20	Cottonseed cake	4.1	5.8	6.9	7.0	7.0	6.1
		Cowpea hay	7.7	7.9	8.9	7.8	7.4	8.0
		Oat straw	7.7	7.9	8.9	7.8	7.4	8.0
		Corn stover	7.7	7.9	8.9	7.8	7.4	8.0

The steers of all four lots were fed cottonseed meal as the sole concentrate. As all the steers were of about the same size, and as a comparison of roughages was to be made, the steers of the various lots received the same amount of cottonseed meal each day. For the first 28-day period the steers of all lots were fed 4.1 pounds of cottonseed meal each per day. The amount of cottonseed meal was gradually increased so that all steers received an average of 5.8 pounds per head the second period, 6.9 pounds the third period, and 7 pounds per head per day during the fourth and fifth periods. The average amount of cottonseed meal consumed daily by each steer for the entire period of 127 days was 6.1 pounds.

The steers of Lot 1, which received sorghum silage as the sole roughage, consumed 40.5 pounds per head daily. Each steer in Lot 2 consumed 36 pounds of silage and 3.7 pounds of corn stover, while each one in Lot 3 ate 36.3 pounds of silage and 3.5 pounds of oat straw. The average daily ration of roughage per steer in Lot 4 was 7.7 pounds each of the following: Cowpea hay, oat straw, and corn stover.

The steers of Lot 1 ate 46 pounds of silage per head daily during the second period, but this amount decreased for the subsequent periods. Each steer fed silage as the sole roughage consumed an average of 42.4 pounds per day for the entire 127-day period.

The steers of Lot 2, which were fed silage with what corn stover they would eat, consumed 41.1 pounds of silage and 3 pounds of corn stover per head daily for the second period. During subsequent periods they ate somewhat less silage and stover. During the last two periods the steers did not seem to care much for the stover and consumed an average of but a little more than 1 pound per head daily.

The steers of Lot 3, which were fed all the silage they would eat and had access to good oat straw, consumed 41 pounds of silage and 1.7 pounds of oat straw per day during the second period and somewhat less roughage during the subsequent periods, eating less than 1 pound of oat straw per head daily during the last two periods.

These rations indicate that while steers which are being fed silage will eat a little dry roughage if placed before them, the amount is small if the silage is palatable and the amount of roughage becomes almost a negligible factor during the latter part of the feeding period. The steers which ate some roughage did not eat so much silage. For the entire period of 127 days the steers of Lots 2 and 3 ate exactly the same amount of silage, namely, 38.6 pounds per head per day, and in addition consumed 2.5 and 1.9 pounds of stover and oat straw, respectively, each day. The steers of Lot 1, which received silage alone, consumed on the average 3.8 pounds more silage per head per day than the steers of Lot 2, or, in other words, 2.5 pounds of corn stover or 1.9 pounds of oat straw replaced 3.8 pounds of sorghum silage in the ration.

WEIGHTS AND GAINS.

The following table shows the average initial and final weights per steer of each lot and the total and average daily gains per steer:

TABLE 9.—*Weights and gains (Nov. 26, 1915, to Apr. 1, 1916—127 days).*

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gain per steer.	Average daily gain per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal and sorghum silage	787	1,058	272	2.14
2	Cottonseed meal, sorghum silage, and corn stover	788	1,036	248	1.95
3	Cottonseed meal, sorghum silage, and oat straw	790	1,030	240	1.89
4	Cottonseed cake, cowpea hay, oat straw, and corn stover	787	989	202	1.59

The steers of all lots were nearly uniform in size at the beginning of the experiment, the greatest average variation in weight per steer of any lot being 3 pounds. The final average weight of the steers of Lot 1 was 1,058 pounds; Lot 2, 1,036 pounds; Lot 3, 1,030 pounds; and Lot 4, 989 pounds.

The average gain in weight per steer for Lot 1 was 272 pounds for 127 days, or an average daily gain of 2.14 pounds, which is exceedingly satisfactory. Each steer of Lot 2, which had a small amount of corn stover in addition to the sorghum silage, gained 1.95 pounds daily, while those of Lot 3, which had a supplemental ration of oat straw, gained but 1.89 pounds daily. The steers of Lot 4, which were fed a dry-roughage ration of cowpea hay, oat straw, and corn stover, gained only 1.59 pounds per head per day.

The use of a small amount of dry roughage fed with good sorghum silage failed to cause the steers to make larger daily gains; in fact, it had just the opposite effect. The steers receiving silage alone consumed a larger amount daily and made larger daily gains. A roughage ration composed of one-third cowpea hay, one-third oat straw, and one-third corn stover did not prove satisfactory for fattening steers when cottonseed cake was the sole concentrate fed.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

The following table shows the amount and cost of feeds required to make 100 pounds of gain:

TABLE 10.—*Quantity and cost of feed required to make 100 pounds of gain.* (*November 26, 1915, to April 1, 1916—127 days.*)

Lot No.	Ration.	Pounds of feed to make 100 pounds of gain.	Cost of 100 pounds of gain.
1	Cottonseed meal	284	$7.52
	Sorghum silage	1,978	
2	Cottonseed meal	312	8.26
	Sorghum silage	1,976	
	Corn stover	125	
3	Cottonseed meal	322	8.47
	Sorghum silage	2,041	
	Oat straw	103	
4	Cottonseed meal	383	11.16
	Cowpea hay	504	
	Oat straw	504	
	Corn stover	504	

Lot 1, which was fed on a ration of cottonseed meal and sorghum silage, required 284 pounds of cottonseed meal and 1,978 pounds of silage to make 100 pounds of gain. Each 100 pounds of gain was made at a cost of $7.52. The cost of producing the gains on this lot was lower than for any of the other lots.

Lot 4 received 383 pounds of cottonseed meal and 504 pounds each of oat straw, corn stover, and cowpea hay per 100 pounds gain. The gains in this lot were made at a cost of $11.16. The steers in this lot not only made the smallest gains of all the lots, but the gains were the most expensive. The small gains, which are accounted for by the lack of succulence and palatability in the roughage ration, are responsible for the high cost of gains.

The rate of gains as well as the cost of gains in this experiment seems to indicate that the addition of such roughages as corn stover or oat straw do not add to the value of a silage ration when the silage is made of well-matured sorghum. The outcome of Lot 4 in this experiment emphasizes the value of silage in the fattening ration and that a ration containing so much cheap roughage as stover and oat straw is not well adapted for fattening cattle. It could probably be used to better advantage for wintering feeder and stocker cattle.

FINANCIAL STATEMENT.

The following table gives a financial statement of the purchase, feeding, transportation, and sale of each of the four lots of steers:

Financial statement.

Lot 1, cottonseed meal and sorghum silage:	
To 20 steers, 15,734 pounds, at $5 per hundredweight	$786.70
To 15,455 pounds cottonseed meal at $32 per ton	247.28
To 107,627 pounds silage at $3 per ton	161.44
To freight, yardage, commission, feed, etc.	104.08
Total expenditure	1,299.50
By sale of 20 steers, 19,333 pounds, at $8.45 per hundredweight	1,633.64
Total profit	334.14
Average profit per steer	16.71
Lot 2, cottonseed meal, sorghum silage, and corn stover:	
To 20 steers, 15,718 pounds, at $5 per hundred weight	785.90
To 15,455 pounds cottonseed meal, at $32 per ton	247.28
To 98,014 pounds silage, at $3 per ton	147.02
To 6,233 pounds corn stover, at $5 per ton	15.58
To freight, yardage, commission, feed, etc.	104.08
Total expenditure	1,299.86
By sale of 20 steers, 18,870 pounds, at $8.45 per hundredweight	1,594.51
Total profit	294.65
Average profit per steer	14.73
Lot 3, cottonseed meal, sorghum silage, and oat straw:	
To 20 steers, 15,808 pounds, at $5 per hundredweight	790.40
To 15,455 pounds cottonseed meal, at $32 per ton	247.28
To 97,964 pounds silage, at $3 per ton	146.95
To 4,935 pounds oat straw, at $5 per ton	12.34
To freight, yardage, commission, feed, etc.	104.08
Total expenditure	1,301.05
By sale of 20 steers, 18,900 pounds, at $8.45 per hundredweight	1,597.05
Total profit	296.00
Average profit per steer	14.80
Lot 4, cottonseed meal, oat straw, corn stover, and cowpea hay:	
To 20 steers, 15,735 pounds, at $5 per hundredweight	786.75
To 15,455 pounds cottonseed meal, at $32 per ton	247.28
To 20,387 pounds straw, at $5 per ton	50.97
To 20,387 pounds corn stover, at $5 per ton	50.97
To 20,387 pounds hay, at $10 per ton	101.93
To freight, yardage, commission, feed, etc.	104.08
Total expenditure	1,342.98
By sale of 20 steers, 18,020 pounds, at $8.17 per hundredweight	1,472.23
Total profit	129.25
Average profit per steer	6.46

The steers used in this test were purchased at an average cost of $5 per 100 pounds. After 127 days of feeding the steers of each of the first three lots sold on the St. Louis market for $8.45 per 100 pounds. The steers of Lot 4 brought but $8.17 per hundredweight, as they were not so well finished. The margin between the purchase and the sale price of the steers was exceptionally high. The costs of gains were low and this factor combined with the wide margin tended toward the high profit which was realized on the different lots. Lot 1, which received cottonseed meal and corn silage, showed the greatest profit, and Lot 4 showed the least profit.

SLAUGHTER DATA.

On April 2 the steers were driven 2 miles to Canton, Miss., from which place they were shipped to the St. Louis market. During the 24 hours prior to this they were given only bright oat straw to eat, but were allowed all the water they wished to drink. They were loaded on the cars at 10 a. m., April 2. At 4 p. m., April 4 they arrive in the stockyards at East St. Louis, being in transit 56 hours, which was unusually long for this run. Upon arrival at market they were fed and watered. They were sold the morning of April 5, after taking only a fair fill.

The following table gives the slaughter data for each of the lots:

TABLE 11.—*Slaughter data.*

Lot No.	Ration.	Average farm weight per steer.	Average market weight per steer.	Average shrinkage in transit.		Average weight of carcass.	Per cent dressed.	
							By farm weights.	By market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Cottonseed meal and sorghum silage	1,058	966	92	8.69	549	51.88	56.82
2	Cottonseed meal, sorghum silage, and corn stover	1,036	943	93	8.97	537	51.81	56.92
3	Cottonseed meal, sorghum silage, and oat straw	1,030	945	85	8.25	532	51.65	56.29
4	Cottonseed meal, oat straw, cowpea hay, and corn stover	989	901	88	8.89	491	49.65	54.51

The average shrinkage per head for each lot was as follows: Lot 1, 92 pounds; Lot 2, 93 pounds; Lot 3, 85 pounds; Lot 4, 88 pounds. Lot 3, which received oat straw in addition to cottonseed meal and corn silage, showed the least shrinkage. The shrinkage was more than normal on all lots, probably due to the length of time in transit.

The carcasses were all good, being nicely covered with fat. The dressing percentages of the first three lots were very uniform. The steers of Lot 4 were not so fat as the silage-fed steers, as shown by the dressing percentages; the steers of Lot 4 dressing out almost 2 per cent less than the steers of the other lots.

SUMMARY OF THE EXPERIMENT.

1. The objects of this experiment were: (*a*) to determine whether it is more profitable to feed silage as the sole roughage ration or to supplement it with a small amount of dry roughage, such as corn stover or oat straw, and (*b*) to determine the value of a combination of such common southern roughage as cowpea hay, oat straw, and corn stover for fattening steers.

2. The steers used in this experiment were grade native steers, ranging from one-half to seven-eighths pure-bred Shorthorn, Aberdeen-Angus, Hereford, Red Poll, and Devon. They were above the average of steers found in that section and ranged in age from 2 to 4 years.

3. The steers were divided into 4 lots of 20 each and fed for a period of 127 days. Lot 1 was fed cottonseed meal and sorghum silage; Lot 2 received cottonseed meal, sorghum silage, and corn stover; Lot 3 received cottonseed meal, sorghum silage, and oat straw; Lot 4 was fed cottonseed cake, cowpea hay, oat straw, and corn stover.

4. Lot 2 started with a daily average consumption of 3.7 pounds of stover per head, decreasing to 0.6 pound in the last period. Lot 3 commenced with a daily average consumption of 3.5 pounds of oat straw per head, decreasing to 0.8 pound in the last period. These rations indicate that while steers being fed silage will eat a little dry roughage if placed before them, the amount is small if the silage is palatable, and becomes an almost negligible factor during the latter part of the feeding period. The steers which ate some roughage did not eat so much silage.

5. The average daily gains per head for the period of 127 days were 2.14, 1.95, 1.89, and 1.59 pounds, for Lots 1, 2, 3, and 4, respectively. The use of a small amount of dry roughage fed with good sorghum silage failed to cause the steers to make larger gains; in fact, it had just the opposite effect. The steers receiving silage alone consumed a larger amount daily and made larger daily gains.

6. A roughage ration consisting of one-third cowpea hay, one-third oat straw, and one-third corn stover did not prove so satisfactory for fattening steers when cottonseed cake was the sole concentrate fed.

7. The total cost of 100 pounds gain was $7.52, $8.26, $8.47, and $11.16 for lots 1, 2, 3, and 4, respectively. The rate of gains, as well as the cost of gains in the experiment, seems to indicate that the addition of such roughages as oat straw and corn stover do not add to the value of a silage ration.

8. The outcome of Lot 4 emphasizes the value of silage for fattening cattle and indicates that such cheap roughage is not adapted for the purpose. It probably could be used to better advantage for wintering feeder and stocker cattle.

9. The profit per head in Lot 1 was $16.71; Lot 2, $14.73; Lot 3, $14.80, and Lot 4, $6.46. The exceptionally high margin combined with the low cost of gains tended toward the high profits realized in the various lots.

10. Lot 4 was not so well finished and brought a lower market price.

IV. A COMPARISON OF SOME COMMON FARM-GROWN ROUGHAGES FOR FATTENING STEERS (EXPERIMENT OF 1916–17).

INTRODUCTION.

This test, conducted on the Canton Stock Farm at Canton, Miss., is a duplication of the work at the same station the previous year. As before, Mr. S. S. Jerdan had charge of the work, and the test was carried out under the same general conditions as the experiments of previous years. Owing to a lack of cowpea hay, it was not possible to feed a lot of steers as Lot 4 had been fed in the winter of 1915–16.

OBJECT AND PLAN OF THE WORK.

The objects were identical with those stated under Part III and serve to furnish a check or certification of the results obtained in the test of 1915–16.

The test was planned to duplicate the work of the previous winter at the same station, with the omission of Lot 4 for the reason above stated. The steers were purchased in the fall, dehorned, carried two weeks on preliminary feed, then divided into three similar lots of 20 each and fed as follows: Lot 1, cottonseed meal and sorghum silage; Lot 2, cottonseed meal, sorghum silage, and corn stover; Lot 3, cottonseed meal, sorghum silage, and oat straw.

CATTLE USED.

Sixty head of steers were selected from various points in Madison County, Miss. They ranged from 2 to 4 years of age and were grade stock, showing Shorthorn, Hereford, Aberdeen-Angus, Red Poll, and Devon breeding, while a trace of Jersey blood was evident in a few of them. At the beginning of the test they averaged 856 pounds per head. They were a thrifty lot of steers and were larger and of better quality than the average in the State.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed meal used was clean and bright, analyzing about 36 per cent crude protein. The sorghum silage was of fine quality, and very palatable to the cattle. The oat straw had been baled in the fall and put into the barn, so it was bright and of high quality. The corn stover also was very good.

The feeds were charged against the steers at the following prices:

Cottonseed meal	per ton	$33.00
Sorghum silage	per ton	3.00
Corn stover	per ton	5.00
Oat straw	per ton	5.00

The cottonseed meal was purchased early in the fall at the above price. Three dollars per ton covered the cost of growing and putting up the silage. Local market prices were placed upon the stover and straw.

METHODS OF HANDLING AND FEEDING THE CATTLE.

The 60 steers were purchased in October, brought to the farm, and allowed the run of stalk fields and lespedeza meadows. Two weeks before they were put on regular feed they were dehorned and started on a preliminary ration of cottonseed meal and sorghum silage. After dehorning, the flies were very troublesome, which, together with the difficulty of getting some of the steers to eat silage and meal, caused quite material losses in weight.

On November 23, 24, and 25, individual weights of all the steers were secured and the average taken as the initial weights of the steers. During the progress of the experiment each lot was weighed every 28 days, and individual weights were again taken on two consecutive days at the conclusion of the test and averaged for the final weights.

Experimental feeding began on November 24. Feeding was done about 7 a. m. and 5 p. m. each day. Water and salt were supplied as during the previous winter. Dry roughage was kept in the racks for the steers of Lots 2 and 3 at all times, fresh roughage being placed in the racks each morning after the silage was fed.

The lots, sheds, and feeding equipment were the same as those used in the previous winter's experiment.

AVERAGE DAILY RATIONS.

The avearge daily rations per head by 28-day periods, and for the entire feeding period of 128 days, is shown in Table 12.

TABLE 12.—*Average daily ration per head by 28-day periods (Nov. 24, 1916, to Mar. 23, 1917—120 days).*

Lot No.	Number of steers.	Ration.	First period.	Second period.	Third period.	Fourth period.	Fifth period (8 days).	Entire period (120) days).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	20	Cottonseed meal	2.7	5.1	6.5	7.2	7.7	5.5
		Sorghum silage	34.4	43.2	49.2	49.5	42.8	43.9
2	20	Cottonseed meal	2.7	5.1	6.5	7.2	7.7	5.5
		Sorghum silage	31.3	37.9	40.6	40.5	38.3	37.6
		Corn stover	1.9	3.0	3.3	3.4	2.9	2.9
3	20	Cottonseed meal	2.7	5.1	6.5	7.2	7.7	5.5
		Sorghum silage	32.9	36.4	40.2	39.9	37.4	37.4
		Oat straw	1.8	2.5	2.3	2.4	1.2	2.2

It will be noted that the steers were on feed 120 days. The amount of cottonseed meal fed was uniform for each lot, while the roughages were different for each lot.

All the cattle were started on 2 pounds of cottonseed meal per head daily, which amount was increased during the first 28-day period, so that for this period each steer in the three lots ate an average of 2.7 pounds daily. They were given all the silage they would eat, and in addition Lots 2 and 3 were given what dry roughage they would consume.

Some of the steers had never been fed meal and silage and considerable difficulty was encountered in teaching a few in each lot to eat these feeds. Several head were stall fed for a few days until they became accustomed to the feeds. When they had once started eating well they gave no further trouble.

The allowance of cottonseed meal was increased gradually until in the last period the steers of each lot were getting 7.7 pounds daily per head. The roughage also was increased until the steers were on a full feed of cottonseed meal, after which time less roughage was eaten.

In Lot 2 one pound of corn stover replaced about 2 pounds of silage in the ration. Each pound of oat straw added to the ration of Lot 3 replaced about 3 pounds of silage.

Only about 50 per cent of the corn stover was actually eaten, as most of the dry stalks were refused by the steers. It was estimated that 25 per cent of the straw was likewise refused. These waste feeds were pulled down under the steers' feet and could not be weighed back.

WEIGHTS AND GAINS.

Table 13 gives the average initial and final weights per head for each lot, and the total and daily gains per head:

TABLE 13.—*Weights and gains (Nov. 24, 1916, to Mar. 23, 1917—120 days).*

Lot No.	Ration.	Average initial weight per steer.	Average final weight per steer.	Average total gain per steer.	Average daily gain per steer.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	Cottonseed meal and sorghum silage	856	1,078	222	1.85
2	Cottonseed meal, sorghum silage, and corn stover	856	1,084	228	1.89
3	Cottonseed meal, sorghum silage, and oat straw	856	1,073	218	1.82

The above figures indicate that the addition of stover or oat straw to the cottonseed meal and silage combination had little effect so far as producing gains is concerned. The steers which had corn stover in addition to meal and silage made slightly better gains, which is contrary to the results for the previous winter. In each test, however, the difference was so small as to be almost negligible. The steers of Lot 3, which were given oat straw, again made the poorest showing. Considering the type of steers used and the amount of feed consumed, the gains were quite satisfactory.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

The quantity and cost of feeds required to produce 100 pounds of gain in the case of each lot of steers are shown in Table 14.

TABLE 14.—*Quantity and cost of feed required to make 100 pounds of gain (Nov. 24, 1916, to Mar. 23, 1917—120 days).*

Lot No.	Ration.	Pounds of feed to make 100 pounds gain.	Cost of feed for 100 gain.
1	Cottonseed meal	299	$8.49
	Silage	2,372	
2	Cottonseed meal	292	8.18
	Silage	1,981	
	Corn stover	155	
3	Cottonseed meal	305	8.42
	Silage	2,057	
	Oat straw	121	

In this feeding trial the use of stover and straw to supplement the silage served to lower slightly the cost of gains by reducing the silage required for the same amount of gain. With the steers of Lot 2 less cottonseed meal was needed to produce 100 pounds of gain than was required when silage was the sole roughage received. However, there are no outstanding variations in these figures.

FINANCIAL STATEMENT.

The cost of the steers in the fall, the cost of feeds to fatten them, the charges for marketing, the gross receipts, and the profits are shown for each lot in the following statement:

Financial statement.

Lot 1, cottonseed meal and sorghum silage:	
To 20 steers, 17,115 pounds, at $5.56 per hundredweight	$951.59
To 13,315 pounds cottonseed meal at $33 per ton	219.70
To 105,590 pounds sorghum silage, at $3 per ton	158.39
To freight, yardage, commission, etc.	103.31
Total expenditure	1,432.99
By sale of 20 steers, 20,340 pounds, at $10.89 per hundredweight	2,215.03
Total profit	782.04
Average profit per steer	39.10

Lot 2, cottonseed meal, sorghum silage, and corn stover:	
To 20 steers, 17,129 pounds, at $5.56 per hundredweight	$952.37
To 13,315 pounds cottonseed meal, at $33 per ton	219.70
To 90,255 pounds sorghum silage, at $3 per ton	135.38
To 7,040 pounds corn stover, at $5 per ton	17.60
To freight, yardage, commission, etc.	103.31
Total expenditure	1,428.36
By sale of 20 steers, 20,370 pounds, at $10.99 per hundredweight	2,238.66
Total profit	810.30
Average profit per steer	40.51
Lot 3, cottonseed meal, sorghum silage, and oat straw:	
To 20 steers, 17,112 pounds, at $4.46 per hundredweight	951.43
To 13,995 pounds cottonseed meal, at $33 per ton	230.92
To 89,679 pounds sorghum silage, at $3 per ton	134.52
To 5,282 pounds oat straw, at $5 per ton	13.21
To freight, yardage, commission, etc.	103.31
Total expenditure	1,433.39
By sale of 20 steers, 20,010 pounds, at $10.77 per hundredweight	2,155.08
Total profit	721.69
Average profit per steer	36.08

The steers were purchased in the fall for $5.56 per hundredweight. After being fed 120 days and held on the farm 8 days longer, they were shipped to the St. Louis market. There the steers of Lot 1, which had been fed cottonseed meal and silage, sold for an average of $10.89 per hundredweight; those of Lot 2 brought $10.99 per hundredweight, while those of Lot 3 sold for $10.77 per hundredweight. The market prices, while not widely different, indicate the relative finish of the steers of the three lots, and the profits were greatest on the steers which were finished best.

The margin of selling was $5.33 per hundredweight for Lot 1, $5.43 for Lot 2, and $5.21 for Lot 3. Such margins would in themselves largely account for the large profit realized from the steers.

The average profit per steer was $39.10 for Lot 1, $40.51 for Lot 2, and $36.08 for Lot 3. These figures indicate the efficiency of the rations used. At the same time the wide margin realized between the buying and selling prices must be considered one of the chief factors determining the large profit.

The steers fed cottonseed meal, silage, and corn stover made the largest profit, and the steers fed cottonseed meal, sorghum, silage, and oat straw made the smallest profit.

SHRINKAGE AND SLAUGHTER DATA.

As stated before, the experimental feeding was concluded March 24, at which time the supply of silage was exhausted. The steers were held until April 1 in order to appear for a farm demonstration at the Canton Stock Farm. Silage for the steers during this time was purchased from neighbors, but changing feed, driving, and the excitement caused by crowds of farmers made all the cattle lose weight between March 24 and April 1. For this reason the average final farm weights shown in Table 15 do not coincide with those shown in Table 13.

The steers were weighed at 7 a. m., April 1, driven two miles to the loading station, and were on their way at 11 a. m. They arrived at the St. Louis stockyards at 2 p. m., April 3, having been in transit about 54 hours.

The average shrinkage per head was low for the time in transit, but the steers had been losing weight during the days previous to shipping, which accounts for the comparatively low shrinkage. The amount of shrinkage varied only slightly, being highest in Lot 1 and lowest in Lot 2.

The steers were given feed and water in the yards during the afternoon and night of April 3, and were sold the following morning. They were slaughtered the next day, April 5, and the carcass weights recorded as below:

TABLE 15.—*Slaughter data.*

Lot No.	Ration.	Average farm weight per steer.	Average market weight per steer.	Average shrinkage in transit.		Average weight of carcass.	Per cent dressed.	
							By farm weights.	By market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Cottonseed meal and sorghum silage	1,067	1,017	50	4.68	598	55.10	57.81
2	Cottonseed meal, sorghum silage, and corn stover	1,064	1,019	45	4.23	593	55.73	58.19
3	Cottonseed meal, sorghum silage, and oat straw	1,048	1,001	47	4.47	578	55.15	57.74

The carcasses were well covered with fat and were pronounced by the butchers as well finished. Little variation was found in the degree of finish of the different lots of steers, as the dressing percentages show. It will be noted that these dressing percentages are rather high for this class of cattle, which speaks well for the efficiency of the rations fed.

SUMMARY OF THE EXPERIMENT.

1. The objects of this feeding test were to study the effect of a supplemental allowance of corn stover and oat straw to a basic ration of cottonseed meal and silage for fattening mature steers, and to furnish data by which former work of a similar nature might be checked.

2. The work was planned so that it would be a repetition of the test of the winter of 1915–16.

3. The steers used were mature twos, threes, and fours, carrying from one-fourth to three-fourths pure blood of the various beef breeds, including the Devon and Red Poll. They were better steers than the average found in the State.

4. The steers were divided into three lots of 20 each and fed as follows: Lot 1, cottonseed meal and sorghum silage; Lot 2, cottonseed meal, sorghum silage, and corn stover; Lot 3, cottonseed meal, sorghum silage, and oat straw.

5. Equal quantities of cottonseed meal were fed to the steers of the three lots, beginning at 2 pounds per head, and increased to 7.7 pounds during the latter part of the feeding period. The steers of Lot 1 ate an average daily ration of 43.9 pounds of silage, while those of the other two lots consumed practically 6 pounds less daily per head, which amount was replaced by a daily consumption of 2.9 pounds of corn stover per head in the case of Lot 2, and 2.2 pounds of oat straw in Lot 3.

6. The average daily gains per head for the 120-day feeding period were 1.85 pounds, 1.89 pounds, and 1.82 pounds for the steers of Lots 1, 2, and 3, respectively. Thus it is seen that the addition of stover and straw had very little effect upon the rate of gains.

7. The cost per 100 pounds gain was $8.49, $8.18, and $8.42, for Lots 1, 2, and 3, respectively. These gains were put on cheaply, and there is very little variation in the costs in the different lots. The addition of stover and straw to the cottonseed-meal and silage combination lowered the cost of gains slightly.

8. The relatively cheap cottonseed meal and silage, combined with the extremely wide margin of selling, largely accounts for the high profits realized from feeding these steers. The average profit per steer, after deducting the cost of feeds and marketing, was $39.10, for Lot 1, $40.51 for Lot 2, and $36.08 for Lot 3.

9. The steers in Lot 1 dressed out 57.81 per cent, those in Lot 2, 58.19 per cent, and those of Lot 3, 57.74 per cent, which indicates well-finished carcasses.

V. SUMMARY AND CONCLUSIONS OF THE FOUR YEARS' WORK.

SUMMARY OF RESULTS.

Table 16 shows in condensed form the chief features and results of the four years' work and permits an easy study and comparison of the figures:

TABLE 16.—*Summary table of four years' steer feeding.*

Group I.	Lot 1.—Cottonseed meal and cottonseed hulls.		Lot 2.—Cottonseed meal and corn silage.		Lot 3.—Cottonseed meal, cottonseed hulls, and corn silage.	
	1913–14	1914–15	1913–14	1914–15	1913–14	1914–15
Number of steers	20	25	20	26	20	26
Number of days fed	84	143	84	143	84	143
Average daily gain per head.....pounds..	2.48	1.38	2.51	1.15	2.58	1.67
Average cost of feed per 100 pounds gain...	$8.88	$10.70	$6.19	$11.26	$7.89	$8.90
Average selling margin	$1.50	$1.68	$1.50	$1.78	$1.50	$1.83
Average profit per head	$5.99	[1] —$1.62	$11.74	$2.27	$7.69	$2.13

Group II.	Lot 1.—Cottonseed meal and sorghum silage.		Lot 2.—Cottonseed meal, sorghum silage, and corn stover.		Lot 3.—Cottonseed meal, sorghum silage, and oat straw.		Lot 4.—Cottonseed cake, cowpea hay, oat straw, and corn stover.	
	1915–16	1916–17	1915–16	1916–17	1915–16	1916–17	1915–16	1916–17
Number of steers fed	20	20	20	20	20	20	20	....
Number of days fed	127	120	127	120	127	120	127	....
Average daily gain per head..pounds..	2.14	1.85	1.95	1.89	1.89	1.82	1.59	....
Average cost of feed per 100-pound gain	$7.52	$8.49	$8.26	$8.18	$8.47	$8.42	$11.16	....
Average selling margin	$3.45	$5.33	$3.45	$5.43	$3.45	$5.21	$3.17	....
Average profit per head	$16.71	$39.10	$14.73	$40.51	$14.80	$36.08	$6.46	....

[1] Minus sign shows a loss.

FIRST TWO WINTERS' FEEDING.

Inspection of the data presented in the first group shows that there was a difference of nearly two months in the feeding period for the two years and that the average daily gains were much greater for the steers fed only 84 days. The short-fed steers received a heavier ration and, notwithstanding the fact the meal and hulls cost more per ton than they did the following year, they made gains more cheaply in all the lots. They also were sold on a narrow margin but returned much larger profits than the steers fed in the succeeding winter.

Comparison of the results secured by the use of the different rations indicates a slight advantage in the rate and cost of gains produced in favor of the ration of meal, silage, and hulls (Lot 3). But it will be recalled that the poor showing made during the second year's trial was due chiefly to the muddy condition of the lots and to the poor quality of the silage, the latter disadvantage reflecting most severely on the steers of Lot 2, which had no other roughage. Yet the steers fed only cottonseed meal and silage made the largest profit in each instance. The ration of cottonseed meal and hulls (Lot 1) proved the least satisfactory of the three rations tried, as the steers of this lot returned the least profit the first year and lost money in the second year. All the steers were sold on narrow margins, and the profits were only moderate.

LAST TWO WINTERS' FEEDING.

In the last two winters' feeding, the data of which are given under Group II of the summary table, the feeding periods for the two years were practically equal, the conditions for feeding improved, and all the feed was of high quality.

Omitting Lot 4, which was carried only one year, the figures show that larger gains were made in each lot in the third year, 1915–16, chiefly owing to the heavier ration of cottonseed meal for that year. The cost of gains was quite uniform in each lot during the two years' trials, the largest variation being in Lot 1, where the difference was $0.97 per 100 pounds. The wide margins on which all the steers were sold in the last two years' tests are outstanding, ranging from $3.17 to $5.43 per 100 pounds. These large margins, together with good gains produced economically, are responsible for the remarkable profits realized on these cattle. The differences in profits shown in each lot for the two years are due mainly to the larger selling margins realized on the steers the last year.

The results obtained from feeding the different rations show that the steers of Lot 1, fed cottonseed meal and sorghum silage, made the most rapid gains and made them more cheaply than the steers of any other lot. The ration of cottonseed meal, silage, and corn stover proved to be a little less efficient than cottonseed meal and silage alone, while the meal and silage supplemented with oat straw, which was fed to Lot 3, did not produce quite so rapid or so cheap gains as the second ration. The ration of cottonseed meal and dry roughages, which was given to Lot 4, did not produce results satisfactory as to rate and cost of gains.

The profits from the various lots show that the first three rations were successfully fed, there being practically no difference in Lots 1 and 2, which returned the most profits. Lot 3, because of slightly smaller and more expensive gains, returned a smaller profit, while Lot 4 would have been fed at a loss had it not been for the wide selling margin.

CONCLUSIONS.

The four years' feeding work with southern steers furnishes data from which some valuable conclusions may be drawn.

1. The outstanding efficiency of corn or sorghum silage in rations for fattening steers is distinctly brought out by these feeding tests. Good gains are produced economically by the use of cottonseed meal and silage, or cottonseed meal and silage supplemented with dry roughage, such as cottonseed hulls, corn stover, or oat straw. However, satisfactory results in finishing steers for the block can not be expected from silage of poor quality.

2. A ration of cottonseed meal and cottonseed hulls produces less rapid and more expensive gains in fattening steers than a ration in which good silage forms all or most of the roughage portion of the ration. If hulls are available at a reasonable price, they can be used economically to supplement a ration composed chiefly of cottonseed meal and silage.

3. Cattle receiving cottonseed meal and a heavy feed of silage eat only a small quantity of dry roughage, such as corn stover or straw, but the consumption of such roughage reduces the total amount of silage consumed.

4 The use of cheap dry roughage for supplementing a silage ration has little effect on the rate or economy of gains. When such feeds are available on the farm and are not needed for wintering stock or for breeding animals, they should be utilized as supplements in the rations of fattening cattle.

5. Cottonseed meal or cake supplemented with dry roughage, such as cowpea hay, straw, and stover, does not produce as rapid or economical gains on steers as rations containing a generous quantity of corn or sorghum silage.

6. It is often more profitable to feed heavy rations over a short period, as was done in the winter of 1913–14, than to feed lighter rations over a longer period. The condition of the steers when feeding begins and the market price are the chief factors that will determine whether the steers are to be fed over a short or a long feeding period.

7. In these experiments feeding pens and lots which were fairly dry and furnished dry sleeping quarters were conducive to better gains on the steers than those which were muddy.

8. Steers having the best finish brought the highest prices per 100 pounds and returned the most profit. This indicates that it is a safe policy for the feeder to finish his cattle well.

9. Cattle sold on large margins usually bring good profits, even if the cost of finishing has been high. Hence, buying feeders at right prices, or raising them economically, chiefly on farm-grown feeds, such as silage, stover, straw, and pasture, will usually insure a satisfactory financial outcome.

10. Taken as a whole, the results of the tests reported in this bulletin show that the southern farmer can feed steers on cottonseed meal or cake and corn or sorghum silage, with or without other farm-grown roughage, and produce satisfactory gains at comparatively cheap cost, and can market well-finished steers for good prices if he is in a tick-free section. By so doing he not only utilizes his farm-grown crops but adds to his farm in the form of manure the fertilizing elements of the cottonseed meal fed, thus carrying out a system of diversified, permanent, and profitable farming.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 763

Contribution from the States Relations Service
A. C. TRUE, Director.

Washington, D. C. PROFESSIONAL PAPER June 6, 1919

LESSONS ON DAIRYING FOR RURAL SCHOOLS.[1]

By Alvin Dille, *Assistant in Agricultural Education.*[2]

CONTENTS.

INTRODUCTION.

There are few branches of agriculture that take as little fertility from the soil and at the same time returns a profit to the farmer as dairy farming. While teaching dairy farming is not the purpose of this bulletin, yet it is the basis of the lessons presented. These lessons present the subject from the standpoint of clean milk production, milk products, milk as a food in the home and as a supplement to other food materials, and have been prepared to give to the organized school work in elementary agriculture additional impetus in dairying, to provide material for instruction that is within the range of elementary pupils, and to furnish a topic for home projects that may be worked out with profit to every community and with real educational value to the pupils concerned.

SOURCES OF INFORMATION.

Practically all the subject matter for class use and instructions for home projects will be found in bulletins available, either free or at a small cost. Almost every State agricultural college has published

[1] Prepared under the direction of F. E. Heald, Specialist in Agricultural Education, States Relations Service, U. S. Department of Agriculture, Washington, D. C.

[2] The writer is indebted to the Dairy Division of the Bureau of Animal Industry and to the Office of Home Economics for valuable assistance in preparing this bulletin.

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one or more bulletins on some phase of dairying, and in most instances these may be had for the asking. Address the dean of the agricultural college.

The Farmers' Bulletins of the United States Department of Agriculture referred to in this bulletin will cover most of the topics to be studied. Bulletins in this list will be sent free, so long as the supply lasts, to any resident of the United States, upon application to his Senator, Representative, or Delegate in Congress, or to the Chief of the Division of Publications, U. S. Department of Agriculture, Washington, D. C. Because of the limited supply, applicants are urged to select only a few numbers, choosing those which are of special interest, and ordering but one copy of each. When the free supply has been exhausted, a number are yet for sale. Apply to the Superintendent of Documents, Government Printing Office, Washington, D. C., who has these bulletins for sale at 5 cents each. Other publications of this department are for sale by the Superintendent of Documents, but these are more often technical bulletins, and of interest to those only who wish to specialize in the subject.

Frequently revised classified lists of department publications on different phases of agriculture, one of which is on the subject of dairying, are issued by the Division of Agricultural Instruction, States Relations Service, U. S. Department of Agriculture, for teachers' use. The teacher will find that a number of the textbooks on dairying are suited to her needs, and that some of the elementary textbooks may be used by the pupils. Dairy cattle breeders' associations and dairy equipment concerns publish some interesting literature that may be had for the asking. Usually one or more dairy journals will be taken in the community, or a general farm paper with a well edited dairy section. Pupils should be encouraged to bring these to school. Clippings may be made of articles of interest and filed carefully. An easy and effective system of filing is to use pasteboard cases, which may be purchased or made by the pupils from pasteboard boxes, and to file the bulletins in these boxes by subject.

In addition to the Farmers' Bulletins and other Department Bulletins, the Dairy Division, Bureau of Animal Industry, issues a number of circulars on various phases of dairying which may be obtained directly from that division.

THE SURVEY.

One of the means by which the teacher may become informed about the dairy interests of the district is a dairy survey. The pupils may assist in obtaining this information, but a first-hand knowledge obtained by the teacher will be a valuable aid.

This survey should include the kind of farm (crop or stock farm), purpose of dairy cows (commercial or home use), breed of cattle, feeds raised on farm, feeds purchased, records kept, milk tested, how milk is disposed of, and dairy conveniences. This information may be collected and tabulated.

A map of the district may be procured, or, if not available, one can be drawn on a large sheet by the pupils. On this map the homes and farms of the pupils are to be located. Place signs, emblems, or colored bits of paper to represent various facts from your tabulations; for example, colored circles to represent dairy breeds, squares to represent milk disposal, etc. Additional facts may be placed on this map, taking especial note of new cows, improvements, etc.

ILLUSTRATIVE MATERIAL.

Construct a chart showing the points of a typical dairy cow. On a large card mount pictures of the different breeds of dairy cows. Construct charts showing relative milk production of the cows of a herd; also one showing the percentage of butter fat from different cows. Preserve notable dairy records. Make diagrams showing the food value of milk; others comparing the food value of milk with that of other foods. Samples of feed raised or used in the district may be placed on exhibit. Make drawings showing a section of a model dairy barn; of a model milk house.

Pupils may construct actual models of dairy barns, models of stalls, stanchions, feed racks, etc. Drawings may be made or illustrations cut from magazines and papers and pasted on cardboard sheets showing by comparison the food value of a quart of milk with certain portions of other foods. (Farmers' Bulletin No. 363.)

Milk pails of various sorts may be borrowed from homes in the district or from dealers. If possible, dairy cows of different types may be brought to the school grounds and studied first hand. The teacher should enlist the services of the county agent in this work.

Write to the Division of Agricultural Instruction, States Relations Service, U. S. Department of Agriculture, Washington, D. C., for lists of lantern slide sets with lecture syllabi on the different phases of dairying. These sets of slides are loaned to teachers free of charge.

THE HOME PROJECT.

It is agreed by teachers of agriculture that instruction in that subject should follow certain definite lines: (1) It should be seasonal. (2) It should be local in its interests and development. (3) It should meet the interests of the pupils. (4) It should be practical. The home-project plan affords the best means of meeting these conditions, especially the practical side. The pupil is working out for himself the principles and theories taught in the classroom.

The term "home project," applied to instruction in elementary and secondary agriculture, includes each of the following requisites: (1) There must be a plan for work at home covering a season more or less extended. (2) It must be a part of the instruction in agriculture of the school. (3) There must be a problem more or less new to the pupil. (4) The parents and pupil should agree with the teacher on the plan. (5) Some competent person must supervise the home work. (6) Detailed records of time, method, cost, and income must be honestly kept. (7) A written report based on the record must be submitted to the teacher. This report may be in the form of a booklet. The club project should be identical with the home project from the school point of view.

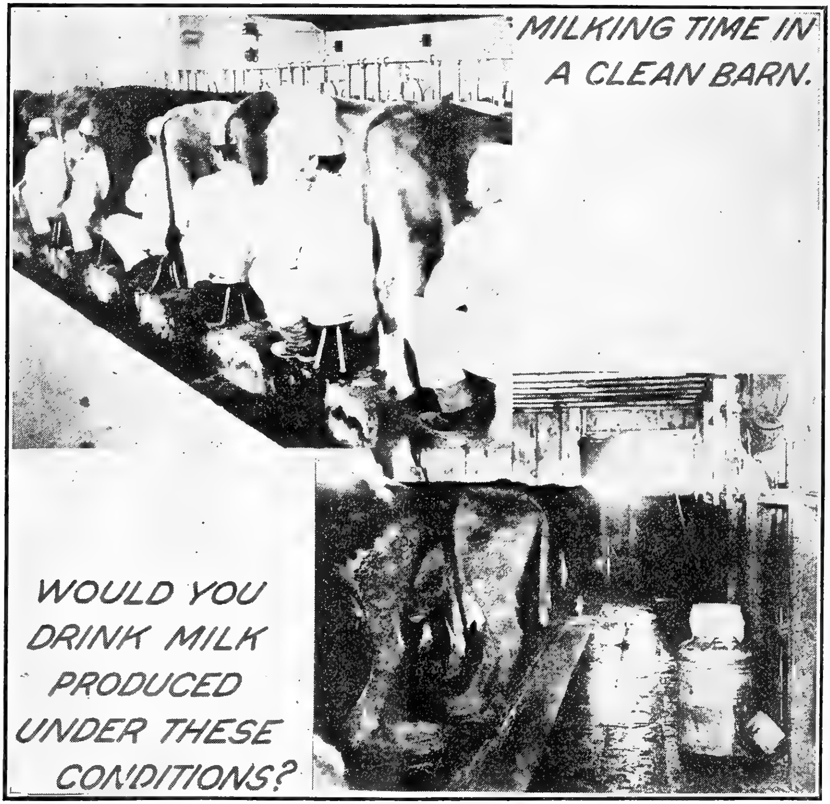

FIG. 1.—Contrasted milking quarters.

The home-project work may take two distinct directions in this series of lessons. One, project A type, will be the business phase of the subject of dairying and will include clean milk production, weighing and testing, marketing, computing profit and loss, inspection of the herd, judging, and purchasing. The other, project B type of work, will bear a close relation to the home and will develop more the home economics side. It will begin with the production of clean milk and include care and handling, manufacture of dairy products, use of milk in the home, food values, use of by-products of milk, and cooking with milk.

The general dairy practice of the district will in some measure determine the direction of the project, although the second type of home project is important to develop in any dairy community.

LESSON I. PRODUCING CLEAN MILK.

Sources of information.—Farmers' Bulletins 602, 748, 976, and 1019. Department Bulletin 642. Bulletins from the State agricultural college.

Topics for study.—Meaning of clean milk: If milk is kept comparatively free from bacteria at source of production and is kept cold, the chances are good of its reaching the ultimate consumer carrying only a comparatively small number of bacteria.

Types of bacteria in milk: Upon what does the number of bacteria in milk depend?

Sources of milk contamination: From the udder, dust in air and on udder and flanks of cow, the milker, unclean milk utensils, impure water supply, and disease in the herd. (Fig. 1.)

Importance of clean milk: Less danger to the consumer of contracting disease, keeps sweet longer, and makes higher grade of products.

Relation of milk to health: Unclean milk sometimes cause of outbreaks of epidemics; clean milk important to the producers; protection to health of family; better prices for milk; satisfied customers.

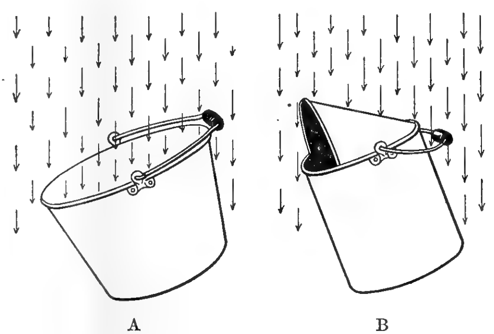

FIG. 2.—Two types of milk buckets: (A) Open top, undesirable; (B) top partially covered, desirable.

How to obtain clean milk: (1) The care of the cow—health, test for tuberculosis, condition of udder, external condition, dirt on body, grooming, washing, clipping, bedding, disposal of manure, feed, fresh water.

(2) The stable—location, surroundings, drainage, ventilation, sunlight, floors, stalls, cleanliness.

(3) The milkhouse—location, arrangement, ventilation, cleanliness, equipment, water supply, etc.

(4) Utensils—material, cleaning, sterilizing, need of cleaning.

(5) Milking—where cows should be milked; care of cow before milking (grooming and cleaning); preparation by the milker (clothing, hands, milking-stool, milk-pail); types of pails (fig. 2); dry hand versus wet hand milking. Stress importance of the milker's health and the danger of contagious diseases being transmitted by the milk.

(6) Cooling milk—water tanks, ice houses. (Write Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture, for information.)

Practical exercises.—Cleaning cow stable, brushing and washing cow before milking.

Care of milk utensils, seeing that they are properly washed, sterilized, and aired.

Testing of milk, as follows: Take a sample of milk from a cow whose flanks and udder have not been cleaned and another from a cow that has been cleaned. Set them together and note which sours quicker. Make sediment test as follows: Strain a quart of milk through absorbent cotton and note the sediment collected on the cotton (sediment tests may be made of the milk of the cows from different farms); carefully dry these cotton pads and place them on exhibition. Compare the sediment tests. Account for the different results. If there is a commercial dairy in the district, sediment tests may be made of this milk. Make survey of sanitary conditions of the barn, milking place, and place where milk is handled after milking, reports to be made in writing (owners' names need not be mentioned). In this survey, score the farms using the score card printed in the supplement (see p. 28), extra copies of which may be obtained upon application by the instructor to the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture, Washington, D. C.

Illustrative material.—Mounted specimens of sediment tests (fig. 3), showing tests under different conditions, may be made by pupils and teacher. Pictures of model dairy farms and dairy barns may be mounted on pasteboard. Samples of various forms of milk pails may be borrowed from either a dealer or from homes in the district. These may be brought before the class and inspected. In case neither are available, drawings of these pails can be made and mounted for class use.

Home projects.—The production of clean milk will lend itself to either project A or project B. Students should now select the type of project they are to work out, and begin with the production of clean milk. Practicums may include milking the cow under sanitary conditions, care of the stable, and care of the milk vessels.

Correlations.—A written report of a visit to a dairy barn or farm, with special attention to the production of clean milk, will make a good lesson in language. Other reports on tests for sediment, and on clean dairy practice, will also be of use in language classes. A booklet prepared on the entire lesson, with a record of the dairy practice of the community, will make an excellent language project.

The pupils may assist in the preparation of illustrative charts giving practice work in drawing.

A discussion of bacteria, both harmful and useful, their methods of growth and reproduction, how they cause disease, the manner in which they are carried from place to place, the ways in which they enter the body, and methods of control and prevention may be studied with profit in the subject of physiology and hygiene.

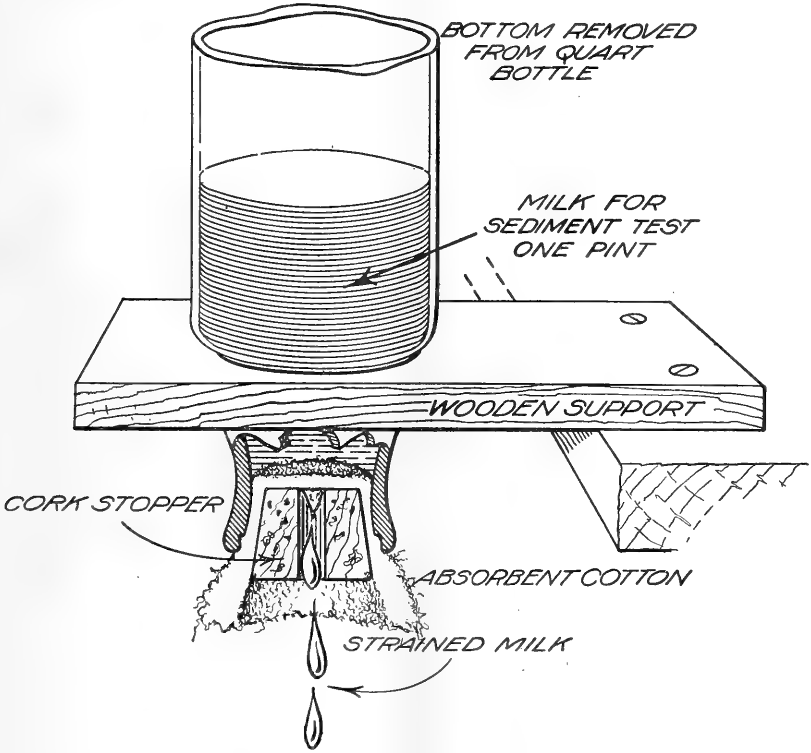

FIG. 3.—Simple apparatus for sediment test.

LESSON II. THE CARE OF MILK AND CREAM.

Sources of information.—Farmers' Bulletins 413, 490, 602, 623 689, 748, 976, and 1019. Bulletins from the State agricultural college.

Topics for study.—The milk producer having done his duty in delivering clean milk to the home, it then depends much upon the care and handling as to how long it will remain sweet and free from contamination.

How milk becomes unfit for food: (1) Placing it in unclean vessels. (2) Exposing it unnecessarily to the air. (3) Failing to keep it cold up to the time of using it. (4) Exposing it to flies. Discuss these sources and methods of handling in each case, and the tendency of milk to absorb bacteria, odors, and other impurities. Avoid having uncovered milk in close contact with food of any kind, especially strong-smelling foods.

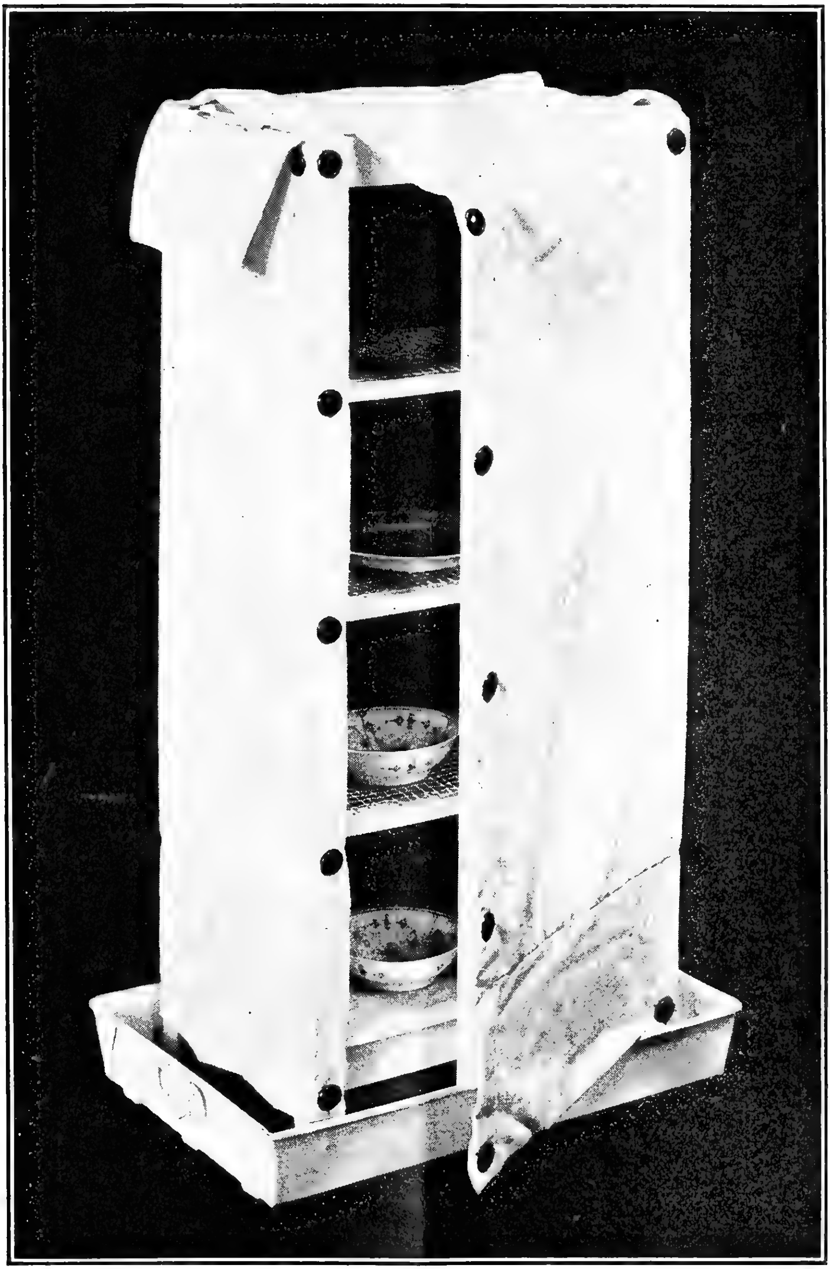

FIG. 4.—The iceless refrigerator.

Care of milk after milking: Straining—discuss best methods. Cooling—need of; how done. Coolers—the refrigerator, homemade cooler (fig. 4); care of the refrigerator; dangers of an unsanitary one. Care of vessels—cleaning, sterilizing. (See Farmers' Bulletin 748 for a simple sterilizer for utensils.)

Practical exercises.—Have some samples of clean milk brought to school and experiment with them as follows: Place some milk (1) in an unclean bottle, (2) in a bottle in which the milk is exposed to open air of schoolroom, (3) in another in which flies have been, and (4) in a bottle which has been thoroughly boiled for 5 minutes and carefully closed up. Place these bottles where other conditions will be equal, and note the time it takes each to sour and the changes that take place in each sample.

Have samples of various kinds of strainers brought to school. Strain milk samples through each, making a sediment test after straining, comparing each with the same test of unstrained milk. Dry the cotton pads and mount same with a label, giving description.

Pupils may construct under the teacher's directions a homemade refrigerator. In case the home has no refrigerator, the construction of one for the home may be made a short project.

Visit the creamery and note the methods of handling and cooling milk or cream, making a written report of the trip.

Illustrative material.—Collect samples of various kinds of milk bottles and covers, milk vessels, and strainers of various types. Clip and mount illustrations from dairy supply catalogues and farm journals, showing modern milk utensils. (Refrigerator dealers will provide ample material for the study of the refrigerator.)

Home projects.—The care of the milk and cream on the farm will be a part of either home project A or B, or the pupil may take this lesson alone as a shorter project. This would be practical if the milk was not prepared and sold. If the whole milk was marketed, then the handling and bottling and marketing of milk could be assigned as a project.

Correlations.—For language: A booklet on the care of milk in the home, illustrated by drawings or clipped pictures; reports neatly written of work done in practical exercises, and how the home takes care of milk and cream; report of the visit to the creamery.

For drawing: Sketches of equipment for handling milk, milk bottles, vessels, and strainers, mounted on cardboard, will give practical work in drawing.

LESSON III. WEIGHING.

Sources of information.—Write to the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture, for information. Consult with the dairy department, State college of agriculture; also with the county agent.

Topics for study.—To build up a herd of cows intelligently and to eliminate those that are not paying their way, it is necessary to keep adequate records of production, feeding, and breeding.

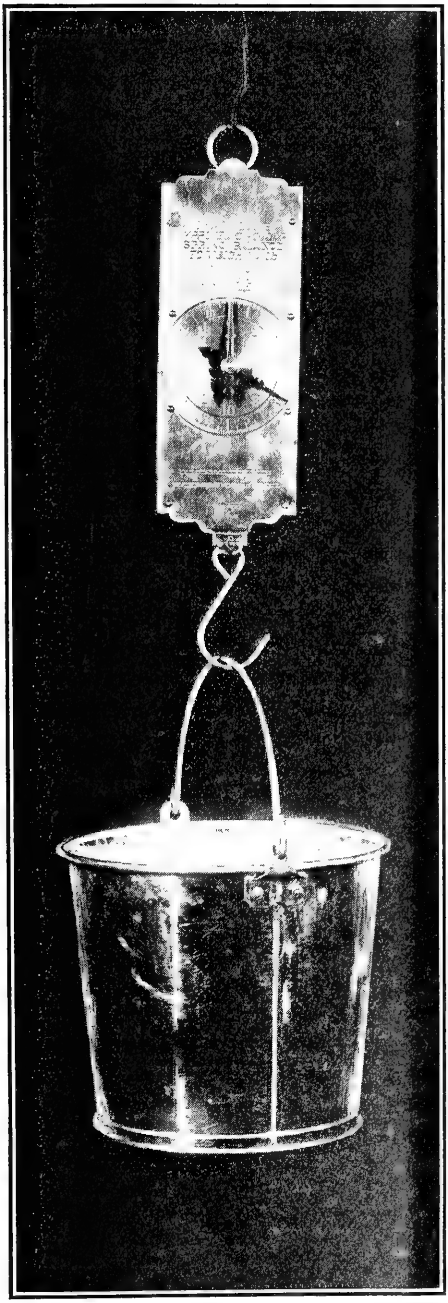

FIG. 5.—Outfit for weighing milk.

A simple piece of home work under direction may be developed so that the farm children may have valuable problems and at the same time obtain results that will be useful to the parents. Such a plan will establish a point of contact between school, home, and the child.

The equipment for weighing is simple, consisting of a spring balance reading in tenths of pounds (fig. 5), costing $3 to $5 if bought new, and a series of record sheets, which may be ruled by the pupil himself. What cows are being tested in the district? State the advantages of a milk record. How often should the milk be weighed?

Practical exercises.—Encourage the pupils to adopt the practice of weighing daily the milk of each cow. A contest in milk production will stimulate interest. Duplicates of the record sheets may be posted side by side in the schoolroom, where the pupils will have an opportunity of comparing records.

Illustrative material.—Copies of milk records of the best dairy cows may be obtained and posted in the classroom for inspection. The records made by the pupils may be compared with these records.

Charts showing a comparison between the records of these champion cows and the best cows of the district may be made by the pupils.

Home projects.—The weighing of milk and keeping a record of the same belongs to project A type, and may be assigned alone as a short-time project.

Correlations.—Construct various problems showing the difference and the percentage of difference in the weekly and monthly milk record of two or more cows; others showing the percentage of gain or loss in the milk record of a cow in consecutive weeks or months.

LESSON IV. TESTING.

Sources of information.—Bureau of Animal Industry (U. S. Department of Agriculture) Document A–12, Chemical Testing of Milk and Cream.

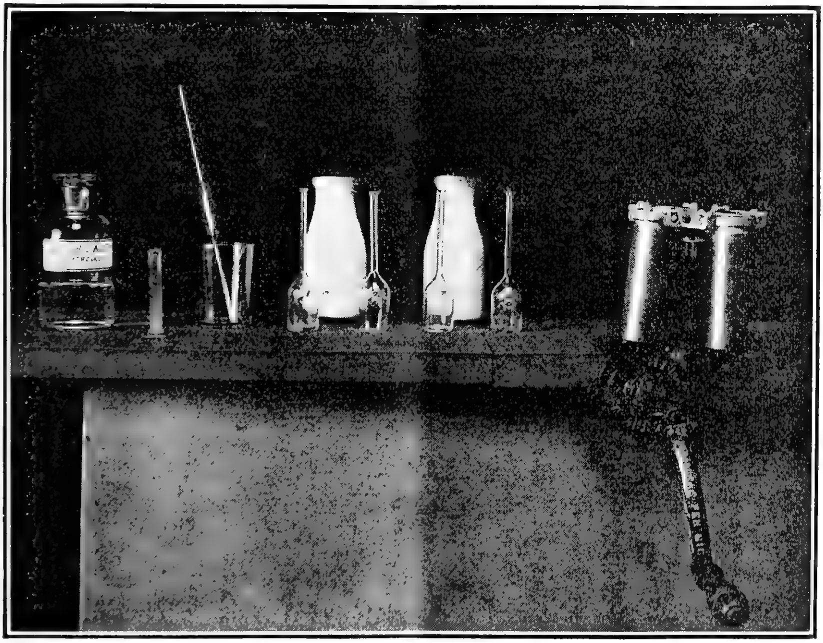

FIG. 6.—Outfit for testing milk.

Topics for study.—A simple Babcock tester should be a part of the equipment of every rural school (fig. 6). A machine may be purchased for a small sum or, in case no fund for its purchase is available, one can probably be borrowed from some dairy farmer in the district.

Require the pupils to bring to school samples of milk and give them practice in testing milk. First have the test made by two students, and be certain the entire class understands each step in the process. Then divide the class into groups and supervise them until they are reasonably accurate, using milk from one cow only as a check. When they have learned to make the test accurately, they should select carefully samples of milk and make the test to determine the value of the cows at home as butter-fat producers.

The members of the class having Babcock testers at home should be required to make reports on the tests made. (*Caution.*—Too much emphasis can not be placed upon the danger of burns from the careless handling of sulphuric acid. Pupils should be warned to be very careful in handling it.) Give the pupils opportunity to test the milk at home regularly, and encourage them to combine the records of weighing milk at home with these tests at school to find the butter-fat production of each cow.

Practical exercises.—A junior cow-testing association may be organized among the members of the class. The cows at home may be tested by the class, observing the rules of the association and keeping records of same.

Illustrative material.—Construct charts showing the comparative amounts of butter fat in the milk of different cows; others showing the total amount produced in a given period; others showing the records of the best cows of the district.

Home projects.—Project A will require the testing of the milk of the dairy cows. For other projects, the weighing and testing of a dairy cow for a long or short period; the testing of the milk of a dairy herd and keeping the records.

Correlations.—Write up reports of the milk tests made at school and at home. Have the pupils make sketches of the parts of the milk-testing equipment, and charts showing quantity of butter fat in the milk of different cows.

Find how many pounds of butter fat in 3,000 pounds of milk testing 4.2 per cent.

A farmer has 12 cows in his dairy herd, each averaging 25 pounds of milk daily. How many pounds of milk does he get in 30 days? If the milk tests 4.3 per cent butter fat, how many pounds produced each day; for the 30 days? Find its value at $37\frac{1}{2}$ cents per pound.

Develop similar problems from information gathered at home.

LESSON V. RECORDS AND MARKETING.

Sources of information.—State agricultural college bulletins.

Topics for study.—This lesson follows naturally after the lessons on weighing and testing. The three are so closely related that one can not be taught successfully without the others. It would be the best thing for the teacher to teach these three lessons as parts of a unit.

Review briefly the methods of weighing and testing. Discuss the advantages of each. Suggest that neither could be of any permanent service unless records were made. Discuss how and when to make records. Suggest simple forms for the pupils to make. In what form is the milk of the district sold? Are any provisions made for cooperative marketing? What special provisions have been made for selling butter? Is the milk sold locally or shipped to other markets? If shipped, to what markets does it go?

What are the regulations in your district concerning the handling of milk? What devices and sanitary conveniences have the dairy farms for the handling and marketing of milk?

What is the amount and value (estimated) of the milk sold in the district? Of the cream? Other dairy products? Make a comparison between the amount of milk produced and the amount marketed.

Practical exercises.—Require the students to rule their own forms and to keep records of both weights of milk and percentage of butter fat, making separate records for each cow in the herd. This may be extended over a period of time making a good home project. In addition to the milk and butter fat record a feed record may also be kept.

Problems.—A farmer has two cows, each producing 6,000 pounds of milk yearly. The first cow's milk yields 3.2 per cent butter fat, and the second, 5.8 per cent. What is the difference in fat produced by the two cows? Suppose the fat is worth 37½ cents per pound. What is the money value of the butter fat yielded by each cow?

The same farmer has two other cows. The first gives 8,000 pounds of milk testing 3.2 per cent butter fat; the second gives 5,000 pounds of milk testing 5.6 per cent butter fat. Which is the more valuable cow? Construct other problems, using local records.

Home project.—The home project of type A may be assigned to the pupil beginning with the production of clean milk, and ending with the marketing of the same, keeping all records and summarizing at the close of the project period, which may cover several weeks, showing the total cost of production, gross returns, and net profit or loss.

LESSON VI. PROFIT AND LOSS—GOOD AND POOR COWS.

Sources of information.—Farmers' Bulletins 578, 589, 743, 893, and 993.

Topics for study.—The final results of testing and weighing the milk production of a dairy cow will be to determine whether she is not only paying her way but also returning to her owner a fair margin of profit. These facts may be definitely discovered by comparing milk records with feeding records and other costs, and striking a balance to determine losses or gains.

Impress upon pupils (1) the need of records and tests; (2) the importance of studying the records, drawing comparisons and striking balances, with the final end in view of determining whether the dairy cow in question is worthy of her keep.

How many cows in the district whose records are being kept? How many farms that keep dairy cows? Are the pupils keeping records at home? What organizations among the local dairy farmers? Suggest the organization of a cow-testing association.

Practical exercises.—Comparative charts showing the standing of two or more cows in milk production, pounds of butter fat and cost of feed, may be made by the pupils, using data they have obtained

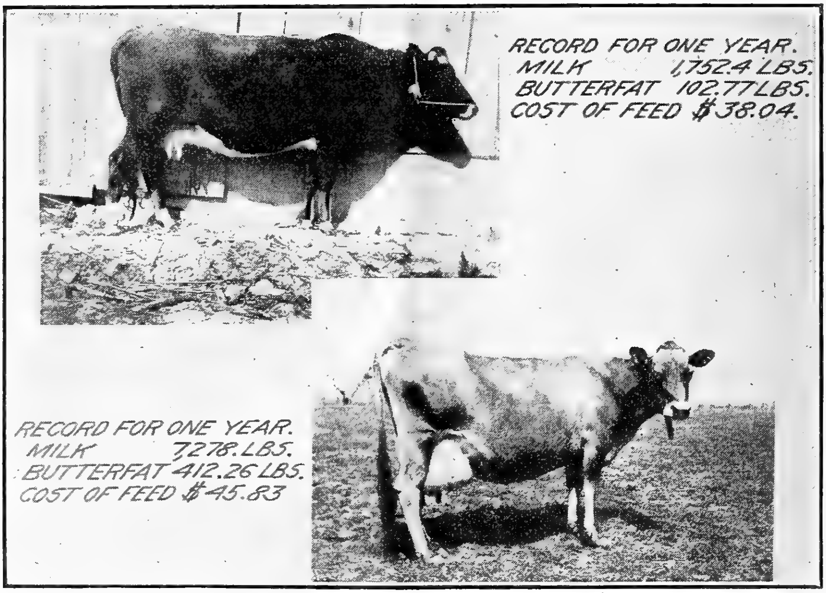

FIG. 7.—Contrasting types of dairy cows.

from their own work in preceding lessons. Problems on costs, production, profits, and losses should be constructed, the aim of this lesson being to impress forcibly the need of knowing what the dairy cow is really doing, thereby eliminating the unprofitable cow, or having an opportunity to develop the profitable one. (Fig. 7.)

LESSON VII. JUDGING AND PURCHASING.

Sources of information.—Farmers' Bulletins 355, 743, and 893. Department Bulletin 434.

Topics for study.—The unprofitable cow being discovered, the problem now is one of discarding the nonpayer and purchasing the profit-making cow.

A brief study of the types of dairy cows and of the points of a dairy cow should be made. (Fig. 8.) Send to your State agricultural college or the U. S. Department of Agriculture for a score card for dairy cows, and study it carefully.

Chief breeds of dairy cows: Origin, characteristics of each, milk and butter fat records.

The points of a good dairy cow.

The champion milk and butter fat records in the United States. The amount of milk produced, together with the percentage of butter fat in same, determines the value of the cow.

Sources of income: Milk and butter fat. Market requirements.

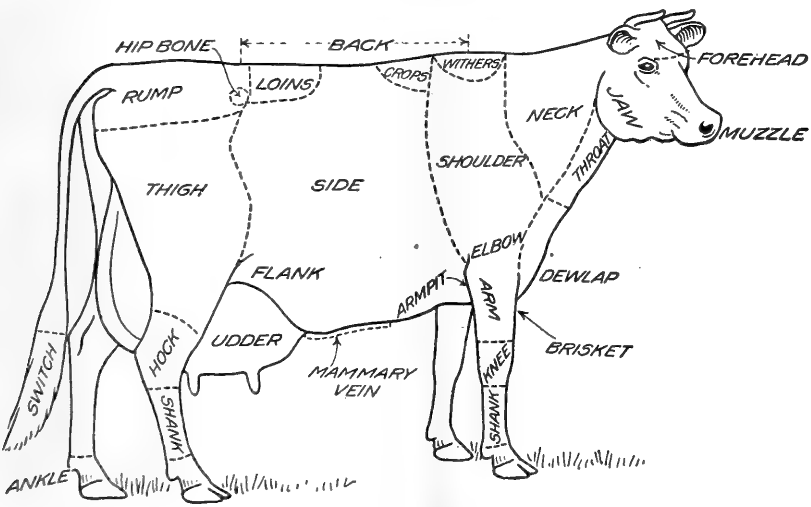

FIG. 8.—Chart showing the parts of a dairy cow.

Breeds prevailing in the community; personal preference; nature of the country and climate; current price; estimate of the future of the breed.

Practical exercises.—Visit a dairy farm in the district and make a study of the types of dairy cattle. Secure cooperation of county agent for exercises in judging dairy cows. From the dairy survey prepare a report showing the number and breed of pure-bred cows, grades, and scrubs. Make a study of the milk and butter produced by these cows. What breed of dairy cow most common in the district? Is there any special reason for this? What herds could be improved? How many farms have pure-bred stock? What breed is your cow?

Illustrative material.—Cut out pictures of dairy cows of different breeds, mount them on cardboard, and paste below a brief description of the cow as to origin, records, etc. Collect and mount pictures of famous dairy farms. If there be any good dairy farms or herds in the district, apply to the owner for photographs of his cows and farm.

If possible, make local photographs of the profit-making cows and the nonpayers and mount them together with their records on the same card.

Home projects.—Project A will be well nearing completion when the dairy herd is culled and selected. A good type of project will be to weigh, test, record, and make comparisons between cost and production to be in position to discard the cow that does not pay a profit.

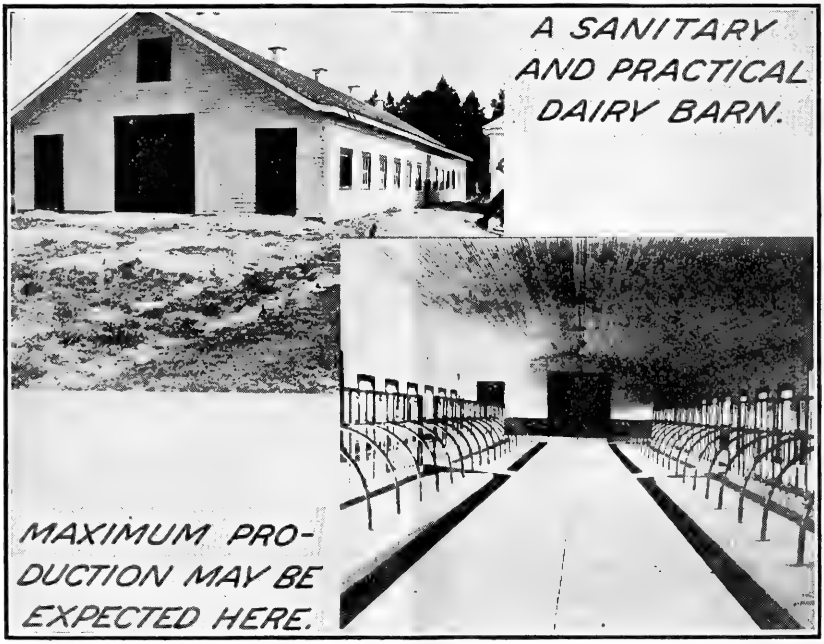

Fig. 9.—A good type of dairy barn.

Correlations.—Compute the value of the dairy cows of the district. Make an estimate of the value of the milk produced in one month.

Compare the purchase price of a good dairy cow with the net value of her milk production for a year; estimate the percentage of profit she pays on the investment.

Make out a written report on the different breeds of dairy cattle in the district. Locate the original homes of these breeds. On a map of the United States locate the chief dairy sections, and find out, if possible, the prevailing type of dairy cattle in each section.

What noted dairy herds in your State? What breeds are they?

LESSON VIII. CARE AND HANDLING OF THE DAIRY COW AND BARN.

Sources of information.—Farmers' Bulletins 578, 602, 689, and 777. Bulletins from the State college of agriculture.

Topics for study.—Care of the cow: The cow must be in good health; tests must be made for tuberculosis.

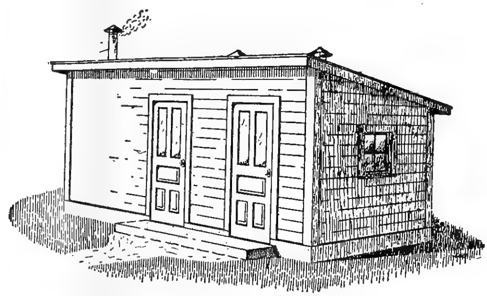

Fig. 10.—An inexpensive sanitary dairy house. Perspective view.

Comfort: Roomy quarters; clean bedding. Feed: Clean, wholesome feed; balanced rations. (Avoid moldy and decayed feeds.) Water: Clean and fresh; free from contamination; provisions for warming in cold weather.

Regular handling: Feed and milk at definite hours. If a change of feed is made, make this change gradually.

Pleasant surroundings: No ill-treatment or abuse, scolding or chasing. Is the practice of sending the dog to chase up the cows at milking time a good one?

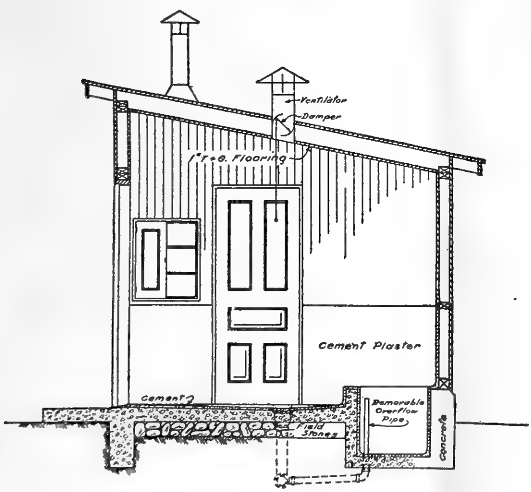

Fig. 11.—Cross section through dairy house shown in figure 10.

The barnyard: Dry, well drained, clean, south exposure, protected from winds.

The stable (fig. 9): Located on high ground; good natural drainage; free from places where flies may breed; provisions for removal of manure; separation of cows from other animals by a tight partition, walls and ceiling tight; 4 square feet of glass to each cow; ample ventilation; floors kept clean by sweeping and washing, walls kept free from dirt; stalls comfortable and easy stanchions provided.

The milk house (figs. 10, 11, and 12): Location—convenient to stable, but free from dust and odors, and well drained. Purpose—to provide a place where dairy products may be handled; planned to save labor. (Farmers' Bulletin 689 shows a good plan.) Cleanliness always kept in mind—concrete floors, round edges; tight ceilings; screened doors and windows; plenty of sunlight; ample supply of cold running water, clean and convenient.

Practical exercises.—Inspect a dairy barn or stable for the points mentioned, making a written report on the same. Similar reports may be made on the barns and stables of the district, names being omitted, and the reports being written. Similar reports can also be made on the care and treatment of the cow.

Make models of sanitary dairy barns, stalls, stanchions, milk houses and a list of equipment. Make trips to various milk houses. Note the handling of commercial milk both by the dairies and farmers.

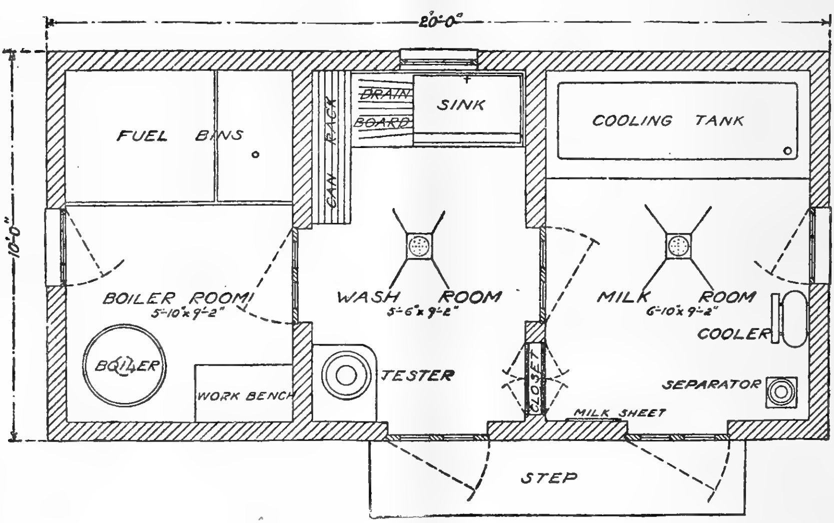

FIG. 12.—Floor plan of dairy house, showing general arrangement.

Draw a plan of the arrangement of the stables inspected, and compare this plan with the plans of a model dairy barn. (Write to the U. S. Department of Agriculture and to the State agricultural college for bulletins and other information about dairy barns and milk houses.)

Correlations.—Prepare reports in the form of booklets on the correct care and handling of the dairy herd, and contrast this with the general method of the district.

Write up a report of a visit to a dairy farm. Prepare a report on the general conditions in the district concerning places of handling milk.

Make drawings of some of the stables of the district. Prepare a plan of a dairy barn of the district, and, by way of comparison and contrast, make a copy of the plan of a model barn, plans of which may be obtained from the State agricultural college.

LESSON IX. BUTTER MAKING.

Sources of information.—Farmers' Bulletin 876. State college of agriculture bulletins.

Topics for study.—Extent and importance of butter making on the farm. Quality and preparation of cream. Cream separation methods—gravity, shallow pan, deep setting, dilution, centrifugal. What is the chief disadvantage of the dilution plan? Discuss advantages of each plan.

Cream separator—kinds, location, setting up, running, cleaning. When is it advisable for a farm to own a separator?

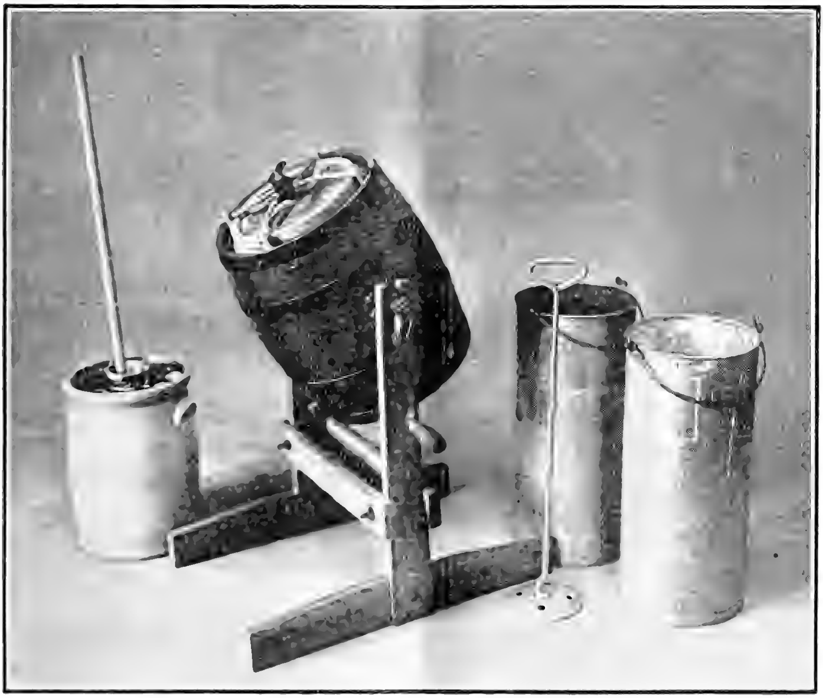

FIG. 13.—Apparatus for butter making.

Cooling the cream—various methods; an inexpensive plan for the farm home; ripening; usual plan; cause of souring; importance of correct temperature and proper ripening; creamery methods of ripening; the "starter" method, directions for making and using.

Churning—time, temperature; results of too high a temperature; preparing the churn; adding color; churning; difficult churning.

Preparing the butter for use—washing, salting, working; discuss each.

Show results of butter not properly washed, salted, and worked. The package. Equipment for farm butter making. (Fig. 13.)

Summary of steps in butter making.

Practical exercises.—With small shallow pans and with deep bottles using the same amount of milk from the same cow, demonstrate the difference between shallow pan and deep setting methods of separation. If possible, secure the loan of a cream separator from a dealer, or borrow one from a home in the district. Make a study of the parts of the separator, having the class become familiar with its parts. Demonstrate its use. Give practical demonstration of running the separator and of cleaning its parts after use. Impress upon the pupils the need of keeping it thoroughly clean. If a small churn can be borrowed, an exercise in churning should be given, followed by a demonstration in washing, salting, and working the butter.

A visit to the grocery stores will show very clearly the advantage of the neat package, both as to appearance and as to price of the butter per pound. A butter-making contest may be held, and the butter judged by a score card, copies of which may be obtained from the State agricultural college, or use the one suggested on page 29.

This contest may also be developed into a community contest, inviting the parents to take part. It should be held at the schoolhouse. The assistance of the county agent should be obtained. A practical demonstration of correct butter making should be given, and at the same time the modern butter-making equipment should be assembled. The dealer will usually leave with the teacher any or all of the equipment.

Home projects.—The use and care of the separator for a given period. If no separator is available in the home, then the pupil may separate the cream by one of the other processes, preferably the deep-setting method, writing up an account of her work.

Ripening the cream, churning and preparing the butter for either sale or table use may be given to the pupil for a useful project. Where butter making is the manner in which the milk is disposed of, a butter record of the dairy cows, comparing the income therefrom with the cost of feed, or a comparative study extending over a period of 60 days, showing the results from the sale of cream with those from the sale of butter, may be made.

Correlations.—If the milk has been tested for butter fat, problems showing the difference between the butter fat in a given weight of milk and the actual butter produced from the same weight, and the percentage of gain or loss should be computed. Problems showing the income from the sale of whole milk and the sale of butter should be made, and others showing the relative incomes from the sale of cream and the sale of butter, taking into consideration only the amount of each produced and the sale price.

The pupils may write up a description of a separator and its use. They may prepare a booklet on butter making, a neat cover design, and write up the various steps in butter making, illustrating these steps either by original drawings or by pictures clipped from various sources.

LESSON X. FOOD VALUE OF MILK. ITS USE IN THE HOME.

Sources of information.—Farmers' Bulletins 363, 413, 717, and 824. Bulletins from the State college of agriculture.

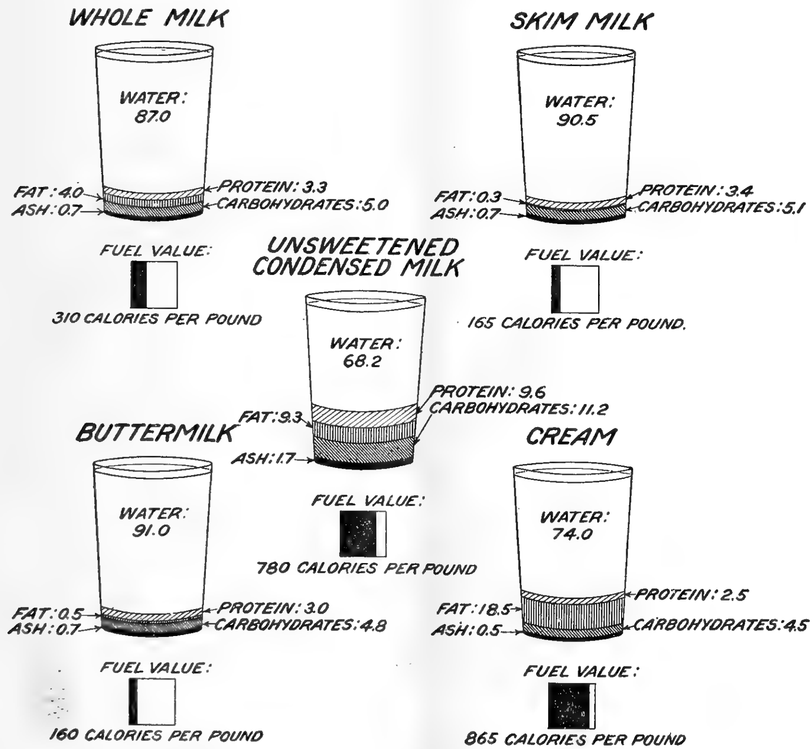

FIG. 14.—Percentage composition and fuel value per pound of whole milk and some milk products. The constituents are expressed in per cent, the fuel values in calories per pound.

Topics for study.—Kinds of milk. Composition and characteristics of whole milk, skim milk, condensed milk, buttermilk; flavor. Importance of clean milk. Sources of dirt. Milk as a disease carrier.

Methods of preserving milk—cold, heat. What are the advantages and disadvantages of each method?

Digestibility of milk; compared with other foods. Review the process of digestion. Relative value of cooked and raw milk. Milk for infants—special infant foods.

Compare nutritive value of milk with other common foods. (Fig. 14.) Of what food value is skim milk? Compare costs of nutrients in milk with those in other foods. What can you say of the cost of milk as a food when compared with other foods? Compare the food value of a quart of milk with meat and eggs and reach a conclusion as to the economy in the use of milk as a food.

Use in home—milk dishes; in bread, soups, desserts, milk products, butter, cheese, buttermilk, whey, clabber, and fermented milk products.

Practical exercises.—Construct a chart showing the composition of milk; another showing comparative food values of milk and other foods.

Make a report on the amount of milk used as food in the homes of the district, and state the ways in which it is used. Determine also what milk products are used as a food in the home. How is the skim milk disposed of?

Illustrative material.—Secure from manufacturers samples of milk foods and forms of commercial milk products. Place these on exhibition.

Construct a chart showing the composition of milk. Make up a collection of recipes wherein milk is largely used. Construct a chart showing the ways in which milk and its products may be used as food.

Correlations.—The preparation of milk dishes both at home and in school affords work for the class in home economics. A study of foods and food values belongs both to home economics and physiology. In the physiology class, a study of digestion in general, and tracing the digestion of milk will give a valuable lesson.

LESSON XI. COTTAGE CHEESE.

Sources of information.—Farmers' Bulletins 363, 413, and 850. Office of Secretary Circular 109.

Topics for study.—Cottage cheese as a desirable food. Quality and requisites—quality of milk the first consideration; clean utensils.

A simple process for home use—souring, forming the curds, cutting, heating, straining, working, flavoring, and storing. Use of starters—homemade, commercial. Pasteurization.

Cottage cheese making on a large scale—setting, cutting, heating and stirring, drawing and salting; making cheese with rennet and pepsin; yield of cheese; marketing; home equipment.

What is the food value of cottage cheese? Suggest combinations with other foods that will restore the balance. This will lead to the preparation of special cottage cheese dishes in combinations with other foods. This is an excellent way to use skim milk.

One hundred pounds of skim milk fed to hogs produces 4.8 pounds of dressed pork, while if made into cottage cheese, it will produce 15 pounds of cheese, and will furnish nearly seven times the amount of protein and nearly as much energy. Therefore skim milk should be used as a human food, and only the excess fed to farm stock.

Practical exercises.—Cottage cheese may be made in the schoolroom. The milk may be donated, and the equipment needed may either be donated or purchased. The cottage cheese thus made may be used for a part of the school lunch.

For a practicum, the students may make cottage cheese at home, making a written report upon the process. A "Cottage-cheese week" campaign may be held and not only the pupils, but the housewives should be encouraged to make and use cottage cheese during the week. Charts can be made showing the comparative value of cottage cheese with other foods. Assemble a model equipment for making cottage cheese.

Correlations.—The use of cottage cheese in connection with the daily meals; cottage cheese in combination with other foods to make a balanced ration.

All these may be worked out in connection with the lessons in home economics.

LESSON XII. THE USE OF MILK AND ITS PRODUCTS IN COOKERY.

Sources of information.—Farmers' Bulletins 363, 413, 487, 717, 824, and 850.

Topics for study.—Review food value of milk. Discuss value of milk as a food for children.

Ways to use milk in cooking—white sauce, milk soups, chowders, cereals cooked in milk, and desserts made from milk.

Skim milk—nutritive value; uses—in general cooking, for cottage cheese and whey or clabber.

Cheese—comparison with other foods; food values; its economical use in the diet.

Cheese dishes in place of meat—cheese fondue (equal to a pound of beef), cheese soufflé (equal to a pound of beef and a pound of potatoes), baked rice and cheese (equal to one-fourth pound of beef).

Practical exercises.—Have the pupils make a list of recipes wherein milk and milk products are used in cooking; prepare another list wherein milk is used as a supplement to other foods. Some of the recipes may be prepared in the schoolroom, and used as a part of the school lunch; others are to be worked out at home. Especial attention is to be paid to the use of milk and milk products to supplement other foods.

A day may be set apart as "Milk food day," and small prizes given for the best display of dishes cooked with milk or milk products, and others for milk dishes used as a substitute. The patrons of the district should be invited and the county agent should be asked to be present and to lecture on milk.

Illustrative material.—Charts showing food values have already been suggested in former lessons. Sets of charts showing the comparative value of milk and its products may be made and will prove of service to the class.

Home projects.—This lesson offers home project work of the second type, and is closely related to similar work in home economics. Pupils may undertake projects of short time duration in cooking with milk or in using milk dishes or milk products. In either case, the work should be carefully written up, the recipes copied in the report, and a summary of the work made with some comparative costs and food value.

Correlations.—The study of foods and food values, milk, and its use as a food, may well be correlated with the lessons in physiology. The home economics class will find abundant material for practice work in this lesson. They may prepare the recipes suggested, copy them neatly on separate cards, and file them, one set being prepared for the school, and each pupil preparing a set for home use. Menus containing the balanced ration in which milk is largely used, may be planned and worked out both at home and at school. The preparation of other dishes to go with the milk dishes will form another series of lessons in home economics.

In language work, written exercises telling how the dishes were prepared, the careful writing up of the recipes, and reports on home project work will be found useful.

For arithmetic, a series of problems in which the cost of milk and eggs and the cost of is milk found and a comparison made, will be found valuable exercises.

SUPPLEMENT.

DAIRY COW SURVEY OF THE DISTRICT.

District.................. Town.................... State....................

Teacher.. Date................

Pupils' survey committee...

Farm and location.	Breed.	Number of cows.			Estimated value of each.	Sires.	Young stock.		Average production per cow.
		Pure bred.	Grade.	Scrub.			Pure bred.	Grade.	

DAIRY PRACTICE SURVEY.

Owner and location.	Feeding practice.				Average cost of feeding.	Milk disposal.						
	Feeds raised on farm.		Feeds purchased.									
	Roughage.	Concentrate.	Roughage.	Concentrate.		Total amount of milk.	Butter fat, per cent.	Whole milk sold, amount.	Cream sold, amount.	Butter sold, amount.	Home use, amount.	Fed to stock, amount.

DAIRY SURVEY—STABLE AND MILK-HOUSE CONVENIENCES.

The stable.							The milk house.						
									Equipment.				
Construction.	Drainage.	Floors.	Ceiling and walls.	Manure disposal.	Water supply.	Ventilation.	Construction.	Water supply.	Cooler.	Sterilizer.	Separator.	Milk pails.	Light, screens, and ventilation.

DISTRICT DAIRY COW SUMMARY.

Date....................

Breeds.	Number of cows.		Young stock		Purebred sires.	Total of breed.	Percentage of all.
	Purebred.	Grade.	Purebred.	Grade.			
Jersey							
Holstein							
Ayrshire							
Guernsey							
Scrub							
Total in district							

MILK AND FEED RECORD FOR THE MONTH OF ...., 19 .

Date of Babcock test.................... Owner of herd..........................

Address.................................. Name of reporter..........................

Name of cow.[1]	Total milk.	Butter fat.	Butter fat.	Butter or cream.	Price per gallon.	Price per pound.	Value.	Value skim milk fed.[2]	Value skim milk sold.[2]	Total value.	Cost of feed.	Income over feed cost.	Feed for the month.					
													Hay.	Silage or soiling crops.	Grains fed.			Value of pasture.
	Lbs.	*Per ct.*	*Lbs.*	*Lbs.*	*Cts.*	*Cts.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Cts.*

Cost of feed per ton.	Note when cows freshen, dry off, are bought, or are disposed of.	Remarks.

[1] Enter also names of dry cows and cost of feed.
[2] Price of skim milk fed, ... cents per hundred; skim milk sold, ... cents per gallon.

NOTE.—The instructor may obtain sample sheets of this record by applying to the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture.

DAILY MILK AND FEED RECORD FOR MONTH OF ...., 191 .

Owner of herd, ... Post office, ... State, ...

Name	....			....			....		
Breed	....			....			....		
Daily feed record	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–31
Pounds hay @ —— per ton	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pounds silage @ —— per ton	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pounds grain @ —— per ton	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pounds ..... @ —— per ton	.....	.....	.....	.....	.....	.....	.....	.....	.....
Days pasture @ —— per month	.....	.....	.....	.....	.....	.....	.....	.....	.....

Date.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
.... 1	.....	.....	.....	.....	.....	.....
.... 2	.....	.....	.....	.....	.....	.....
.... 3	.....	.....	.....	.....	.....	.....
.... &c.	.....	.....	.....	.....	.....	.....
.... 30	.....	.....	.....	.....	.....	.....
.... 31	.....	.....	.....	.....	.....	.....
Total	.....	.....	.....	.....	.....	.....

Total for month	....
Butter fat, per cent	....
Butter fat, pounds	....
Price per pound or gallon: Milk	....
Price per pound or gallon: Butter fat	....
Price per pound or gallon: Butter	....
Price per pound or gallon: Cream	....
Value	....
Value skim milk @ — cents per gallon or hundredweight	....
Total value	....
Cost of feed	....
Profit	....

NOTE.—The instructor may obtain sample sheets of this record by applying to the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture.

SANITARY INSPECTION OF DAIRY FARMS.

Score Card.

Indorsed by the Official Dairy Instructors' Association.

Note.—Reverse side may contain information concerning owner, number of cows, milk production and disposal, and inspection.

Equipment.	Score. Perfect.	Score. Allowed.
COWS.		
Health	6	......
Apparently in good health 1		
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed 5		
(If tested within a year and reacting animals are found and removed, 3.)		
Food (clean and wholesome)	1	......
Water (clean and fresh)	1	......
STABLES.		
Location of stable	2	......
Well drained 1		
Free from contaminating surroundings 1		
Construction of stable	4	......
Tight, sound floor, and proper gutter 2		
Smooth, tight walls and ceiling 1		
Proper stall, tie, and manger 1		
Provision for light: Four square feet of glass per cow	4	......
(Three square feet, 3; 2 square feet, 2; 1 square foot, 1. Deduct for uneven distribution.)		
Bedding	1	......
Ventilation	7	......
Provision for fresh air, controllable flue system 3		
(Windows hinged at bottom, 1.5; sliding windows, 1; other openings, 0.5).		
Cubic feet of space per cow, 500 feet 3		
(Less than 500 feet, 2; less than 400 feet, 1; less than 300 feet, 0.)		
Provision for controlling temperature 1		
UTENSILS.		
Construction and condition of utensils	1	......
Water for cleaning	1	......
(Clean, convenient, and abundant.)		
Small-top milking pail	5	......
Milk cooler	1	......
Clean milking suits	1	......
MILK ROOM OR MILK HOUSE.		
Location: Free from contaminating surroundings	1	......
Construction of milk room	2	......
Floor, walls, and ceilings 1		
Light, ventilation, screens 1		
Separate rooms for washing utensils and handling milk	1	......
Facilities for steam	1	......
(Hot water, 0.5.)		
Total	40	......

Methods.	Score. Perfect.	Score. Allowed.
COWS.		
Clean	8	......
(Free from visible dirt, 6.)		
STABLES.		
Cleanliness of stables	6	......
Floor 2		
Walls 1		
Ceilings and ledges 1		
Mangers and partitions 1		
Windows 1		
Stable air at milking time	5	......
Freedom from dust 3		
Freedom from odors 2		
Cleanliness of bedding	1	......
Barnyard	2	......
Clean 1		
Well drained 1		
Removal of manure daily to 50 feet from stable	2	......
MILK ROOM OR MILK HOUSE.		
Cleanliness of milk room	3	......
UTENSILS AND MILKING		
Care and cleanliness of utensils	8	......
Thoroughly washed 2		
Sterilized in steam for 15 minutes 3		
(Placed over steam jet, or scalded with boiling water, 2.)		
Protected from contamination 3		
Cleanliness of milking	9	......
Clean, dry hands 3		
Udders washed and wiped 6		
(Udders cleaned with moist cloth, 4; cleaned with dry cloth or brush at least 15 minutes before milking, 1.)		
HANDLING THE MILK.		
Cleanliness of attendants in milk room	2	......
Milk removed immediately from stable without pouring from pail	2	......
Cooled immediately after milking each cow	2	......
Cooled below 50° F	5	......
(51° to 55°, 4; 56° to 60°, 2.)		
Stored below 50° F	3	......
(51° to 55°, 2; 56° to 60°, 1.)		
Transportation below 50° F	2	......
(51° to 55°, 1.5; 56° to 60°, 1.)		
(If delivered twice a day, allow perfect score for storage and transportation.)		
Total	60	......

Equipment................. Methods...................... Final score......................

Note 1.—If any exceptionally filthy condition is found, particularly dirty utensils, the total score may be further limited.

Note 2.—If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

The instructor may obtain sample sheets of this record by applying to the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture.

SCORE CARD FOR DAIRY COWS.

(Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture.)

Points.		Perfect score.	Per-centage value.	Stu-dent's score.	Instruc-tor's score.
1. General form		9			
Wedge shaped, when viewed from side, top, and front	6				
Size for the breed—Jersey, 800 pounds; Guernsey, 1,050 pounds; Ayrshire, 1,000 pounds; Holstein, 1,200 pounds	3				
2. Quality		7			
Hide—thin, mellow, pliable, and loose	2				
Hair—fine, soft	1				
Secretions—abundant, yellowish	1				
Flesh—muscular, free from bunchiness	1				
Veins—large and prominent	1				
Bone—fine and clean	1				
3. Head		6			
Forehead—broad between the eyes and dished according to breed	1.0				
Face—medium in length, clean cut in outline, dished below eyes	.5				
Nostrils large	1.0				
Muzzle—broad, but not coarse	1.0				
Jaws—wide at base, strong	.5				
Ears—medium sized, thin, hair fine, blood vessels showing, secretion abundant	.5				
Eyes—full, prominent, clear, and bright	1.0				
Horns—small at base, incurving, attached close together at poll	.5				
4. Neck		2			
Moderately thin, of good length, nearly free from loose skin, neatly joined, throat clean.					
5. Forequarters		11			
Shoulders—withers sharp; shoulder blades lean	2				
Chest—broad and deep, well-sprung fore-ribs; large heart girth; moderately full crops; brisket light	8				
Forelegs—straight, fine bone, strong	1				
6. Body—capacity		18			
Back—straight, strong, vertebræ prominent	5				
Ribs—long, flat, well sprung, wide apart	3				
Abdomen (barrel)—long, deep, broad, well held up; loin broad, strong, and level; flanks low	10				
7. Hindquarters		12			
Hips—wide apart, prominent	3				
Rump—long, wide, level	3				
Pin bones—widely spaced, on level with hips	3				
Thighs—incurving; escutcheon broad, extending well up on pin bones	1				
Tail—tapering, fine boned, long and neatly set on; switch, long	1				
Hind legs—squarely placed not sickle-hocked, bone fine	1				
8. Mammary system		35			
Udder—large; quarters even and not cut up between; extending well up behind and well forward in front; not fleshy; soft and pliable	20				
Teats—squarely placed; even in size; of convenient size for milking; free from lumps, not leaky or hard to milk	8				
8. Mammary veins and wells—veins long, branching, tortuous, entering body well forward; wells large	7				
Total		100			

Indicate score on the following basis: 1.0, perfect; 0.9, very slight defect; 0.8, slight defect; 0.7, defective; 0.6, marked defect; and 0.5, poor.

The number of points given for any particular part of the animal should be multiplied by the per cent given that part by the student. For example, an animal with defective wedges is given a rating of 0.7, which, multiplied by 6, the point allowed for perfect score, gives 4.2 as the final score for wedge-shaped.

BUTTER SCORE CARD.

	Scale.	Score.	Remarks.
Flavor	45		
Texture	25		
Color	15		
Salt	10		
Package	5		
Total	100		

SUGGESTIONS ON HOW TO MAKE A SIMPLE CHART TO REPRESENT THE COMPOSITION OF MILK.

Fourteen ounces water in a pint bottle.
One-half ounce melted butter in ½ ounce vial.
One-half ounce cheese (protein) in ½ ounce vial.
Seven-eighths ounce milk sugar in 1 ounce vial.
One-eighth ounce salt (mineral matter) in smallest vial.
Label neatly and mount on cardboard.

DAIRY BREEDERS' ASSOCIATIONS.

Letters addressed to the secretaries of these associations will bring interesting material for the use of the teacher.

American Guernsey Cattle Club. Wm. H. Caldwell, secretary, Peterboro, N. H.

American Jersey Cattle Club. R. M. Gow, secretary, 324 West Twenty-third Street, New York, N. Y.

Ayrshire Breeders' Association. C. M. Winslow, secretary, Brandon, Vt.

Brown Swiss Cattle Breeders' Association. Ira Inman, secretary, Beloit, Wis.

Holstein-Friesian Association of America. Frederick L. Houghton, secretary, Brattleboro, Vt.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO DAIRYING.

FARMERS' BULLETINS AVAILABLE FOR FREE DISTRIBUTION.

363. Use of Milk as Food.
413. Care of Milk and Its Use in the Home.
487. Cheese: Economical Uses in the Diet.
578. Making and Feeding of Silage.
602. Clean Milk: Production and Handling.
623. Ice Houses and the Use of Ice on the Dairy Farm.
689. Plan for a Small Dairy House.
717. Food for Young Children.
743. The Feeding of Dairy Cows.
748. A Simple Steam Sterilizer for Farm Dairy Utensils.
777. Feeding and Management of Dairy Calves and Young Dairy Stock.
824. How to Select Foods. III. Foods Rich in Protein.
825. Pit Silos.
850. How to Make Cottage Cheese on the Farm.
876. Making Butter on the Farm.
893. Breeds of Dairy Cattle.
927. Farm Home Conveniences.
930. Marketing Butter and Cheese by Parcel Post.
976. Cooling Milk and Cream on the Farm.
993. Cooperative Bull Associations.
1019. Straining Milk.

OTHER DEPARTMENT PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Office of Secretary Circular 109, Cottage Cheese Dishes.

Department Bulletin 744, Cooling Milk and Storing and Shipping It at Low Temperature.

Department Circular 26, Delicious Products of the Dairy.

Bureau of Animal Industry Circular 195, A Plan for a Small Dairy House.

Bureau of Animal Industry Circular 204, Officials, Organizations, and Educational Institutions Connected with the Dairy Interests.

Bureau of Animal Industry Document A-12, Chemical Testing of Milk and Cream.

FOR SALE BY SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Farmers' Bulletin 337, Cropping Systems of New England Dairy Farms. Price, 5 cents.

Farmers' Bulletin 349, Dairy Industry in the South. Price, 5 cents.

Farmers' Bulletin 490, Bacteria in Milk. Price, 5 cents.

Farmers' Bulletin 589, Homemade Silos. Price, 5 cents.

Department Bulletin 177, The Production and Consumption of Dairy Products. Price, 5 cents.

Department Bulletin 319, Fermented Milk. Price, 5 cents.

Department Bulletin 356, Milk and Cream Contests. Price, 5 cents.

Department Bulletin 434, Judging the Dairy Cow as a Subject of Instruction in Secondary Schools. Price, 5 cents.

Department Bulletin 642, The Four Essential Factors in the Production of Milk of Low Bacterial Content. Price, 15 cents.

Bureau of Animal Industry Circular 197, Directions for Home Pasteurization of Milk. Price, 5 cents.

Bureau of Animal Industry Circular 218, Legal Standards for Dairy Products. Price, 5 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 764

Contribution from Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. **PROFESSIONAL PAPER.** **July 5, 1919**

FACTORS INFLUENCING THE CARRYING QUALITIES OF AMERICAN EXPORT CORN.

By E. G. BOERNER,
Grain Supervisor.

CONTENTS.

INTRODUCTION.

Large quantities of American corn are normally exported to Europe each year. Investigations conducted by the United States Department of Agriculture have shown that a considerable amount of the corn exported previous to the World War arrived in Europe in a heated, damaged, and spoiled condition.[1]

During the latter stages of the war the authorities who had control of the shipping of large amounts of corn to Europe took steps to insure that only such corn as would safely stand any voyage without spoiling was exported. Some of the requirements imposed were more strict than appear to be necessary under normal conditions, and, since such normal conditions will again obtain after the close of the war, the data presented in this bulletin will be of general interest to the export trade.

The carrying qualities of export corn during shipment to Europe depend for the most part on the moisture content and the quality and condition of the corn as loaded, the length of the voyage, the season of the year during which shipped, the weather conditions during the shipment, and the position of stowage of the corn in the vessel. In order to determine the influence of each of these factors under varying conditions, eight representative cargoes of corn were accompanied from the United States to various European ports, and one additional cargo (cargo No. 5) was thoroughly sampled at the time of loading in America and again at the time of discharge in Europe.[2] In the investigations covering the cargoes which were accompanied to Europe, observations and tests were made daily from the time the corn was put into the vessels until it was discharged in Europe. During the loading of these cargoes, electrical resistance thermometers were placed at various definite positions in the corn. These thermometers were extended by "leads" to the deck of the ship so that they could be conveniently connected to a temperature indicator as illustrated in figure 2, thus making it possible to obtain a record of the changes in the temperature of the corn in the various positions of stowage. The temperatures were recorded each day that the weather permitted during the voyage.

As the electrical-resistance thermometers were being placed in the corn, 3-quart samples were taken from the corn surrounding each thermometer, with which to determine the changes in the quality

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[1] These data are given in U. S. Department of Agriculture, Bureau of Plant Industry, Circular No. 55. This publication, of which J. D. Shanahan, C. E. Leighty, and the writer are the authors, is now out of print. Since the investigations reported in this bulletin are a continuation of those discussed in Circular No. 55, the subject matter discussed in that publication regarding moisture content as a factor influencing the carrying qualities of export corn, germination, and fermentation in export corn, the keeping qualities of export corn influenced by its position of stowage in the steamship, and the length of the voyage and season of the year when shipped in relation to the carrying qualities of corn has been freely used in this bulletin in the discussion of those factors.

[2] Cargoes Nos. 1, 2, 3, and 8 were accompanied to Europe by the writer; cargoes Nos. 4 and 9 were accompanied by John H. Cox; cargo No. 6 was accompanied by Laurel Duval, and cargo No. 7 was accompanied by R. C. Miller, grain supervisors, formerly assistants in grain standardization. The investigations reported herein were made in the Office of Grain Standardization of the Bureau of Plant Industry under the direction of Dr. J. W. T. Duvel, crop technologist in charge. Since July 1, 1917, the grain standardization investigations of the Department of Agriculture have been administered by the Bureau of Markets in connection with the enforcement of the United States grain standards Act.

and condition of the corn during the voyage. One-half of each sample was retained for analyses and the other half put into a "trap" or crossed wire container, which was then fastened to the thermometer and recovered as the corn was being discharged in Europe. The purpose of using the wire containers was to secure certain definite samples with which to correlate the effects of the changes in temperature during the voyage on corn differing in moisture content and the degree of soundness at the time of loading. As will be shown later, the corn in the various vessels at the time of loading varied considerably in the factors of quality and condition. Likewise, a large proportion of the corn became hot and damaged while it was in the vessels. The records show that the quality and condition of the corn at the time of loading, the position of stowage in the vessel, the length of the voyage, the season of the year during which the corn was shipped, and the weather conditions during the voyage, each influenced, to a great extent, the carrying qualities of the corn during the time it was in the vessels.

MOISTURE CONTENT AS A FACTOR INFLUENCING THE CARRYING QUALITIES OF EXPORT CORN.

The moisture content of corn, and of other grains as well, is the primary factor determining their capacity to carry safely in ocean transit without deterioration. Corn in which the moisture content is sufficiently low will carry safely under ordinary conditions of ocean transit for any reasonable length of time during any season of the year, no matter where it is stowed in the vessel, while corn containing a high moisture content is constantly in danger of heating at any time owing to a variety of contributing causes. Thoroughly air-dried corn contains from about 12 to 13 per cent of moisture. Such corn may be shipped for export at any time under ordinary conditions with little or no danger from heating in transit, and this is practically true also of corn containing up to 14 per cent moisture provided fermentation has not started. The fact that certain lots of corn contain higher percentages of moisture does not necessarily mean that they will not stand ocean shipment safely. The corn may be perfectly sound, the voyage may be short, the air temperature at the time of loading and during the voyage may be low, no disturbing influence such as heat radiating from the ship's boilers and engine rooms and shaft tunnels may be encountered, and the corn kept practically in cold storage. Under such most favorable conditions, corn with a relatively high moisture content may sometimes be safely carried. Cargoes of such corn are often landed upon the quays in Europe in a perfectly cool condition, which corn, upon being exposed to warm atmospheric conditions often becomes hot and unfit for reshipment in a short time. When corn "goes out of condition" the effect of its relative moisture content immediately becomes evident. Corn with a low moisture content requires a much longer time to reach that stage designated as "hot" or to become discolored or "damaged" by the process of heating, than corn with a high moisture content, while corn with a high moisture content will heat, become discolored, and lose weight by evaporation quickly, and the processes of deterioration are accelerated with each additional per cent of moisture much more rapidly than the proportionate increase in the moisture content. When corn of a low moisture content is found in a heating condition, it can ordinarily be restored to a cool condition with but a slight amount of handling and ventilating and without much, if any, loss in value through discoloration, while corn with a high moisture content, when heated in any considerable bulk, quickly becomes badly discolored and damaged and is restored to a cool condition with great difficulty and a great amount of handling only with more or less damage to its quality and a corresponding loss in value.

It will be noted from the following charts and tables that many of the samples showed a higher moisture content at the time of discharge in Europe than the corn had at the time of loading. It is not thought possible under ordinary conditions of ocean transportation for corn or other grain, confined as it is in the holds of ships, to take on moisture from the air, as grain from semiarid regions is said to do when otherwise transported to more humid regions. This is especially true when the moisture content of the corn as shipped is high. There are two means by which the moisture content in any part or the whole of the ship's corn cargo may be increased during transportation: (1) Transfer of moisture by air currents caused by changes in temperature, and (2) by chemical changes within the corn kernel. As to the first means, corn containing excessive moisture and situated so that the moisture can escape when subjected to heat, will give off moisture and become drier. The moisture thus given off in a ship's hold, in case the temperatures in the hold are not uniform, finds its way to the usual air space above the corn and under the deck, passing thence as water to other parts of the hold where it condenses on the cooler corn, the cooler deck, and the sides of the ship. This process, augmented as time goes on by the second means, may increase considerably the moisture content of the corn in some portions of the hold or cargo.

The second means by which the moisture content of the corn may be increased is by the change in the chemical composition of the kernel, the effect of which is more evident in corn that is heating badly. Conditions of temperature and moisture may be favorable in some part of the cargo for fermentation to begin and to continue with more or less vigor. The heat generated in this process is gradually transmitted to the surrounding portions, starting and increasing fermentation, which decomposes the grain and liberates its water of composition, thus increasing the amount of moisture in some portions or in the whole cargo, if conditions are not disturbed, without any addition whatever of moisture from outside sources. From these causes, the grain in many of the shipments examined was found to be damp and heating at the top, while that beneath was cool, and the iron decks and sides of the ship were found to be quite wet from the condensed moisture from the heating corn.

GERMINATION AND FERMENTATION IN EXPORT CORN.

In the grain trade the germinating season, so called, is said to be a special season in the year during which grain is customarily planted in the ground. The limits of this season are generally understood to extend from the middle of March to the middle of June. It is generally believed that there is a natural and inherent tendency in grain to germinate during that season and that the heating of grain in storage and in transit during those months is due primarily to this tendency. Sprouted corn was occasionally found in the cargoes examined, but only at the top of the bulk, where considerable additional moisture had been supplied, either through condensation as described elsewhere or from outside sources, and where the corn had access to fresh air. In order that corn, or any of the grains, may germinate, there must be present: (1) Air or ogygen, (2) heat, and (3) moisture. If one or more of these are absent, germination will not take place, but if all are present at the same time and in sufficient quantities and the germ of the corn be alive, germination will take place, regardless of the time, the place, or the season of the year. There can be no doubt that the same conditions of temperature and moisture that favor germination or the active growth of the germ of the grain, are favorable also to the growth of molds and bacteria as well as the production and action of certain ferments and enzymes which have the power of changing the composition of the grain kernels and which in their action produce heat sufficient to cause the heating of the grain. Fermentation is the principal danger to which damp grain in storage or in transit is exposed. Corn in which fermentation has begun need not necessarily be hot or even perceptibly heating, but the action is usually indicated by a peculiar, faintly sour odor present. The presence of this odor should serve as a warning to the shipper or handler of grain, because corn in which the odor is present soon becomes hot if not frequently and thoroughly ventilated, especially if its moisture content is high. The process of fermentation develops acid within the corn kernel, and the degree to which fermentation has taken place in any given lot of corn may be very closely determined by the acidity test and is expressed in this publication in terms of "acidity c. c." The maximum limit of acidity allowed by Australian and Italian law in corn to be consumed for human food is 30 c. c. and this is also the maximum limit allowed by the pure food board of South Carolina in corn entering that State. Corn testing over 30 c. c. in acidity is such that no reputable grain man in this country would class it in any of the numerical grades. In several hundred samples of corn tested by the department, corn on the farms averaged 18.1 c. c., corn received at terminal markets 20.4 c. c.,[1] and the corn discharged at foreign ports averaged 30.4 c. c. in acidity. It will be of interest to note that of these samples, those taken from the farm tested 76.5 per cent in germination, samples received at terminal markets tested 58.8 per cent in germination, and samples taken at foreign ports tested 31 per cent in germination, showing that there is a close relation between the soundness of corn as determined by the acidity test and its viability.[2]

THE KEEPING QUALITIES OF EXPORT CORN INFLUENCED BY ITS POSITION OF STOWAGE IN THE STEAMSHIP.

Practically all of the corn that is exported to Europe from the United States is carried in bulk, with the exception of small quantities placed in sacks, which are used for trimming the cargo in order to prevent the bulk grain from shifting with the rolling and pitching of the ship. When the corn is thoroughly air-dried, it is not a matter of great importance where or how it is stowed, as long as it does not come in contact with the sea water, green or wet shifting boards, or damp or wet freight or wet lumber, etc. Where the shipments of corn contained a percentage of moisture much above that of thoroughly air-dried corn, it was found that at least some of the corn was often in a heating condition at the time of discharge. Where the heating occurred in positions of stowage free from the engine and boiler-room bulkheads and the shaft tunnels, the greatest heat and the most severe damage were found at the surface, the less heat and the less degree of damage the farther the distance down in the hold. When the damaged corn was located in that section of the ship contiguous to the boiler and engine-room bulkheads or to the propeller shaft tunnels, the greatest heat and the most severe damage were found nearest to those bulkheads and shaft tunnels, and the less heat and less degree of damage the farther the distance from them. The usual situation in such cases is clearly indicated in figures 17 and 54.

LENGTH OF THE VOYAGE AND SEASON OF THE YEAR WHEN SHIPPED, IN RELATION TO THE CARRYING QUALITIES OF CORN.

It appears from these investigations that if the corn when loaded in the ships is sound and dry, the length of the voyage has little or no

[1] The method of determining the acidity of corn is given in Department of Agriculture, Bulletin 102, entitled "Acidity as a factor in determining the degree of soundness of corn."

[2] The germination tests given in this report were made by the Seed Laboratory of the Department of Agriculture.

effect on its condition, but when it is shipped with a high moisture content and is stowed in such a way as to be subjected to heat from the inside of the ship, or is shipped during warm seasons of the year when it is subjected to considerable heat from the atmosphere and water, the length of the voyage is a very important factor, especially if the heating begins early in the voyage, in which case the heat is gradually diffused with each succeeding day and a higher temperature by action of ferments and enzymes, is developed in the corn already hot. Thus, with each succeeding day, more of the sound corn begins to heat and the corn already heating becomes more severely damaged.

CARGO No. 1.

Cargo No. 1 consisted of 240,000 bushels of corn, which was discharged at three ports in Denmark. The grain was loaded on the 6th, 7th, and 8th of March, 1910. The vessel sailed on the 8th of March and arrived at Copenhagen April 1, where the discharge of the corn was begun on April 4. The last of the corn in the vessel was discharged at Aalborg on April 15. The length of the voyage to Copenhagen was 24 days. The average time the corn was in the vessel was 34 days and the maximum time 41 days.

DESCRIPTION OF THE CORN.

The cargo contained four lots of corn, each of which was quite distinct in quality and condition from the others. For the purpose of designating these lots in the following pages, they will be called natural "Southwestern," natural "Central," dried "A," and dried "B" corn. Although the origin of each lot could not be definitely determined, the most reliable data available show that the corn designated as natural "Southwestern" was grown in the southwestern part of the corn belt, presumably in Texas and Oklahoma; that designated as natural "Central" originated in the central part of the corn belt, probably chiefly in Illinois; the lots designated as dried "A" and dried "B" were from the same section as the natural "Central" corn, but had been artificially dried.

STOWAGE OF THE CORN.

As is shown in figure 1, each cargo hold of the vessel was filled with corn, except hold 1, which had an air space on the top of the corn of about 4 feet on the port side and of about 6 feet on the starboard side of the shifting boards. Holds 1 and 2 contained only natural "Central" corn. Hold 3 contained both natural "Central" and natural "Southwestern" corn. The natural "Southwestern" corn, amounting to about 6,000 bushels, was stowed near the central part of the hold under the middle and after hatches, and the natural "Central" corn was stowed both immediately above and below the natural "Southwestern" corn. Hold 4 contained natural "Central" and the two lots of artificially dried corn, the natural "Central" being stowed in the upper part of the hold directly under the forward hatch, and separated from the dried corn by wooden staves and a tarpaulin. The dried "A" corn was the upper portion of the dried corn under the two forward hatches of hold 4, and the dried "B" corn filled the remainder of the hold.

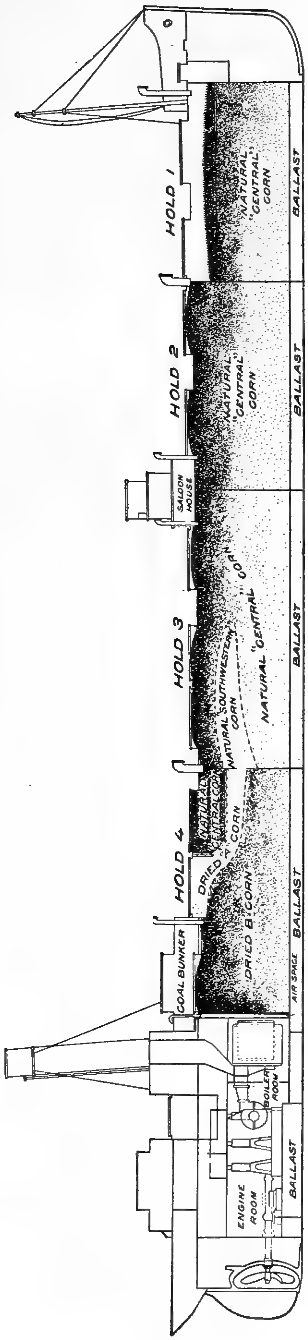

Fig. 1.—Diagram showing the arrangement of the steamship and the stowage of the four lots of corn in the holds. The heavy shading represents heat-damaged corn as discharged.

CONDITION OF THE CORN AS LOADED.

The ranges in the more important factors, showing the quality and condition of the four lots of corn as loaded and as discharged, are shown by holds in Table 1, while the detailed analyses of the samples taken from each lot of corn are shown in Table 2. From these two tables it will be seen that there was a marked difference in the quality and condition of the four lots of corn at the time of loading, each lot considered separately, however, being quite uniform throughout. The average condition of each of the four lots of corn as loaded is shown in Table 3. As seen in Table 3, the natural "Central" corn contained the most moisture, the average being 18.7 per cent. The natural "Southwestern" and the dried "A" corn were both relatively low in moisture content, the averages for these being 14.7 per cent and 14.9 per cent, respectively, while the dried "B" corn averaged 16.3 per cent. The average germination was the highest in the natural "Southwestern" corn, 84 per cent, and the lowest in the dried "B" corn, 32 per cent. The averages for the natural "Central" and the dried "A" corn were 51 per cent and 50 per cent, respectively. The dried "B" corn contained the highest degree of acidity, the average being 27.5 c. c., and the dried "A" corn contained the lowest, the average of which was only 22.5 c. c. The average acidity for the natural "Southwestern" and the natural "Central" corn was 25.8 and 26.6 c. c., respectively.

TABLE 1.—*Range in the principal factors showing quality and condition of the corn in cargo No. 1, as loaded and as discharged by holds.*

Holds.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
Hold No. 1:						
Natural "Central" corn—	°F.	*Per cent.*	c. c.	*Per cent.*	*Per cent.*	*Pounds.*
As loaded	53- 59	18.4-19.3	21.0- 28.5	45-72	85.2-98.7	50.5-53.0
As discharged	60-143	17.5-23.1	24.0-101.0	0-80	0-90.1	45.5-55.3
Hold No. 2:						
Natural "Central" corn—						
As loaded	50- 58	18.6-19.9	21.0- 32.0	28-66	90.6-96.4	51.5-53.5
As discharged	67-140	18.6-20.2	25.5- 52.0	0-79	0-94.6	47.0-53.8
Hold No. 3:						
Natural "Central" corn—						
As loaded	50- 63	17.6-19.2	22.0- 30.0	35-62	91.7-97.2	52.0-54.0
As discharged	55-136	18.8-25.8	25.5- 79.0	0-77	0-89.8	42.5-52.0
Natural "Southwestern" corn—						
As loaded	59- 59	13.9-15.1	22.5- 30.0	77-88	94.6-98.9	52.5-53.5
As discharged	68- 94	14.9-16.4	23.5- 26.5	49-82	96.3-97.8	52.5-52.5
Hold No. 4:						
Natural "Central" corn—						
As loaded	59- 59	18.8-18.8	28.0- 28.0	56-56	95.9-95.9	53.5-53.5
As discharged	144-148	17.8-46.2	38.5- 60.5	0- 0	0- 0	48.5-48.5
Dried "A" corn—						
As loaded	62- 62	14.9-14.9	22.0- 23.0	49-51	96.7-97.4	53.5-54.0
As discharged	79- 80	15.7-17.1	27.0- 28.0	36-59	90.6-94.1	51.0-51.5
Dried "B" corn—						
As loaded	62- 67	15.8-17.2	23.0- 32.0	22-45	77.6-94.1	50.0-53.5
As discharged	74-144	14.5-25.1	27.5- 49.0	0-25	0-88.9	48.5-52.8

Considering all the factors for each lot of corn, it is seen, as far as the three factors of moisture, acidity, and germination are concerned, that the natural "Central" and dried "B" lots were both poor in quality and condition when loaded. The natural "Southwestern" and the dried "A" corn were both in good condition, having a low moisture content, and were likewise better than either of the other two lots in the factors of acidity, germination, sound kernels, and weight per bushel.

As brought out somewhat in detail in the following discussion, there was a close relation between the soundness and condition of the corn at the time of loading and its behavior during the voyage.

TABLE 2.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded.*

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°F.	*Per ct.*	c. c.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Hold 1, natural "Central" corn	1	53-59	18.5	24.0	56	94.2	1.1	5.1	52.5
	2		18.5	25.0	59	95.6	.6	3.0	52.0
	3		18.8	21.0	....	98.7	.0	3.0	52.0
	4		18.6	25.0	72	96.2	.3	3.6	52.0
	5		18.5	28.5	67	96.3	.2	2.9	53.0
	6		18.5	26.5	60	90.6	.4	2.9	52.5
	7		18.4	25.0	66	96.1	.8	3.2	53.0
	8		19.3	26.5	45	85.2	.5	3.5	50.5

TABLE 2.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded*—Continued.

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°*F.*	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Hold 2, natural "Central" corn	9	50–58	19.1	28.5	......	90.6	.3	3.1	52.0
	10		19.5	32.0	28	92.0	.5	2.7	51.5
	11		18.6	25.5	37	95.4	.5	2.5	52.5
	12		19.2	21.0	43	95.6	.4	3.1	52.0
	13		18.9	28.5	36	95.5	.5	3.0	......
	14		18.8	27.5	47	93.5	.1	2.4	......
	15		18.6	27.0	57	96.4	.4	3.1	53.0
	16		18.7	25.0	66	95.0	.2	2.4	53.0
	17		18.7	26.5	39	92.5	.3	2.8	52.0
	18		18.7	25.5	44	94.4	1.1	4.4	52.0
	19		19.9	26.0	46	92.4	1.5	4.5	52.0
	20		18.6	27.0	48	95.1	.5	5.9	53.0
	21		18.8	26.5	46	94.6	.3	3.1	53.0
	22		18.6	29.5	46	94.2	.5	3.7	53.5
	23		18.7	25.5	56	96.0	1.0	3.6	52.5
Hold 3, natural "Southwestern" corn	24	59	13.9	22.5	88	98.9	.3	4.5	53.0
	25	59	15.1	25.0	87	97.7	.4	7.1	53.5
	26	59	15.0	30.0	77	94.6	3.3	6.9	52.5
Hold 3, natural "Central" corn	27	50–63	18.8	30.0	35	93.6	.7	3.9	52.5
	28		19.2	26.0	52	96.2	.2	1.4	52.5
	29		18.7	27.0	46	91.9	.3	2.3	52.0
	30		18.5	30.0	45	95.8	.3	1.4	52.5
	31		18.5	28.5	39	95.2	.4	3.8	53.0
	32		18.4	25.0	52	97.2	.1	2.6	52.0
	33		18.6	29.5	57	93.8	.3	2.6	52.5
	34		17.6	27.5	49	92.4	.4	2.4	53.0
	35		18.7	22.0	52	96.1	.1	1.6	53.5
	36		18.9	29.0	57	93.3	.2	2.2	53.0
	37		18.5	28.5	55	94.6	.6	5.1	54.0
	38		18.8	28.0	......	94.9	.2	3.8	53.0
	39		19.0	26.5	52	94.1	.3	3.2	53.0
	40		18.0	26.0	62	91.7	.4	1.6	52.5
	41		18.3	......	......	95.0	.4	3.2	52.5
	42		18.6	28.0	50	93.4	.8	3.4	52.0
	43		18.3	24.0	61	96.0	.2	3.0	52.5
	44		18.7	26.5	59	96.8	.3	3.3	52.5
Hold 4, natural "Central" corn	45	59	18.8	28.0	56	95.9	.5	3.2	53.5
Hold 4, dried "A" corn	46	62	14.9	22.0	51	96.7	.2	3.1	53.5
	47	......	14.9	23.0	49	97.4	1.0	6.2	54.0
Hold 4, dried "B" corn	48	62–67	16.1	29.5	22	92.4	.6	4.6	53.5
	49		16.3	27.5	27	90.1	.4	4.4	53.0
	50		16.1	25.5	32	91.2	.4	3.3	53.5
	51		16.3	27.5	38	89.0	1.2	2.7	51.0
	52		16.4	28.0	29	86.6	.5	1.4	52.0
	53		17.2	32.0	45	84.4	12.6	9.4	50.0
	54		16.8	25.0	37	90.7	.7	2.7	53.0
	55		15.9	28.5	35	91.3	1.2	8.0	53.0
	56		15.8	23.0	31	77.6	16.0	20.2	53.0
	57		16.4	28.0	22	94.1	.6	5.0	52.5

TABLE 3.—*Average condition of the four lots of corn as loaded.*

Kind of corn.	Hold No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°*F.*	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Natural "Central"	1	56	18.6	25.2	61	94.1	0.5	3.4	52.2
	2	55	18.9	26.8	46	94.2	.5	3.4	52.4
	3	55	18.6	27.2	51	94.6	.3	2.8	52.7
	4	59	18.8	28.0	56	95.9	.5	3.2	53.5
Total natural "Central"	......	55	18.7	26.6	51	94.4	.4	3.1	52.5
Natural "Southwestern"	3	59	14.7	25.8	84	97.0	1.3	6.2	53.0
Dried "A"	4	62	14.9	22.5	50	97.0	.6	4.6	53.5
Dried "B"	4	64	16.3	27.5	32	88.7	3.4	6.2	52.5

TEMPERATURE CHANGES DURING THE VOYAGE.

The first readings of the resistance thermometers were made on March 8, just after the ship left the dock at the beginning of the voyage. With the exception of a few stormy days, readings were made for 25 days thereafter, or until April 2, the day after the ship arrived at Copenhagen. The manner of reading the temperatures of the electrical resistance thermometers is illustrated in figure 2. The temperature of the corn at the time of loading varied from 50° to 67° Fahrenheit. During the voyage much of the corn became very hot. The changes in the temperature of the corn varied considerably in the different positions of stowage and were influenced by the quality, condition, and temperature of the corn when loaded, the boiler heat, the air and water temperatures, and the position of stowage in the ship with reference to height from the bottom of the holds.

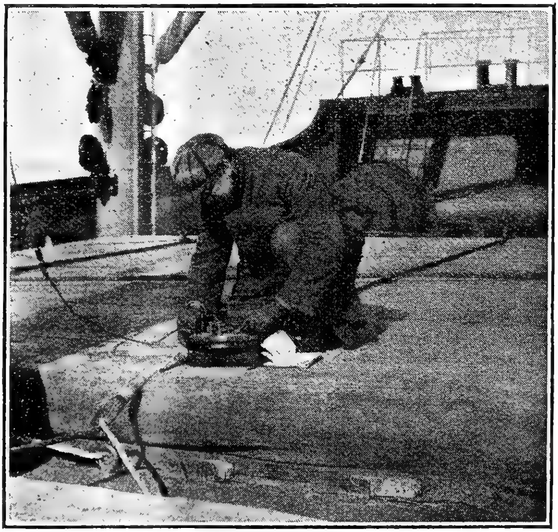

FIG. 2.—Reading the temperature of an electrical resistance thermometer during the voyage.

The air and water were generally of about the same temperature, save during the latter part of the voyage, when the air was usually colder than the water. The water temperature varied considerably at different stages of the voyage, depending on whether the ship was in harbor, the Gulf Stream, the arctic current, or in the North Sea.

INFLUENCE OF WATER TEMPERATURE.

The outside walls of the ship consisted of plates of steel, against which the outside layers of the corn rested without any protection. Steel being a good conductor of heat, the temperature of the corn stowed contiguous to these walls was nearly the same as that of the water, as is shown by the temperature records of thermometer 17, figure 5, and thermometer 31, figure 8. The temperature of the corn located a little further in was less affected, as is shown by the temperature records of thermometer 4, figure 3, thermometer 7, figure 4, and thermometer 29, figure 6. The influence of the water temperature gradually decreased with the distance from the sides. The same relation existed with reference to the temperature of the corn located in the bottom of the holds, but not to the same extent as along the sides because of the air space in the ballast tanks and also because the bottoms of the holds were covered by a wooden flooring.

TABLE 4.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as discharged in Denmark—samples taken in order in the holds from top to bottom.*

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°F.	Per ct.	c. c.	Per ct.	Per ct.	Per ct.	Per ct.	Pounds.
Hold 1, natural "Central" corn	58	143	....	49.0	1	0	0.1	1.6	....
	59	138	23.1	101.0	0	0	.3	1.4	....
	60	140	17.6	46.0	0	0	.7	4.3	....
	61	140	17.5	50.0	0	0	1.8	4.1	45.50
	62	132	....	38.0	10	54.7	.2	5.1	48.00
	63	130	17.9	43.0	1	10.2	.6	5.7	47.25
	64	....	19.3	28.5	18	89.7	.4	2.6	49.00
	65	130	19.2	43.5	0	25.4	.4	3.6	47.00
	66	100	19.5	28.0	49	85.3	.4	2.9	50.75
	67	75	19.4	25.5	54	65.4	3.0	6.5	50.75
	68	112	18.5	25.5	57	59.4	.4	4.7	49.00
	69	92	19.7	27.0	53	82.2	2.8	10.2	51.25
	70	....	17.8	35.0	0	0	.2	3.5	....
	71	....	18.8	24.0	65	80.2	.5	2.0	52.00
	72	65	19.2	24.0	80	66.4	1.9	3.7	53.00
	73	67	19.2	26.0	70	72.0	.6	5.9	55.25
	74	60	19.2	27.5	66	90.1	.7	5.7	52.00
Hold 2, natural "Central" corn	75	140	19.7	43.5	0	0	.2	2.8	47.75
	76	134	19.8	52.0	0	0	.9	3.5	47.00
	77	110	20.2	31.0	1	83.7	.5	2.8	....
	78	89	....	27.0	23	88.0	.1	1.7	....
	79	113	18.6	31.5	30	81.6	.6	3.6	50.00
	80	87	19.2	34.5	8	63.0	.2	4.2	....
	81	77	19.2	....	....	....	....	....	51.75
	82	67	19.1	28.0	50	73.3	.8	7.6	51.25
	83	....	19.0	27.0	77	94.6	.5	7.0	53.75
	84	67	19.5	29.0	60	87.4	.2	5.7	51.25
	85	....	19.4	25.5	79	91.4	.2	5.3	53.00
Hold 3, natural "Southwestern" corn	86	94	14.9	26.5	49	96.6	.2	6.0	....
	87	73	15.9	23.5	79	96.3	1.7	5.4	52.50
	88	68	16.4	24.0	82	97.8	.6	4.7	....
Hold 3, natural "Central" corn	89	....	20.1	32.5	28	43.2	.7	2.7	48.50
	90	136	18.9	48.0	0	0	.5	3.1	46.50
	91	130	25.8	79.0	1	0	.5	2.1	42.50
	92	130	19.2	40.5	0	0	.1	2.6	46.00
	93	130	20.3	42.0	0	0	1.3	2.8	44.50
	94	129	18.8	42.0	0	0	.1	3.9	....
	95	119	19.1	38.0	0	83.4	.1	2.0	....
	96	124	19.0	45.0	0	0	.4	1.4	....
	97	118	19.1	35.0	0	69.7	1.0	2.6	....
	98	76	20.1	33.0	31	44.7	.1	3.7	....
	99	95	18.9	41.5	0	0	1.8	4.4	....
	100	72	19.8	25.5	77	79.5	.5	5.2	50.00
	101	81	20.0	30.0	43	87.8	.2	4.7	51.50
	102	67	20.2	26.5	52	89.8	.1	3.7	....
	103	55	19.5	27.0	63	87.1	.2	3.9	51.75
	104	55	19.0	27.0	73	68.5	1.0	4.2	52.00
	105	70	19.5	26.0	64	75.8	.2	3.0	51.50
	106	67	18.9	28.0	63	68.4	.2	2.1	....
Hold 4, natural "Central" corn	107	144	17.8	38.5	0	0	.3	4.8	48.50
	108	148	46.2	60.5	0	0	0	....	....
Hold 4, dried "A" corn	109	80	17.1	27.0	36	94.1	.2	5.2	51.50
	110	79	15.7	28.5	59	90.6	1.6	10.2	51.00
Hold 4, dried "B" corn	111	144	25.1	49.0	0	0	.7	5.7	....
	112	142	16.9	43.0	0	0	1.6	5.5	....
	113	125	14.5	39.0	0	0	.6	5.2	51.75
	114	136	14.5	39.0	2	0	2.0	9.6	51.75
	115	135	15.9	53.0	0	0	.3	6.5	49.50
	116	90	15.2	34.5	21	45.0	.4	5.7	51.75
	117	124	....	48.0	0	0	.6	6.0	50.50
	118	125	16.6	43.5	0	0	.7	3.2	49.00
	119	129	16.9	33.0	2	0	3.5	7.9	51.50
	120	90	15.2	34.5	0	63.9	.3	5.6	48.50
	121	110	15.5	40.5	0	0	.2	3.7	48.50
	122	120	15.2	44.0	0	0	1.2	....	50.50
	123	110	17.1	34.0	0	56.1	2.2	7.9	52.75
	124	89	16.8	32.5	24	88.9	.2	5.7	50.50
	125	80	15.5	34.5	24	82.1	.6	4.6	50.00
	126	74	15.3	27.5	25	76.2	.2	1.7	51.50
	127	114	....	35.0	0	0	.9	3.4	48.75

TEMPERATURE CHANGES IN TOP AND BOTTOM OF HOLDS.

With reference to the temperature changes in the corn located in the upper part of the holds as compared to the temperature changes in the corn in the middle and bottom parts, it will be seen in figures 3 to 6 and Tables 7 and 8, that the corn in the upper part of the holds began to heat first and had the highest temperatures at the end of the voyage. The corn just below the top layers was the next to begin to heat and had the next highest temperature at the end of the voyage.

This order held true with considerable regularity through to the corn in the bottom portion of the holds, although not to such a great extent where there were outside influences, such as the temperature of the sea water, which affected the corn stowed near the sides of the ship, and the heat from the boilers, which was transmitted through the boiler-room bulkhead.

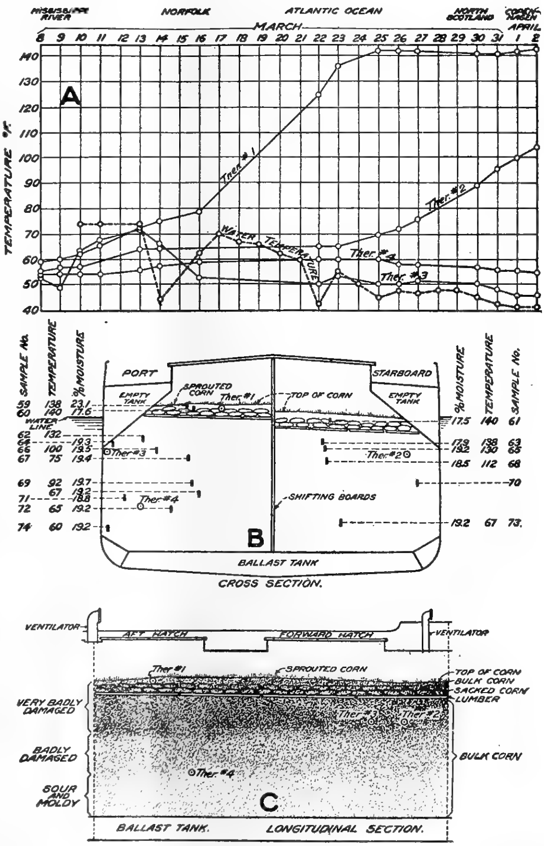

FIG. 3.—Hold 1: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

Thus, in the natural "Central" corn in hold 1 (thermometer No. 1, fig. 3) the temperature of the corn in the top portion began to increase from the beginning of the voyage and had a temperature of 142.5° F. at the end of the voyage, which was an increase of 83.5° F.; while the corn located about one-third of the distance down in the hold (thermometer No. 2) did not begin to show a rapid daily increase until about the thirteenth day out, and had a temperature of only 103.5° F. at the end of the voyage, an increase of 47.5° F. The corn in the bottom layer had a temperature of only 55° F. at the end of the voyage, as shown by the temperature record for thermometer 4, figure 3. The corn in this position did not become hot and actually showed a lower temperature at the end of the voyage than during the middle of the voyage, because of the influence of the water temperature. The same order prevailed in the natural "Central" corn in the other holds in which it was stowed, although the temperature in each relative position varied somewhat in the various holds. The natural "Southwestern" corn in hold 3 and the dried "A" corn under the forward and middle hatches in hold 4, as is shown by the temperature records for thermometers 11 and 30 in figures 5 and 7, did not become hot during the voyage for reasons explained elsewhere.

The upper portion of the dried "B" corn immediately under the dried "A" lot in the forward part of hold 4 (sample 115, fig. 6) had a temperature at the end of the voyage of 135° F., as against 113° F. for the corn in the bottom of the hold (thermometer record 23, fig. 7). This same relation held true for the dried "B" corn located under the after hatch, as is shown by the temperature records of thermometers 21, 22, 26, and 29, and also for the corn located against the boiler-room bulkhead, although the latter was affected by the heat from the boilers. The above condition is almost invariably true in all cargoes containing heating corn.

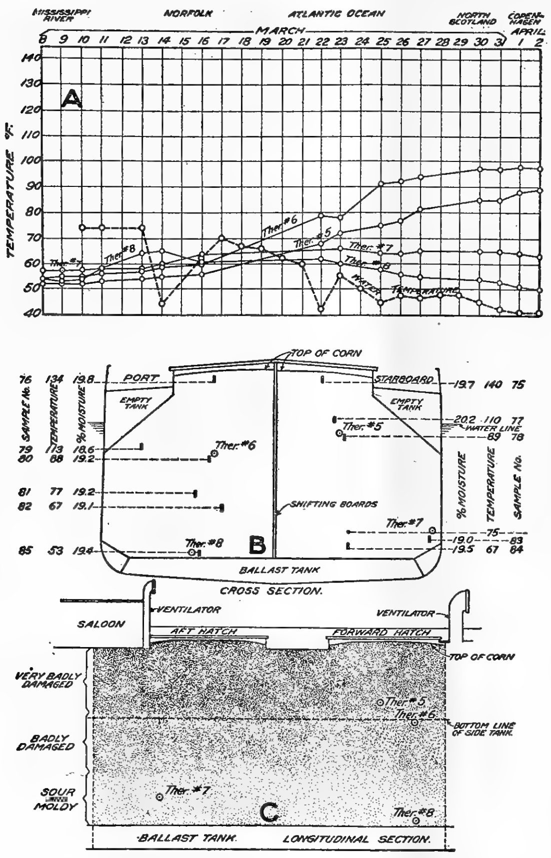

FIG. 4.—Hold 2: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

INFLUENCE OF BOILER HEAT.

The heat generated in the boiler room exerted considerable influence on the temperature of the corn stowed contiguous to the boiler-room bulkhead. As hot air always moves upward and cold air downward, this influence would naturally be expected to affect the corn stowed against the upper part of the boiler-room bulkhead more than that which was stowed against the lower part, which proved to be the case in this shipment. That part of the dried "B" corn which was located against the upper part of the boiler-room bulkhead increased in temperature at a much faster rate during the early part of the voyage than the corn in any other position in the ship. The temperature of all the corn stowed along this bulkhead registered under 65° F. at the time of loading. From early morning until 4 o'clock in the afternoon of the day of sailing, March 8, the ship's boilers were under pressure of steam, and considerable heat was generated in the boiler room. In this short time the temperature of the corn located against the upper part of the bulkhead had increased to 76° F., as shown by the temperature record of thermometer 18 in figure 6, while the corn at the same height in the hold, not more than 8 feet away from the bulkhead, was only 62° F., as is shown by temperature record of thermometer 22. Eight days later the corn against the upper part of the boiler-room bulkhead had increased to 102° F., while the temperature of the corn located only 8 feet away was only 65° F. From March 17 to 19, inclusive, the weather was stormy, and no more readings were made until March 20, 12 days after sailing, by which time the temperature of the corn along the upper part of the bulkhead had increased to 118° F., a total increase of over 53° F.,

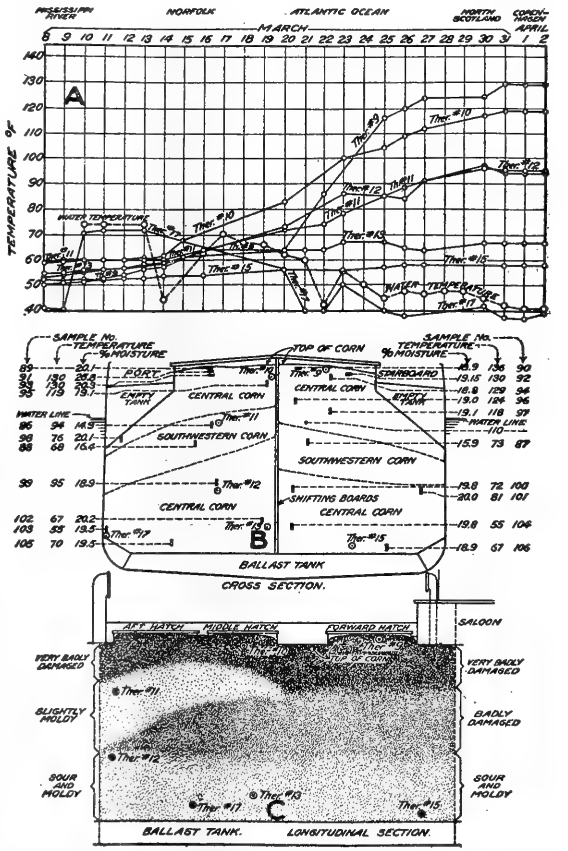

FIG. 5.—Hold 3: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples as secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

and the corn stowed 8 feet away from the bulkhead had increased to 80° F., or an increase of only 18° F., but during the next few days the temperature of the corn in the latter position increased very rapidly.

When the ship arrived at Copenhagen on April 1, the temperatures of the corn stowed against the upper, middle, and bottom parts of the boiler-room bulkhead, as is shown by the temperature records for thermometers 18, 24, and 27, were 140°, 118°, and 75° F., respectively, as against 122° and 59° F., for the corn stowed 8 feet from the bulkhead and the same height as the upper and lower positions (there was no record for the middle position) as is shown by the temperature records for thermometers 22 and 29. Note that the corn near the boiler-room bulkhead had a higher temperature by 18° F. in the upper position and by 16° F. in the lower position than the corn located at the same height but 8 feet from the bulkhead.

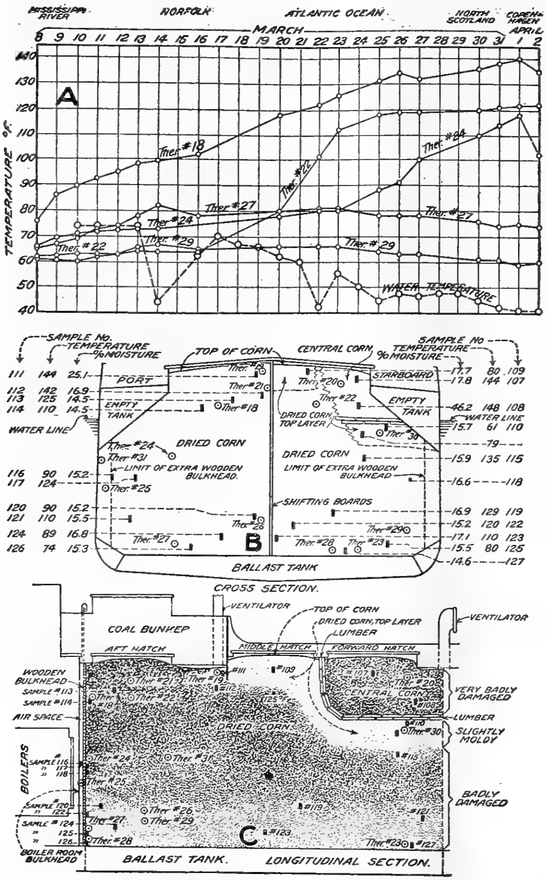

FIG. 6.—Hold 4: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

After the ship was docked at Copenhagen, the fires were put out under the main boilers and the effect was quite noticeable on the corn located near the boiler-room bulkhead. The next day, April 2, the temperature of the corn located against the upper part of the bulkhead had decreased 5 degrees as against no decrease for the corn the same height only 8 feet away, the temperatures for these two positions that day being 135° and 122° F., respectively. The temperature of the corn against the middle of the bulkhead (thermometer 24), about half way to the bottom, was 102° F., on April 2, a decrease of 16 degrees from the previous day, and the temperature of the corn against the unprotected part of the boiler-room bulkhead at the extreme side of the hold (thermometer 25) was reduced from 95° F. on April 1 to 82° F. on April 2, a decrease of 13° F. During the voyage the temperature of the corn in the last-named position was affected by both the heat from the boilers and the water temperature.

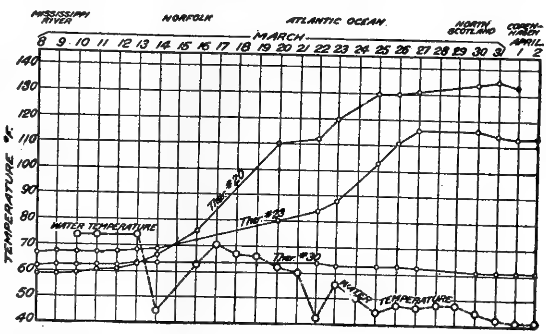

FIG. 7.—Diagram showing temperature records for the corn stowed in the forward part of hold 4.

In connection with the temperatures of the dried "B" corn in hold 4, in the different positions of stowage at the end of the voyage, it is interesting to note at what stage of the voyage the first rapid increase in temperature began. The corn which was stowed next to the upper part of the boiler-room bulkhead (thermometer 18) showed a rapid increase from the beginning of the voyage; next the temperature of the corn in the top layer, immediately under the after ventilator, began to increase rapidly about March 16. At this time in the voyage the ship encountered cold air and the vapor escaping from the heating corn began to condense in the ventilator and fall back on the corn as water. The upper layer of corn a short distance from the boiler-room bulkhead began to increase rapidly in temperature about March 20 and that stowed along the middle part of the boiler-room bulkhead about March 23.

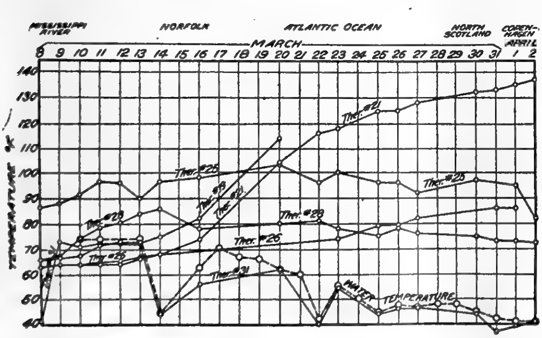

FIG. 8.—Diagram showing temperature records for miscellaneous electrical resistance thermometers in hold 4. (Cargo No. 1.)

CONDITION OF THE CORN AS DISCHARGED.

When the hatches were opened in Denmark, the corn in all of the holds gave off moisture in the form of vapor in great volume, as is illustrated in figure 9, which shows the formation of a dense fog as the result of the warm moisture laden air from hold 4 coming in contact with the cold outside air. When the cargo was discharged it was found that much of the corn had undergone severe deterioration during the voyage.

The detailed analyses of the samples taken from the corn as discharged are shown in Table 4 and the average condition of each lot of corn as discharged is shown in Table 5.

TABLE 5.—*Average condition of the four lots of corn as discharged in Denmark.*

Kind of corn.	Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°F.	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Natural "Central"	1	96	19.1	35.5	42	54.4	1.0	4.5	50.7
	2	96	19.4	33.5	29	64.0	.4	4.2	50.2
	3	90	19.7	34.6	35	50.9	.5	3.5	49.4
	4	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central"		[1] 95	19.4	35.0	33	54.0	.6	4.0	49.9
Natural "Southwestern"	3	78	15.7	24.7	70	96.9	.8	5.4	52.5
Total dried "A"	4	80	16.4	27.8	48	92.4	.9	7.7	51.3
Total dried "B"	4	119	[2] 15.7	40.8	4	17.4	.9	5.7	50.8

[1] Sample 108 not included. [2] Sample 111 not included.

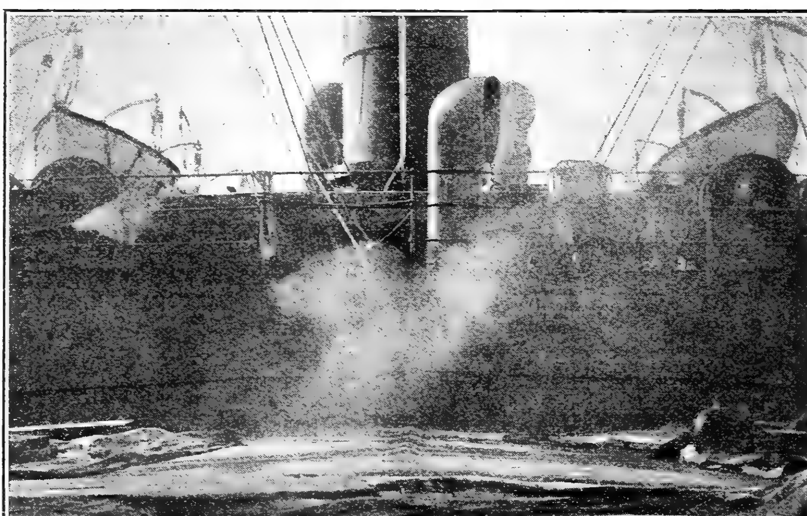

FIG. 9.—Moisture from heating corn escaping from a ventilator and from an open hatch at the end of the voyage. (Cargo No. 1.)

It will be seen from Table 4 that the natural "Central" corn which had an average moisture content of 18.7 per cent and an average acidity of 26.6 c. c. at the time of loading, was badly damaged in the upper part of all holds at the time of discharge. The corn was hot, discolored, very sour, and badly affected with molds. As is shown in figures 3 to 6 and Table 4, the degree of damage, as well as the temperature of the corn, gradually decreased toward the bottom of the holds, where the corn was not discolored, but was noticeably sour and more or less affected with molds. The damaged and packed condition of the corn in the upper part of holds 1 and 2 at time of discharge is illustrated in figure 10. The corn in hold 1 did not entirely fill the hold, and the top of the corn was covered with a heavy growth of sprouted corn, as is shown in figure 12.

The comparison of the average condition of each lot of corn, as loaded and as discharged, is given in Table 6. As shown in this table, the natural "Southwestern" corn in hold 3, which had an average moisture content of 14.7 per cent and an average acidity of 25.8 c. c. when it was loaded, arrived in practically the same condition as when loaded, although the natural "Central" corn stowed both immediately above and below it was hot and damaged and badly packed, as is illustrated in figure 5. The natural "Southwestern" corn "run" freely during the discharge, thus leaving overhanging walls of natural "Central" corn, these overhanging walls at times projecting as much as 2 feet or more.

TABLE 6.—*Comparison of the average condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded, with the average condition of each lot as discharged in Denmark.*

Kind of corn.	Hold.	Condition of corn as—	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
			° F.	*P. ct.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*
Natural "Central"	1	Loaded	56	18.6	25.2	61	94.1	0.5	3.4	52.2
	1	Discharged	96	19.1	35.5	42	54.4	1.0	4.5	50.7
	2	Loaded	55	18.9	26.8	46	94.2	.5	3.4	52.4
	2	Discharged	96	19.4	33.5	29	64.0	.4	4.2	50.2
	3	Loaded	55	18.6	27.2	51	94.6	.3	2.8	52.7
	3	Discharged	90	19.7	34.6	35	50.9	.5	3.5	49.4
	4	Loaded	59	18.8	28.0	56	95.9	.5	3.2	53.5
	4	Discharged	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central"		Loaded	55	18.7	26.6	51	94.4	.4	3.1	52.5
		Discharged	[1] 95	19.4	35.0	33	54.0	.6	4.0	49.9
Natural "Southwestern"	3	Loaded	59	14.7	25.8	84	97.0	1.3	6.2	53.0
	3	Discharged	78	15.7	24.7	70	96.9	.8	5.4	52.5
Dried "A"	4	Loaded	62	14.9	22.5	50	97.0	.6	4.6	53.5
	4	Discharged	80	16.4	27.8	48	92.4	.9	7.7	51.3
Dried "B"	4	Loaded	64	16.3	27.5	32	88.7	3.4	6.2	52.5
	4	Discharged	119	[2] 15.7	40.8	4	17.4	.9	5.7	50.8

[1] Sample 108 not included. [2] Sample 111 not included.

Figure 6 and Table 6 show that the dried "A" corn in hold 4, which had an average of 14.9 per cent of moisture and an average acidity of 22.5 c. c. when it was put on board, also arrived in Denmark in practically as sound a condition as when it was loaded, notwithstanding that both the "Central" corn, which was stowed immediately above it, and the dried "B" corn, just beneath it, was hot and badly damaged. Figure 6 and Table 6 also show that the dried "B" corn in hold 4, which had an average moisture content of 16.3 per cent and an average acidity of 27.5 c. c. at the time of loading—the highest acid content of any lot in the shipment—was hot and badly damaged throughout when discharged with the exception of a small quantity along the bottom in the afterpart of the hold, which was not hot but was badly packed, sour, and affected with molds. This dried "B" corn was so badly packed that it formed perpendicular walls from the top to the bottom of the hold (about 20 feet) when it was being discharged, as is illustrated in figure 11.

"SWEAT" AND SPROUTED CORN IN THE HOLDS.

When the cargo arrived in Denmark the top layer of corn in hold 1 was sprouted as is shown in figure 12, the sprouts in many instances measuring 8 inches and more in length. This hold, which was not entirely filled with corn, was, as already stated, the only hold in which there was a free circulation of air from the forward to the after ventilators. This free circulation of outside air over the corn supplied the necessary oxygen and kept the top layers of kernels cool enough through evaporation to germinate. The necessary moisture needed for germination, in addition to the moisture present within the kernels, was supplied by the "sweat" dropping from the deck above. In other holds in which the circulation of air was impeded there was only a very slight amount of sprouted corn, the sprouted kernels being found only under some of the hatch beams. The air was very "heavy" in these holds due to the oxygen having been used up and replaced by carbon dioxide.

FIG. 10.—Damaged corn in the upper part of hold 2 at time of discharge. (Cargo No. 1.)

What is known as "sweat" in a corn cargo is water that has condensed on the underside of the cooler deck or on the sides of the ship when the temperature on the outside of the hold is lower than the temperature on the inside. This "sweat" on the underside of the deck falls back onto the corn in the form of water, as illustrated in figures 13 and 14. In the rolling and pitching of the ship, most of the "sweat" on the underside of the deck works its way to the deck beams and from there it falls onto the corn where it supplies the necessary moisture for germination or fermentation as the case may be. The sprouted corn immediately under those beams in hold 1 showed a much more vigorous growth than at other places. During the voyage the moisture from the heating corn could be plainly seen escaping from the ventilators and especially from the after ventilators in hold 4, shown in figure 9, where it was first noticed on the sixth day out when cold air was encountered which condensed the excess moisture in the warm air from the hold into fog.

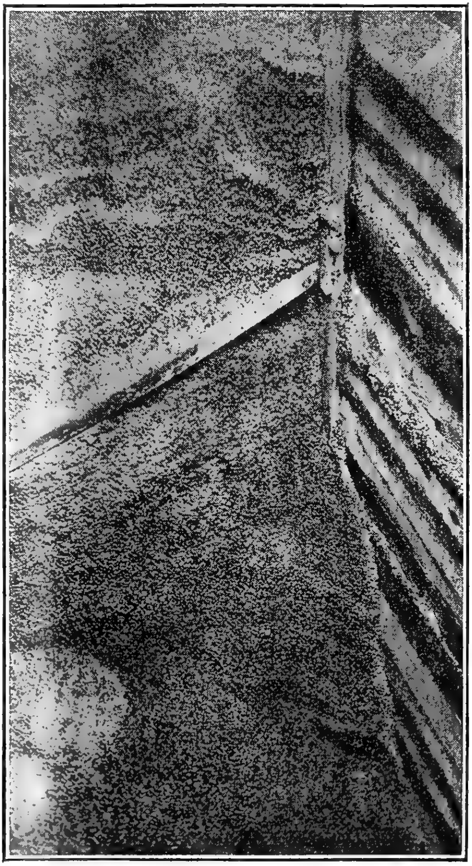

FIG. 11.—Perpendicular wall of hot and damaged dried "B" corn in hold 4 at time of discharge. (Cargo No. 1.)

MOISTURE TEST ALONE NOT SUFFICIENT TO DETERMINE CARRYING QUALITY OF CORN.

The moisture test alone is not sufficient to determine the carrying quality of corn, there being other factors which must also be considered. Based on the moisture test alone, the dried "B" corn stowed in the bottom part of hold 4 should have been in better condition at the end of the voyage than the natural "Central" corn in the bottom of holds 1, 2, and 3, which at the time of loading had an average of 2.4 per cent more moisture than the dried "B" corn. The condition at the end of the voyage of these two lots of corn, however, proved to be the reverse, and the explanation of it is that although the dried "B" corn contained on an average less moisture than the natural "Central" corn, the dried "B" corn was less sound as shown by the acidity test. The combination of a comparatively high moisture and high acid content caused the dried "B" corn in the lower part of the hold to become hot during the voyage. As will be seen by thermometer 23 (fig. 7), which was located near the forward bulkhead in the bottom of hold 4, the temperature of the corn at that point was 113.5° F. at the end of the voyage, as against a temperature of only 67° F. for thermometer 13 (fig. 5), in hold 3 located in the bottom portion of the natural "Central" corn only a short distance from thermometer 23.

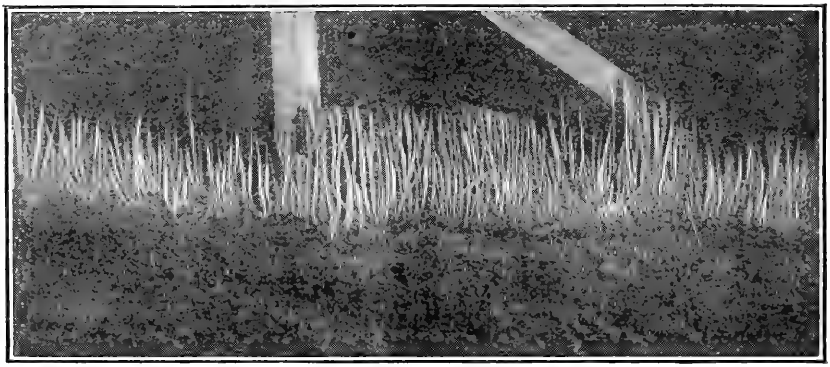

FIG. 12.—Illustrating the sprouted condition of the surface layer of corn in hold 1 when the cargo arrived in Denmark. (Cargo No. 1.)

The difference between the keeping qualities of corn containing a high moisture content and showing a high acid test and of corn in which these two factors are low was illustrated in

FIG. 13.—Showing where "sweat" had dropped from the underside of the deck onto the bags of corn in the upper part of the hold. (Cargo No. 1.)

holds 3 and 4. In hold 3 the natural "Southwestern" corn, which at time of loading was lower on an average by 4 per cent in moisture content and by 0.8 c. c. in acidity than the natural "Central" corn in the same hold, remained sound, while the natural "Central" corn surrounding it became badly damaged. Also, in hold 4 the dried "A" corn, which at time of loading was lower by 1.4 per cent in moisture and by 5 c. c. in acidity than the dried "B" corn, remained sound, while the dried "B" corn in the same relative position of stowage as the dried "A" corn became badly damaged.

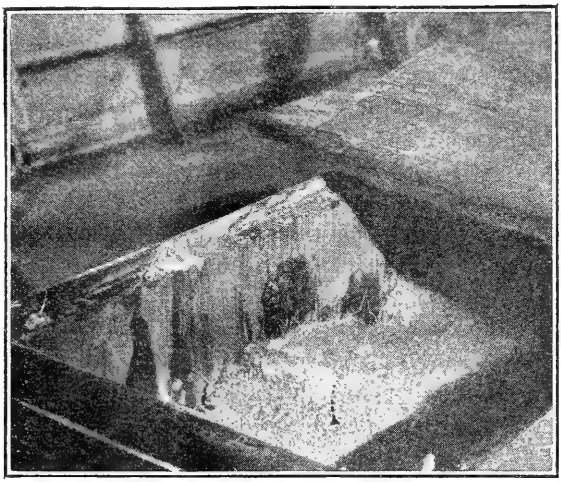

FIG. 14.—Illustrating the results of "sweat" on the top portion of the corn under the hatch in hold 3. (Cargo No. 1.)

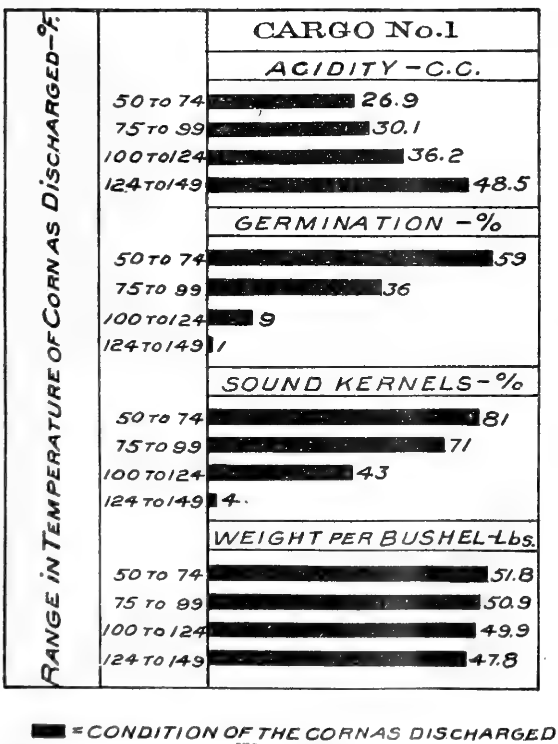

FIG. 15.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 1.)

CORRELATION OF THE CHANGES IN TEMPERATURE AND THE CHANGES IN ACIDITY, GERMINATION, MOISTURE CONTENT, AND TEST WEIGHT PER BUSHEL.

The comparison of the average condition of the natural "Central," natural "Southwestern," dried "A" and dried "B" corn in each hold; also the comparison of the averages for the total corn of each lot at the time of loading with the averages at time of discharge in Denmark are shown in Table 6. The average condition of the corn in each lot in the top third, middle third, and bottom third of holds at time of discharge in Denmark is shown in Table 7, and the condition of the individual samples that were put into the crossed wire containers at the time the corn was loaded compared to the condition of each at the time when the corn was being discharged is shown in Table 8. It will be seen from these tables that, with a few unimportant exceptions, there was on an average quite a noticeable change in the acid content, germination, percentage of sound kernels, and weight per bushel during the voyage corresponding quite closely with the changes in the temperature in each lot of corn and in each position of stowage. As is seen from Table 6, the acidity was generally greater, while the weight per bushel and percentages of germination and sound kernels were generally less at the end of the voyage than at the beginning, the greatest differences being apparent in most cases in the corn which had increased the most in temperature, as is shown in figure 15.

TABLE 7.—*Average condition of each lot of corn in the top third, middle third, and bottom third of holds as discharged in Denmark.*

Kind of corn.	Place of stowage in hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
Natural "Central" corn:		°F.	P. ct.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.
Hold 1	Upper third	132	19.2	53.4	9	29.5	0.5	3.0	47.9
	Middle third	93	18.8	27.4	46	57.4	1.4	5.4	50.8
	Bottom third	64	19.2	25.8	72	76.2	1.1	5.1	53.4
Hold 2	Upper third	128	19.9	42.2	0	27.9	.5	3.0	47.4
	Middle third	92	19.0	31.0	20	77.5	.3	3.2	50.9
	Bottom third	67	19.3	27.4	67	86.7	.4	6.4	52.3
Hold 3	Upper third	127	20.0	44.6	3	21.8	.5	2.6	45.6
	Middle third	81	19.7	32.4	38	53.0	.7	4.5	50.8
	Bottom third	63	19.4	26.9	63	77.9	.3	3.4	51.8
Hold 4	Upper third	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central," natural "Southwestern," dried "A," and dried "B" corn:									
Natural "Central"	Upper third	[1] 131	19.6	46.3	3	22.9	.5	3.1	47.0
Dried "A"		80	16.4	27.8	48	92.4	.9	7.7	51.3
Dried "B"		137	[2] 15.3	42.5	0	0	1.2	6.5	51.8
Natural "Central"	Middle third	88	19.2	30.7	34	62.5	.7	4.3	50.8
Dried "B"		119	15.9	44.8	5	11.3	.5	5.4	50.2
Natural "Southwestern"		78	15.7	24.7	70	96.9	.8	5.4	52.5
Natural "Central"	Bottom third	64	19.3	26.8	66	80.5	.5	4.8	52.4
Dried "B"		102	15.9	35.1	8	40.8	1.0	5.1	50.3

[1] Sample 108 not included. [2] Sample 111 not included.

THE HANDLING OF THE CORN AS DISCHARGED.

Much of the corn was so badly damaged that the marine leg could not be used to discharge it. All of the dried "B" corn in hold 4 on account of its packed condition had to be discharged by use of buckets or bags and winches. Discharging corn with bags or buckets is a slow process and necessitates much extra labor and time, thus allowing any hot corn that the cargo may contain to become more severely damaged and also giving time for the damage in the affected location to spread to the surrounding sound corn.

FIG. 16.—Hot corn from the cargo piled on the open quay being conditioned by hand shoveling. (Cargo No. 1.)

TABLE 8.—*Comparison of the condition of the corn samples in crossed-wire containers as loaded and as discharged.*

Kind of corn.	Condition of corn as—	Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Weight per bushel.	Location of sample in hold.
			°F.	P. ct.	c. c.	P. ct.	P. ct.	P. ct.	Lbs.	
Natural "Central"	Loaded	1	59	18.5	28.5	67.0	96.3	0.2	53.0	Top.
	Discharged	1	143	......	49.0	1.0	0	.1	....	
	Loaded	1	53	18.8	21.0	......	98.7	0	52.0	5 feet down near outside.
	Discharged	1	68	19.3	28.5	18.0	89.7	.4	49.0	
	Loaded	1	56	18.5	26.5	60.0	90.6	.4	52.5	16 feet down near outside.
	Discharged	1	104	17.8	35.0	0	0	.2	....	
	Loaded	2	50	19.2	21.0	42.5	95.6	.4	52.0	10 feet down.
	Discharged	2	89	......	27.0	23.0	88.0	.1	....	
	Loaded	2	50	18.9	28.5	36.0	95.5	.5	....	13 feet down.
	Discharged	2	88	19.2	34.5	8.0	63.0	.2	....	
	Loaded	3	50	18.7	22.0	52.0	96.1	.1	53.5	Top.
	Discharged	3	129	18.8	42.0	0	0	.1	....	
	Loaded	3	59	18.5	28.5	38.0	95.2	.4	53.0	4 feet down.
	Discharged	3	119	19.1	38.0	0	83.4	.1	....	
Natural "Southwestern."	Loaded	3	59	15.1	25.0	87.0	97.7	.4	53.5	10 feet down.
	Discharged	3	94	14.9	26.5	49.0	96.6	.2	....	
Natural "Central"	Loaded	3	55	18.0	26.0	62.0	91.7	.4	52.5	Bottom.
	Discharged	3	67	18.9	28.0	63.0	68.4	.2	....	
Dried "B"	Loaded	4	66	15.9	28.5	35.0	91.3	1.2	53.0	Top, under ventilator.
	Discharged	4	141	25.1	49.0	0	0	.7	....	
Dried "A"	Loaded	4	62	14.9	23.0	49.0	97.4	1.0	54.0	Top.
	Discharged	4	79	15.7	28.5	59.0	90.6	1.6	51.0	
Dried "B"	Loaded	4	67	16.8	25.0	37.0	90.7	.7	53.0	Bottom.
	Discharged	4	114	......	35.0	0	0	.9	48.75	

It was necessary to begin treating all of the damaged corn almost immediately after it was discharged from the steamship. Some of the corn from the bottom of the three forward holds which was in fair condition when discharged, "went out of condition" and became hot within a short time after being landed, and this also had to be handled at once. The damaged corn from this cargo was ventilated by hand shoveling, each shovelful being thrown into the air in such a manner that the kernels became separated and fully exposed to the air. Figure 16 shows how a part of the hot corn from this cargo, which was piled on the open quay, was treated to stop the process of fermentation.

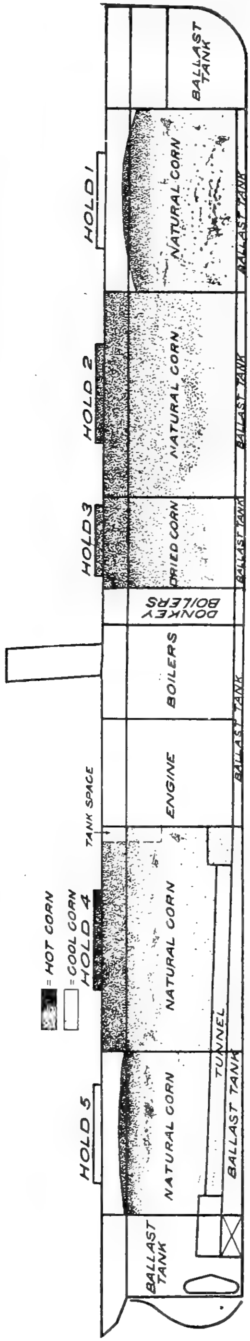

FIG. 17.—Diagram showing arrangement of the steamship and stowage of the corn in the holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 2.)

CARGO No. 2.

Cargo No. 2 consisted of 211,064 bushels of corn, of which 30,500 bushels had been artificially dried. The corn was loaded February 27, 28, March 1, and 2, 1911. The vessel sailed March 3 and arrived at Aalborg, Denmark, April 5, where 88,827 bushels of the corn were discharged from April 5 to 11. The steamship was then taken to Copenhagen, Denmark, where the remaining 122,237 bushels in the cargo were discharged, the last of the corn being taken out on April 20. The maximum time that any of the corn was in the vessel was 53 days, the average time for the Aalborg lot being 39 days and for the Copenhagen lot 47 days. The length of the ocean voyage to Aalborg was 33 days and to Copenhagen 40 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds. As is shown in figure 17, holds Nos. 2, 3, and 4 were entirely filled with corn, while holds 1 and 5 were each filled only to the main deck, leaving an air space of about 8 feet on top of the corn in the central or "trunk" part of the holds.

The dried corn was stowed in hold 3, and the natural corn in holds 1, 2, 4, and 5.

Holds 1 and 2 were located free from the ship's machinery; hold 3 was located just forward of the boiler room; hold 4 was located just aft of the engine room in the bottom part of which was the shaft tunnel, which also extended through the bottom of hold 5.

TABLE 9.—*Range in the principal factors showing quality and condition of the corn as loaded and as discharged by holds.*

[Holds 1, 2, 4, and 5, natural corn; hold 3, dried corn.]

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	51.0– 54.0	18.3–19.2	17.9– 19.9	61.0–77.0	93.1–97.0	52.8–53.5
As discharged	59.0–110.0	16.2–43.6	21.8– 65.7	0–75.0	0–95.6	46.3–54.0
Hold 2:						
As loaded	53.0– 60.0	18.5–18.7	18.7– 19.7	45.0–78.0	94.7–95.6	53.5–53.8
As discharged	58.0–148.0	17.6–34.6	20.8– 75.5	0–78.0	0–96.6	44.0–52.8
Hold 3:						
As loaded	65.0– 74.0	15.2–15.8	20.4– 24.1	34.0–61.0	85.0–96.5	54.0–55.0
As discharged	74.0–155.0	13.0–54.6	23.5–110.8	0–43.0	0–93.7	45.3–54.0
Hold 4:						
As loaded	52.0– 60.0	18.5–19.5	18.5– 24.6	58.0–77.0	92.7–97.5	52.0–54.5
As discharged	59.0–135.0	13.6–48.1	21.1– 83.9	0–69.0	0–96.0	43.3–53.5
Hold 5:						
As loaded	53.0– 55.0	18.3–19.2	19.5– 22.4	62.0–75.0	90.3–95.9	52.5–53.8
As discharged	61.0–140.0	11.1–18.7	23.1– 31.3	0–61.0	0–95.7	47.8–52.0

CONDITION OF THE CORN AS LOADED.

The condition of the natural and dried corn was quite uniform throughout in each lot at the time of loading, as is shown in Table 9, but there was considerable difference in the average condition of the two lots. It will be seen in Table 10 that the averages for various factors in the natural corn as loaded were as follows: Moisture content 18.8 per cent, acidity 19.8 c. c., germination 66.3 per cent, sound kernels 94.7 per cent, and weight per bushel 53.39 pounds; while the averages for the dried corn were: Moisture content 15.5 per cent, acidity 21.9 c. c., germination 43.2 per cent, sound kernels 93.5 per cent, and weight per bushel 54.42 pounds. Comparing the two lots, it is seen that the natural corn was the better in that it had a lower average acidity by 2.1 c. c., a higher average germination by 23.1 per cent, and more sound kernels by 1.2 per cent, but was poorer in that it contained on an average more moisture by 3.3 per cent and a correspondingly lower weight per bushel by a little over one pound.

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The first temperature readings of the resistance thermometers were made March 1, and thereafter each day that the weather permitted until April 6, the day after the steamship arrived in Denmark. In a few instances the readings were continued until April 15.

TABLE 10.—*Average condition of the corn as loaded compared with the average condition as discharged.*

Kind of corn and hold.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Natural corn:	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
Hold 1	53.0	73.6	18.6	18.3	18.7	25.9	67.2	44.4	95.3	80.8	52.95	51.16
2	56.3	113.5	18.6	18.9	19.4	35.1	62.2	18.1	95.1	23.4	53.56	49.52
4	55.6	95.8	18.9	18.1	20.0	29.8	66.9	25.8	94.6	54.1	53.50	49.93
5	53.8	88.3	18.7	18.2	20.4	26.3	66.8	29.9	94.0	72.9	53.35	50.60
Total natural corn	54.8	94.1	18.8	18.3	19.8	29.4	66.3	28.4	94.7	66.8	53.39	50.20
Dried corn:												
Hold 3	69.6	106.8	15.5	15.1	21.9	31.6	43.2	13.2	93.5	49.6	54.42	51.86

Samples Nos. 43 and 46 in hold 1, 52 in hold 2, 61 in hold 3, and 64 in hold 4, were not included in the average as discharged.

The temperature of the corn as loaded varied from 51° F. in the natural corn to 74° F. in the dried corn, the averages for the two lots in even numbers being 55° and 70° F. At the time of discharge, the maximum temperatures of the corn in the various holds were as follows: Hold 1, 110° F.; hold 2, 148° F.; hold 3, 155° F.; hold 4, 135° F.; and hold 5, 140° F. During the time that the corn was in the vessel a large proportion of both the natural and the dried corn became hot, discolored, moldy, and badly damaged.

When the temperature of corn at 51° and 74° F. is raised through inherent causes, deterioration becomes apparent at about 90 to 100° F. and increases very rapidly thereafter if the temperature continues to rise. The temperature records show that the corn reached 100° F. in the different holds as follows: hold 1 in 35 days, hold 2 in 14 days, hold 3 in 19 days, hold 4 in 22 days, and hold 5 in 24 days. This is interesting in connection with the average time that the corn remained in the vessel, which, as already stated, was 39 days for the Aalborg lot and 47 days for the Copenhagen lot.

The wide difference in the rate at which the temperature of the corn changed depended on its position of stowage with reference to height from the bottom of the holds. Where the corn was stowed free from the ship's machinery, it changed the most and became badly damaged in the upper part of the holds. As is shown by the accompanying diagrams, the temperature and degree of deterioration of the corn at the end of the voyage gradually decreased from the surface toward the bottom where the corn in all holds, excepting that in hold 3 and along the shaft tunnel in holds 4 and 5, was in a sound condition.

The air and water temperatures during the loading period averaged close to 50° F. and were generally somewhat higher than the temperature of the corn for the first six days of the ocean voyage. The air temperature was above 70° F. for the first four days and the water temperature remained above 70° F. for the first six days of the voyage, after which the temperature of both suddenly dropped and remained under 60° F. during the remainder of the voyage. During the latter part of the voyage the air temperature dropped to below 30° F. and the water temperature to nearly 30° F.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 1.

As is shown in figure 18, the temperature of the corn near the surface on a level with the main deck changed but little during the first 12 days, after which there was a steady daily increase until it had reached 102° F. on April 6, or 35 days after the first reading was made. The upper portion of the corn to a depth of approximately 4 feet below the surface was in a heating condition when the corn was discharged. The remainder of the corn in the hold changed but little in temperature during the voyage.

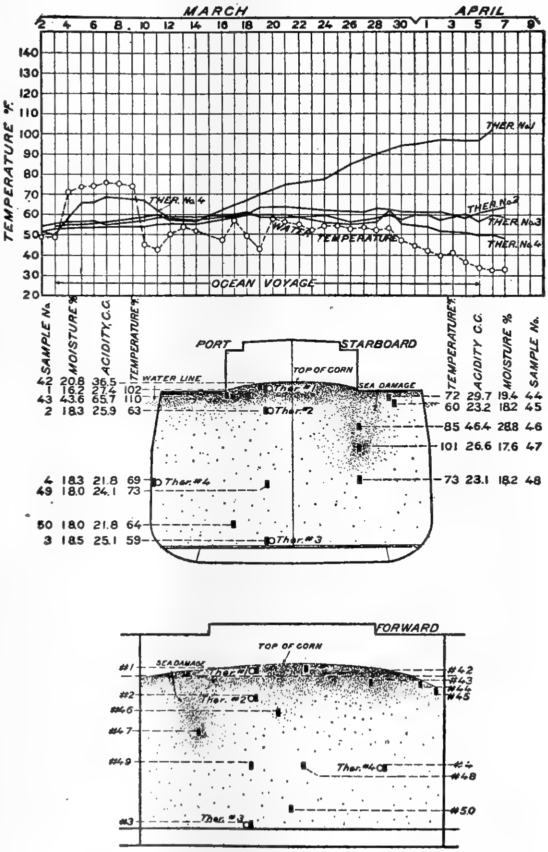

Fig. 18.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

Sample No. 42 in Table 11, which was taken from the surface of the corn, and sample No. 1, which was taken from the wire container fastened to thermometer No. 1, show the damaged condition of the corn near the surface as discharged. Samples Nos. 43 and 46, which were both badly damaged, represent only a small amount of corn. The first was "sweat"-damaged and the latter sea-damaged from water having leaked through a small hole in the deck.

The average condition of the corn in the hold as discharged is shown in Table 10. Compared to the condition of the corn as loaded, it will be seen from the table that there was an average increase of 7.2 c. c. in acidity and an average decrease of 22.8 per cent in germination; 14.5 per cent in sound kernels and 1.79 pounds in test weight per bushel.

TABLE 11.—*Condition of the natural corn in hold 1 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 1, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; *indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	°F.	P. ct.	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Pounds.	Pounds.
42	......	......	......	20.8	......	36.5	......	5	......	33.4	......	47.25
T 1	54	102	18.8	16.2	17.9	27.4	70	39	97.0	40.4	52.75	50.50
*43	......	*110	......	*43.6	......	*65.7	......	*0	......	*0	......	......
44	......	72	......	19.4	......	29.7	......	13	......	69.9	......	50.00
45	......	60	......	18.2	......	23.2	......	55	......	93.8	......	50.00
T 2	52	63	18.5	18.3	18.9	25.9	77	50	93.1	93.8	52.75	52.00
*46	......	*85	......	*28.8	......	*46.4	......	*3	......	*0	......	*46.25
47	......	101	......	17.6	......	26.6	......	29	......	85.8	......	51.00
48	......	73	......	18.2	......	23.1	......	37	......	92.6	......	51.75
49	54	73	18.3	18.0	19.1	24.1	66	75	94.4	95.2	53.50	53.25
T 4	51	69	18.4	18.3	17.9	21.8	61	54	96.9	94.2	52.75	50.75
50	......	64	......	18.0	......	21.8	......	65	......	95.2	......	54.00
T 3	54	59	19.2	18.5	19.9	25.1	62	67	95.1	95.6	53.00	52.25

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 2.

Fully three-fourths of the corn in hold 2 became hot during the voyage. The greatest increase in the temperature of the corn was at the surface and the lowest at the bottom of the hold. The corn at the surface, when the ship reached port on April 5, was 148° F., that one-third down was 115° F., that two-thirds down 85° F., while that at the bottom of the hold had a temperature of only 50° F. These facts are shown in figure 19.

The temperature of the corn in this hold was under 60° F., in all positions of stowage when loaded. By March 11, 8 days after the steamship sailed, the temperature of the corn near the surface, as is shown by the temperature record for thermometer 5, had increased to 73° F.; during the next 8 days the temperature increased 58° and reached 131° F. on March 19; during the next 10 days to March 29, the increase was more gradual, reaching 149° F. on that day, after which it remained practically stationary until the ship reached port, April 5. The corn located one-third of the distance down, as is seen by the temperature record for thermometer 5, had increased to 68° F. by March 14, and to 118° F. by March 29, which was the maximum point reached before the vessel reached port. The corn located two-thirds of the distance down, as shown by the temperature record for thermometer 7, increased gradually in temperature until 88° F. was reached April 5. Thermometer 8 shows that the temperature of the corn near the bottom did not go over 63° F. and during the latter part of the voyage decreased to 50° F. being influenced by the water temperature.

When the hatch was opened soon after the steamship arrived in Aalborg it was seen that the corn was badly damaged on top. The corn immediately under the hatch was discharged as far down as the main deck, but as there did not appear to be any improvement in the condition, the receivers at this port refused to take any more of it, and consequently the remainder of the corn was left in the hold from about a week to 10 days longer. During this time the temperature of the corn located one-third of the distance down in the hold increased from 115° to 140° F., and the corn stowed two-thirds of the distance down, which was still sound on arrival, increased from 88° to 117° F., and was badly heat discolored when it was discharged. That at the surface had a temperature of over 145° F. for 20 days. As is seen in figure 19, the heat damage finally extended fully three-fourths of the distance down, as the temperature there was 105° F. when the corn was discharged. The grain capacity of this hold was over 73,000 bushels, and as previously stated was entirely filled with corn.

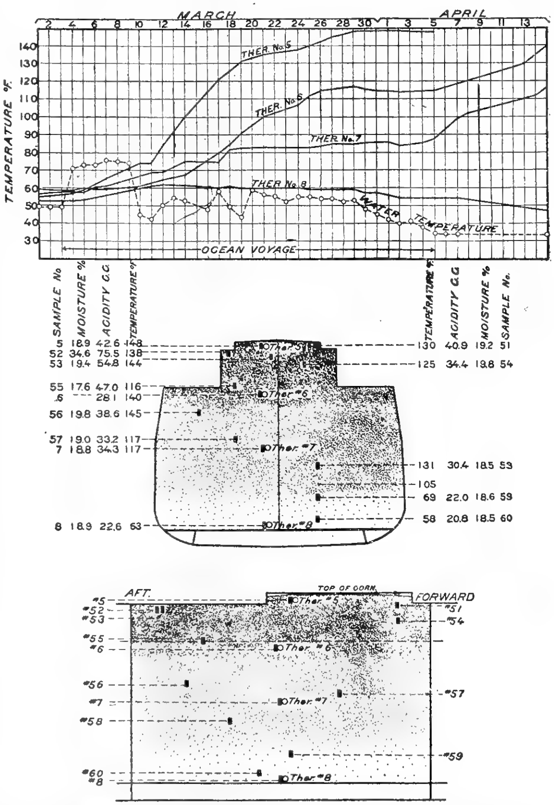

FIG. 19.—Hold 2: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

As is shown in Table 12, only the corn near the bottom of the hold showed any germination or sound kernels at the end of the voyage. Table 10 shows that the averages for the corn in this hold, as discharged, were: Acidity 35.1 c. c., germination 18.1 per cent, sound kernels 23.4 per cent, and weight per bushel 49.52 pounds. This was an increase over the condition, as loaded, of 15.7 c. c. in acidity, and a decrease in even numbers of 44 per cent in germination, 72 per cent in sound kernels, and 4 pounds in weight per bushel.

TABLE 12.—*Condition of the natural corn in hold 2 as loaded and the change in condition while the corn was in the vessel—Samples taken in order in the hold, from top to bottom.*

[T 5, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	°F.	P. ct.	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Pounds.	Pounds.
T 5	55	148	18.6	18.9	19.7	42.6	64	0	94.7	0	53.50	47.75
51	......	130	......	19.2	......	40.9	......	0	......	0	....	48.25
*52	......	*138	......	*34.6	......	*75.5	......	*0	......	*0	....	*48.00
53	......	144	......	19.4	......	54.8	......	0	......	0	....	44.00
54	......	125	......	19.8	......	34.4	......	0	......	0	....	48.50
55	......	116	......	17.6	......	47.0	......	0	......	0	....	50.00
T 6	60	....	18.5	....	18.7	28.1	72	....	95.3	....	53.75	....
56	......	145	......	19.8	......	38.6	......	0	......	0	....	48.50
57	......	117	......	19.0	......	33.2	......	0	......	0	....	51.25
T 7	57	117	18.6	18.8	19.6	34.3	68	0	95.6	0	53.50	50.00
58	......	131	......	18.5	......	30.4	......	0	......	0	....	49.25
59	......	69	......	18.6	......	22.0	......	65	......	94.5	....	51.75
60	......	58	......	18.5	......	20.8	......	78	......	90.2	....	52.75
T 8	53	63	18.7	18.9	19.5	22.6	45	75	94.8	96.6	53.50	52.25

CHANGE IN TEMPERATURE AND CONDITION OF THE DRIED CORN IN HOLD NO. 3.

Hold 3 contained artificially dried corn, all of which, excepting a small amount along the bottom, became hot and badly damaged during the voyage. Even the corn along the bottom, although it did not get hot, was sour, moldy, and badly packed when discharged. The average temperature of this dried corn when it was loaded was about 15° F. higher than the average for the natural corn in the other four holds of the ship. In that part of the corn that was located away from the boiler-room bulkhead, the greatest change in temperature took place in the upper portion. The temperature of the corn near the surface increased 13° F. the first 17 days after it was loaded, after which the increase was more rapid, reaching 137° F. when the ship reached port, as is shown by the temperature record of thermometer 9 in figure 20. The temperature of the corn in the central part of the hold, about 4 feet under the surface, increased in about the same manner as the corn at the surface, but the temperature was generally somewhat lower, having a temperature record of 135° F. on April 7, as is shown by the readings for thermometer 11. The temperature of the corn stowed a little over half way down in the center of the hold increased but little during the first nine days, but from then on steadily increased until 107° F. was reached on April 8, as shown by the temperature record for thermometer 14.

The temperature of the corn near the center of the bottom of the hold increased 19 degrees during the first two weeks, reaching its maximum of 89° F. April 14, after which it gradually became cooler, being affected by the water temperature, and dropped to 79° on April 8.

TABLE 13.—*Condition of the dried corn in hold 3 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 9, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	*°F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 9	70	137	15.6	18.3	24.1	41.4	44	0	85.0	0	54.75	45.25
* 61	......	*155	......	*54.6	......	*110.8	......	*0	......	*0	......	......
T 10	74	91	15.5	16.2	21.6	42.0	38	5	90.5	38.0	54.00	50.50
T 11	71	135	15.4	14.8	21.3	35.7	38	0	94.4	0	54.25	53.00
T 12	68	134	15.3	14.6	23.2	36.8	48	0	92.8	0	54.00	52.50
62	......	115	......	15.4	......	32.0	......	0	......	23.2	......	50.50
T 19	68	106	15.8	13.6	22.1	36.7	61	2	92.8	34.4	54.25	50.50
T 20	68	74	15.6	13.0	21.7	23.5	42	43	96.5	85.8	54.25	54.00
63	......	108	......	15.5	......	29.8	......	0	......	33.6	......	52.00
T 14	68	107	15.5	15.2	21.5	29.5	44	15	95.7	76.9	54.25	53.25
T 13	67	109	15.2	14.2	21.5	24.6	34	21	94.0	85.3	55.00	53.50
T 15	65	105	15.3	15.0	20.4	26.5	38	18	95.0	83.5	54.75	52.00
13	71	......	15.8	......	21.6	......	50	......	95.5	......	54.50	......
T 17	70	89	15.8	15.6	22.1	28.0	47	31	94.8	90.0	54.75	53.50
16	70	78	15.2	15.3	21.8	25.2	35	36	94.9	93.7	54.25	53.75

As is shown in Table 13, the corn became badly damaged in the upper part of the hold, the degree of damage gradually decreasing toward the bottom. It will be seen in Table 10 that the averages for various factors in the analyses of the corn as discharged were as follows: Acidity 31.6 c. c., germination 13.2 per cent, sound kernels 49.6 per cent, and 51.86 pounds test weight per bushel, which, compared with the average condition of the corn as loaded, was an increase of 9.9 c. c. in acidity and a decrease of 30 per cent in germination; 43.9 per cent in sound kernels; and a little over 2.5 pounds in test weight per bushel.

INFLUENCE OF BOILER HEAT ON THE CORN.

There were three main boilers and two donkey boilers in the stokehold. The donkey boilers were located near the middle of the bulkhead which separated the stokehold from hold 3. This bulkhead was lined with a plank sheeting on the cargo side, but there was no second bulkhead to form an air space. There were coal bunkers over and on both sides of the stokehold, as is shown in figures 20 and 22. Steam was kept up in the donkey boilers during the loading period, and the effect of the heat generated was plainly noticeable on the corn stowed contiguous to this bulkhead opposite the boilers, as is shown by the temperature records for thermometers 13, 14, and 15 in figure 21. The corn located next to the bulkhead opposite the donkey boilers showed a rapid increase in temperature at the time of loading, while steam was kept up in the boilers, and showed a higher temperature than the corn located the same height but some distance back from the bulkhead until March 27, when it was lower. When steam was again generated in the donkey boilers at the end of the voyage, the effect of the heat on the corn stowed next to the bulkhead opposite the boilers became apparent, the temperature increasing 20 degrees in two days. The corn near the surface which was stowed along the bulkhead that separated hold 3 from the coal bunker did not get as hot as the corn that was stowed the same height back from the bulkhead, as is shown by the temperature records for thermometers 10, 11, and 12. The hatch over the coal bunker was kept open and afforded ventilation in the bunker until March 18, but during the next week, when rough weather was encountered and the hatch was kept closed, the temperature of the corn contiguous to the bulkhead increased 23 degrees, as is shown by the temperature record for thermometer 10. The corn stowed along the bottom of hold 3 near the boiler-room bulkhead had a lower temperature during the greater part of the voyage than the corn some distance away, and this can be accounted for in that the temperature at the bottom of the boiler room was kept cool by the fresh air that rushed from the ventilators and took the place of the heated air that was forced out at the top.

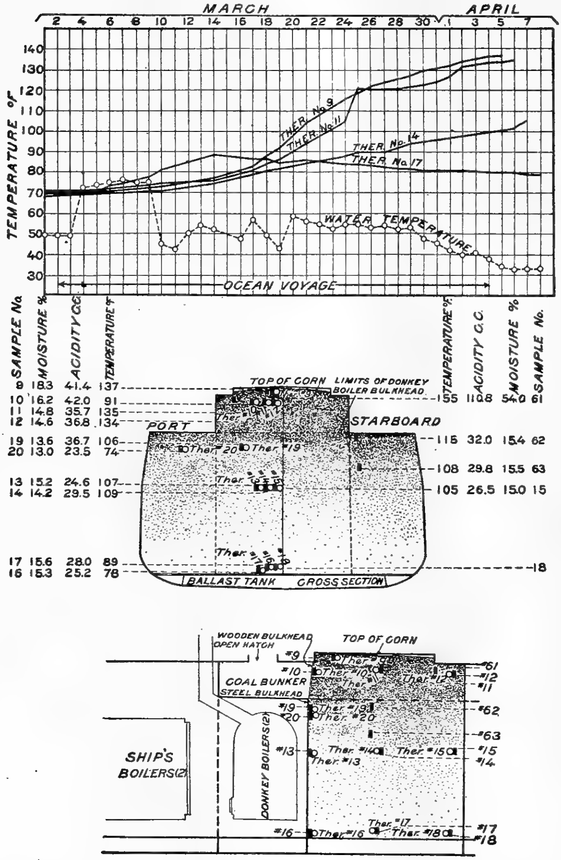

FIG. 20.—Hold 3: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

The effect on the corn of the heat generated in the boilers is shown further by the temperature records of thermometers 19 and 20, which were located against the upper part of the bulkhead, 19 opposite the boilers and 20 ten feet away opposite a ventilated coal bunker, as shown in figure 22. Thermometer 19 registered an increase of 17° F. the first two days after the corn was loaded, while thermometer 20 registered an increase of only 1° F. during this time. Thermometer 19 registered a higher temperature than thermometer 20 during the whole voyage. Thermometer 19 registered over 100° F.

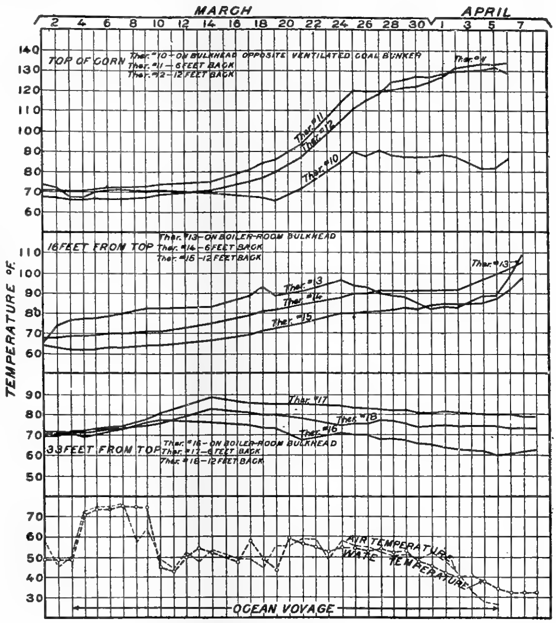

FIG. 21.—Hold 3: Temperature records showing the effect of boiler heat on the temperature of corn. (Cargo No. 2.)

from March 16 to March 26, after which the temperature steadily dropped until April 2, when steam was again generated in the donkey boilers, the heat immediately affecting the temperature of the corn, which increased 22 degrees in four days. On April 6 the corn surrounding thermometer 19 had a temperature of 106° F. as compared with a temperature of but 59° F. for the corn surrounding thermometer 20.

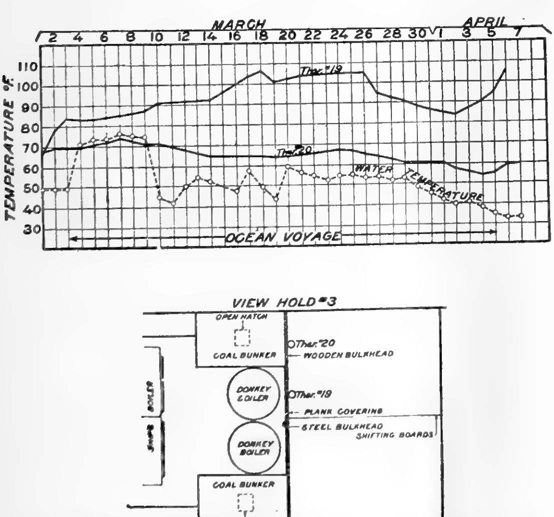

FIG. 22.—Hold 3: Temperature records showing the effect of boiler heat on the temperature of corn. (Cargo No. 2.)

It will be seen in Table 14 that the corn surrounding thermometer 19, opposite the donkey boilers, underwent by far the most deterioration. Sample

No. 19, which was fastened to thermometer 19, as compared with sample No. 20, which was fastened to thermometer 20, showed a greater increase in acidity during the voyage by 10.8 c. c., and a greater decrease in germination by 59 per cent, sound kernels by 47 per cent, and weight per bushel by 3.5 pounds.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 4.

During the voyage the natural corn in hold 4 became hot and badly damaged in the upper part of the hold and along the shaft tunnel in the bottom, as is shown in figure 23. The greatest damage in the corn occurred near the surface and decreased with the distance downward.

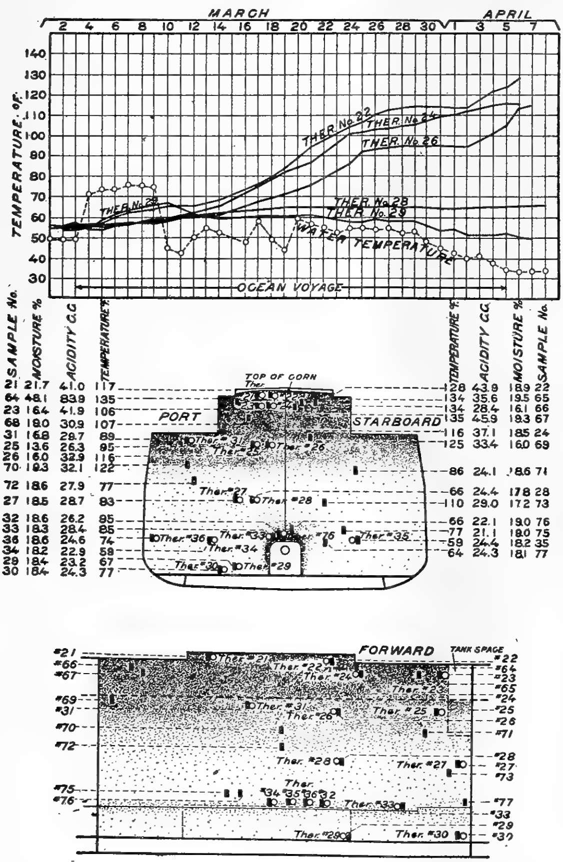

FIG. 23.—Hold 4: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

The temperature of the corn in this hold as loaded varied from 50° to 62° F. In the first 11 days of the ocean voyage ending March 12, the temperature near the surface about 20 feet back from the engine-room bulkhead increased from 55° to 68° F.; by March 29 the temperature had reached 114° F. and by April 6, it was 128° F. as shown by the temperature record for thermometer 22 in figure 23. The temperature of the corn located about 4 feet down increased at about the same rate as at the surface, but did not start to increase so soon; the temperature at this point was 115° F. on April 6, as compared with 128° F. for the surface corn. (See temperature record for thermometer 24.)

It was still longer before the increase in temperature of the corn located about 12 feet below the surface began to be pronounced.

By March 26, the temperature had increased to 93° F., after which it remained practically stationary until April 2, but during the next five days it showed a rapid increase and was 116° F. on April 7, as is shown by the temperature record for thermometer 26. It should be noted that the temperature increased rapidly in the three positions mentioned from the 12th to the 24th of March, a period of the voyage during which the weather was rough. Thermometer 28, located about two-thirds of the distance down in the hold, indicated a temperature of 66° F. on April 8, which was an increase of but 9 degrees during the voyage. The temperature of the corn near the bottom of the hold varied somewhat with the water temperature, reaching its maximum of 67° F. on March 10, after which it gradually decreased to 49° F. on April 7, at which time the water temperature was 33° F.

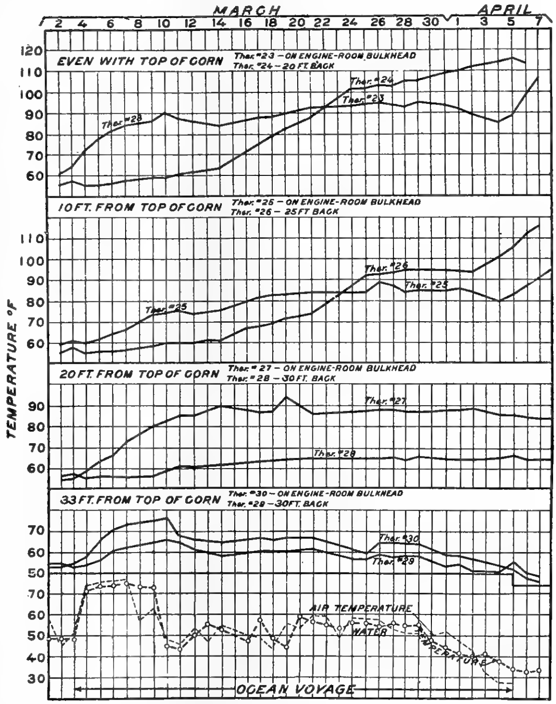

FIG. 24.—Hold 4: Temperature records showing the effect of heat from the engines on the temperature of corn. (Cargo No. 2.)

TABLE 14.—*Effect of boiler heat on the corn.*

Sample No.	Location along the bulkhead.	Increase.		Decrease.			
		Temperature.	Acidity.	Moisture.	Germination.	Sound kernels.	Weight per bushel.
		° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
19	Opposite donkey boiler	38	12.6	2.2	59	58.4	3.75
20	Opposite coal bunker	6	1.8	2.6	(1)	10.7	.25

1 No change.

Note that the temperature of the corn was over 100° F. near the surface for 14 days before it was discharged, 4 feet under the surface for 13 days, and 12 feet under the surface for 3 days.

INFLUENCE OF ENGINE HEAT ON THE CORN.

It will be seen by the temperature records in figure 24 that the temperature of the corn located next to the bulkhead separating hold 4 from the engine room was influenced to a considerable extent by the temperature in the engine room, expecially during the early part of the voyage.

There was an unventilated water-tank space next to the engine room bulkhead in the upper part of the hold, which was separated from the cargo space by a board bulkhead that was not air-tight. Thermometer 23, which was located next to the tank-space bulkhead in the upper part of the corn, indicated an increase from 60° to 90° F., or an increase of 30 degrees the first 8 days ending March 10, during which time the corn stowed the same height but about 20 feet back from the bulkhead increased only 3 degrees and did not reach 90° F. until about March 21, 11 days later.

TABLE 15.—*Condition of the natural corn in hold 4 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 21, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the average.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	°F.	P. ct.	P. ct.	c.c.	c.c.	P. ct.	P. ct.	P. ct.	P. ct.	Pounds.	Pounds.
T 21	52	117	19.5	21.7	20.1	41.0	60	0	95.5	0	53.25	45.50
T 22	54	128	19.1	18.9	20.2	43.9	73	0	91.1	0	53.50	43.25
*64	......	*135	......	*41.1	......	*83.9	......	*0	......	*0	....	....
65	......	134	......	19.5	......	35.6	......	0	......	13.7	....	48.00
66	......	134	......	16.1	......	28.4	......	0	......	0	....	48.25
67	......	135	......	19.3	......	45.9	......	0	......	0	....	45.50
T 23	56	106	19.3	16.4	20.0	41.9	73	6	94.0	29.6	52.50	49.50
T 24	56	116	19.0	18.5	24.6	37.1	58	0	93.0	0	54.50	51.00
68	......	107	......	19.0	......	30.9	......	0	......	15.9	....	49.00
69	......	125	......	16.0	......	33.4	......	0	......	0	....	49.50
T 31	56	89	18.6	16.8	19.5	29.7	63	22	94.4	55.8	54.25	50.75
T 25	60	95	18.6	13.6	20.1	26.3	73	52	97.5	86.4	53.50	....
T 26	56	116	18.5	16.0	18.6	32.9	62	16	92.8	42.7	53.75	49.75
70	......	122	......	19.3	......	32.1	......	0	......	34.5	....	49.25
71	......	86	......	18.6	......	24.1	......	38	......	84.7	....	50.50
72	......	77	......	18.6	......	27.9	......	29	......	83.0	....	51.00
T 27	57	93	18.6	18.5	19.2	28.7	70	0	96.3	57.2	53.00	48.00
T 28	56	66	18.8	17.8	18.7	24.4	66	68	95.9	95.8	54.00	53.00
73	......	110	......	17.2	......	29.0	......	6	......	49.5	....	51.00
75	......	77	......	19.0	......	21.1	......	54	......	85.8	....	51.75
76	......	66	......	19.0	......	22.1	......	42	......	91.9	....	52.00
T 32	57	85	19.1	18.6	21.1	26.2	58	27	94.1	89.7	52.00	50.00
T 33	57	95	19.0	18.3	20.7	28.4	70	9	92.7	55.5	53.75	50.00
T 36	53	74	19.2	18.6	18.5	24.6	68	65	95.5	96.0	53.25	51.50
T 34	55	59	18.8	18.2	18.7	22.9	71	69	95.1	86.5	54.00	53.50
77	......	64	......	18.1	......	24.3	......	22	......	84.6	....	48.75
T 35	55	59	18.7	18.2	20.3	24.4	61	69	97.0	95.4	54.00	53.25
T 30	54	77	19.7	18.4	20.4	24.3	67	59	94.2	86.0	53.50	52.50
T 29	55	67	18.9	18.4	19.8	23.2	77	68	95.4	94.5	53.25	52.25

During the first part of the voyage, to March 23, thermometer 25, located against the lower part of the tank-space bulkhead about 10 feet from the surface, also indicated a higher temperature than thermometer 26, located the same height but some distance back in the hold. During the remainder of the voyage the temperature of the corn stowed next to the tank-space bulkhead did not vary a great deal until the last few days when it increased 21 degrees in 3 days near the surface of the corn and 15 degrees in 4 days 10 feet below the surface. The temperature of the corn stowed back from the tank space continued to increase irregularly during the whole of the voyage and reached 115° F. near the surface and 116° F. 10 feet below the surface before it was discharged. Thermometer 27, located next to the engine room bulkhead about 20 feet from the surface of the corn indicated an increase from 56° to 90° F., or an increase of 34 degrees during the first 12 days ending March 14, as compared with an increase from 56° to 62° F., or 6 degrees, in the corn stowed the same height but some distance back from the bulkhead, as was indicated by thermometer 28. From March 14 on there was but little change in either position. The temperature of the corn near the bottom varied somewhat with the water temperature, as is shown by the temperature records for thermometers 29 and 30, that near the bulkhead being generally somewhat higher than the corn some distance back.

The corn stowed next to the tunnel was affected by the heat which penetrated the tunnel from the engine room, the details of which are explained under the discussion of the changes that took place in the corn in hold 5.

The changes in the condition of the corn during the voyage in various positions of stowage in the hold are shown in Table 15. The averages of the corn as discharged were: Acidity 29.8 c. c., germination 25.8 per cent, sound kernels 54.1 per cent, and 49.93 pounds test weight per bushel, which was an average increase during the voyage of 9.8 c. c. in acidity, and an average decrease of 41.1 per cent in germination, 40.5 per cent in sound kernels, and a little over 3.5 pounds in test weight per bushel.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 5.

About one-fifth of the natural corn in hold 5 became heat damaged while it was in the vessel. The heating corn was found at the top to about one-fourth the distance down and also along the shaft tunnel. In the heating corn on top the highest temperature and the greatest damage were found at the surface, while in the heating corn along the shaft tunnel, the highest temperature and the greatest damage were found in the corn located against the tunnel.

The temperature of the corn in this hold at time of loading varied from 53° to 55° F. During the voyage the corn near the surface on a level with the main deck gradually increased in temperature until it reached a maximum of 122° F. on April 2, 3 days before the ship was docked, as is shown by the temperature records for thermometer 38 in figure 25. The temperature of the corn about

5 feet below the surface and the remainder of the corn in the hold, excepting that which was located on and near the shaft tunnel, changed but little before the cargo arrived in Denmark, as is shown by the temperature records for thermometers 38 and 41. But, during the discharge of the cargo, which took 15 days, the corn at the new surfaces formed from day to day would frequently get hot from one day to another. Thus the corn nearly halfway down in the hold was cool and sound when it was first exposed but got hot before it was discharged, as is shown by sample No. 82 in figure 25, which had a temperature of 112° F. This same condition also occurred in the corn in hold 4.

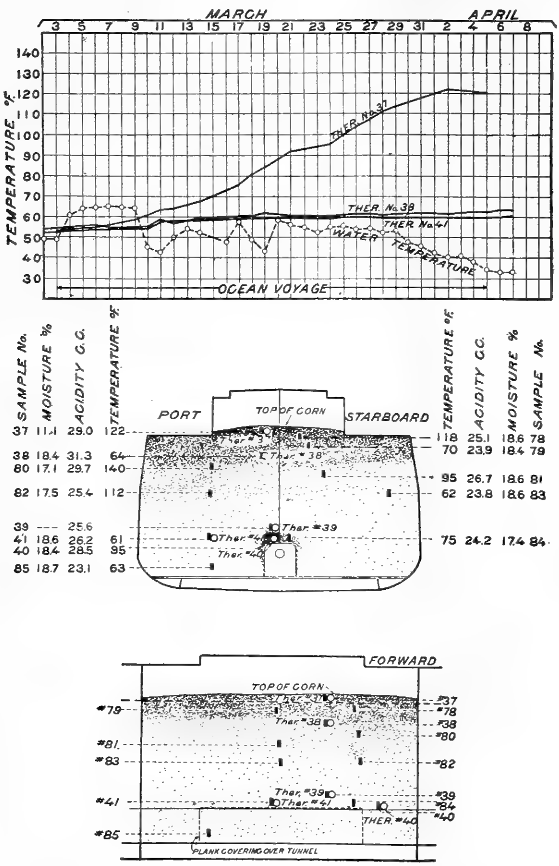

FIG. 25.—Hold 5: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

Table 16 shows the condition of the individual samples as discharged as compared to the condition as loaded. It will be seen in Table 10 that the averages for the corn as discharged were: Acidity, 26.3 c. c., germination 29.9 per cent, sound kernels 72.9 per cent, and weight per bushel 50.6 pounds, which was an average increase from the condition as loaded of 5.9 c. c. in acidity, and an average decrease of 36.9 per cent in germination, 21.1 per cent in sound kernels, and 2.75 pounds in test weight per bushel.

INFLUENCE OF TUNNEL HEAT.

The temperature of the corn located next to the shaft tunnel in holds 4 and 5 was noticeably affected by the tunnel temperature, as is shown in figures 26 and 27. The tunnel was constructed from steel and was unprotected, excepting that part of it which was directly under the hatches, where it had a plank covering. In hold 4, five thermometers were placed in the corn the same height as the top of the tunnel, as is illustrated in figure 26. Thermometer 36 was located on the steel side of the ship, where the temperature varied with and was always about the same as that of the sea water. Two thermometers were placed halfway between the tunnel and the outside, thermometer 34 on the port side and 35 on the starboard side, and the temperature of the corn in both of these positions remained practically the same throughout the whole of the voyage. The two remaining thermometers were placed on the tunnel, thermometer 32 on the unprotected steel part and 33 on the plank protected part. The temperature records for thermometers 32 and 33 show that the temperature next to the tunnel remained unchanged until the ship began to sail at the beginning of the voyage, after which there was an immediate and rapid increase during the next seven days, reaching a maximum of 95° F. on March 10. During this period the corn that was located against the steel part of the tunnel was the first to show a rapid increase, and also the greatest daily increase, in temperatures. After March 10 there was a decided drop in both the air and water temperatures, and also a corresponding drop in the temperature of the corn next to the tunnel. The corn, however, remained above 80° F. until April 1, after which there was again a decided drop in temperature corresponding to the drop in the air and water temperatures at this time. The corn located against the steel part of the tunnel was, however, in this case the first to show the decrease, and also showed the greatest daily decrease, a condition which was just the reverse of that at the beginning of the voyage. This illustrates the fact that the unprotected steel tunnel is a better conductor of heat than when it is protected by a plank sheeting. During practically the whole of the voyage, the temperature of the corn stowed next to the tunnel was over 20 degrees higher than the temperature of the corn stowed halfway out from the tunnel.

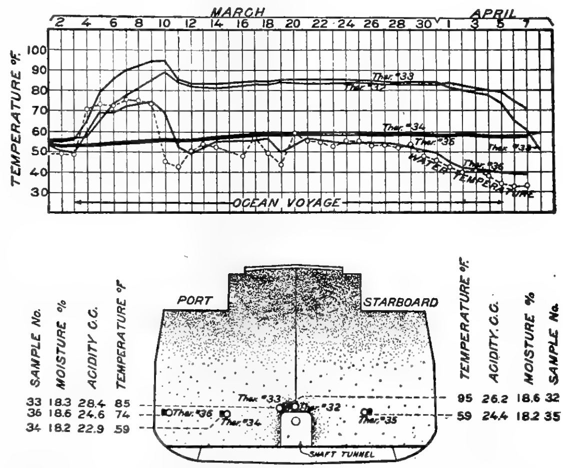

FIG. 26.—Hold 4: Temperature records of the electrical resistance thermometers and "trap" samples located at the height of the top of the shaft tunnel. Samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

TABLE 16.—*Condition of the natural corn in hold 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 37, etc., represents samples in crossed-wire containers fastened to resistance thermometers of the same numbers; * indicates not included in the average.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 37	53	122	19.1	11.1	19.9	29.0	75	20	93.2	47.7	53.75	51.00
78	......	118	......	18.6	......	25.1	......	0	......	64.0	....	49.50
79	......	70	......	18.4	......	23.9	......	55	......	93.7	....	52.00
T 38	53	64	19.2	18.4	22.4	31.3	66	55	90.3	89.0	52.50	52.00
80	......	140	......	17.1	......	29.7	......	0	......	0	....	47.75
81	......	95	......	18.6	......	26.7	......	30	......	80.0	....	49.25
82	......	112	......	17.5	......	25.4	......	44	......	88.6	....	49.25
83	......	62	......	18.6	......	23.8	......	49	......	95.7	....	50.25
T 39	54	71	18.7	....	19.5	29.6	62	4	95.9	89.8	53.25	....
T 40	55	95	18.4	18.4	19.9	28.5	63	0	95.1	35.2	53.50	51.00
84	......	75	......	17.4	......	24.2	......	13	......	87.2	....	51.00
T 41	54	61	18.3	18.6	20.6	26.2	68	58	95.5	84.8	53.75	52.00
85	......	63	......	18.7	......	23.1	......	61	......	92.4	....	51.75

The influence of the tunnel heat on the corn in hold 5, is illustrated by the temperature records for thermometers 39, 40, and 41 in figure 27. Thermometer 40 was located on the steel part of the tunnel, thermometer 39 about 3 feet above the plank covered part of the tunnel, and thermometer 41 the same height as the top of the tunnel but halfway out toward the side of the ship. Thermometer 40 indicated a rapid increase in temperature during the first week after the vessel sailed, and registered 95° F. on March 10. The temperature decreased to 86° F. on March 11, after which it did not vary much until the steamship arrived at Denmark, when the temperature dropped 16 degrees in four days. The temperature of the corn along the tunnel varied with the water and air temperature, but was considerably higher after the first few days. Thermometer 39 located 3 feet above the plank covered part of the tunnel registered

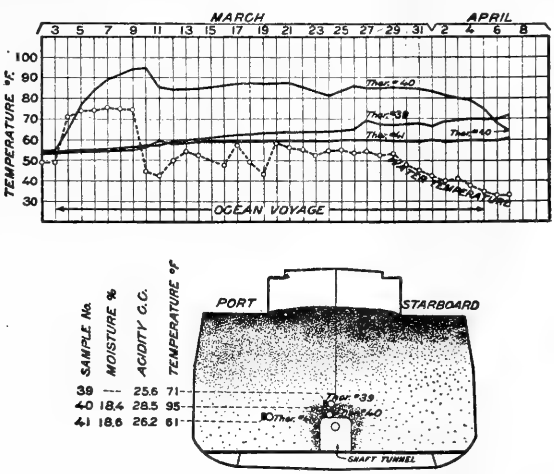

FIG. 27.—Hold 5: Temperature records of the electrical resistance thermometers, location of the thermometers, and "trap" samples located at the height of the top of the shaft tunnel. Samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

an increase of but 17 degrees during the voyage, and thermometer 41 located halfway out registered an increase of only 7 degrees. The temperature of the corn stowed against the tunnel did not go above 95° F. in either hold, but the corn became sour and moldy and was in a dangerous condition for storage after it was discharged.

TABLE 17.—*Changes that took place in the condition of the corn located on the shaft tunnel compared with the changes in the corn stowed the same height in the holds but located halfway between the tunnel and the side of the vessel.*

Sample No.	Location.	Increase in temperature.	Decrease in moisture content.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
Hold 4:		° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
32	On tunnel, wooden part	28	0.5	25.5	31	4.4	2.00
33	On tunnel, steel part	38	.7	38.5	61	37.2	3.75
32 and 33[1]	On tunnel	33	.6	32.0	46	20.8	2.87
34 and 36[2]	Tunnel height, halfway out	12	.6	25.7	2	4.0	1.12
Hold 5:							
40	On tunnel	40	.0	42.5	63	59.9	2.50
41	Tunnel height, halfway out	7	[3] .3	28.0	10	10.7	1.75

[1] Data represent averages for samples Nos. 32 and 33.
[2] Data represent averages for samples Nos. 34 and 36.
[3] Increase.

It will be seen in Table 17 that the corn stowed against the tunnel underwent a more severe deterioration than the corn stowed the same height but halfway out toward the side of the hold; and also, that the corn stowed along the steel side of the tunnel became more damaged than the corn stowed against the plank covered part of the tunnel.

"SWEAT" AND FERMENTATION IN THE HOLDS.

The effects of "sweat" were shown very distinctly immediately under the hatch combings and deck beams in each hold. The "sweat" which condensed on the under side of the deck fell on the surface of the corn where it supplied the necessary moisture for fermentation. While the amount of corn that was damaged by "sweat" alone was not very large, the fermentation which it started and the heat which was generated, spread to the unaffected parts and in that way caused much damage as a result of the long voyage. This condition usually happens early in the voyage. Table 18 shows the result of "sweat" on the corn located immediately under the hatch beams.

TABLE 18.—*Effect of "sweat" on the corn which was located immediately under the hatch beams.*

Sample No.	Hold No.	Temperature.	Moisture content.	Weight per bushel.	Germination.	Acidity.	Sound kernels.
		° *F.*	*Per cent.*	*Pounds.*	*Per cent.*	*c. c.*	*Per cent.*
43	1	110	43.6	(1)	0	65.7	0
52	2	138	34.6	48.00	0	75.5	0
61	3	155	54.6	(1)	0	110.8	0
64	4	135	48.1	(1)	0	83.9	0

[1] Too wet.

In fermenting corn, the moisture contained within the kernels is liberated quite rapidly, and escapes in the form of vapor. After the cargo arrived in Aalborg, the hot corn under the hatch in hold 2 was discharged to a depth of about 8 feet, and then the hatch closed again. While the hatch was open, there was no "sweat" dropping from the hatch beams because the heated moisture-laden air escaped through ventilation, but, a short time after the hatch had been closed the water was found to be dripping from the deck and hatch beams quite rapidly, which stopped again after the hatch had been opened a few minutes. During the voyage all of the ventilators leading to the corn were kept closed.

CORRELATION OF THE CHANGES IN THE TEMPERATURE OF THE CORN AND THE CHANGES IN SOUND KERNELS, ACIDITY, GERMINATION, AND TEST WEIGHT PER BUSHEL.

It was seen in the tables giving the detailed analyses of the samples that considerable change took place in the temperature and condition of the corn in the various positions of stowage while the corn was in the vessel. The increase in the temperature of the corn in the holds of a vessel is brought about principally through (1) inherent causes, usually fermentation, which produces heat, and (2) external influences, such as higher air and sea-water temperatures and the heat from the ship's machinery, which penetrates the cargo holds and frequently induces fermentation. As the corn in bulk does not afford sufficient ventilation for the heat to escape, the temperature continues to increase until the corn gets hot. The maximum temperature recorded in this cargo as discharged was 155° F.

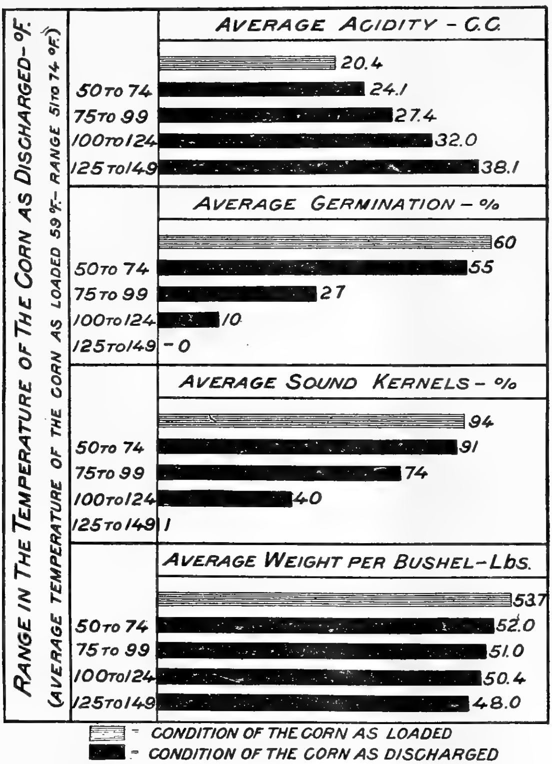

FIG. 28.—Diagram showing the correlation of the temperature and condition of the corn samples in crossed-wire containers as loaded and as discharged. (Cargo No. 2.)

The temperature of hot corn often decreases after the corn has been fermenting for some time, due no doubt to the more or less complete destruction of the compounds and tissues upon which the biochemical processes act.

By examining figure 28, it will be seen that there is a close relation between the deterioration of the corn and the increase in temperature.

CARGO No. 3.

Cargo No. 3 consisted of 145,714 bushels of natural corn. The corn was loaded December 22 and 23, 1911. The vessel sailed December 24 and arrived in Bremerhaven January 7, where the corn was discharged from January 10 to 14. The length of the ocean voyage was 14 days. The maximum time that any of the corn was in the vessel was 23 days and the average time 21 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds, as is shown in figure 29, and each of the holds was only partly filled with corn. The vessel had two shaft tunnels running through the bottom of holds 3, 4, 5, and 6, one of which carried steam pipes that supplied the steam for the rudder machinery. Both tunnels were ventilated.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 19 and 20. The averages for the various factors in the corn as loaded were as follows: Moisture content 19.3 per cent, acidity 16.8 c. c., germination 73.4 per cent, sound kernels 93.4 per cent, weight per bushel 54.5 pounds. The corn at this time had an average temperature of 32° F. It will be noted that the corn was in very sound condition as indicated by the extremely low acidity test of 16.8 c. c.

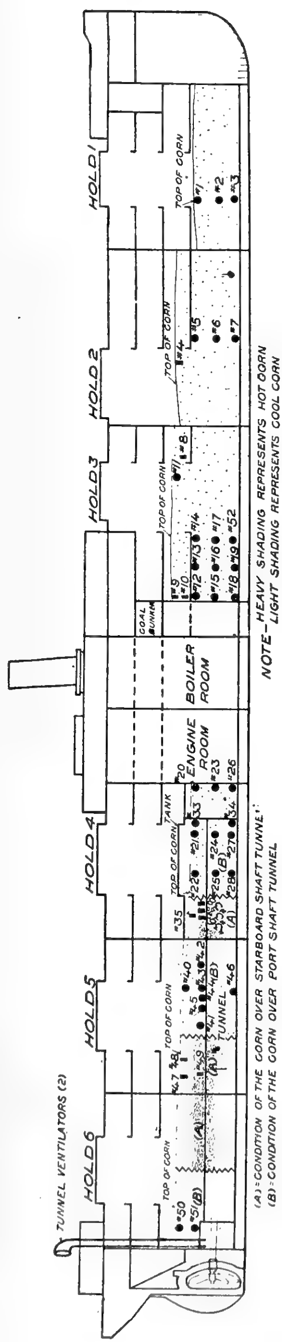

FIG. 29.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn discharged. (Cargo No. 3.)

TABLE 19.—*Range in the principal factors showing quality and condition of the corn in cargo No. 3, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	32.0– 32.0	18.7–19.0	14.0–15.0	74.0–80.0	90.8–94.5	54.0–55.5
As discharged	36.0– 37.0	18.1–18.6	18.5–20.5	79.0–82.0	89.8–95.8	53.7–54.2
Hold 2:						
As loaded	30.0– 31.0	18.3–18.8	15.5–16.5	71.0–81.0	93.1–95.3	53.5–55.5
As discharged	34.0– 41.0	17.4–18.8	17.5–20.5	66.0–78.0	92.0–94.3	53.5–56.0
Hold 3:						
As loaded	31.0– 32.0	18.1–19.7	14.0–18.0	71.0–80.0	90.8–96.2	54.0–55.5
As discharged	33.0– 48.0	17.6–19.4	16.0–19.0	60.0–87.0	82.8–97.0	52.3–55.0
Hold 4:						
As loaded	31.0– 46.0	19.1–20.6	16.0–20.5	61.0–78.0	91.2–94.7	53.0–56.0
As discharged	42.0–132.0	17.9–26.8	18.0–46.0	0–82.0	0–96.3	41.5–56.0
Hold 5:						
As loaded	27.0– 32.0	19.1–20.8	16.5–19.0	55.0–85.0	90.6–95.7	52.0–55.0
As discharged	32.0–119.0	18.6–22.9	17.5–37.0	0–84.0	0–95.8	46.0–54.5
Hold 6:						
As loaded	28.0– 32.0	18.4–19.3	15.5–17.0	82.0–91.0	95.7–98.7	55.0–56.0
As discharged	37.0– 52.0	18.3–18.9	18.0–18.0	80.0–91.0	92.1–97.1	54.5–55.0

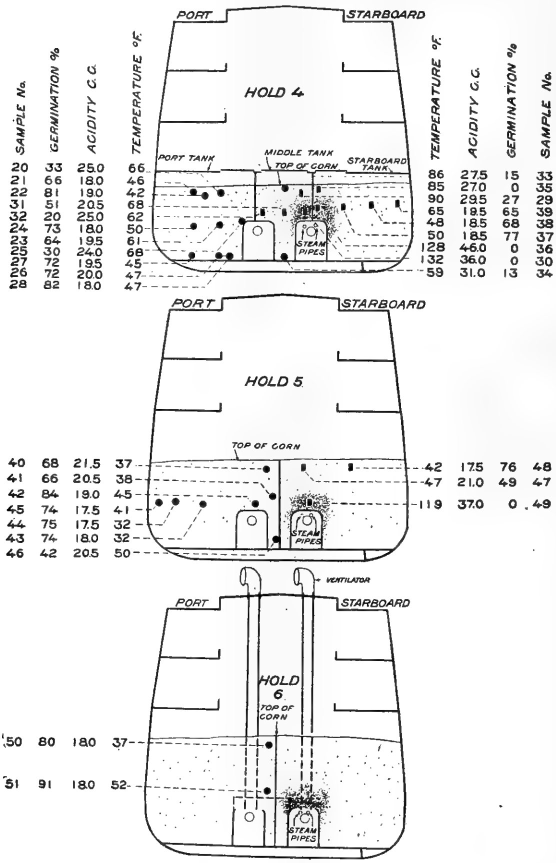

FIG. 30.—Illustrating the position of stowage of the corn in holds 4, 5, and 6, cargo No. 3, and the effect of the heat from the shaft tunnel on the corn surrounding the starboard tunnel. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 3.)

Table 20.—*Condition of the corn in cargo No. 3 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	°F.	°F.	P. ct.	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.
1	32	36	18.9	18.5	15.0	20.0	79	82	90.8	90.9	55.50	54.00
2	32	37	18.7	18.6	14.0	20.5	73	80	91.5	89.8	54.50	54.50
3	......	......	19.0	18.1	15.0	18.5	79	79	94.5	95.8	54.00	53.75
Hold 2:												
4	......	41	......	17.9	......	18.0	......	78	......	92.7	......	56.00
5	31	35	18.3	18.2	15.5	17.5	70	75	93.1	92.0	53.50	54.00
6	30	39	18.7	17.4	16.5	20.5	73	66	95.3	93.1	54.50	54.50
7	31	33	18.8	18.8	16.0	19.0	80	75	95.0	94.3	55.50	53.50
Hold 3:												
8	......	42	......	19.2	......	19.0	......	75	......	89.1	......	55.00
9	......	45	......	19.0	......	17.5	......	75	......	94.6	......	54.00
10	......	48	......	19.4	......	19.0	......	60	......	88.3	......	52.00
11	32	37	18.2	17.5	17.5	17.0	75	71	92.1	93.6	55.00	54.00
12	30	43	19.7	18.1	15.5	18.0	73	76	93.5	94.0	54.00	52.50
13	31	33	19.0	18.4	16.5	17.0	74	69	95.2	97.0	54.00	52.25
14	31	36	18.5	18.7	14.0	18.5	78	77	96.2	82.8	55.00	53.50
15	31	43	18.7	18.0	16.0	16.0	73	77	94.2	97.0	55.00	54.50
16	31	34	18.1	17.9	17.0	16.0	79	85	90.8	95.1	55.50	54.25
17	32	33	19.1	18.8	17.5	18.0	70	76	91.5	93.9	54.50	53.75
18	32	38	19.2	19.0	18.0	17.5	73	83	92.9	91.0	54.00	54.50
19	32	41	18.7	17.6	14.5	19.0	77	74	93.6	92.6	55.00	54.00
Hold 4:												
Port side—												
20	46	66	19.6	18.6	17.0	25.0	67	33	93.0	59.0	55.00	50.75
21	33	46	19.1	18.9	17.5	18.0	67	66	93.2	90.4	56.00	55.00
22	32	42	19.3	18.7	18.0	19.0	61	81	91.2	87.7	53.50	54.00
23	36	61	19.5	19.0	17.0	19.5	78	64	92.9	92.2	55.00	52.75
24	31	50	19.4	19.0	17.0	18.0	70	73	94.7	87.3	55.00	53.00
25	34	68	19.3	18.5	16.5	24.0	69	30	93.0	75.2	54.50	50.75
26	37	47	19.8	18.6	19.0	20.0	69	72	92.2	89.4	53.00	53.25
27	32	45	19.6	19.3	17.0	19.5	67	72	92.0	90.2	54.00	52.75
28	34	47	19.7	18.7	17.0	18.0	70	82	93.9	88.7	54.50	53.00
Middle—												
33	33	86	19.3	18.4	16.0	27.5	76	15	93.8	55.6	55.00	50.50
29	......	90	......	18.6	......	29.5	......	27	......	51.2	......	45.25
30	......	132	......	18.6	......	36.0	......	0	......	......	......	43.50
31	......	68	......	19.1	......	20.5	......	51	......	88.6	......	53.00
32	......	62	......	19.1	......	25.0	......	20	......	67.8	......	56.00
34	33	59	20.6	18.9	20.5	31.0	68	13	93.3	53.8	54.75	51.00
Starboard side—												
35	......	85	......	18.1	......	27.0	......	0	......	2.2	......	45.50
36	......	128	......	26.8	......	46.0	......	0	......	0	......	41.50
37	......	50	......	19.1	......	18.5	......	77	......	96.3	......	55.00
38	......	48	......	17.9	......	18.5	......	68	......	91.0	......	55.00
39	......	65	......	19.2	......	19.5	......	65	......	88.5	......	51.25
Hold 5:												
Port side—												
40	32	37	19.8	18.6	18.0	21.5	77	68	91.7	90.6	52.50	52.25
41	32	38	20.8	19.6	19.0	20.5	55	66	94.3	87.6	54.00	54.00
42	32	45	19.1	19.2	19.0	19.0	84	84	95.7	94.4	54.50	53.25
43	27	32	19.3	19.3	16.5	18.0	84	74	93.0	95.8	55.00	53.00
44	29	32	19.5	19.0	17.0	17.5	67	75	94.6	94.5	55.00	54.00
45	31	41	20.0	19.6	18.0	17.5	73	74	92.3	93.2	52.00	53.25
46	32	50	20.5	18.9	17.5	20.5	63	42	90.6	85.5	55.00	53.00
Starboard side—												
47	......	47	......	20.5	......	21.0	......	49	......	91.4	......	52.50
48	......	42	......	19.4	......	17.5	......	76	......	94.2	......	54.50
49	......	119	......	22.9	......	37.0	......	0	......	0	......	46.00
Hold 6:												
50	32	37	19.3	18.9	17.0	18.0	81	80	95.7	92.1	56.00	55.00
51	28	52	18.4	18.3	15.5	18.0	90	91	98.7	97.1	55.00	54.50

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The top of the corn in each hold of the vessel was either below or near the water line. In holds 1, 2, and 3 there was very little change in the condition of the corn during the voyage, as shown in figure 29 and Table 20. In holds 4, 5, and 6, which contained two shaft tunnels along the bottom, the corn became badly damaged over and along the starboard tunnel. This is illustrated in figure 30. It will be seen in the cross section of hold 4 that samples Nos. 30 and 36, which were taken from the corn a short distance above the starboard tunnel, had a temperature of 132 and 128° F. and tested 36 and 46 c. c. in acidity. The corn in both samples had lost all vitality and was badly discolored. Compared to these, samples Nos. 37, 38, and 39, which were taken in the starboard tank from about the same height, but some distance away, did not exceed 65° F. in temperature and 19.5 c. c. in acidity, and sample No. 35, which was taken from directly above the tunnel, but near the surface of the corn, had a temperature of but 85° F. Sample No. 29, which was also taken from above this tunnel, but near the surface of the corn, had a temperature of 90° F. The starboard shaft tunnel, which had the two steam pipes in it, had a temperature inside the tunnel considerably higher than the temperature in the port shaft tunnel, which did not have any steam pipes in it. The corn surrounding the port shaft tunnel was "packed," moldy, and sour, and had a higher temperature than the corn a short distance away from the tunnel, but it was not hot or discolored. The same condition of damaged corn along and over the starboard shaft tunnel, as found in hold 4, was also found in holds 5 and 6, as will be seen from the cross sections of these holds. Sample No. 49, which was taken from the corn about a foot from the starboard shaft tunnel in hold 5, had a temperature of 119° F., and an acidity of 37 c. c., while sample No. 47, taken from directly above it, near the surface of the corn, had a temperature of only 47° F., and an acidity of 21 c. c., and

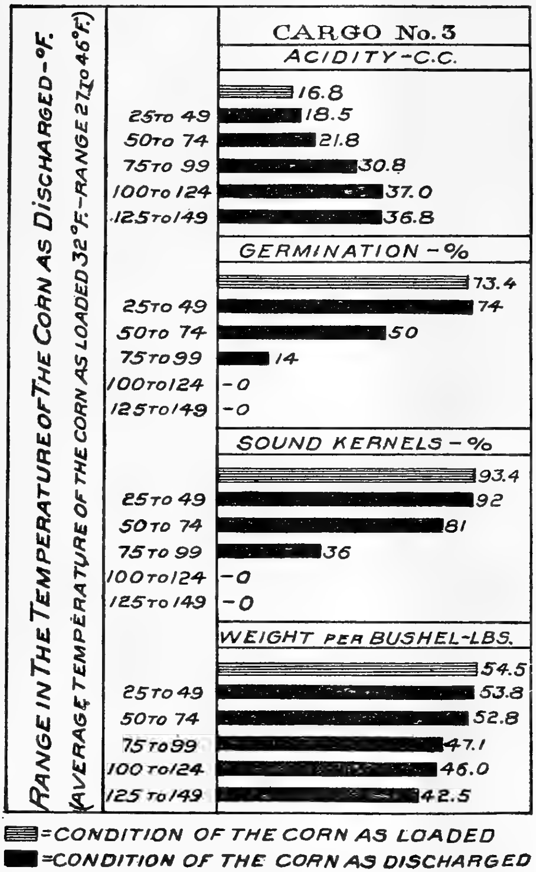

FIG. 31.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 3.)

sample No. 42, taken from the corn about a foot from the port tunnel, had a temperature of 45° F., and an acidity of only 19 c. c. Sample No. 43, which was taken from the same height in the corn, but half-way between the tunnel and the outside of the hold, had a temperature still colder, 32° F., and an acidity of only 18 c. c. Table 19 shows the total range in each factor and condition of the corn by holds as loaded and as discharged. Table 20 shows the condition of each sample taken from the corn as it was being loaded and the condition of each sample that was taken from the corn as being discharged. The correlation of temperature changes and changes in condition of the corn is illustrated in figure 31.

CARGO No. 4.

Cargo No. 4 consisted of 197,142 bushels of natural corn. The corn was loaded February 20 and 21, 1911. The vessel sailed February 22 and arrived at Bremerhaven on March 8, where the corn was discharged March 9 to 16. The length of the ocean voyage was 14 days. The maximum time that any of the corn was in the vessel was 24 days and the average time 20 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds, as is shown in figure 32. Hold 3 was entirely filled with corn, and the remaining holds were only partly filled with corn. The vessel had two shaft tunnels running through the bottom of holds 4, 5, and 6, neither of which tunnels carried steam pipes and both of which were ventilated.

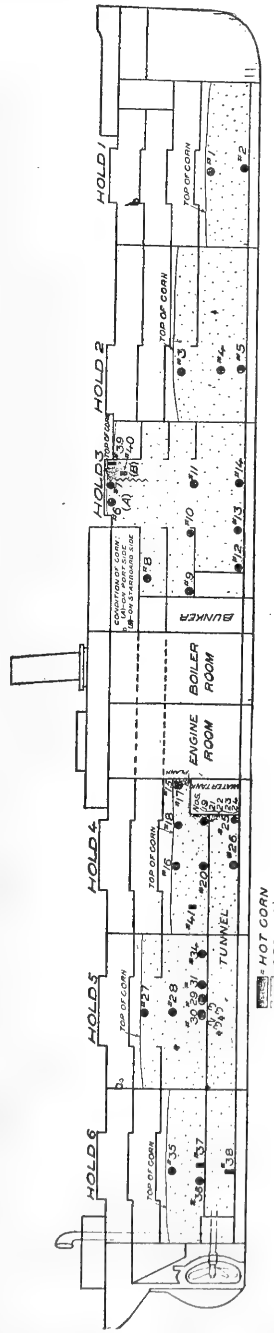

FIG. 32.—Diagram showing arrangement of the steamship and stowage of the corn in the holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 4.)

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 21 and 22. The averages for the various factors of the corn as loaded were as follows: Moisture content 19.5 per cent, acidity 21.0 c. c., germination 69.9 per cent, sound kernels 94.0 per cent, weight per bushel 53.4 pounds. The corn at the time of loading had an average temperature of 37.6° F.

TABLE 21.—*Range in the principal factors, showing quality and condition of the corn in cargo No. 4, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
Hold 1:	°F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
As loaded	35. 0– 37. 0	19. 4–19. 6	20. 0–21. 0	61. 0–63. 0	93. 5–94. 2	53. 2–54. 2
As discharged	39. 0– 49. 0	19. 3–19. 6	20. 5–20. 5	56. 0–66. 0	90. 8–91. 6	53. 0–53. 0
Hold 2:						
As loaded	34. 0– 34. 0	19. 0–19. 9	19. 0–22. 0	63. 0–75. 0	93. 3–96. 6	53. 0–53. 0
As discharged	39. 0– 44. 0	18. 6–20. 4	20. 5–27. 0	32. 0–67. 0	73. 9–93. 7	53. 0–53. 5
Hold 3:						
As loaded	34. 0– 39. 0	18. 5–20. 3	19. 5–22. 5	58. 0 82. 0	89. 1–95. 6	52. 7–54. 0
As discharged	40. 0–118. 0	18. 4–38. 1	17. 0–49. 0	78. 0	93. 4	48. 0–53. 7
Hold 4:						
As loaded	35. 0– 48. 0	18. 9–20. 7	19. 5–23. 0	68. 0–78. 0	89. 7–97. 2	52. 2–54. 2
As discharged	40. 0– 79. 0	18. 1–20. 8	19. 0–39. 0	12. 0–61. 0	48. 6–91. 7	48. 5–54. 0
Hold 5:						
As loaded	36. 0– 38. 0	17. 6–19. 7	20. 0–25. 0	60. 0–76. 0	89. 6–95. 4	51. 5–55. 0
As discharged	38. 0– 65. 0	17. 7–20. 0	18. 0–24. 5	48. 0–77. 0	82. 9–94. 8	45. 5–53. 5
Hold 6:						
As loaded	37. 0– 38. 0	18. 8–19. 0	20. 0–20. 0	80. 0–84. 0	91. 5–93. 9	54. 0–55. 0
As discharged	39. 0– 60. 0	18. 5–19. 2	18. 0–21. 0	64. 0–86. 0	89. 6–91. 3	52. 5–53. 5

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The steamship carrying this cargo was of practically the same construction as the vessel carrying cargo No. 3, except that it did not have any steam pipes in either of its shaft tunnels. The corn was loaded to varying heights in each of the six holds, only hold 3 being entirely filled with corn. With the exception of small amounts of corn in the upper part of hold 3 and the forward part of hold 4, the corn in this cargo changed but little during the voyage and arrived in Europe in good condition. The detailed results of the analyses of the samples taken from this cargo are shown in Table 22.

Hold 1 was filled about one-third full of corn. The corn as discharged ranged from 39° to 49° F. in temperature, 20.5 c. c. in acidity, 56 to 66 per cent in germination, and 90.8 to 91.6 per cent in sound kernels.

Hold 2 was more than half-filled with corn. The corn as discharged ranged from 39° to 44° F. in temperature, 20.5 to 27 c. c. in acidity, 32 to 67 per cent in germination, and 79.9 to 93.7 per cent in sound kernels. Sample No. 3 represents a thin layer of corn at the surface which was somewhat moldy and had started to go out of condition. It tested 27 c. c. in acidity, germinated 32 per cent, and had 73.9 per cent of sound kernels. Neither of the two other samples taken from this hold lower down in the corn tested over 21 c. c. in acidity or contained less then 93.5 per cent of sound kernels.

TABLE 22.—*Condition of the corn in cargo No. 4 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
1	35	39	19.6	19.6	20.0	20.5	61	56	94.2	91.6	54.25	53.00
2	37	49	19.4	19.3	21.0	20.5	63	66	93.5	90.8	53.25	53.00
Hold 2:												
3	34	39	19.7	20.4	21.5	27.0	63	32	96.6	73.9	53.00	53.00
4	34	39	19.9	18.6	22.0	21.0	75	67	93.7	93.5	53.00	53.50
5	34	44	19.0	20.0	19.0	20.5	64	59	93.3	93.7	53.00	53.00
Hold 3:												
39	......	118	......	20.1	......	32.5	......	0	......	8.7	....	48.00
6	34	57	20.3	19.4	22.5	23.0	70	54	95.3	91.3	53.50	51.75
7	34	59	20.1	19.8	20.0	23.0	76	52	93.1	87.2	53.00	51.50
40	......	118	......	......	......	29.0	......	1	......	......	......	......
8	35	42	19.8	19.1	19.5	17.0	61	71	95.6	91.8	53.75	53.00
9	39	59	19.3	19.4	21.0	22.0	70	55	91.4	86.6	53.50	51.25
10	37	40	19.6	19.5	21.5	18.0	64	70	92.6	93.4	53.00	53.75
11	36	46	19.2	19.3	19.5	18.5	82	78	92.8	92.6	54.00	52.50
12	37	53	19.2	19.0	22.0	27.5	58	46	90.2	80.2	52.75	51.50
13	36	49	18.5	18.4	19.5	20.0	60	65	92.6	90.6	53.25	51.75
14	36	49	19.4	19.9	21.0	20.0	64	67	89.1	91.1	53.00	52.25
Hold 4:												
15	43	58	18.9	18.2	22.0	25.0	78	40	96.4	87.1	54.25	51.25
17	35	65	19.4	18.1	19.5	27.0	76	23	94.7	73.9	55.00	50.50
18	36	40	19.7	19.4	20.5	23.5	73	53	95.2	89.5	54.00	53.00
16	37	41	20.2	19.3	23.0	19.0	69	61	92.3	89.4	53.50	54.00
41	......	70	......	19.0	......	22.5	......	31	......	82.5	....	50.50
19	40	66	19.5	20.2	20.5	27.0	71	33	95.1	75.1	53.25	49.75
20	37	53	20.1	....	22.0	23.0	69	60	94.6	91.7	53.50	52.75
21	40	84	20.0	19.0	20.0	32.0	74	27	93.8	64.0	53.25	49.25
22	48	81	21.0	19.0	21.0	39.0	68	26	89.7	52.7	52.75	49.50
23	42	79	20.3	19.4	20.0	29.0	69	36	95.7	72.8	53.25	48.50
24	48	70	20.3	20.2	19.5	39.0	72	12	93.2	48.6	52.25	51.00
25	39	58	20.2	19.6	21.5	23.0	78	59	96.6	87.6	53.50	51.50
26	40	53	20.7	20.8	21.0	24.0	75	61	97.2	90.3	52.75	51.25
Hold 5:												
27	36	44	19.4	18.8	22.5	20.0	63	53	92.5	93.5	52.50	52.00
28	38	42	19.7	20.0	22.0	19.0	71	77	91.8	93.3	51.50	45.50
29	36	38	19.4	19.5	21.5	19.0	73	69	92.1	92.3	53.25	....
30	37	38	18.4	19.2	25.0	23.5	60	59	95.4	88.0	54.00	52.25
31	36	38	19.3	19.0	23.0	20.0	62	70	94.9	91.2	53.25	51.75
32	38	62	17.8	18.7	22.5	25.0	76	55	89.6	82.9	55.00	53.50
33	38	42	19.2	19.0	20.0	18.0	73	76	92.2	94.8	48.00	53.00
34	37	65	17.6	17.7	21.5	24.5	74	48	95.0	92.6	54.00	....
Hold 6:												
35	37	39	18.8	18.5	20.0	19.0	80	86	91.5	90.8	54.00	53.00
36	38	59	19.0	19.2	20.0	18.0	84	74	93.9	91.3	55.00	53.50
37	38	60	......	19.0	......	20.0	......	72	......	89.6	......	52.50
38	37	57	......	18.7	......	21.0	......	64	......	90.0	......	52.50

Hold 3 was entirely filled with corn. A small amount of the corn along the starboard side at the top was hot and damaged, as is shown in figure 33. It will be seen that samples Nos. 39 and 40 taken from this hot corn each had a temperature of 118° F. and an acidity of 32.5 c. c. in the first and 29 c. c. in the second sample. None of the kernels in sample No. 39 would sprout, and only 1 per cent of sample No. 40 had any vitality. There was a steam pipe opposite this hot corn which ran along the deck close to the hatch. This steam pipe carried live steam to the winches along the deck and was under pressure of steam during the first few days after the hold was filled with corn and again for a few days at the end of the voyage before the corn in this hold was discharged. Compared with the hot corn, samples Nos. 6 and 7, taken from the corn near the surface on the port side of the hatch, had a temperature of but 57° and 59° F., an acidity of only 23 c. c. each, and a germination of 54 and 52 per cent, respectively. None of the remaining samples taken from the hold had a temperature higher than 59° F.

Hold 4 was about half filled with corn. In the lower part of the hold there was a water tank, extending across the hold against the forward bulkhead, opposite the engine room. The corn stowed immediately against this tank was heating at the end of the voyage but was only slightly discolored. That portion of the corn next to the tank which surrounded the shaft tunnels was more damaged than the corn located toward the sides of the hold. The averages for the samples taken from the corn located at a height even with the top of the shaft tunnels are shown in Table 23. It will be seen that those samples which represented the corn stowed next to the water tank had on an average a higher temperature by 23° F., more acidity by 10.3 c. c., was poorer in germination by 33.2 per cent, had less sound kernels by 29 per cent, and had a lower test weight by 3.1 pounds per bushel than sample No. 20, which represents corn stowed some distance back from the tank and away from the shaft tunnels.

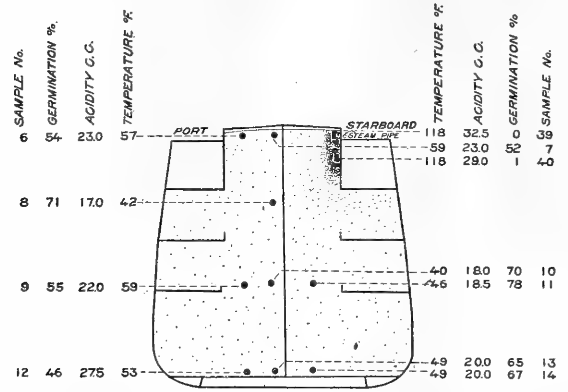

FIG. 33.—Cross-section of hold 3, cargo No. 4, showing location of heat-damaged corn in the upper part of the hold opposite a steam pipe on the deck. Heavy shading represents heat-damaged corn as discharged. (Cargo No. 4.)

TABLE 23.—*Averages for the samples taken from the corn at tunnel height.*

Samples located at tunnel height hold 4.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Against tank (Nos. 21, 22, 23, 24)[1]	76	33.3	26.8	62.7	49.60
Free from tunnels and tank, No. 20	53	23.0	60.0	91.7	52.75

[1] Data represent averages for these samples.

That part of the corn at the surface (in hold 4), which was located next to the engine-room bulkhead over the water tank, was out of condition, being sour, moldy, and "packed." Compared to the condition of the corn at the surface, which was located back some distance from the bulkhead, the corn stowed against the engine-room bulkhead had, on an average, a higher temperature by 21° F., a higher acidity by 4.8 c. c., and lower germination by 25.5 per cent, less sound kernels by 8.9 per cent, and a lower test weight per bushel by 2.6 pounds.

Hold 5 was nearly three-quarters filled with corn. In this hold the corn ranged from 38° to 65° F. in temperature, 18 to 24.5 c. c. in acidity, 48 to 77 per cent in germination, and 82.9 to 94.8 per cent in sound kernels. The corn was in good condition when discharged except for a small amount located near the shaft tunnels, which was slightly out of condition. Of the corn located at the same height as the top of the tunnels, that which was stowed on and between the tunnels had, on an average, a higher temperature by 6° F., a higher acidity by 4 c. c., a lower germination by 11.2 per cent, less sound kernels by 16.1 per cent, and a lower test weight per bushel by 0.5 pound than the corn stowed half way between the tunnels and the outside of the hold, as shown in Table 23.

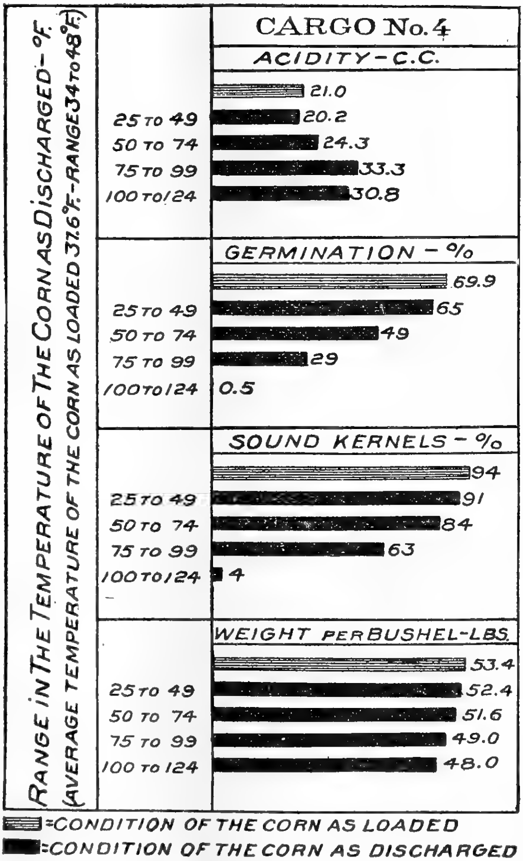

FIG. 34.—Correlation of the temperatures and condition of the corn as loaded and as discharged. (Cargo No. 4.)

Hold 6 was about one-half filled with corn. The corn as discharged ranged from 39 to 60° F. in temperature, 18 to 21 c. c. in acidity, 64 to 86 per cent in germination, and 89.6 to 91.3 per cent in sound kernels. The condition of the corn in this hold, like that in hold 5, was sound when discharged except that a small amount of corn stowed next to the shaft tunnels was slightly out of condition. Table 22 shows the condition of each sample taken as the cargo was being loaded and as the cargo was being discharged.

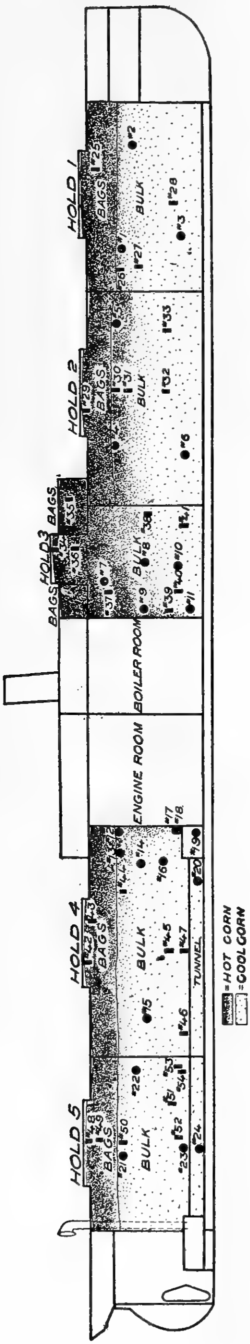

FIG. 35.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 5.)

The correlation of temperature changes and changes in condition of the corn is illustrated in figure 34.

CARGO No. 5.

Cargo No. 5 consisted of 185,571 bushels of natural corn. The corn was loaded April 20 to 24, 1911. The steamship sailed April 25 and arrived at Dunkirk, France, May 13, where the corn was discharged from May 18 to 27. The length of the ocean voyage was 18 days. The maximum time that any of the corn was in the vessel was 38 days and the average time 31 days. This cargo was not accompanied to Europe, but was thoroughly sampled at time of loading in America and again at time of discharge in France.

STOWAGE OF THE CORN.

The steamship had five cargo holds, as shown in figure 35. This shipment was a full cargo, each hold being entirely filled with corn.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 24 and 25. The averages for the various factors of the corn as loaded were as follows: Moisture content 19.2 per cent, acidity 24.4 c. c., germination 59.1 per cent, sound kernels 95.2 per cent, and weight per bushel 53.4 pounds. The corn at the time of loading had an average temperature of 38° F.

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

As already stated, the steamship carrying cargo No. 5 had each of its five holds entirely filled with corn. As the cargo was being discharged in Europe, it was found that the corn in the upper portion of each hold was badly damaged. This damaged condition is illustrated in figure 35. As will be seen in Table 24, the temperature of the corn as discharged ranged from 59° to 138° F. in hold 1, 61 to 142° F. in hold 2, 53 to 140° F. in hold 3, 59 to 140° F. in hold 4, and 64 to 138° F. in hold 5. The temperature in a general way was the highest at the surface of the corn and decreased toward the bottom. It will be seen in figure 36 and Table 25 that all of the corn in the lower portion of the holds was not hot, but the corn was very poor in condition.

TABLE 24.—*Range in the principal factors showing quality and condition of the corn in cargo No. 5, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	°F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	[1]38.0	19.4–19.8	23.4–28.0	45.0–63.0	85.7–95.9	53.0–53.5
As discharged	59.0–138.0	....	28.3–48.6	0–52.0	0–90.2	48.5–53.5
Hold 2:						
As loaded	[1]38.0	18.6–19.7	19.8–27.4	56.0–72.0	92.0–97.0	54.0–54.5
As discharged	61.0–142.0	....	25.4–69.3	0–36.0	0–73.9	48.0–53.3
Hold 3:						
As loaded	[1]38.0	18.8–19.7	22.6–28.6	45.0–62.0	91.0–96.0	52.8–53.8
As discharged	53.0–140.0	....	29.1–72.7	0–62.0	0–69.2	46.5–53.5
Hold 4:						
As loaded	[1]38.0	16.6–19.6	21.2–25.4	56.0–74.0	94.1–98.8	53.0–53.8
As discharged	59.0–140.0	....	23.7–67.1	0–64.0	0–87.2	47.0–53.3
Hold 5:						
As loaded	[1]38.0	19.2–20.1	23.2–24.4	48.0–65.0	94.8–98.2	52.5–53.5
As discharged	64.0–138.0	....	26.7–71.4	0–44.0	0–68.6	46.8–51.5

[1]Average temperature for the cargo.

TABLE 25.—*Condition of the corn in cargo No. 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	*°F.*	*°F.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
25		138	......	......	36.4	......	0	......	0	....	48.50
1		135	19.4	28.0	48.6	45	0	85.7	0	53.00	49.25
26		85	......	......	38.7	......	24	......	32.0	....	51.50
2	[1]38	75	19.8	26.2	39.7	53	36	93.6	16.4	53.25	51.00
27		61	......	......	32.8	......	52	......	72.4	....	52.25
3		63	19.6	23.4	30.8	63	34	95.9	57.3	53.50	53.25
28		59	......	......	28.3	......	36	......	90.2	....	52.50
Hold 2:											
29		138	......	......	65.4	......	0	......	0	....	48.00
4		133	19.7	27.4	52.4	56	0	92.0	0	54.25	48.50
5		139	18.9	27.2	52.7	60	0	93.2	0	54.50	51.00
30	[1]38	142	......	......	69.3	......	0	......	0	....	48.50
31		115	......	......	34.0	......	0	......	0	....	52.00
32		82	......	......	40.7	......	28	......	62.8	....	50.50
33		91	......	......	39.0	......	36	......	55.0	....	50.00
6		61	18.6	19.8	25.4	72	26	97.0	73.9	54.00	53.25

[1] Average for the hold.

TABLE 25.—*Condition of the corn in cargo No. 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom*—Continued.

Hold and sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	° F.	° F	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.
Hold 3:											
34		138			72.7		0		0		46.50
35		131			59.4		0		0		48.00
36		136			58.2		0		0		50.50
7		129	19.7	22.6	71.0	62	0	93.3	0	52.75	48.00
37		140			60.7		0		0		48.50
8		122	19.7	28.6	49.2	50	6	94.9	12.5	53.50	50.00
9	[1] 38	108	19.6	26.0	57.2	45	0	94.4	0	53.50	50.50
38		95			24.3		62		69.2		52.50
39		90			43.8		2		16.3		49.50
10		95	18.8	25.8	32.4	45	38	96.0	50.6	53.75	52.50
40		53			29.1		28		66.1		53.50
41		71			31.0		18		66.6		52.00
11		81	18.8	24.0	41.6	56	6	91.0	40.5	53.25	51.50
Hold 4:											
42		140			67.1		0		0.7		47.00
43		131			57.6		6		5.8		49.50
12		104	19.4	25.2	61.4	63	0	97.6	0	53.75	47.50
13		127	18.9	24.2	29.0	57	0	95.9	0	53.75	48.50
44		77		23.8	42.2		30		55.4		51.50
14		77	16.9	23.8	29.9	66	38	94.1	78.6	53.25	52.00
15		74	19.4	25.4	40.2	63	26	97.9	60.1	53.75	51.50
16	[1] 38	95	19.6	23.0	32.6	56	12	98.8	45.4	53.00	51.00
45		59			23.7		64		87.2		53.00
17		72	19.6	22.8	25.4	61	38	97.0	56.7	53.25	52.25
18		72	16.6	21.2	27.9	74	34	95.0	75.6	53.25	52.00
46		85			31.9		32		50.2		51.00
47		68			25.9		52		79.4		53.25
19		65	19.2	22.8	30.4	74	30	96.4	73.7	53.25	53.25
20		63	18.9	22.8	36.3	71	10	97.5	64.5	53.50	51.50
Hold 5:											
48		138			57.7		0		0		46.75
49		115			58.0		4		0		49.50
21		97	19.2	24.4	34.0	53	20	94.8	42.3	53.50	51.50
50		69			26.7		28		58.6		51.50
22		101	20.0	24.4	45.0	48	10	98.2	16.2	52.50	51.00
51	[1] 38	77			36.8		28		68.6		51.00
52		77			71.4		16		57.0		51.00
53		93			41.9		16		42.1		49.50
54		77			41.4		44		54.5		50.50
23		81	20.1	23.2	48.7	60	18	96.7	45.9	52.50	51.00
24		64	20.1	24.4	40.5	65	24	97.4	48.8	52.75	51.50

[1] Average for the hold.

As is seen from cross section of hold 1, in figure 36, the corn in this hold as discharged ranged in temperature from 138° F. near the surface to 59° F. in the lower part of the hold. The heat-discolored corn extended from the surface to a little over one-fourth down in the hold. The two samples taken from the heat-discolored corn, sample No. 25 from a short distance below the surface and sample No. 1 from the lower portion of the hot corn, had temperatures of 138° and 135° F. and tested 36.4 and 48.6 c. c. in acidity. None of the kernels in either sample would germinate. Only one sample taken from the corn that was not heat-discolored tested under 30 c. c. in acidity. This sample, No. 28, was taken about 7 feet from the bottom of the hold. It had a temperature of 59° F., tested 28.3 c. c. in acidity and germinated 36 per cent, but sample No. 3, taken from still lower in the hold, had a temperature of 63° F., and tested 30.8 c. c. in acidity, with a germination of 34 per cent. Sample No. 26, taken from the upper part of the corn that was not heat discolored, had a temperature of 85° F., tested 38.7 c. c. in acidity, and germinated 24 per cent.

The temperature of the corn in hold 2 as discharged ranged from 142° F. in the heat-discolored corn in the upper part of the hold to 61° F. in the lower part of the hold, as shown in figure 36. All of the corn in the upper part of the hold was heat-discolored. None of the kernels from the samples taken from the heat-discolored corn sprouted in the germination test, and the samples taken from the cooler corn in the lower half of the hold tested low in germination. All of the samples taken from the various parts of the hold,

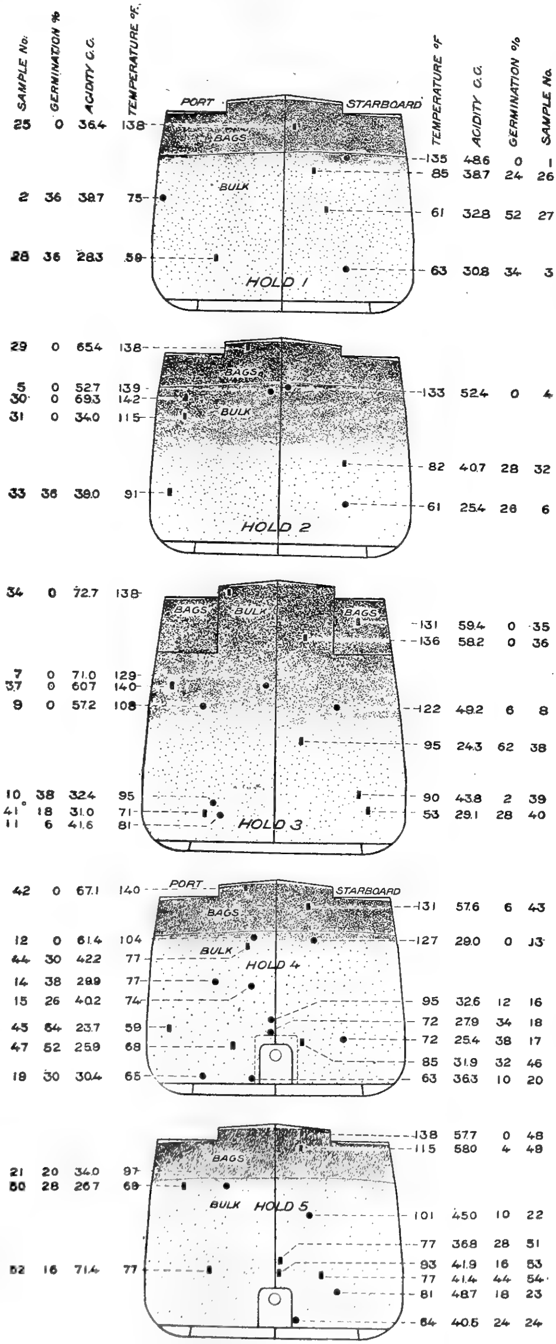

FIG. 36.—Cross-sections, holds Nos. 1 to 5, inclusive, showing the locations from which the samples were taken from the corn. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 5.)

with one exception, tested over 30 c. c. in acidity. Sample No. 6, taken about 7 feet from the bottom, tested 25.4 c. c. in acidity, but sample No. 33, taken about the same distance from the bottom but on the opposite side of the hold, tested 39 c. c. in acidity.

Hold 3 was one deck higher than the remaining holds in the vessel. In this hold the heat-discolored corn extended from the surface to about halfway down in the hold. The temperature of the corn, as is shown in figure 36, ranged from 140° F. in the heat-damaged corn in the upper part of the hold to 53° F. near the bottom on the starboard side. Only one sample, No. 8, in the heat-discolored corn, showed any vitality; it germinated 6 per cent. Two samples taken from the lower part of the hold, Nos. 39 and 11, tested 2 per cent and 6 per cent in germination. Both were high in acidity, testing 43.8 c. c. and 41.6 c. c. in acidity. Two samples, Nos. 38 and 40, taken from the lower half of the hold, tested under 30 c. c. in acidity. Sample No. 38, taken from the upper part of the corn that was not heat-discolored, tested 24.3 c. c. in acidity and germinated 62 per cent, while sample No. 40 taken about 5 feet from the bottom on the starboard side tested 29.1 c.c. in acidity and germinated 28 per cent. Sample No. 34, taken from the corn at the surface, showed the highest acidity test. This sample had a temperature of 138° F., tested 72.7 c. c. in acidity, and contained no corn that would germinate.

As will be seen from figure 36, the temperature of the corn in hold No. 4, as discharged, ranged from 140° F. at the surface to 59° F. in the lower part of the hold. Only one sample, No. 43, taken from the heat-discolored corn in the upper one-fourth of the hold showed any vitality; it germinated 6 per cent, tested 57.6 c. c. in acidity, and had a temperature of 131° F. Sample No. 42, taken from the corn at the surface, had a temperature of 140° F., tested 67.1 c. c. in acidity, and had no corn that would germinate. The heat-discolored corn extended about one-fourth the distance down in the hold. The corn in contact with the shaft tunnel in the lower part of the hold was more sour, packed, and moldy than that surrounding it, but it was not heat-discolored. The same condition extended along the shaft tunnel in hold 5.

The condition of the corn in hold 5 was very similar to that in hold 4. The heat-discolored corn extended about one-fourth the distance down from the surface, and the remainder of the corn in the hold was very poor in condition. Sample No. 48, at the surface, had a temperature of 138° F., tested 57.7 c. c. in acidity, and had lost all vitality. Sample No. 24, taken from the bottom, had a temperature of 64° F., tested 40.5 c. c. in acidity, and germinated 24 per cent. The condition of the corn that was not heat-discolored varied greatly at different positions of stowage. Sample No. 50, which was taken from the bulk corn just under the heat-damaged position, had a temperature of 69° F., tested 26.7 c. c. in acidity, and germinated 28 per cent, while sample No. 22, taken from the corn nearly halfway down the hold, had a temperature of 101° F., tested 45 c. c. in acidity, and germinated 10 per cent. Sample No. 50 was the only one taken from the corn in this hold which tested under 30 c. c. in acidity, and only two other samples, Nos. 21 and 51, tested under 40 c. c. in acidity. Table 26 shows the average condition of the corn in the cargo as loaded compared with the average condition of the corn which was not heat damaged and of that which was heat discolored, as discharged, the average being based upon the samples that were taken from the corn, the positions of which are illustrated in the diagrams in figures 35 and 36.

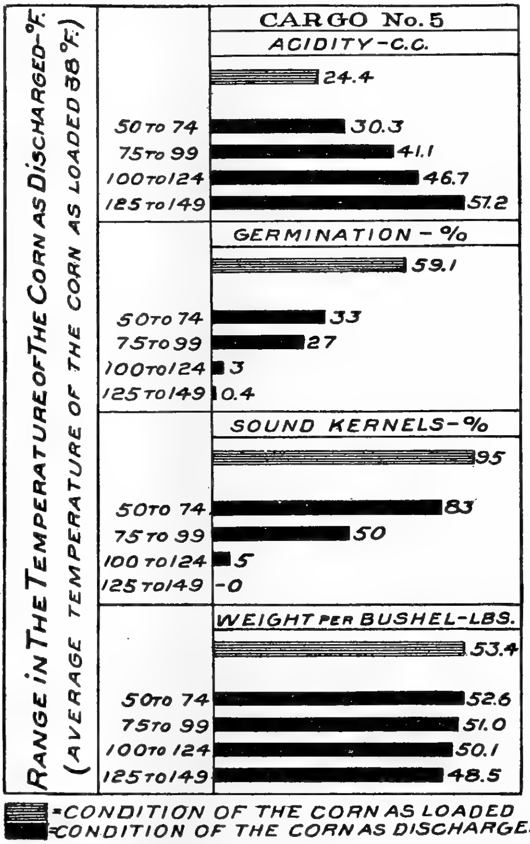

FIG. 37.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 5.)

TABLE 26.—*Showing the average condition of the corn as loaded, the average condition of the corn as discharged, and the average condition of the heat-damaged corn as discharged.*

Stage.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	°F.	c.c.	Per cent.	Per cent.	Pounds.
Average as loaded	38	24.4	59.1	95.2	53.4
Average of cool corn as discharged	77	35.6	29.0	56.8	51.6
Average of heat-damaged corn as discharged	130	55.9	1.0	1.0	48.8

It will be seen in the table that there was considerable deterioration during the voyage in the corn that did not become heat-discolored and that the corn which did become heat-discolored was very badly damaged.

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 37.

CARGO No. 6.

Cargo No. 6 consisted of 200,270 bushels of corn, part of which was natural corn and part of which was artificially dried corn. It was loaded March 21 to 27, 1911. The steamship sailed March 28 and arrived in Rotterdam, Holland, April 17, where the corn was discharged from April 18 to April 22. The length of the ocean voyage was 20 days; the maximum time any of the corn was in the vessel was 32 days; and the average time was 27 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds, as is shown in figure 38. This shipment was a full cargo, each hold being entirely filled with corn. Holds 1, 2, 3, and 5 were filled with natural corn, and hold 4 contained artificially dried corn.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 27, 28, and 29. It will be noted from Table 28 that, on an average, the dried corn in hold 4 had a temperature of 50° F., was relatively high in acidity (27 c. c.) and low in germination (45.6 per cent), but had a low moisture content (15.6 per cent). Sound kernels, as determined by mechanical analysis, averaged 92.5 per cent. The natural corn in the remaining holds of the cargo had an average temperature of 42° F., acidity of 24.3 c. c., germination of 65.3 per cent, and 95.7 per cent of sound kernels, but was high in moisture content, which averaged 20.2 per cent.

TABLE 27.—*Range in the principal factors showing quality and condition of the corn in cargo No. 6 as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c.c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	41.0– 50.0	19.7–20.6	22.5–24.2	63.0–76.0	93.7–96.3	52.5–53.8
As discharged	42.0– 53.0	19.0–20.0	26.3–41.4	16.0–55.0	53.4–85.8	49.5–51.0
Hold 2:						
As loaded	39.0– 49.0	19.2–20.4	21.9–27.2	52.0–73.0	95.4–97.7	53.0–53.3
As discharged	45.0–140.0	15.0–27.0	24.8–65.2	0–50.0	3.2–93.7	46.0–52.0
Hold 3:						
As loaded	37.0– 40.0	20.1–20.9	22.9–24.4	61.0–82.0	94.0–98.0	52.0–53.0
As discharged	44.0–140.0	17.6–20.4	22.8–59.5	0–55.0	1.5–76.1	45.5–51.0
Hold 4:						
As loaded	43.0– 56.0	14.7–16.3	23.2–31.0	24.0–61.0	86.1–96.5	53.0–54.8
As discharged	50.0– 85.0	14.4–16.2	25.5–32.7	7.0–52.8	57.9–95.6	52.0–53.5
Hold 5:						
As loaded	40.0– 44.0	19.7–20.9	22.4–28.6	56–0–73.0	93.9–97.1	52.0–53.5
As discharged	44.0–120.0	18.8–21.0	22.9–54.9	5.0–66.0	35.3–97.3	47.5–52.3

TABLE 28.—*Average condition of the dried corn and of the natural corn in cargo No. 6 as loaded.*

Kind of corn and where stowed.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c.c.*	*Per cent.*	*Per cent.*	*Pounds.*
Dried corn, hold 4	50	15.7	27.0	45.6	92.5	53.91
Natural corn, holds 1, 2, 3, and 5	41	20.2	24.3	65.3	95.7	53.00

TABLE 29.—*Condition of the corn in cargo No. 6, natural corn, as loaded, and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold, kind of corn, and Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1, natural corn:	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
1	45	53	20.4	19.0	22.5	26.3	64	55	93.7	85.8	53.00	50.50
2	41	......	20.4	......	......	......	......	......	96.0	......	52.50	......
3	50	......	19.7	......	......	......	......	......	95.1	......	53.25	......
4	44	50	20.6	20.0	23.5	39.3	64	16	94.7	53.4	53.25	50.00
5	41	42	20.2	19.5	22.9	30.8	63	26	94.8	69.5	53.25	......
6	44	49	20.6	19.7	24.2	30.2	76	26	94.0	64.4	53.75	51.00
7	41	45	19.9	19.8	23.8	41.4	72	19	96.3	62.5	53.00	49.50
Hold 2, natural corn:												
8	......	140	......	15.0	......	65.2	......	6	......	12.1	......	46.75
9	40	50	20.1	19.6	23.5	33.7	61	46	95.4	80.4	53.00	50.75
10	49	57	19.8	19.8	22.9	47.9	66	16	97.7	65.6	53.25	50.50
11	......	100	......	27.0	......	48.7	......	0	......	10.8	......	......
12	......	90	......	......	......	56.3	......	6	......	59.0	......	......
13	......	130	......	20.2	......	57.4	......	0	......	3.2	......	46.00
14	39	49	19.2	19.0	27.2	24.8	66	50	96.8	93.7	53.25	52.00
15	40	45	20.4	19.8	25.5	31.5	52	26	96.7	53.1	53.00	......
16	46	93	20.1	19.4	21.9	38.7	73	22	96.1	55.9	53.00	50.50
Hold 3, natural corn:												
17	40	98	20.4	20.4	22.9	42.2	68	18	97.4	42.6	53.00	49.50
18	40	140	20.9	17.6	24.2	59.5	62	0	94.0	1.5	52.00	45.50
19	......	138	......	......	......	48.6	......	0	......	3.9	......	......
20	40	130	20.3	18.6	23.4	56.2	61	0	95.7	8.3	53.00	50.50
21	38	51	20.1	19.7	23.3	35.0	78	28	95.6	50.8	53.00	50.00
22	37	44	20.1	19.4	24.0	22.8	82	55	98.0	76.1	53.00	51.00
Hold 4, dried corn:												
23	53	80	15 5.	16.0	24.4	29.7	48	29	94.4	65.7	54.75	52.50
24	54	54	16.0	15.4	31.0	32.7	47	46	88.4	85.7	54.50	53.50
25	51	64	15.5	14.8	......	30.5	44	29	86.1	63.9	54.00	53.50
26	......	80	......	......	......	26.6	......	7	......	63.0	......	......
27	48	53	16.0	14.4	26.8	27.6	58	52	94.9	95.6	54.25	53.50
28	54	56	16.3	16.2	23.2	27.3	56	42	96.5	75.7	54.50	53.50
29	50	50	16.0	15.3	27.6	29.8	55	35	92.7	75.3	54.25	52.50
30	56	55	16.2	15.6	23.6	26.4	61	50	95.4	90.6	54.75	53.50
31	53	66	15.7	14.6	25.9	25.5	36	33	94.9	91.8	53.50	52.50
32	49	51	16.3	15.0	29.3	25.6	58	52	87.1	89.3	54.00	52.50
33	......	85	......	......	......	31.7	......	28	......	57.9	......	......
34	50	77	16.0	......	26.2	28.7	44	21	95.1	76.3	53.00	52.00
35	43	50	14.7	15.0	29.6	30.1	24	32	92.7	87.3	53.25	52.00
36	49	55	15.0	15.2	27.6	27.0	39	35	91.9	88.8	53.25	52.00
37	53	61	15.3	15.4	26.9	29.9	36	28	92.7	91.0	53.25	52.00
38	48	51	15.2	......	29.4	29.2	32	18	92.3	79.8	53.50	52.00
Hold 5, natural corn:												
39	41	65	20.5	20.4	28.6	43.8	66	12	97.1	58.4	52.50	49.00
40	41	55	19.6	19.0	26.9	25.8	57	55	94.8	91.0	53.50	52.00
41	42	55	20.7	20.0	22.0	28.3	60	35	95.1	81.0	53.50	51.00
42	......	120	......	21.0	......	49.0	......	10	......	35.3	......	47.50
43	41	50	20.2	18.8	25.6	37.1	56	33	94.0	77.0	52.75	51.25
44	42	47	20.5	19.7	25.3	30.7	61	31	95.9	65.3	53.25	50.50
45	44	70	20.1	19.8	27.8	54.9	62	15	96.1	45.4	52.50	49.25
46	41	54	20.1	19.6	24.1	27.3	58	66	96.1	97.3	53.25	51.00
47	41	44	20.9	19.6	23.0	25.6	63	35	96.8	55.7	52.75	52.25
48	40	47	20.3	18.8	22.4	22.9	73	65	93.9	87.9	53.50	51.50
49	40	44	19.9	18.9	25.2	48.7	69	5	96.0	45.8	52.00	51.25

From this it is seen that although the tests for acidity, germination, and sound kernels showed the dried corn to be poor in quality, its moisture content was lower by 4.5 per cent than natural corn.

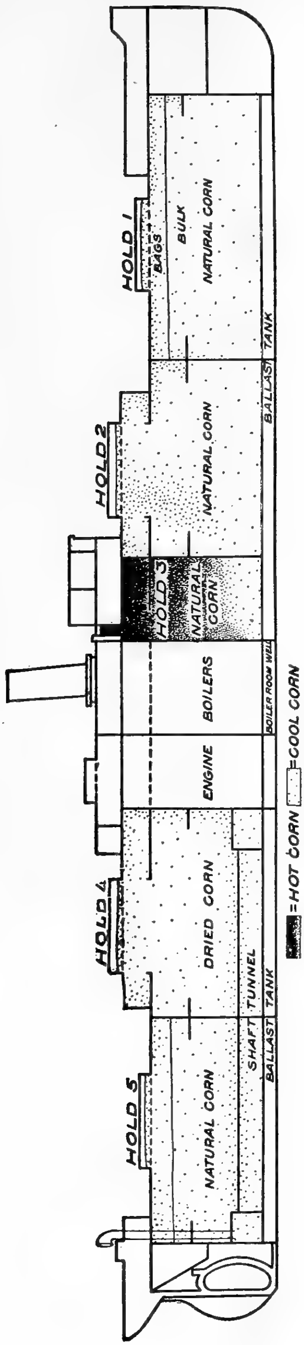

FIG. 38.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 6.)

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

During the voyage the temperature of the corn in various positions of stowage was recorded each day that the weather permitted. Some of the thermometers were read before the vessel sailed, and some were read for some days after the steamship arrived at its port in Europe. The location of the various thermometers and the changes in temperature at those positions are shown in figures 39 to 46, inclusive. The maximum temperatures found in the corn as discharged were 53° F. in hold 1, 140° F. in hold 2, 140° F. in hold 3, 85° F. in hold 4, and 120° F. in hold 5. These were higher than the maximum temperatures of the corn as loaded by 3° F., 91° F., 100° F., 29° F., and 76° F., in holds 1 to 5, respectively. Hold 3, however, was the only one containing any large amount of heat-damaged corn.

In hold 1 the temperature of the corn in various positions of stowage changed but little during the voyage, except along the sides of the holds, as shown by the temperature records in figure 39. As is shown in Table 29, each sample that was placed in a wire container as the cargo was loaded tested lower in quality at the end of the voyage than at the beginning of the voyage in every factor except moisture content. Only one sample, No. 1, tested under 30 c.c. in acidity. This sample was taken from the bagged corn a short distance under the surface and tested 26.3 c.c. in acidity, 55 per cent in germination, 85.8 per cent in sound kernels, and 50.5 pounds in test weight per bushel. Sample No. 7, taken from near the bottom of the hold tested 41.4 c. c. in acidity, 19 per cent in germination, 62.5 per cent in sound kernels and 49.5 pounds in test weight per bushel. The corn at the surface and along the sides of the hold for a short distance down from the top was somewhat sour, moldy, and packed.

In hold 2 some of the corn became badly heat damaged. This damaged corn was found in uneven spots on the starboard side near the after part of the hold and extended from the surface to nearly halfway down in the hold. There was also a small portion that was damaged along the forward bulkhead halfway down in the hold. The temperature of the corn as discharged from this hold ranged from 45° to 140° F. Sample No. 8, taken from the heat-damaged corn just under the top deck on the starboard side, had a temperature of 140° F., and tested 65.2 c. c. in acidity and 6 per cent in germination, while samples Nos. 9 and 10, taken from near the same height in the hold but near the shifting boards in the center, had temperatures of 50° and 57° F. and tested 33.7 and 47.9 c. c. in acidity and 46 and 16 per cent in germination, respectively. Sample No. 13, taken from the heat-damaged corn, 15 feet below the surface, had a temperature of 130° F., tested 57.4 c. c. in acidity, and no kernels sprouted in a germination test. Sample No. 11, taken from near the outside wall of the hold on the starboard side, had a temperature

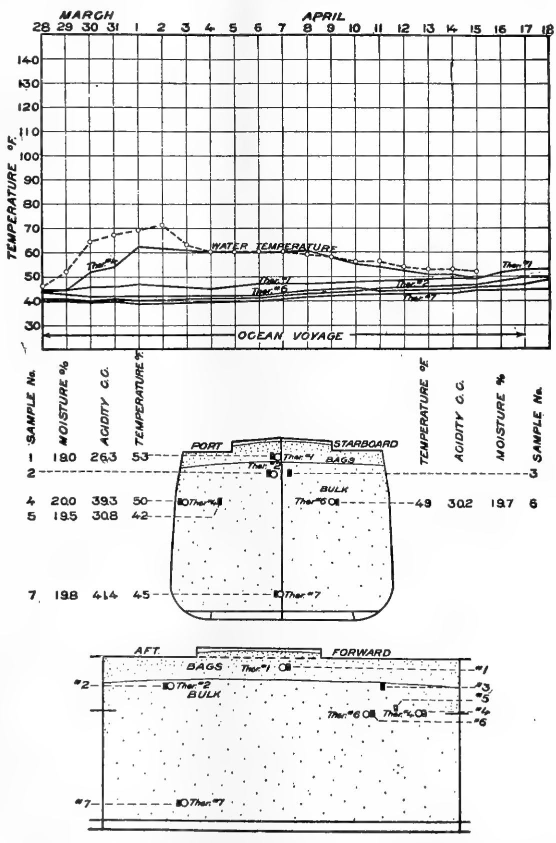

FIG. 39.—Hold 1: Temperature records of electrical resistance thermometers; location of the thermometers in the hold; and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

of 100° F., tested 48.7 c. c. in acidity, and none of it would germinate. Sample No. 14, taken from about the same height in the corn as sample No. 13, had a temperature of but 49° F., tested 24.8 c. c. in acidity, and germinated 50 per cent. Sample No. 16, taken from near the bottom on the starboard side had a temperature of 93° F., tested 38.7 c. c. in acidity, and germinated 22 per cent. The temperature record for this sample, in figure 40 shows that its temperature was 46° F. when loaded and that from March 28 to April 7 there was but little change, but from then on the temperature increased until it reached 93° F. when discharged. As will be seen in Table 29, only one sample, No. 14, tested under 30 c. c. in acidity at the time of discharge.

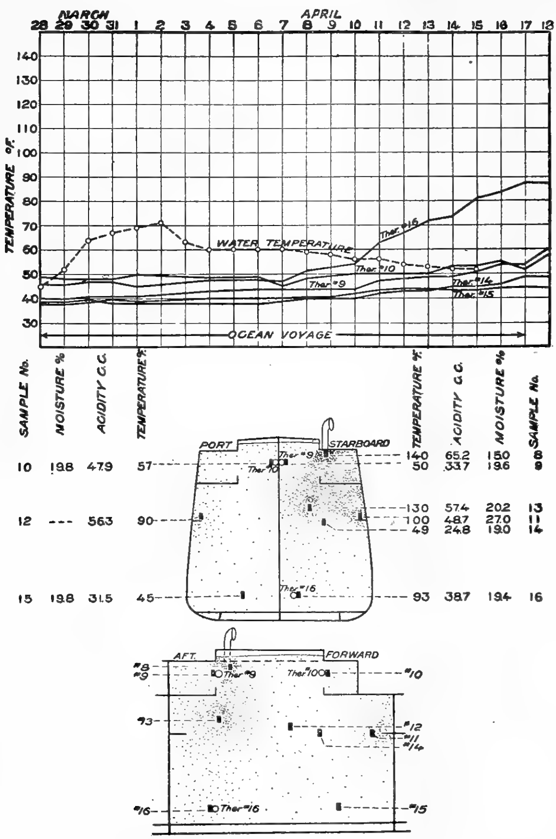

Fig. 40.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

Hold 3 was one deck higher than hold 1, and had a "feeder" rounding one more deck above that. This hold was located just forward of the boiler room. Fully three-fourths of the corn as discharged was badly heat-damaged. The temperature of the corn in this hold at the time of discharge ranged from 44° to 140° F., which was greater by 7 degrees than the minimum and by 100 degrees than the maximum temperatures of the corn when loaded. Thermometer No. 18, which was located in the "feeder" about 4 feet below the surface of the corn, registered an increase in temperature from the very beginning of the voyage. The maximum temperature recorded during the voyage was 144° F., on April 15, after which there was a slight decrease. The corn surrrounding this thermometer had a temperature of over 120° F. for 10 days before it was discharged. It will be noted that the temperature increased from 40° to 100° F. during the first 10 days of the ocean voyage. Thermometer 17, which was also located in the "feeder," at about the same height as thermometer 18, but next to the bulkhead separating the corn from the ventilated coal bunker, indicated a much slower increase in temperature. On April 8, 11 days after sailing, thermometer 18 indicated a temperature of 120° F.; on April 15 the temperature had increased to 144° F. Thermometer 19, located in the port side a little over halfway down from the surface of the corn, indicated an increase of 30° F. during the first 10 days and 63° F. during the last 11 days of the voyage, a total of 93° F. for the whole voyage. Temperature records for thermometers 21 and 22, located a few feet from the bottom of the hold, show that there was but little change in temperature in these places of stowage. Samples Nos. 18, 20, and 22, which were attached to thermometers of the same numbers, had temperatures of 140°, 130,° and 44° F., when discharged, and tested 59.5, 56.2, and 22.8 c. c. in acidity. Samples Nos. 18 and 20 had lost all vitality, but sample No. 22 germinated 55 per cent. Only one sample in this hold at the time of discharge tested under 33 c. c. in acidity.

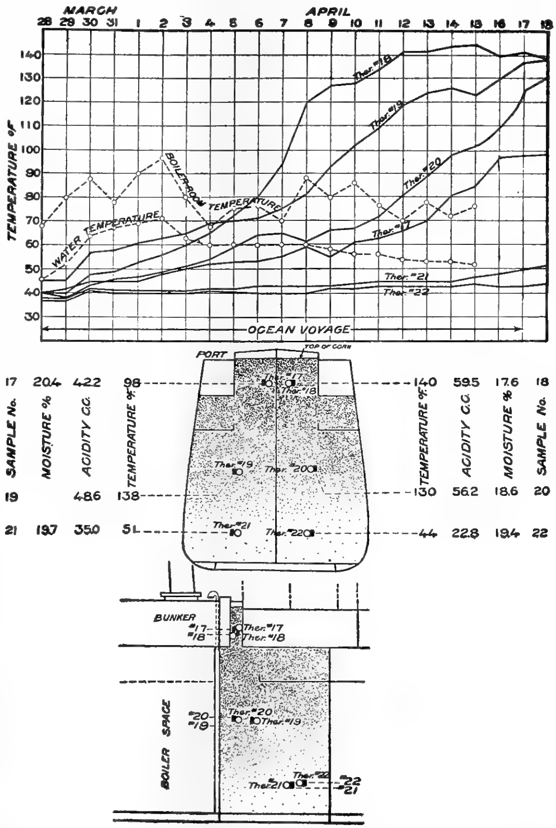

FIG. 41.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

Hold 4 was one deck higher than holds 1 and 5. It was located just aft of the engine room and had a shaft tunnel in the bottom which continued through hold 5. The dried corn in this hold changed very little in temperature during the voyage, as is shown in Table 29 and figure 42. The temperature record for thermometer 23 shows that the corn at the surface near the engine room bulkhead increased 27° F. and had a temperature of 80° F. at the end of the voyage, while the temperature of the corn at the same height in the after part of the hold was the same when discharged as when loaded, as shown by the temperature record for thermometer 24. The corn stowed next to the engine-room bulkhead about 6 feet from the bottom, increased 8 degrees, and the corn stowed at the same height in the after part of the hold increased 7 degrees, as is shown by the records for thermometers 35 and 37. The effect of the engine heat on the corn is shown in Table 30.

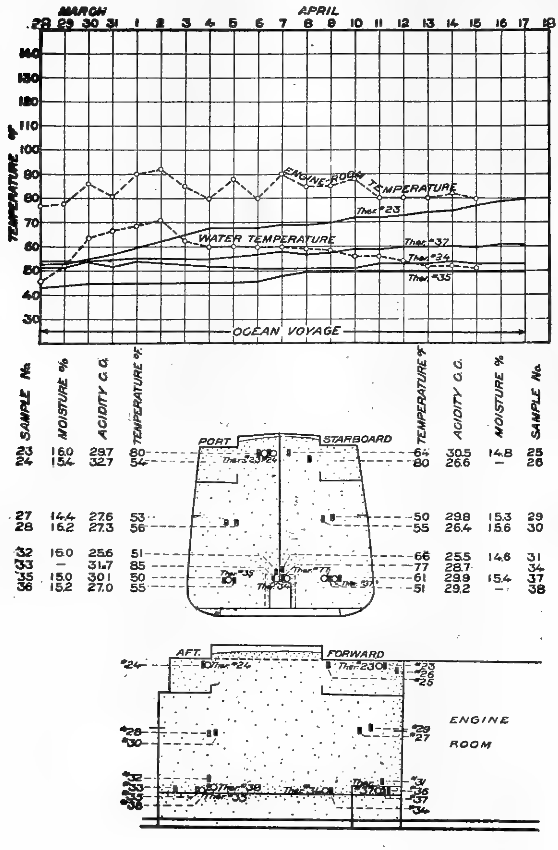

FIG. 42.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

TABLE 30.—*Effect of the engine-room heat on the corn located next to the engine-room bulkhead in hold 4, cargo No. 6.*

Sample No.	Increase in temperature.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
	° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
23[1]	27	5.3	19	28.7	2.25
24[2]	0	1.7	1	2.7	1.00

[1] Sample was located at surface against engine-room bulkhead.
[2] Sample was located same height as No. 23, but some distance from the engine-room bulkhead.

TABLE 31.—*Effect of the shaft tunnel heat on the corn stowed next to the shaft tunnel in hold 4, cargo No. 6.*

Sample No.	Increase in temperature.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
	° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
34[1]	27	2.5	23	18.8	1.00
35 and 38*[2]	5	.1	3	8.9	1.37

[1] Sample was located on the shaft tunnel.
*Average for these two samples.
[2] Sample was located same height as No. 34, but halfway between shaft tunnel and the sides of the hold.

The effect on the corn of the heat from the engine room which penetrated through the shaft tunnel in the bottom of the hold is shown in Table 31. The corn located directly on the shaft tunnel increased 27° F. during the voyage, while the corn located the same height as the tunnel, but halfway between the tunnel and the sides of the hold, increased 7 degrees on the port side and 8 degrees on the starboard side, as is shown in figure 43. There was no heat-discolored corn in the hold at the end of the voyage, but the corn at the surface along the upper part of the engine-room bulkhead and along the top of the shaft tunnel was musty, somewhat moldy, and "packed." The corn in the hold ranged from 50° to 85° F. in temperature and 25.5 to 32.7 c. c. in acidity (4 samples tested slightly over 30 c. c. and 12 samples tested under 30 c. c. in acidity), from 7 to 52 per cent in germination, and from 57.9 to 95.6 per cent in sound kernels.

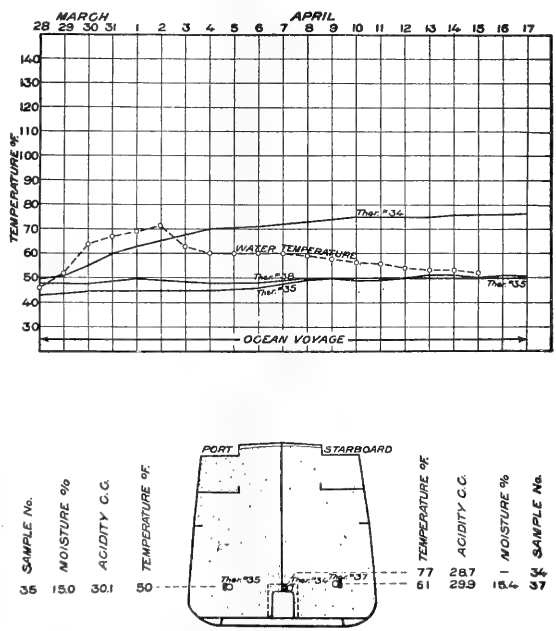

FIG. 43.—Hold 4: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 6.)

The corn in hold 5 as discharged varied from 44° to 120° F. in temperature, from 22.9 to 54.9 c. c. in acidity, and from 5 to 66 per cent in germination. A small amount of the corn a few feet under the surface in the after part of the hold was heat-damaged. Sample No. 42 taken from the heat-damaged corn had a temperature of 120° F. and tested 49 c. c. in acidity. The corn located along the upper part of the shaft tunnel was sour, moldy, and "packed." The corn near the tunnel increased more in temperature than the corn stowed the same height in the hold but located half-way between the tunnel and the sides of the hold, as is shown by comparing the records for thermometers 45, 46, and 48, and figure 45. The corn located directly on the tunnel increased more in temperature and acidity and decreased more in germination, sound kernels, and weight per bushel than the corn which was located some distance from the tunnel, also the natural corn in this hold, located on the shaft tunnel, underwent more deterioration than the dried corn located on the shaft tunnel in hold 4.

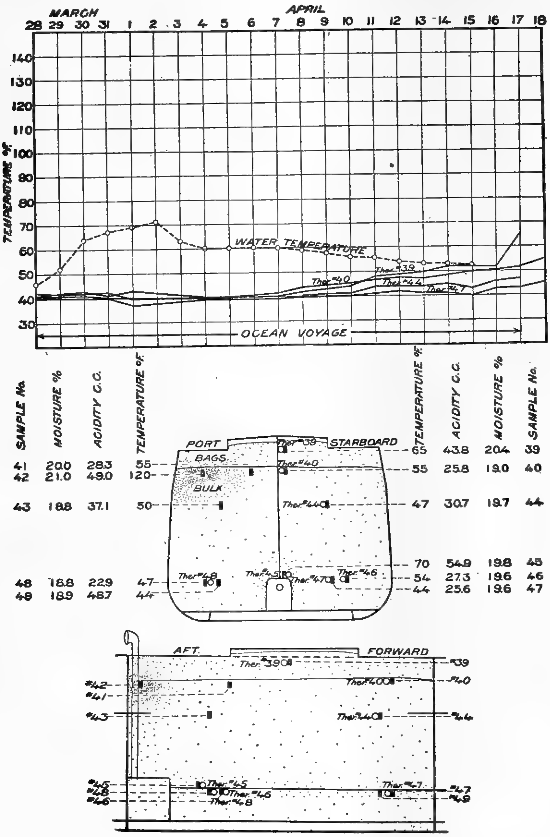

FIG. 44.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 46.

CARGO No. 7.

Cargo No. 7 consisted of 171,428 bushels of natural corn. The corn was loaded March 23 to 27, 1911; the steamship sailed March 31 and arrived at Belfast, Ireland, April 21, where the corn was discharged from April 22 to May 9. The length of the ocean voyage was 21 days; the maximum time that any of the corn was in the vessel was 47 days, and the average time was 39 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds. The corn was stowed in four holds, holds 2, 3, 5, and 6. Only hold 2 was entirely filled with corn, although the corn in hold 3 was loaded to the same height, but this hold had one more deck. Hold 5 was about two-thirds filled, and hold 6 was a little over half filled with corn. The vessel had two shaft tunnels along the bottom of holds 5 and 6. Both of these shaft tunnels were ventilated.

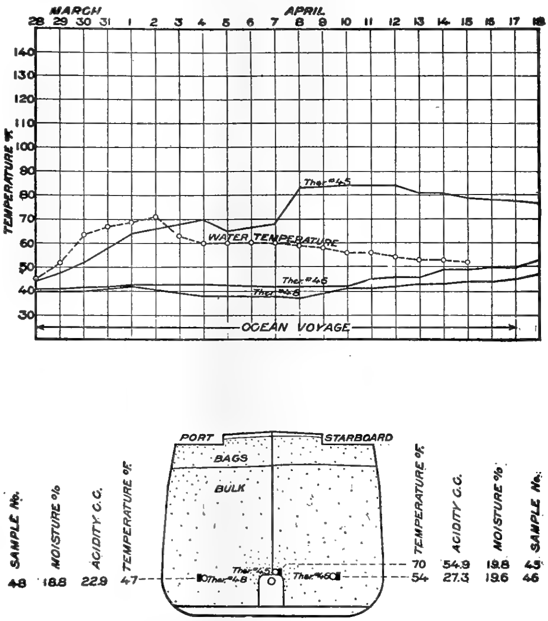

FIG. 45.—Hold 5: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 6.)

CONDITION OF THE CORN AS LOADED.

The corn in this cargo was natural corn. The condition of the corn as loaded is shown in Tables 32 and 33. The averages for the various factors of the corn as loaded were as follows: Moisture content 18.4 per cent, acidity 23.8 c. c., germination 60.2 per cent, sound kernels 95.2 per cent, and test weight per bushel 53.5 pounds. The average temperature of the corn as loaded was 62° F.

TABLE 32.—*Range in the principal factors showing quality and condition of the corn in cargo No. 7, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Pre cent.*	*Per cent.*	*Pounds.*
Hold 2:						
As loaded	61.0– 67.0	16.4–18.4	26.1–29.9	46.0–64.0	90.2–96.1	52.8–54.5
As discharged	68.0–146.0	14.0–18.9	28.0–43.2	0–60.0	0–88.7	47.0–53.5
Hold 3:						
As loaded	56.0– 66.0	17.8–18.9	19.9–26.2	50.0–73.0	90.1–98.1	51.5–54.0
As discharged	65.0–141.0	16.2–20.1	27.6–47.7	0–65.0	0–91.8	47.0–53.8
Hold 5:						
As loaded	61.0– 65.0	18.5–19.0	22.1–25.9	42.0–73.0	93.9–97.7	53.5–54.5
As discharged	69.0–147.0	16.8–35.8	27.7–70.0	0–71.0	0–84.0	43.0–52.8
Hold 6:						
As loaded	57.0– 64.0	18.5–19.1	20.7–24.2	56.0–68.0	93.9–97.7	53.3–54.0
As discharged	68.0–122.0	17.1–19.1	27.5–43.4	0–61.0	0–84.8	48.0–53.8

TABLE 33.—*Condition of the corn in cargo No. 7, natural corn, as loaded, and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in crossed-wire containers.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 2:	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
T 1	67	146	17.8	18.0	26.1	42.8	47	0	95.4	0	53.25	47.00
T 2	63	126	18.4	16.7	26.9	38.2	58	1	95.5	1.0	54.00	50.50
36				14.0		33.8		6		39.5		52.50
T 3	63	76	18.4	17.9	29.9	43.2	46	3	96.1	21.1	54.50	51.50
37		116		18.5		28.4		28		65.5		50.00
38		112		18.9		33.7		3		9.1		49.50
39		82		17.7		28.0		36		70.9		51.50
40		70		17.8		29.0		47		77.2		53.00
T 4	65	69	16.4	17.2	27.1	32.0	58	42	90.5	88.7	53.50	52.25
T 5	66	82	17.2	16.8	27.7	31.0	64	60	90.2	87.4	52.75	52.50
41		68		17.6		29.0		37		85.8		53.00
T 6	61	70	17.7	17.2	28.5	29.3	60	51	90.8	77.1	53.00	52.75
T 7	64	68	18.3	18.3	26.7	32.6	60	60	92.2	84.5	53.75	53.50
42			18.3		26.3		53		93.8		53.50	
43			17.7		28.2		61		95.4		53.50	
44			17.3		27.1		61		92.6		53.00	
Hold 3:												
T 8	66	141	18.5	18.3	22.2	43.6	60	0	96.0	0	53.25	47.00
T 9	66	140	18.3	17.5	23.8	47.7	62	0	96.1	0	53.25	47.50
45		118		20.1		41.7		14		29.7		47.00
T 10	66	118	18.2	16.2		34.0		34	95.4	18.4	54.00	52.00
46		104		17.3		28.0		51		62.1		51.50
47		78		17.9	22.4	29.6	65	3		80.6		53.00
48		67		18.7		31.7		35		55.7		52.50
49		70		18.1		31.0		44		83.9		52.00
T 11	64	73	18.6	18.2	20.5	31.7	53	65	98.1	91.8	54.00	52.75
T 12	64	72	18.1	18.3	25.0	34.0	62	56	95.5	80.6	53.50	52.25
T 13	64	69	18.1	17.7	21.2	33.8	65	59	97.6	86.5	53.50	53.75
T 14	64	70	18.9	18.6	22.0	27.6	60	61	95.6	82.7	53.00	52.75
T 15	63	72	18.1	17.7	19.9	29.2	63	44	96.8	74.8	53.25	52.00
T 16	62	65	18.8	18.3	20.8	31.0	65	65	95.8	74.8	53.25	52.00
T 17	62	68	18.6	18.0	21.8	31.2	67	57	93.2	84.6	53.00	52.50
T 18	61	69	18.7	18.4	24.8	32.0	55	58	90.1	87.5	51.50	51.25
T 19	58	69	18.8	18.8	26.2	30.8	62	59	94.0	88.7	53.50	53.50
T 20	59	70	18.3	17.7	21.2	30.0	60	64	95.3	78.3	53.75	53.00
T 21	56	72	18.1	18.1	22.4	27.6	61	64	96.7	83.6	54.00	52.50
50			18.2		20.0		73		95.0		53.50	
51			18.0		22.4		59		96.0		53.00	
52			17.8		23.2		61		95.6		53.75	
Hold 5:												
T 22	63	147	18.8	16.8	24.2	47.4	59	0	95.9	0	53.50	47.50
53		135		18.8		36.7		0		2.9		49.75
54				35.8		70.0		0		0		43.00
55		118		19.2		27.7		1		13.3		50.00
56		71		18.1		29.3		62		82.5		52.75
T 23	65	74	18.5	18.5	23.2	32.4	42	56	97.6	76.7	53.75	52.50
T 24	64	77	18.6	18.4	22.9	34.7	73	67	96.1	76.1	53.75	51.75
57		125				51.8		6		5.5		
58		83		18.7		29.6		1		72.4		50.00
T 25	65	90	18.6	18.9	25.9	33.3	63	3	96.4	66.9	54.00	51.00
59		72		18.4		30.5		37		76.4		51.00
T 26	64	79	18.6	18.4	22.1	31.3	68	70	95.8	66.9	54.50	52.00
60		69				28.7		60		62.4		
T 27	64	69	18.5	17.4	25.5	30.3	57	62	96.7	84.4	53.75	52.50
T 28	61	73	18.6	18.6	23.2	30.2	67	71	95.7	69.8	53.50	52.50
61			18.8		24.4		62		97.7		54.00	
62			19.0		23.8		62		95.4		54.00	
63			18.8		25.4		67		93.9		54.00	
Hold 6:												
64		72		17.1		38.1		4		9.8		48.00
T 29	63	122	18.7	18.3	20.9	43.4	57	0	96.3	0	53.50	49.50
65		100		18.9		39.8		0		33.8		51.25
66		80		17.1		31.8		29		76.9		51.50
67		87		19.1		32.8		0		71.4		50.00
T 30	61	87	18.7	18.1	20.7	30.8	56	23	95.4	69.8	53.50	51.25
T 31	63	86	18.8	17.8	23.6	29.9	62	33	95.3	83.1	54.00	52.25
T 32	64	75	18.9	18.2	20.7	30.1	57	55	93.9	74.3	53.25	51.50
T 33	63	68	18.5	18.3	23.7	28.4	56	56	97.7	82.9	53.50	53.75
T 34			18.5	18.3	24.2	33.0	62	61	96.3	84.8	54.00	53.25
T 35	57	69	19.1	18.4	22.3	27.5	68	58	97.1	78.5	53.50	53.00
68			18.6		22.9		59		94.7		54.00	

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

During the voyage the temperature of the corn in the various positions of stowage was recorded each day that the weather permitted. The location of the various thermometers and the changes in temperature at those positions are shown in figures 48 to 53, inclusive. The maximum temperatures found in the corn as discharged were 146° F. in hold 2, 141° F. in hold 3, 147° F. in hold 5, and 122° F. in hold 6. These were higher than the maximum temperatures at the time of loading by 79° F., 75° F., 82° F., and 58° F., respectively. During the time that the corn was in the vessel a large proportion of it became hot, discolored, moldy, and badly damaged. The corn changed the most in condition and became badly damaged in the upper part of the holds. The temperature and degree of deterioration, in a general way, decreased from the surface of the corn toward the bottom of the holds. It will be seen in the accompanying charts that the temperature of the corn reached 100° F. in the following number of days after sailing. Three days in hold 2, 4½ days in hold 3, 8 days in hold 5, 16 days in hold 6. As has already been stated, the average length of time that the corn remained in the vessel was 39 days.

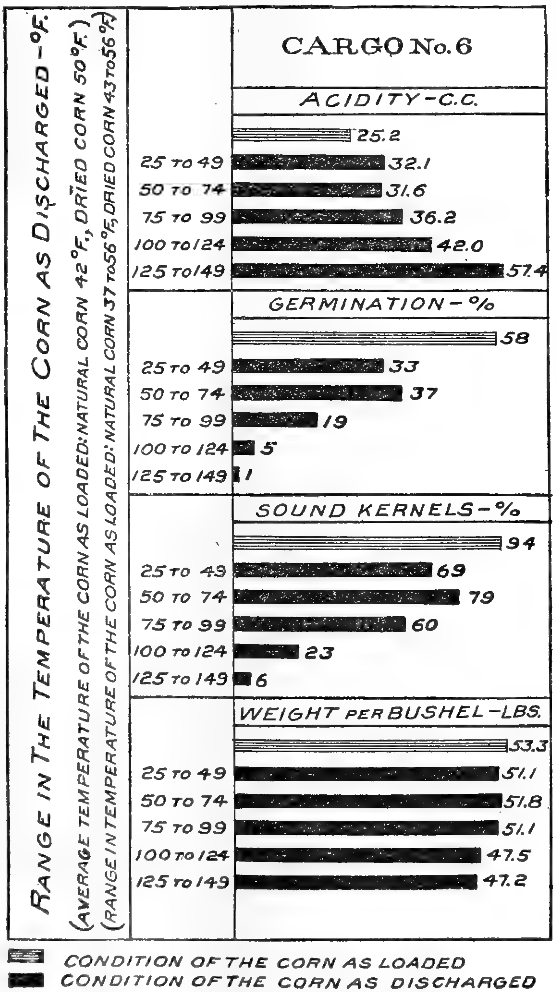

FIG. 46.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 6.)

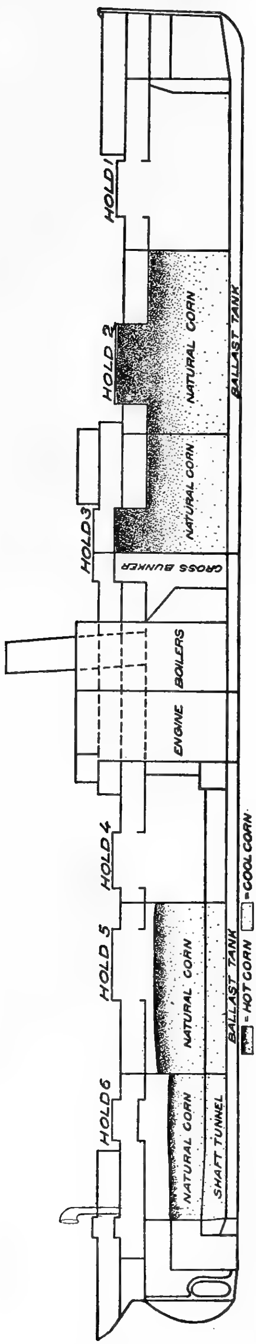

FIG. 47.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 7.)

Hold 2 was entirely filled with corn, the upper part of which became badly heat damaged while it was in the vessel. The corn in this hold as discharged ranged from 68 to 146 degrees in temperature, 14 to 18.9 per cent in moisture, 28 to 43 c. c. in acidity, 0 to 60 per cent in germination, 0 to 88.7 per cent in sound kernels, and 47 to 53.5 pounds in test weight per bushel. As is shown in Table 33, sample 1, taken from near the surface, had a temperature when discharged of 146° F., tested 42.8 c. c. in acidity, had no sound kernels, and none of the corn would germinate. As will be seen by the temperature record for thermomter 1, in figure 48, this thermometer was located near the surface. The corn in this position of stowage increased in temperature very rapidly from the time it was loaded, on March 27, until it was over 140° F., on April 12, after which the increase became more gradual. The corn surrounding this thermometer was very badly damaged on arrival in Europe. Sample 2, which was taken from the corn about one-third of the distance down in the hold, had a temperature of 126° F., tested 38.2 c. c. in acidity, germinated 1 per cent, and had 1 per cent of sound kernels. The temperature of the corn surrounding sample 2 gradually increased from the time that the corn was loaded until it was discharged, as is shown by the temperature record for thermometer 2. Sample 4, taken two-thirds of the distance down in the corn, and sample 7, taken from the bottom of the hold, had temperatures of 69° and 68° F., and tested 32 and 32.6 c. c. in acidity, 42 and 60 per cent in germination, and 88.7 and 84.5 per cent in sound kernels. The temperature of the corn two-thirds of the distance down in the hold remained practically stationary during the voyage, as will be seen by the records for thermometer 4, while the temperature of the corn at the bottom fluctuated somewhat, being influenced to some extent by the temperature of the sea water.

Hold 3 was filled with corn to the second deck. The corn as discharged was badly heat damaged in the upper part of the hold and ranged from 65° to 141° F. in temperature, 27.6 to 47.7 c. c. in acidity, 0 to 65 per cent in germination, 0 to 91.8 per cent in sound kernels, and 47 to 53.8 in test weight per bushel. The corn in this hold at time of loading had a temperature ranging from 56° to 66° F., which temperature increased very rapidly at the surface during the early part of the voyage and was over 120° F. in a week after the vessel sailed; it continued to increase until it reached 141° F. by the time the corn was discharged. This is shown in the temperature record for thermometer 8, figure 49. As will be seen in Table 33, sample No. 8, which was taken from near the surface of the corn, tested 43.6 c. c. in acidity and none of the kernels would germinate. The corn at this position was very moldy, sour, and badly heat damaged. There was not much change in the temperature of the corn located one-third of the distance down in the hold in the first 10 or 12 days of the voyage, but from that time on it increased more rapidly until on April 24 it was 118° F., as is shown by the record for thermometer 10. The corn surrounding this thermometer, as discharged, tested 34 c. c. in acidity and 34 per cent in germination. The temperature of the corn located two-thirds of the distance down in the hold increased only 9° F. during the time it was in the vessel, as is shown by the tempera-

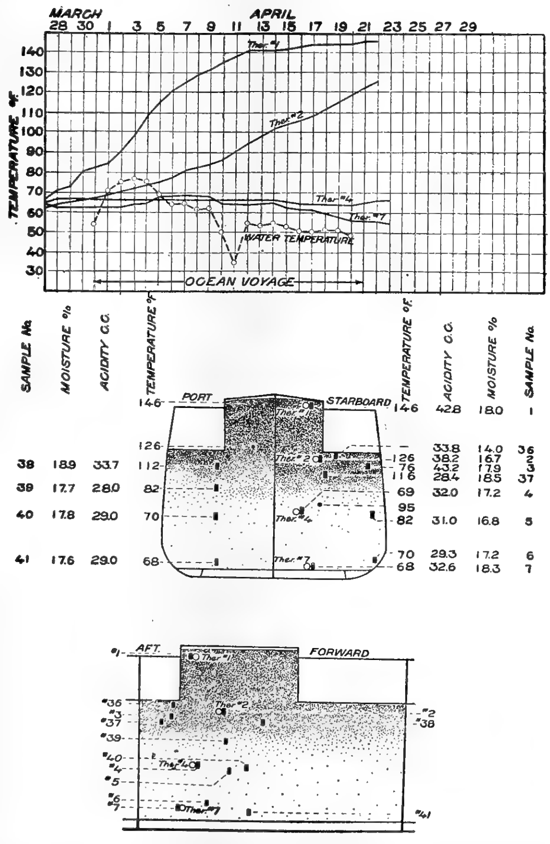

FIG. 48.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

ture record for thermometer 11. Sample No. 11, taken from the corn surrounding thermometer 11, had a temperature of 73° F. and tested 31.7 c. c. in acidity, 65 per cent in germination, and 91.8 per cent in sound kernels. The temperature of the corn in the bottom of the hold varied somewhat with the sea-water temperature, as illustrated by the record for thermometer 19. Sample No. 19, taken from the corn at the bottom of the hold, had a temperature when discharged of 69° F., tested 30.8 c. c. in acidity, 59 per cent in germination, and 88.7 per cent in sound kernels.

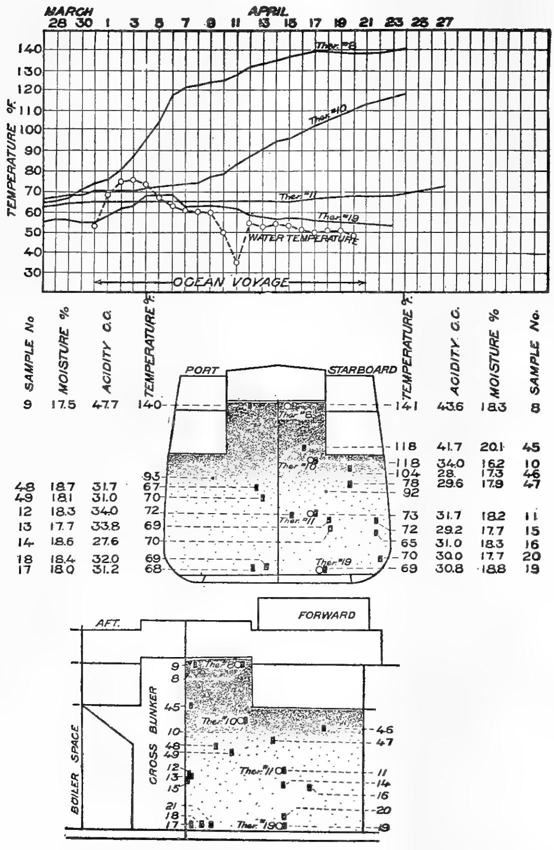

FIG. 49.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

Hold 5 was two-thirds filled with corn, the top part of which became badly heat damaged during the voyage. The corn in this hold, as discharged, ranged from 69° to 147° F. in temperature, 27.7 to 70 c. c. in acidity, 0 to 71 per cent in germination, 0 to 84 per cent in sound kernels, and 43 to 52.8 pounds in test weight per bushel. As will be seen by the temperature record for thermometer 22 in figure 12, the corn near the surface increased from 63° F. on March 24 to 100° F. on April 8 and to 147° F. on April 21. As indicated in Table 33, sample No. 22, which represents the corn surrounding thermometer No. 22, contained no sound kernels or any kernels that would germinate, and tested 47.4 c. c. in acidity and 47.5 pounds in weight per bushel. The corn located halfway down in the hold and at the bottom changed very little in temperature except near the outside walls and along the top of the shaft tunnel. Sample No. 24, taken from near the shifting boards halfway down in the corn, increased from 64 to 77° F. in temperature and when discharged tested 34.7 c. c. in acidity, 67 per cent in germination, 76.1 per cent in sound kernels, and 51.75 pounds in weight per bushel. Sample No. 57, taken from near the side of the hold, a little over halfway down in the corn on the port side, had a temperature of 125° F. and tested 51.8 c. c. in acidity, 6 per cent in germination, and 5.5 per cent in sound kernels. The corn along the top of the shaft tunnel varied in temperature during the voyage, while the temperature of the corn the same height in the hold located halfway from the tunnel and the side of the boat, remained nearly the same throughout the voyage, as is shown by comparing the temperature records for thermometers 25 and 26.

Table 34 shows that the corn surrounding thermometer 25, which was located on the shaft tunnel, tested higher by 2 c.c. in acidity and lower by 67 per cent in germination than the corn surrounding thermometer 26, which was located at tunnel height but halfway between the tunnel and the side of the hold. Four samples taken from hold 5 tested under 30 c. c. and nine samples tested over 30 c. c. in acidity.

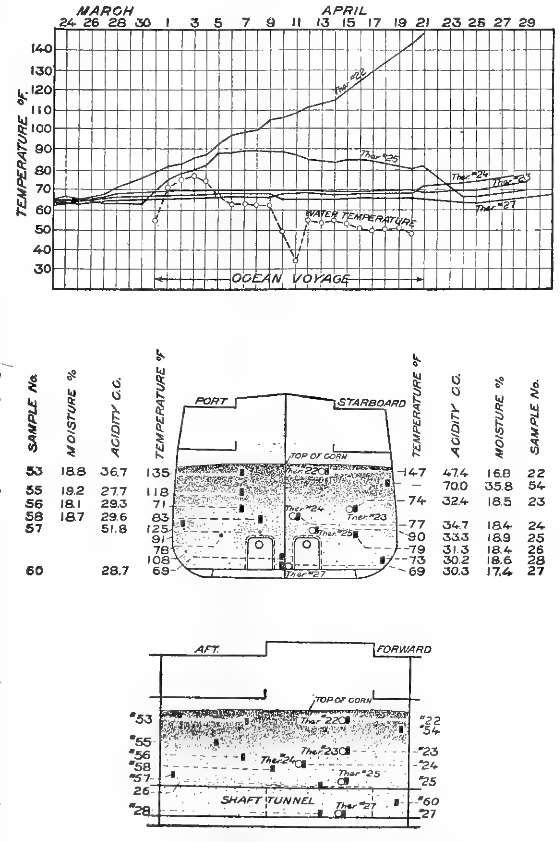

FIG. 50.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

TABLE 31.—*Effect of the shaft-tunnel heat on the corn stowed next to the shaft tunnel in hold 5.*

Sample No.	Location of samples.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
		° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
25	On shaft tunnel	90	33.3	3	66.9	51.0
26	Tunnel height halfway out	79	31.3	70	66.9	52.0

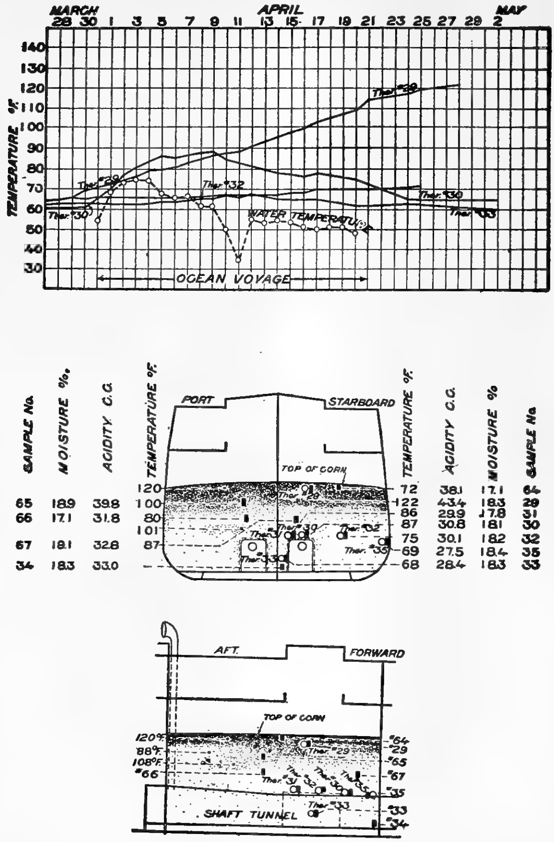

FIG. 51.—Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

Hold 6 was a little more than half filled with corn. The upper part of the corn became badly heat damaged. The corn in this hold as discharged ranged from 68° to 122° F. in temperature, 27.5 to 43.4 c. c. in acidity, 0 to 61 per cent in germination, 0 to 84.8 per cent in sound kernels, and 48 to 53.8 pounds in test weight per bushel. The corn at the surface, where the heat could escape, had a temperature of 72° F. when discharged, as is shown by sample No. 64 in figure 51. The corn just under the surface gradually increased from 63° to 122° F. during the voyage, as is illustrated by the temperature record for thermometer 29. As is shown in Table 33, sample No. 29, which represents the corn surrounding thermometer No. 29, tested 43.4 c. c. in acidity, and 49.5 pounds in weight per bushel, and contained no sound kernels or any kernels that would

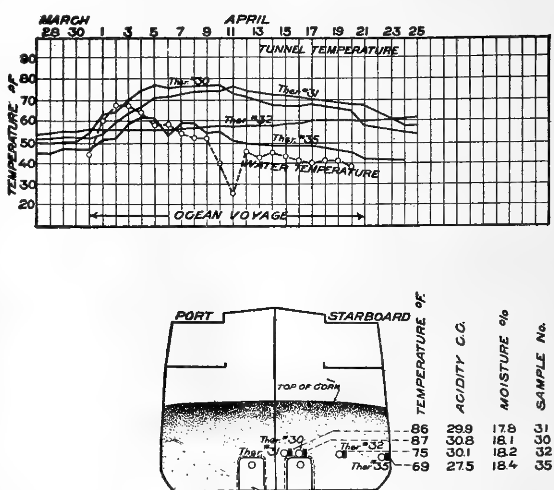

FIG. 52.—Hold 6, showing effect of the heat from the propeller-shaft tunnels on the corn located against the tunnels. (Cargo No. 7.)

germinate. The corn located about 6 feet from the bottom and halfway between the shaft tunnel and the side of the hold increased 11° F. in temperature and tested 30.1 c. c. in acidity, 55 per cent in germination, 74.3 per cent in sound kernels, and 51.5 pounds in weight per bushel, as is shown by sample No. 32, while the corn between the tunnels and near the bottom of the hold increased but 5° F. in temperature and tested 28.4 c. c. in acidity, 56 per cent in germination, 82.9 per cent in sound kernels, and 53.75 pounds in weight per bushel, as is shown by sample No. 33.

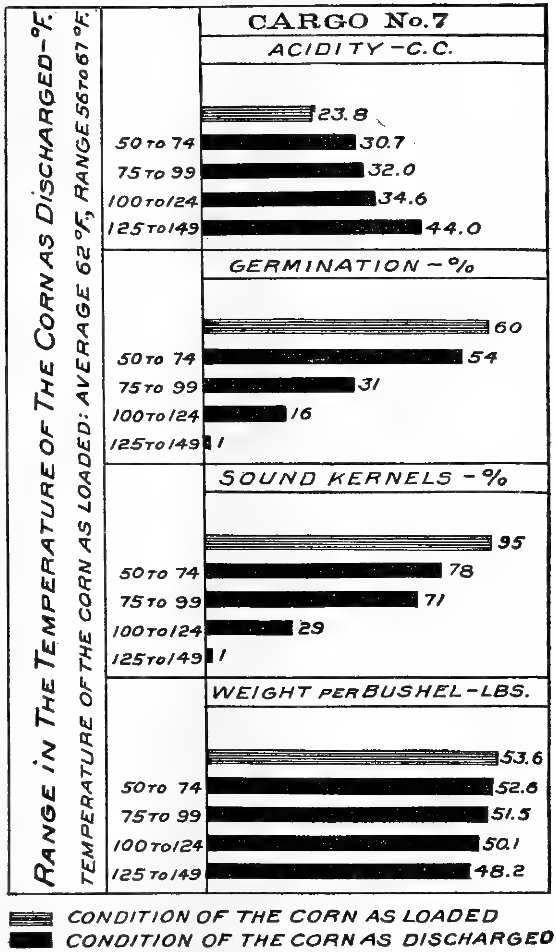

FIG. 53.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 7.)

TABLE 35.—*Effect of the shaft-tunnel heat on the corn stowed next to the shaft tunnel in hold 6.*

Sample No.	Location of samples.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
		° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
30	On unprotected part of shaft tunnel	87	30.8	23	69.8	51.2
31	On plank-protected part of shaft tunnel	86	29.9	33	83.1	52.2
30 and 31	On shaft tunnel[1]	86	30.3	28	71.4	51.7
32	Tunnel height, halfway out	75	30.1	55	74.3	51.5

[1]Average for samples Nos. 30 and 31.

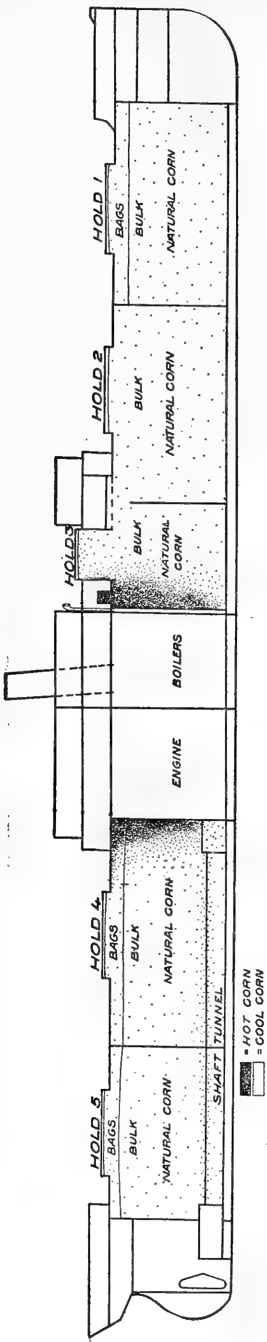

FIG. 54.—Diagram showing the arrangement of the steamship and the stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 8.)

As will be seen in figure 52 and Table 35, the corn which was located on the unprotected part of the shaft tunnel was influenced more by the tunnel temperature and tested poorer when discharged than the corn which was located on the plank-protected part of the tunnel. They also show that the corn in either of the two positions on the shaft tunnel varied considerably more in temperature and tested poorer than the corn located at tunnel height but halfway between the tunnel and the side of the hold. The temperature of the corn at tunnel height near the side of the hold varied with the sea temperature as is illustrated by the temperature record for thermometer 35.

Three samples taken from hold 6 when the corn was being discharged tested under 30 c. c. and eight samples tested over 30 c. c. in acidity.

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 53.

CARGO No. 8.

Cargo No. 8 consisted of 258,092 bushels of natural corn. The corn was loaded from February 27 to March 1, 1912. The steamship sailed March 1 and arrived at Rotterdam, Holland, on March 20, where the corn was discharged from March 20 to March 22. The length of the ocean voyage was 19 days; the maximum time that any of the corn was in the vessel was 23 days, and the average time was 21 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds. As is shown in figure 54, this shipment was a full cargo, each hold being entirely filled with corn.

CONDITION OF THE CORN AS LOADED.

The corn in this cargo was natural corn, and its condition as loaded is shown in Tables 36 and 37. The averages for the various factors of the corn as loaded were as follows: Moisture content 20.1 per cent, acidity 17.6 c. c., germination 49 per cent, sound kernels 88 per cent, and test weight per bushel 52.7 pounds. The average temperature of the corn as loaded was 29° F.

TABLE 36.—*Range in the principal factors showing quality and condition of the corn in cargo No. 8, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	25.0– 32.0	19.9–20.3	17.6–18.5	45.0–66.0	85.5–94.1	52.5 –54.0
As discharged	25.0– 46.0	....	17.8–21.2	24.0–53.0	84.9–93.0	51.75–54.0
Hold 2:						
As loaded	27.0– 32.0	19.9–20.4	16.8–18.6	48.0–57.0	87.0–88.9	52.0 –53.5
As discharged	29.0– 52.0	....	18.0–28.0	10.4–40.0	83.6–91.1	51.2 –53.5
Hold 3:						
As loaded	26.0– 33.0	19.8–20.5	17.6–20.2	36.0–58.0	86.7–91.4	51.5 –53.5
As discharged	28.0–132.0	....	18.2–38.2	0–39.0	2.0–91.1	46.5 –53.5
Hold 4:						
As loaded	26.0– 32.0	19.5–20.3	15.6–19.2	30.0–69.0	85.5–94.1	51.5 –53.5
As discharged	29.0–145.0	....	16.6–50.4	0–45.0	0–95.4	46.0 –53.25
Hold 5:						
As loaded	24.0– 33.0	19.5–20.6	16.6–18.0	37.0–65.0	86.9–91.6	52.5 –53.2
As discharged	27.0– 84.0	....	18.0–32.0	4.0–52.0	58.1–91.0	47.0 –53.5

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The temperatures of the corn in the various positions of stowage were recorded during the voyage each day that the weather permitted. The location of the various thermometers and the changes in the temperature at those positions are shown in figures 55 to 62, inclusive. It will be noted that at the time of loading the average temperature of the corn was very low (30° F.) and that the moisture content was dangerously high (20.1 per cent). However, the acidity was very low (17.6 c. c.), showing that the corn had previously undergone very little deterioration. At the time of discharge it was found that the corn in holds 3 and 4 was damaged along the boiler-room and engine-room bulkheads and there was also a slight amount of damage along the shaft tunnel in the bottom of holds 4 and 5. The maximum temperatures found in the corn as discharged were 46° F. in hold 1, 52° F. in hold 2, 132° F. in hold 3, 145° F. in hold 4, and 84° F. in hold 5. These were higher than the maximum temperatures at the time of loading by 14° F. in hold 1, 20° F. in hold 2, 109° F. in hold 3, 123° F. in hold 4, and 51° F. in hold 5.

There were no facilities for making moisture tests of the samples secured at the port of discharge, and consequently the moisture tests at the time of loading only are given in this report.

TABLE 37.—*Condition of the corn in cargo No. 8 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in crossed-wire containers.]

Sample No.	Temperature.		Moisture content.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	°*F.*	°*F.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
T 1	30	42	19.9	17.6	21.2	45	27	93.3	90.0	53.00	52.75
2		43			20.6		24		87.7		51.75
T 3	32	32	20.3	18.8	20.0	47	27	85.5	84.9	52.50	52.00
4					17.8		36		90.4		54.00
T 5	25	25	20.1	17.8	17.8	66	53	93.8	91.6	54.00	53.75
6		33			21.2		27		93.0		52.75
T 7	31	46	20.2	17.8	19.6	60	30	94.1	86.0	52.50	51.75
Hold 2:											
T 8	32	52	20.1	16.8	18.2	48	34	88.6	88.5	53.50	53.00
T 9	31	49	20.2	17.8	25.4	57	15	88.9	85.8	52.00	52.00
10					28.0		10		84.0		53.00
11					19.2		34		91.1		53.00
T 12	29	30	19.9	18.2	18.2	52	40	88.2	88.0	53.50	52.50
T 13	29	29	20.1	18.6	18.6	55	32	87.0	86.9	52.00	52.00
14		38			18.0		38		86.5		52.25
T 15	27	39	20.4	17.2	18.0	53	28	87.6	83.6	52.00	51.25
Hold 3:											
T 16	27	55	20.1	17.8	21.4	56	29	87.0	82.5	53.00	52.00
T 17	30	68	20.1	19.2	26.2	43	7	89.6	88.4	52.50	50.00
T 18	30	59	20.2	18.4	21.4	49	21	91.4	91.1	53.00	51.00
19		78			38.2		4		61.2		48.00
T 20	31	132	20.1	18.0	27.8	46	0	87.8	2.0	53.00	46.50
T 21	31	32	20.5	18.2	20.4	36	6	91.1	89.6	53.00	52.50
T 22	33	112	20.2	20.2	22.6	58	26	87.9		52.00	51.75
T 23	26	28	19.8	17.6	18.2	56	39	90.4	89.4	53.50	53.50
T 24	33	53	20.4	17.8	18.6	53	32	90.0	84.0	51.50	51.50
25	29		20.3	18.8		47		86.7		51.50	
Hold 4:											
T 26	28	33	20.3	18.4	20.0	48	45	91.9	91.9	53.00	52.75
T 27	30	35	19.9	19.2	20.0	36	31	94.1	94.0	53.00	52.50
28	32		19.8	17.6	24.6	31	20	90.6	79.3	52.50	51.50
29	32		19.9	17.6		39		87.2		52.50	
T 30	32	145	20.2	17.6	43.8	37	0	87.5	0	53.50	46.00
31		140			50.4		1		0		46.50
32	31	32	20.1	18.6	19.2	43	23	89.5	88.7	53.00	52.75
33		45			42.2		14				49.50
34		40			23.6		25		95.3		51.75
35		138			32.0		0		0		46.25
T 36	31	115	19.7	17.2	40.2	30	3	90.0	15.1	53.00	47.50
T 37	32	115	20.2	18.8	40.4	48	0	86.4	0	52.50	46.00
T 38	29	30	20.0	18.0	18.8	47	25	85.9	85.7	53.50	53.25
39		116			39.6		2		15.4		46.50
40		38			19.6		14		95.4		52.25
T 41	32	56	20.0	15.6	16.8	69	31	87.3	82.2	52.50	51.25
T 42	31	48	20.3	17.6	20.2	52	25	87.9	85.4	52.00	52.00
T 43	26	67	19.5	16.0	23.0	67	10	86.1	84.8	51.50	50.00
44		98			37.4		5		30.0		47.75
T 45	27	29	20.2	16.6	16.6	59	34	89.6	89.0	53.00	53.00
T 46	27	31	20.2	17.2	18.8	57	35	90.4	90.0	52.50	52.25
47		38			20.4		26		93.1		52.50
T 48	28	43	20.1	16.8	17.6	30	30	85.5	85.4	53.00	52.50
Hold 5:											
49	30		20.0	17.0		37		88.2		52.50	
50		44			23.4		23		91.0		52.25
T 51	32	32	20.5	17.2	32.0	38	38	89.2	85.9	52.50	51.75
52		38			20.8		28		90.9		53.25
T 53	28	28	20.4	18.0	18.6	65	46	87.1	84.1	53.00	53.00
T 54	29	84	19.8	16.8	29.4	50	4	86.6	58.1	53.25	48.75
55		82			28.2		8		68.0		47.00
56		38			21.4		28		89.9		53.50
T 57	28	29	20.3	16.6	18.8	41	21	91.6	90.5	52.50	52.00
T 58	24	27	19.5	17.2	18.0	61	52	87.4	87.0	53.25	53.25
T 59	28	43	20.1	17.0	19.4	49	26	89.2	87.6	53.00	53.00
T 60	33	43	20.6	16.6	20.6	47	21	88.1	88.0	52.50	52.50

The corn in holds 1 and 2 changed but little during the voyage and was discharged in Europe in good condition.

In hold 3 that part of the corn that was located next to the boiler-room bulkhead in the after part of the hold was hot and badly damaged at the time of discharge. In the damaged corn, as is shown in Table 38, the greatest heat and the most severe damage was found along the upper part of this bulkhead. The corn located along the lower part of this bulkhead was not hot but was slightly sour. The corn located in the forward part of the hold was discharged in a sound condition. The temperature records during the voyage for the corn located next to the upper, middle, and bottom portions of the boiler-room bulkhead, compared to the temperature records of the corn located at the same heights but near the center of the hold, are shown in figure 57. As will be seen from the temperature records in figure 57, the temperature of the corn located against the upper, middle, and bottom parts of the bulkhead was very noticeably affected by the heat from the boilers. Table 38 shows that the corn located against the upper part of the boiler-room bulkhead, at the time of discharge, had a temperature of 132° F., as against a temperature of 32° F. for the corn located the same height in the hold but 15 feet distant from this bulkhead, and that the corn located against the bottom of the boiler-room bulkhead at the time of discharge, had a temperature of 53° F., as against a temperature of 39° F. for the corn

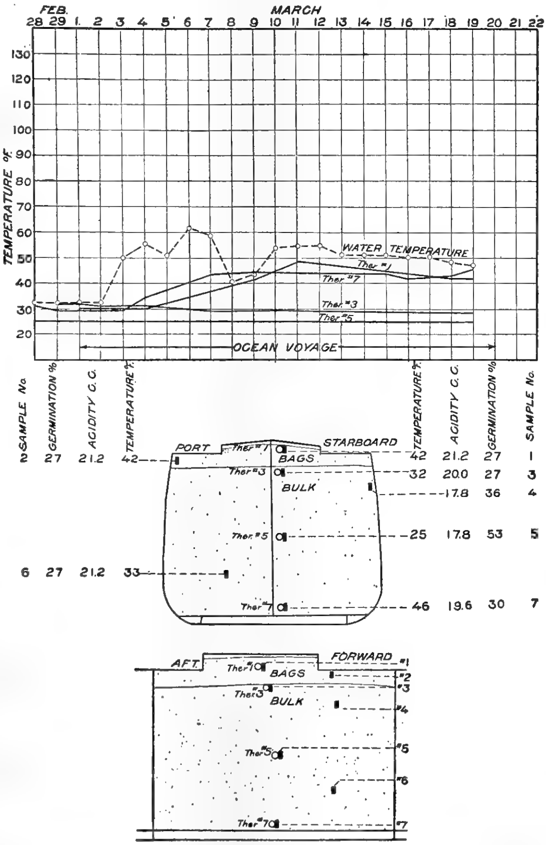

FIG. 55.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

TABLE 38.—*Showing effect of the boiler heat on the corn in hold 3, cargo No. 8.*

Location of corn.		Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
Height in hold.	Distance from boiler-room bulkhead.[2]		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
			° F.	° F.	° F.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	c. c.	c. c.	c. c.	Per ct.	Per ct.	Per ct.
Top	On BRBH	20	31	132	+ 101	20.1	53.00	46.50	−6.50	46	0	− 46	18.0	27.8	+9.8	87.8	2.0	−85.8
Top	15 feet, BRBH.	21	31	32	+ 1	20.5	53.00	52.50	− .50	36	6	− 30	18.2	20.4	+2.2	91.0	89.6	− 1.5
Halfway down	On BRBH	22	33	112	+ 79	20.2	52.00	51.75	− .25	58	26	− 32	20.2	22.6	+2.4	87.9	82.0	− 5.9
Halfway down	15 feet, BRBH.	23	26	28	+ 2	19.8	53.50	53.50	0	56	39	− 17	17.6	18.2	+ .6	90.4	89.4	− 1.0
Bottom	On BRBH	24	33	53	+ 20	20.4	51.50	51.50	0	53	32	− 21	17.8	18.6	+ .8	90.0	84.0	− 6.0
Bottom	30 feet, BRBH.	[3] 25	29	39	+ 10	20.3	51.50	51.50	0	47	28	− 19	17.8	18.0	+ .2	86.7	83.6	− 3.1

CHANGE DUE TO BOILER HEAT.

[In excess of change in corn located same height but from 15 to 30 feet distant from the boiler-room bulkhead.]

Height in hold.	Distance from boiler-room bulkhead.	Sample No.	Temp. As loaded.	Temp. As discharged.	Temp. + or −	Moisture content as loaded.	Weight As loaded.	Weight As discharged.	Weight + or −	Germ. As loaded.	Germ. As discharged.	Germ. + or −	Acidity As loaded.	Acidity As discharged.	Acidity + or −	Sound As loaded.	Sound As discharged.	Sound + or −
Top	On BRBH				+ 100				−6.00			− 16			+ 7.6			−84.3
Halfway down	On BRBH				+ 77				− .25			− 15			+ 1.8			− 4.9
Bottom	On BRBH				+ 10				− .00			− 2			+ .6			− 2.9

[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.
[2] BRBH=boiler-room bulkhead.
[3] No. 25 was lost; Rotterdam data represents sample No. 15 in hold 2, same relative location.

at the bottom of the hold but located 30 feet distant from this bulkhead. This was a higher increase in temperature by 100°, 77°, and 10° F., for the corn located against the upper, middle, and bottom parts of the boiler-room bulkhead, respectively, than the increase in temperature for the corn located at a corresponding depth in the hold but from 15 to 30 feet distant from this bulkhead, and clearly shows the effects of the boiler heat on corn having a high moisture content when stowed in this position in the vessel.

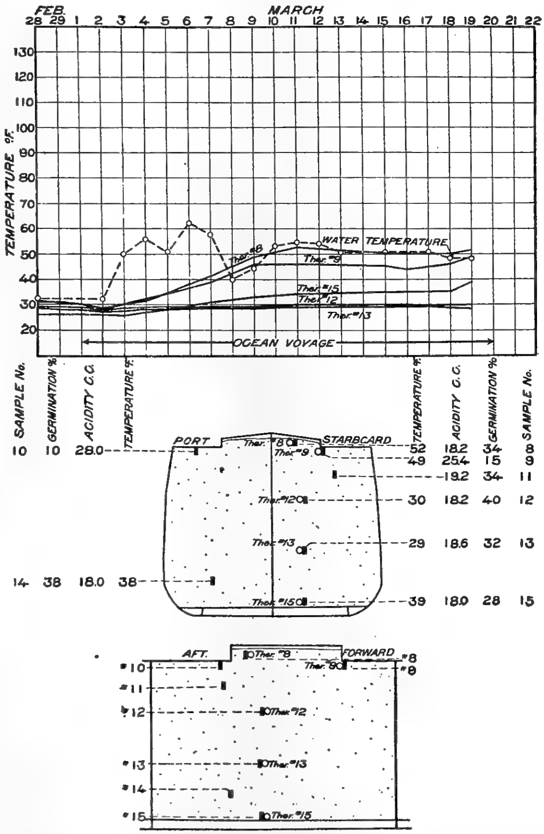

Fig. 56.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

Hold 4 was located just aft of the engine room. The propeller-shaft tunnel was located along the bottom of the hold, and this tunnel also extended along the bottom of hold 5. The corn that was located next to the engine-room bulkhead in the forward part of the hold became hot and badly damaged during the voyage. The corn located against the shaft tunnel in the bottom of the hold at the time of discharge was heating, moldy, and slightly discolored, but the remainder of the corn in the hold was discharged in good condition. As is seen in figure 59, the damaged corn next to the engine-room bulkhead had the highest temperature at the upper part of the bulkhead and the temperature decreased toward the bottom of the hold, also toward the center of the hold. Thermometers 29, 37, and 41, located next to the engine-room bulkhead near the surface, halfway down, and near the bottom of the hold, indicated a rapid increase in temperature from the first day that the corn was in the hold. Thermometer 29, which was located opposite the engine-room bulkhead, near the surface of the corn, did not show as high a temperature during the voyage or at the time the corn was discharged as thermometer 37, which was located next to the engine-room bulkhead halfway down in the hold; this is accounted for by the fact that thermometer 29 was inadvertently placed several feet back from the bulkhead. However, sample No. 30, which was taken from the corn the same height in the hold as sample No. 29, but in contact with the upper part of the engine-room bulkhead, shows a temperature of 145° F. Table 39 shows that the corn located next to the upper part of the engine-room bulkhead increased 113° F. in temperature and 26.2 c. c. in acidity, and decreased 7.5 pounds in test weight per bushel, 30 per cent in germination, and 87.5 per cent in sound kernels. This is in contrast with an increase of only 1° F. in temperature and 0.6 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel, 20 per cent in germina-

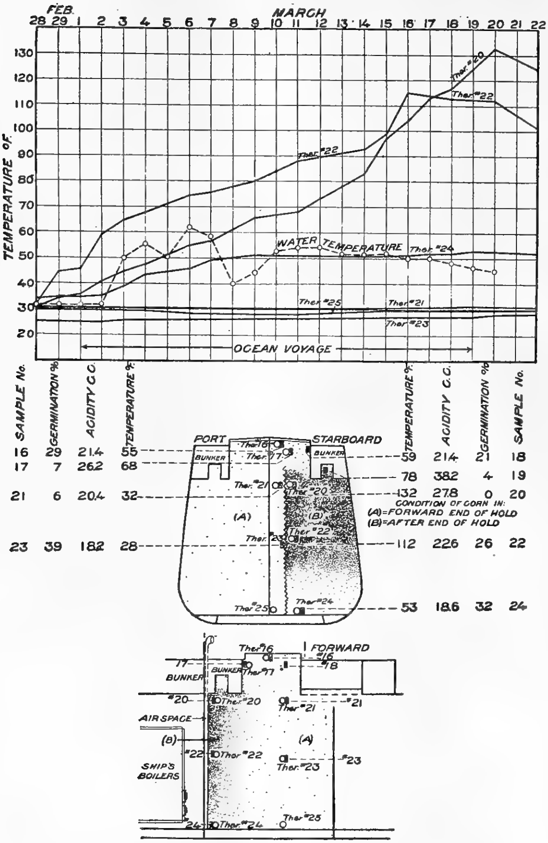

FIG. 57.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

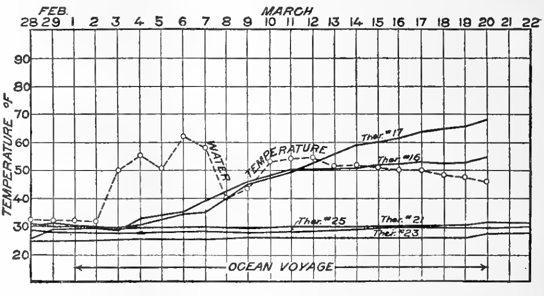

FIG. 58.—Temperature records of the thermometer located from the surface to the bottom of the corn near the center of hold 3. (Cargo No. 8.)

TABLE 39.—*Showing effect of the engine-room heat on the corn in hold 4, cargo No. 8.*

Location of corn.		Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
Height in hold.	Distance from engine-room bulkhead.[2]		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
			° F.	° F.	° F.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	c. c.	c. c.	c. c.	Per ct.	Per ct.	Per ct
Top	On ERBH	30	32	145	+ 113	20.2	53.50	46.00	−7.50	37	0	− 37	17.6	43.8	+26.2	87.5	0	−87.5
Top	12 feet, ERBH	32	31	32	+ 1	20.1	53.00	52.75	− .25	43	23	− 20	18.6	19.2	+ .6	89.5	88.7	− .8
Halfway down	On ERBH	37	32	115	+ 83	20.2	52.50	46.00	−6.50	48	0	− 48	18.8	40.4	+21.6	86.4	0	−86.4
Halfway down	12 feet, ERBH	38	29	30	+ 1	20.0	53.50	53.25	− .25	47	25	− 22	18.0	18.8	+ .8	85.9	85.7	− .2
Bottom	On ERBH	41	32	56	+ 24	20.0	52.50	51.25	−1.25	69	31	− 38	15.6	16.8	+ 1.2	83.3	82.2	− 1.1
Bottom	12 feet, ERBH	42	31	48	+ 17	20.3	52.00	52.00	0	52	25	− 27	17.6	20.2	[3] +2.6	87.9	85.4	− 2.5

CHANGE DUE TO ENGINE HEAT.

[In excess of change in corn located same height but 12 feet distant from the engine-room bulkhead.]

Height in hold.	Distance from engine-room bulkhead.	Sample No.	Temp. As loaded.	Temp. As discharged.	Temp. + or −	Moisture	Wt. As loaded.	Wt. As discharged.	Wt. + or −	Germ. As loaded.	Germ. As discharged.	Germ. + or −	Acid. As loaded.	Acid. As discharged.	Acid. + or −	Sound As loaded.	Sound As discharged.	Sound + or −
Top	On ERBH	......	......	......	+ 112	......	......	......	−7.25	......	......	− 17	......	......	+25.6	......	......	−86.7
Halfway down	On ERBH	......	......	......	+ 82	......	......	......	−6.25	......	......	− 26	......	......	+20.8	......	......	−86.2
Bottom	On ERBH	......	......	......	+ 7	......	......	......	−1.25	......	......	− 11	......	......	[3] −1.4	......	......	+[3]1.4

[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.
[2] ERBH=engine-room bulkhead.
[3] Greater increase in acidity, and decrease in sound kernels in sample located 12 feet back from the engine-room bulkhead was due to mold.

tion and 0.8 per cent in sound kernels for the corn located the same height in the hold but 12 feet distant from the bulkhead. The corn located against the engine-room bulkhead halfway down in the hold increased 83° F. in temperature, 21.6 c. c. in acidity, and decreased 6.5 pounds in test weight per bushel, 48 per cent in germination, and 86.4 per cent in sound kernels. This is in contrast with an increase of only 1° F. in temperature, 0.8 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel, 22 per cent in germination, and 0.2 per cent in sound kernels for the corn located the same height in the hold but 12 feet distant from the bulkhead. The corn located against the lower part

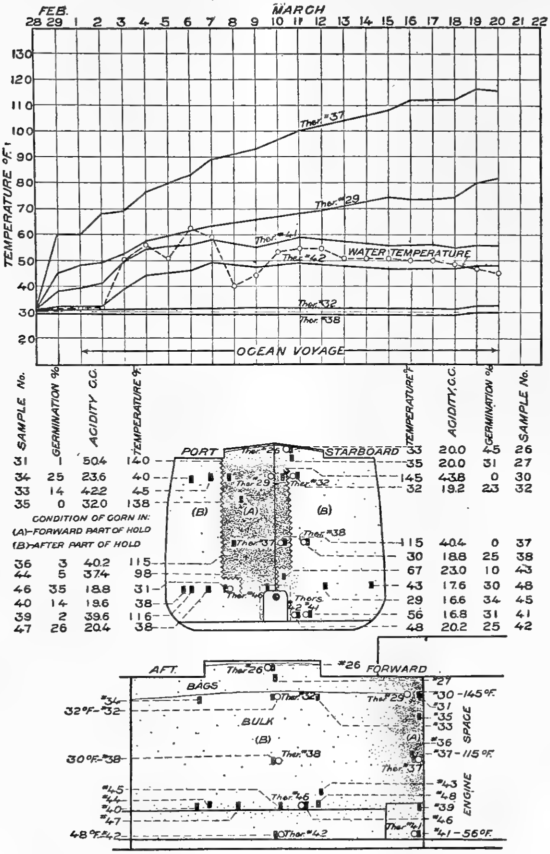

FIG. 59.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

of the engine-room bulkhead was not heating, but the tests showed that it had undergone more deterioration in every factor than the corn in the lower part of the hold but 12 feet back from the bulkhead. The effect of the engine-room heat on the corn located next to the shaft tunnel is described

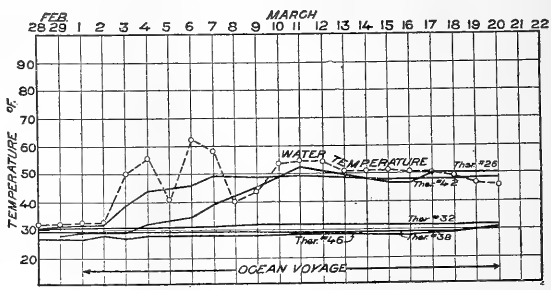

FIG. 60.—Temperature records of the corn located from the surface to the bottom of the corn near the center of hold 4. (Cargo No. 8.)

in the discussion of the condition of the corn in hold 5.

The corn in hold 5 underwent very little deterioration and was discharged in good condition, excepting that portion of the corn that was stowed next to the propeller-shaft tunnel, along the bottom part of the hold, which was in a sour, moldy, and heating condition. As is shown in figure 62, the corn located directly on top of the shaft tunnel began to increase in temperature as soon as the ship got in motion at the beginning of the voyage, and the temperature increased in a regular manner during the remainder of the voyage, while the temperature of the corn stowed the same height in the hold, but halfway between the shaft tunnel and the sides of the hold, remained practically stationary during the whole voyage.

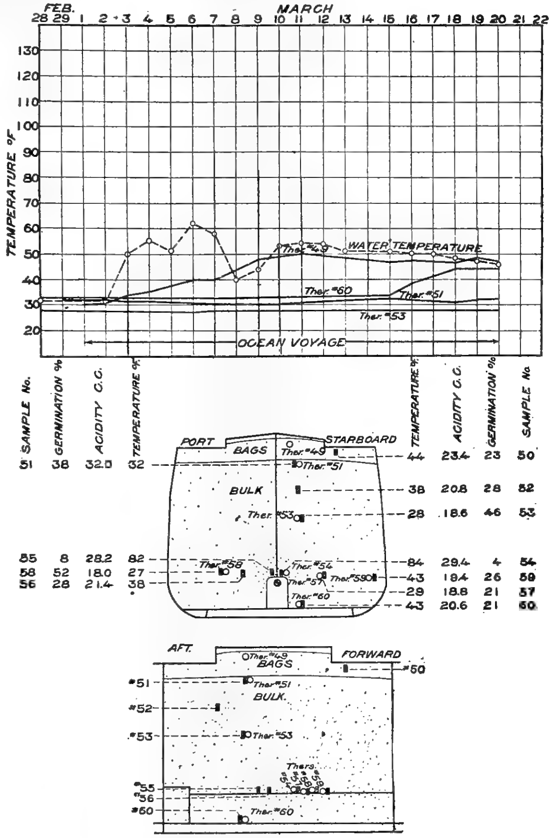

FIG. 61.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

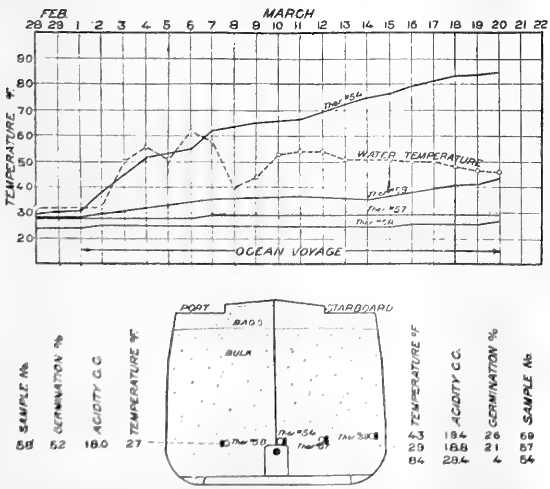

FIG. 62.—Hold 5: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 8.)

Table 40 shows that the corn located directly on top of the shaft tunnel increased 55° F. in temperature, 12.6 c. c. in acidity,

TABLE 40.—*Showing effect of the heat from the shaft tunnel on the corn in hold 5, cargo No. 8.*

Location of the corn.	Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
		° F.	° F.	° F.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	c. c.	c. c.	c. c.	Per ct.	Per ct.	Per ct.
On top of tunnel	54	29	84	+55	19.8	53.25	48.75	−4.50	50	4	−46	16.8	29.4	+12.6	86.6	58.1	−28.5
Tunnel height, half way out	57	28	29	+ 1	20.3	52.50	52.00	− .50	41	21	−20	16.6	18.8	+ 2.2	91.6	90.5	− 1.1
Tunnel height, half way out	58	24	27	+ 3	19.5	53.25	53.25	0	61	52	− 9	17.2	18.0	+ .8	87.4	87.0	− .4
Average tunnel height, half way out		26	28	+ 2	19.9	52.87	52.62	− .25	51	36	−15	16.9	18.4	+ 1.5	89.5	88.7	− .8

CHANGE DUE TO TUNNEL HEAT.

[In excess of change in corn located same height but 10 ft. away from tunnel.]

On tunnel				+53				−4.25			−31			+11.1			−27.7

[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.

and decreased 4.5 pounds in test weight per bushel, 46 per cent in germination and 28.5 per cent in sound kernels. This is in contrast with an average increase of only 2° F. in temperature and 1.5 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel,

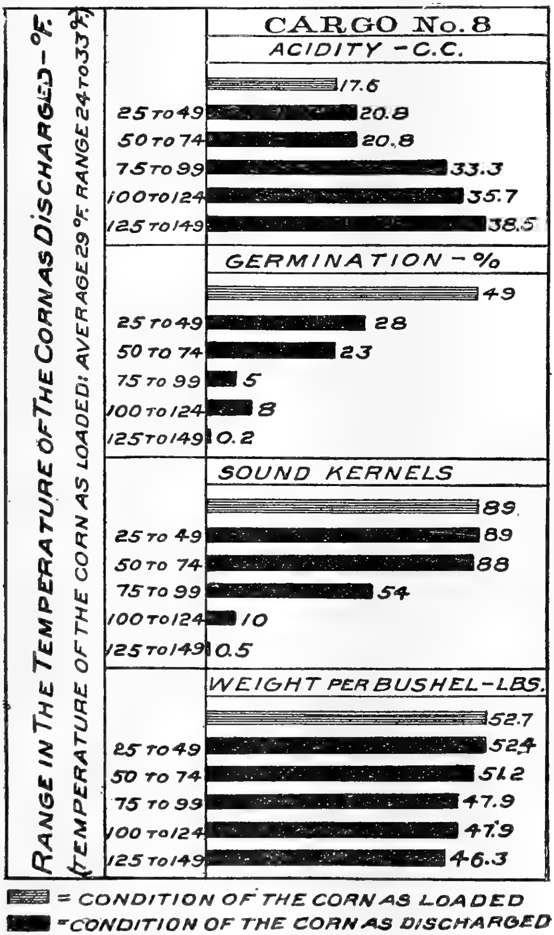

FIG. 63.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 8.)

15 per cent in germination, and 0.8 per cent in sound kernels for the corn located the same height in the hold but 10 feet distant from the shaft tunnel.

The correlation of the temperature changes and the changes in condition of the corn is illustrated in figure 63.

CARGO No. 9.

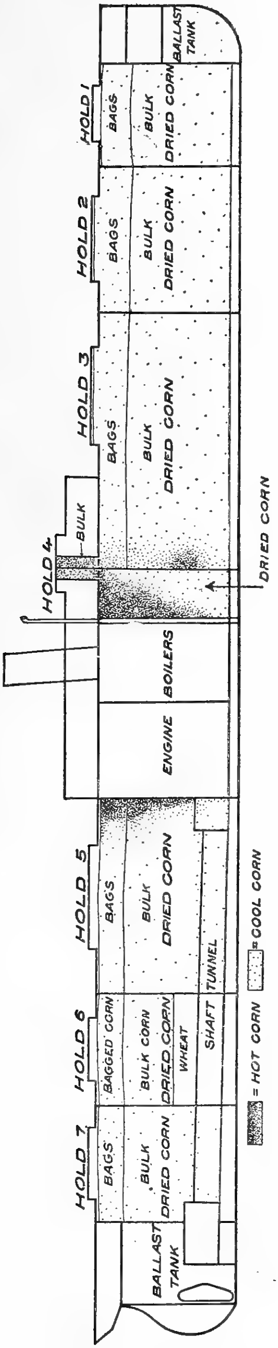

FIG. 64.—Diagram showing the arrangement of the steamship and the stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 9.)

Cargo No. 9 consisted of 268,682 bushels of artificially dried corn. The corn was loaded April 11 to 15, 1912. The steamship sailed April 16 and arrived at Liverpool, England, on May 2, where the corn was discharged from May 3 to May 10. The length of the ocean voyage was 17 days. The maximum time any of the corn was in the vessel was 30 days, and the average time was 24 days.

STOWAGE OF THE CORN.

The steamship had seven cargo holds and, as is shown in figure 64, each hold was entirely filled with corn. Hold 6 had 20,000 bushels of wheat stowed in the lower part of the hold, the upper portion of the hold being filled with corn. Hold 4 was located just forward of the boiler room and hold 5 was located just aft of the engine room. The propeller-shaft tunnel extended along the bottom of holds 5, 6, and 7.

CONDITION OF THE CORN AS LOADED.

All of the corn in this cargo had been artificially dried before loading. The condition of the corn as loaded is shown in Tables 41 and 42. The averages for the various factors of the corn as loaded were as follows: Moisture content 17 per cent, acidity 19.9 c. c., germination 37 per cent, sound kernels 91 per cent, test weight per bushel 53 pounds. The average temperature of the corn as loaded was 51° F. It will be noted from the tables and charts that although the average moisture content at the time of loading was relatively low, it still was not low enough to insure the carrying of the corn safely in all parts of the vessel. In this connection it will be recalled that this shipment was made during the spring months of April and May.

TABLE 41.—*Range in the principal factors showing quality and condition of the corn in cargo No. 9, as loaded and as discharged, by holds.*

Holds.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	43.0– 49.0	16.5–17.7	18.6–21.4	30.0–34.0	88.6–92.5	52.50–53.25
As discharged	44.0– 57.0		19.0–22.8	21.0–31.0	63.5–92.7	52.00–53.50
Hold 2:						
As loaded	49.0– 50.0	16.6–17.5	17.2–23.2	16.0–47.0	85.4–93.2	52.25–53.75
As discharged	49.0– 61.0		18.0–20.6	14.0–49.0	94.6–92.4	52.75–53.75
Hold 3:						
As loaded	47.0– 59.0	17.1–17.9	17.9–26.6	25.0–45.0	85.9–94.9	51.50–54.00
As discharged	46.0–122.0		19.8–40.0	0–38.0	40.0–93.7	47.00–54.25
Hold 4:						
As loaded	47.0– 62.0	16.0–17.4	17.0–22.4	16.0–45.0	89.1–94.7	52.00–53.50
As discharged	54.0–140.0		19.4–35.8	0–45.0	0–94.0	48.25–54.25
Hold 5:						
As loaded	48.0– 59.0	16.4–17.1	17.0–21.6	33.0–48.0	89.3–94.3	52.50–54.00
As discharged	48.0–121.0		17.0–32.8	0–44.0	4.3–93.2	49.25–54.00
Hold 6:						
As loaded	46.0– 59.0	16.8–17.0	20.4–21.4	35.0–43.0	87.1–89.2	52.00–54.00
As discharged	52.0– 56.0		20.2–26.8	10.0–43.0	70.6–89.6	50.00–54.25
Hold 7:						
As loaded	43.0– 55.0	16.9–17.7	17.4–21.2	24.0–43.0	90.7–93.2	53.50–54.50
As discharged	45.0– 61.0		19.6–26.0	29.0–45.0	90.8–93.6	53.25–54.25

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

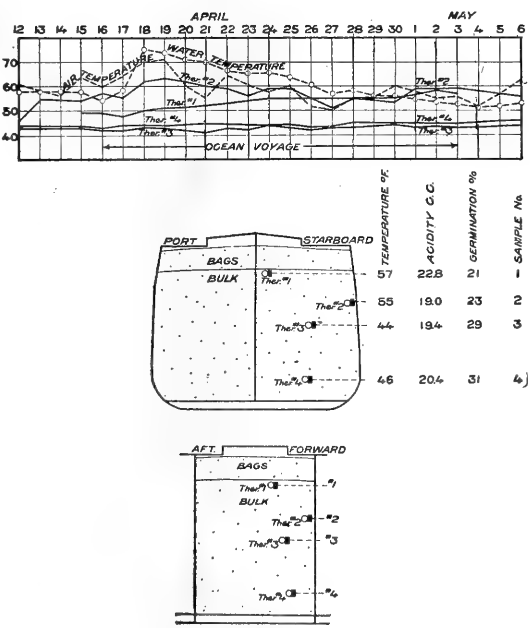

FIG. 65.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

During the voyage, the corn in this cargo became badly damaged next to the upper part of the bulkheads separating the corn from the boiler and engine rooms, also in the "feeder" at the upper parts of holds 3 and 4, and, to a small extent, in the after part of hold 3 and along the shaft tunnel in the bottom of holds 5, 6, and 7. The balance of the corn in the cargo was delivered in Europe in good condition. The maximum temperatures found in the corn as discharged were 57° F. in hold 1, 61° F. in hold 2, 122° F. in hold 3, 140° F. in hold 4, 121° F. in hold 5, 56° F. in hold 6, and 61° F. in hold 7. There were no facilities for making moisture tests for the samples secured at the port of discharge, and the moisture tests of the samples secured at the time of loading only are given for this cargo.

TABLE 42.—*Showing the condition of the dried corn in cargo No. 9 at the time of loading and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in cross-wire containers.]

Sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	° F.	° F.	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.
T 1	49	57	17.7	21.4	22.8	34	21	88.6	63.5	53.25	52.00
T 2	46	55	17.5	18.6	19.0	31	23	92.5	92.7	53.00	53.50
T 3	43	44	16.5	21.0	19.4	31	29	92.5	92.4	52.50	52.50
T 4	44	46	16.5	20.2	20.4	30	31	89.0	88.9	52.50	52.00
Hold 2:											
T 5	49	61	16.6	20.6	19.4	16	14	88.5	87.8	53.25	53.25
T 6	50	53	17.1	21.4	20.6	40	49	85.4	84.6	52.25	53.00
T 7	50	53	17.3	23.2	18.2	40	31	89.6	92.1	53.00	53.75
T 8	49	49	17.5	17.2	20.2	47	40	93.2	92.4	52.75	52.75
T 9	50	54	17.0	19.2	18.0	42	32	91.5	92.1	53.75	53.00
Hold 3:											
T 10	47	70	17.9	17.9	23.0	25	0	88.2	54.0	52.50	51.50
11		106			28.4		14		61.0		50.50
T 12	59	61	17.5	22.2	22.0	44	22	86.8	86.6	52.75	52.25
T 13	55	59	17.6	26.6	24.2	32	21	85.9	83.9	51.50	54.25
T 14	54	48	17.7	19.0	19.8	45	21	92.2	92.2	54.00	52.50
T 15	50	47	17.5	20.2	21.0	45	34	94.5	91.7	53.00	53.00
T 16	55	57	17.7	21.8	20.8	34	36	88.4	92.3	52.50	52.25
T 17[1]	50	50	17.1	21.8	31.0	38	38	92.1	69.1	52.50	49.00
18		122			40.0		3		40.0		47.00
19	50	46	17.2	19.6	21.8	33	28	94.9	93.7	53.00	53.50
Hold 4:											
T 20	48	135	17.0	19.0	33.6	34	0	89.1	15.7	53.00	50.25
T 21	47	139	17.0	19.0	28.4	45	0	92.1	0	52.25	49.50
22		102			27.2		2		36.8		49.25
23			17.0	18.6	30.2	41	2	92.0	44.9	53.50	
24		140			25.8		0		0		48.75
25		62			23.8		31		92.2		53.75
26		132			35.8		0		0		48.25
T 27	55	54	17.3	20.0	20.8	38	26	94.7	94.0	52.50	54.25
T 28	53	60	16.2	18.2	22.8	28	15	94.2	94.0	53.00	53.00
T 29	49	70	17.2	18.0	22.6	45	18	93.1	93.7	52.00	53.00
T 30	56	69	17.4	22.4	22.2	16	10	90.7	90.5	53.25	52.00
31		61			21.6		21		84.4		52.50
T 32	62	58	16.2	17.0	20.8	43	42	92.9	91.2	52.25	53.25
T 33	61	57	16.0	18.6	19.4	20	45	93.8	94.0	52.50	52.75
T 34	57	62	16.5	20.6	21.2	43	36	93.7	92.7	52.00	52.75
Hold 5:											
35		112	17.1	21.6	31.0	48	4	90.6	46.7	54.00	51.75
36		121			32.8		4		56.4		48.25
37		81			21.4		34		89.2		51.75
38		100			27.6		0		4.3		51.25
T 39	53	52	16.8	17.0	18.6	36	41	92.3	93.2	53.25	54.00
T 40	51	50	16.5	18.8	17.0	46	38	90.2	88.5	54.00	53.00
T 41	51	54	17.0	19.4	22.0	33	35	93.8	90.9	53.25	53.50
T 42	59	95	16.9	20.6	22.2	39	28	89.3	88.6	53.00	51.00
T 43	55	72	17.0	19.8	22.6	33	19	89.4	86.9	52.50	51.25
T 44	50	71	16.4	18.2	27.6	36	3	92.6	53.6	54.00	50.00
T 45	48	48	17.0	18.4	19.4	38	44	92.7	92.6	53.50	54.00
T 46	51	75	16.5	19.0	21.6	35	28	94.3	91.0	53.00	52.50
Hold 6:											
T 47	59	56	16.9	21.4	26.8	35	10	87.1	70.6	52.00	50.50
T 48	51	56	16.8	20.4	21.0	38	40	88.8	88.9	53.50	54.25
T 49	46	52	17.0	21.0	20.2	43	43	89.2	89.6	54.00	52.50
Hold 7:											
T 50	55	60	16.9	18.2	19.6	36	45	93.2	91.7	54.50	54.25
T 51	46	55	17.7	21.2	26.0	24	29	90.7	90.8	53.50	54.25
T 52	43	45	17.6	18.8	21.2	30	37	92.5	93.6	54.50	53.75
53	50		17.0	17.6		37		91.9		54.50	
T 54	48	61	16.9	17.4	23.6	43	27	92.0		54.00	53.25

[1] This sample was principally dirt and broken corn, evidently a representative sample of only a few bushels.

The corn in holds 1 and 2 showed practically no change during the voyage and was discharged in sound condition. The temperature records for the thermometers located in the various positions in these holds are illustrated in figures 65 and 66.

Hold 3 had one cargo hold between it and the boiler room, and, although the corn had been artificially dried before loading and there was no opportunity for the heat from the boiler to penetrate this hold, still some of the corn became hot and damaged during the voyage. It will be noted from Table 42 that some of the samples secured at the time of loading tested the highest in acidity (26.6 c. c.) of any samples in the cargo that were secured at that time, showing that at least some of the corn in this hold had undergone considerable deterioration before it was loaded into the hold and was in a dangerous condition for export, with an average moisture content

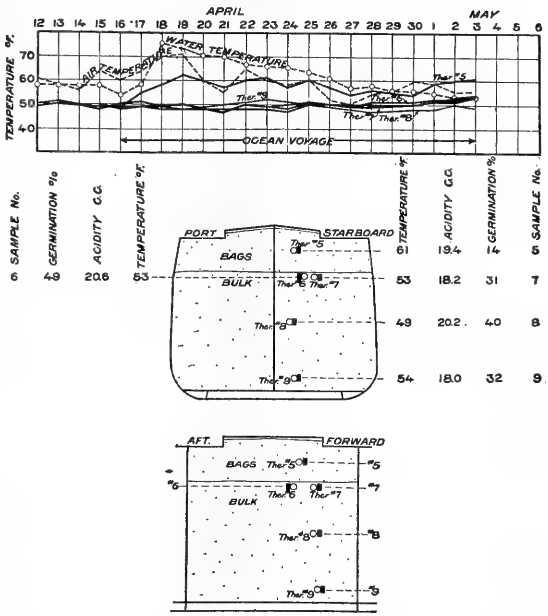

FIG. 66.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

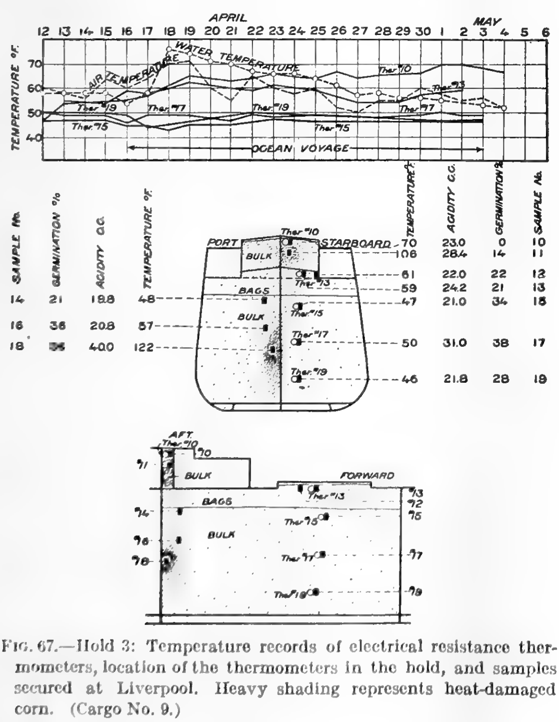

FIG. 67.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

of over 17 per cent when shipped during April and May. The damaged corn was found in the after part of the hold near the shifting boards about halfway down in the hold, also in the feeder which extended down one deck from the top of the corn under the hatchway. This is illustrated in figure 67.

Hold 4 was located just forward of the boiler room. The corn located next to the boiler-room bulkhead became badly heat damaged during the voyage, the greatest heat and the most severe damage being found at the surface of the corn. There were no thermometers located immediately against the boiler-room bulkhead, but thermometer 21, located even with the top of the boiler room halfway back in the hold registered a rapid increase in temperature from the beginning of the voyage. There was a small air space under the deck and above the corn, extending from the feeder in the forward part of the hold to the upper part of the boiler-room bulkhead, and, as soon as full steam was gotten up in the boilers at the beginning of the voyage, the heat generated in the boiler room penetrated the bulkhead and was transmitted to the corn, where fermentation was started and accelerated until the temperature of the corn at this position of stowage had increased from slightly under 50° F. at the beginning of the voyage on April 16, to over 140° F. April 29, an increase of over 90° F. in temperature in 13 days, as is shown in figure 68. The condition of the corn in the various positions of stowage in the hold as loaded and as discharged is given in Table 42.

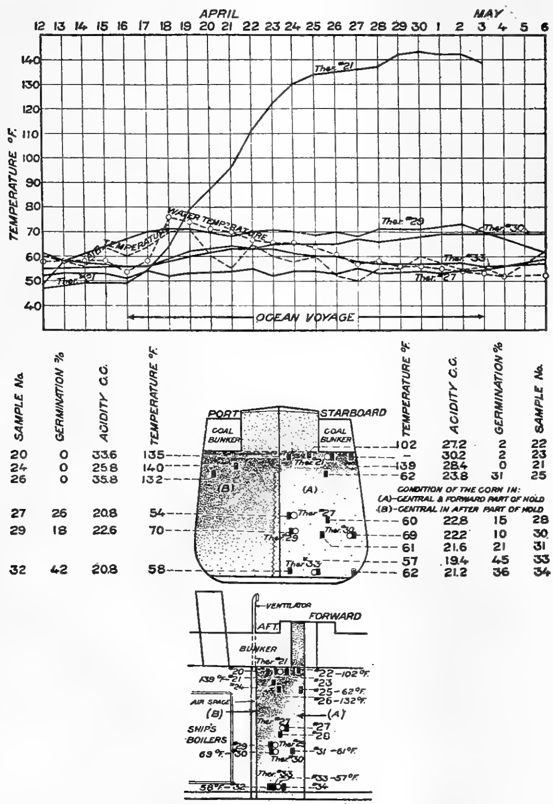

FIG. 68.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

Hold 5 was located just aft of the engine room. The corn located next to the engine-room bulkhead became hot and badly damaged during the voyage. As is usual, the greatest heat and the most severe damage were found next to the upper part of the engine-room bulkhead and less heat and less damage the further the distance back from this bulkhead, and also toward the bottom of the hold. The corn in the remainder of the hold, except that located next to the propeller shaft tunnel, changed very little and was discharged in good condition. The corn located next to the engine-room bulkhead, about 9 feet under the surface of the corn, at the time of discharge had a temperature of 121° F., tested 32 c. c. in acidity, 4 per cent in germination, and 49.25 pounds in test weight per bushel, while the corn located the same height in the hold but about 20 feet distant from the bulkhead, had a temperature of only 52° F., tested 18.6 c. c. in acidity, 41 per cent in germination, 93.2 per cent in sound kernels and 54 pounds test weight per bushel. This is shown by the analysis records for samples Nos. 36 and 39, in Table 42. It will be noted from this table that the corn which was in the center and after part of the hold was discharged in Europe in practically the same condition that it was in when it was loaded into the vessel. The location of the sound and damaged corn in this hold as discharged is illustrated in figure 69.

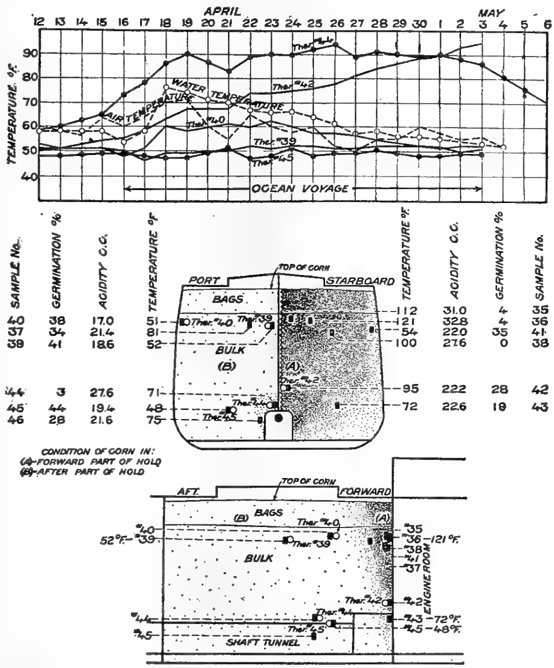

FIG. 69.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

The corn in holds 6 and 7, like that in holds 1 and 2, and in the middle of the after part of hold 5, was discharged in Europe in practically the same condition that it was in at the time of loading into the vessel, except that a small amount of the corn located along the shaft tunnel in the bottom of the three after holds was somewhat musty and sour. The temperature records for the corn in the various

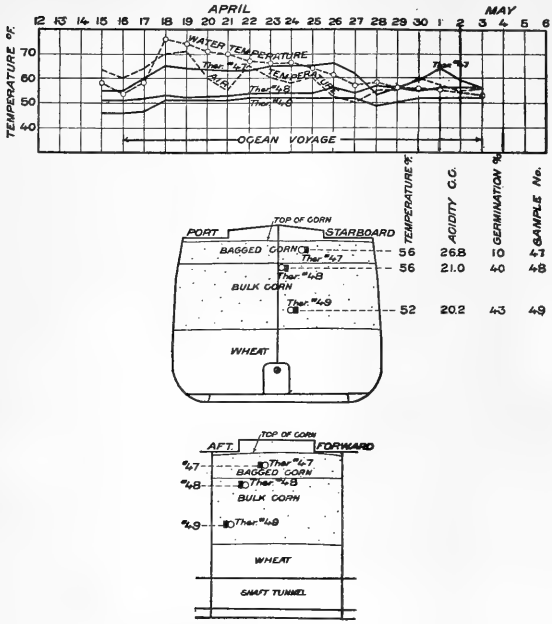

FIG. 70.—Hold 6: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

positions of stowage in holds 6 and 7 are illustrated in figures 70 and 71.

The correlation of the temperature changes and the changes in the condition of the corn is illustrated in figure 72.

SUMMARY.

The results of these investigations may be summarized in very few words:

(1) If the corn was dry and in a sound condition when shipped, it arrived in Europe in a like sound condition, regardless of the position in which it was stowed, the time of year in which it was shipped, or the length of the ocean voyage.

(2) But the higher the percentage of moisture in the corn when shipped, the greater was the danger of spoilage during the voyage.

(3) Various contributing causes worked with the moisture in causing spoilage. A combination of two or more contributing causes resulted in much greater spoilage than one contributing cause alone.

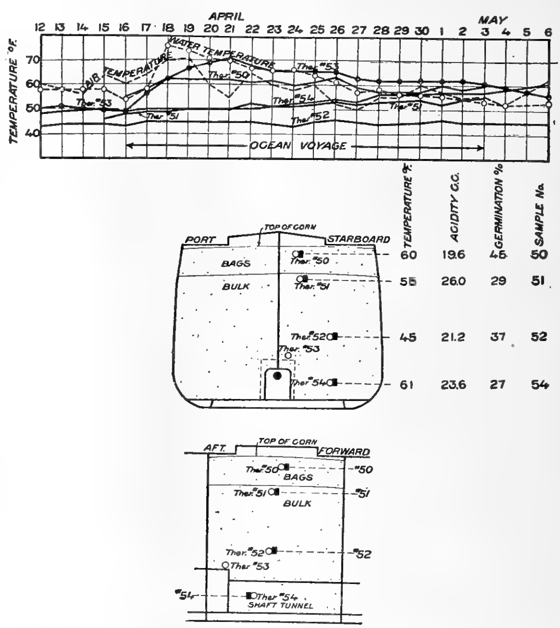

FIG. 71.—Hold 7: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

These conclusions may be verified by a study of Table 43, which is practically a summary of the entire investigation.

It may reasonably be expected, in other export shipments, if the quality and condition of the corn and the shipping conditions are similar to those found in the nine cargoes described, that the quality and condition of the corn on arrival at European ports will be the same as in those cargoes.

As the qualy, condition, and temperature of corn to be exported can be determined before it is delivered on board the vessel, and as the season the year during which shipment is to be made, the place of stowage, and the probable length of voyage are known or can be ascertained, an estimate of the condition of the corn on arrival can be made in advance.

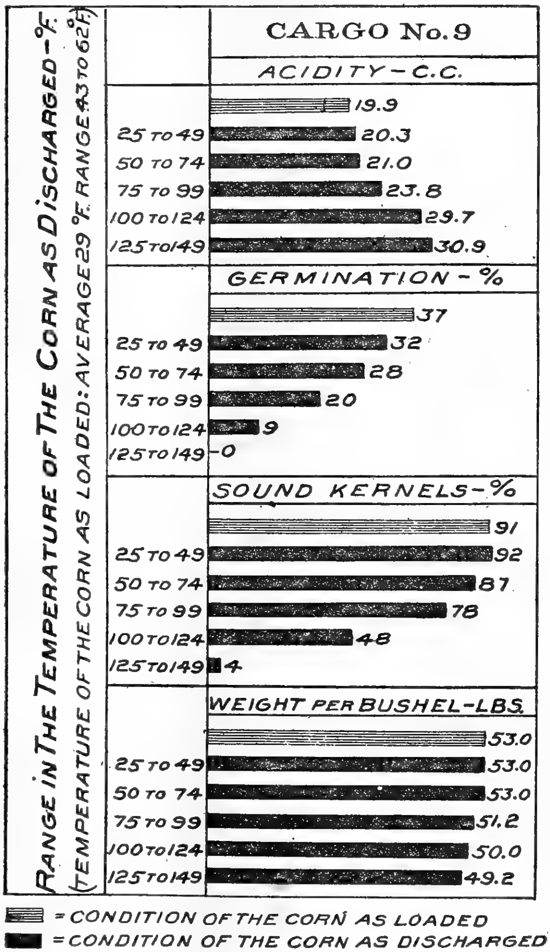

FIG. 72.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 9.)

Table 43.—*Summary of the nine cargoes of corn exported to Europe, showing the average condition of the corn as loaded, by holds, stowage of the corn in the vessel, season of the year in which exported, length of the ocean voyage, average length of time that the corn was in the vessel, and condition of the corn as discharged.*

[Tun.=shaft tunnel; ER=engine room; ERBH=engine-room bulkhead; BR=boiler room; BRBH=boiler-room bulkhead.]

Cargo.	Date of sailing.	Length of ocean voyage.	Average time of corn in vessel.	Average temperature of corn as loaded.	Average moisture content of corn as loaded.	Average acidity of corn as loaded.	Stowage of the corn. Hold No.	Stowage of the corn. Free from or adjacent to the ship's heat.	Stowage of the corn. Location in the hold.	Corn reached 100° F. after sailing.	Condition of the corn as discharged. Maximum temperature as discharged.	Condition of the corn as discharged. Cool or heat damaged as discharged.	Condition of the corn as discharged. Location of the heat-damaged corn.
		Days.	Days.	° F.	P. ct.	c. c.				Days.	° F.		
Cargo No. 1	Mar. 8	24	34	56	18.6	25.2	1	Free	Four-fifths full	11	143	Damaged	Top, one-third of corn.
	...do	24	34	55	18.9	26.8	2	do	Full	(1)	140	do	Top, one-half of corn.
	...do	24	34	55	18.6	27.2	3	do	do	15	136	do	Do.
	...do	24	34	59	14.7	25.8	3	do	Middle		94	Cool	
	...do	24	34	59	18.8	28.0	4	do	Top, one-fourth	10	148	Damaged	Total damaged.
	...do	24	34	62	14.9	22.5	4	do	do		80	Cool	
	...do	24	34	64	16.3	27.5	4	Next ER	Full	7	144	Damaged	Next ERBH and throughout hold.
Cargo No. 2.	Mar. 3	40	47	53	18.6	18.7	1	Free	Four-fifths full	35	110	do	Top, one-fourth of corn.
	...do	40	47	56	18.6	19.4	2	do	Full	11	148	do	Top, three-fourths of corn.
	...do	[2] 33	39	70	15.5	21.9	3	Next BR	do	13	155	do	Top, four-fifths and on ERBH.
	...do	40	47	56	18.9	20.0	4	Next ER and Tun.	do	19	135	do	Top, one-third on ERBH and Tun.
	...do	40	47	54	18.7	20.0	5	Tunnel	Four-fifths full	22	140	do	Top, one-fourth and on tunnel.
Cargo No. 3	Dec. 24	14	21	32	18.7	14.0	1	Free	Bottom, one-third.		37	Cool	
	...do	14	21	31	18.6	16.0	2	do	Bottom, one-half		39	do	
	...do	14	21	31	18.8	16.3	3	Next bunker	Full		48	do	
	...do	14	21	35	19.6	17.5	4	Next ER and Tun.	Bottom, one-third.	(1)	132	Damaged	Along the starboard tunnel containing the steam pipes.
	...do	14	21	31	19.9	17.9	5	Tunnels (2)	do	(1)	119	do	Do.
	...do	14	21	30	18.8	16.3	6	do	do	(1)	132	do	Do.
Cargo No. 4.	Feb. 22	14	20	36	19.5	20.5	1	Free	do		49	Cool	
	...do	14	20	34	19.6	20.8	2	do	Bottom, one-half		44	do	
	...do	14	20	36	19.5	20.7	3	Next bunker	Full	(1)	118	Damaged	Opposite steam pipe along hatch.
	...do	14	20	40	20.0	20.8	4	Next ER and Tun.	Bottom, one-half		79	Cool	
	...do	14	20	37	18.9	22.2	5	Tunnel	Three-fourths full		65	do	
	...do	14	20	38	18.9	20.0	6	do	Bottom one-half		60	do	

Cargo No. 5.	Apr. 25	18	31	38	19.6	25.8	1	Free	Full	(1)	138	Damaged	Top one-third of corn.
	...do...	18	31	38	19.0	24.8	2	...do	...do	(1)	142	...do	Top, one-half of corn.
	...do...	18	31	38	19.3	25.4	3	Next BR	...do	(1)	140	...do	Top, two-thirds of corn and BRBH.
	...do...	18	31	38	18.7	23.4	4	Next ER and Tun	...do	(1)	140	...do	Top, one-third of corn and on BRBH.
	...do...	18	31	38	19.8	24.1	5	Tunnel	...do	(1)	138	...do	Top, one-third of corn.
Cargo No. 6.	Mar. 28	20	27	44	20.2	23.4	1	Free	...do		53	Cool	
	...do...	20	27	43	19.9	24.2	2	...do	...do	(1)	140	Damaged	Top layer.
	...do...	20	27	39	20.3	23.6	3	Next BR	...do	11	140	...do	Next BRBH and top layer.
	...do...	20	27	51	15.7	27.0	4	Next BR and Tun	...do		85	Cool	
	...do...	20	27	41	20.3	25.2	5	Tunnel	...do	(1)	120	Damaged	Top layer and along Tun.
Cargo No. 7.	Mar. 31	21	39	64	17.8	27.4	2	Free	...do	3	146	...do	Upper, one-half corn.
	...do...	21	39	63	18.4	22.3	3	Next bunker	...do	8	141	...do	Do.
	...do...	21	39	64	18.7	24.1	5	Next ERBH and Tun.	Bottom, one-half	5	147	...do	Upper, one-half and along Tun.
	...do...	21	39	62	18.7	22.4	6	Tunnel	Bottom, one-third.	16	122	...do	Upper, one-third and along Tun.
Cargo No. 8.	Mar. 1	19	21	30	20.1	18.0	1	Free	Full		46	Cool	
	...do...	19	21	30	20.1	17.7	2	...do	...do		52	...do	
	...do...	19	21	30	20.2	18.3	3	Next BR	...do	15	132	Damaged	Along BRBH only.
	...do...	19	21	30	20.0	17.5	4	Next ER and Tun	...do	11	145	...do	Along ERBH and Tun.
	...do...	19	21	29	20.1	17.0	5	Tunnel	...do		84	Cool	Out of condition along tunnel.
Cargo No. 9.	Apr. 16	17	24	46	17.0	20.3	1	Free	...do		55	...do	
	...do...	17	24	50	17.1	20.3	2	...do	...do		54	...do	
	...do...	17.	24	52	17.5	21.2	3	...do	...do	(1)	106	Damaged	Surface next to coal bunker
	...do...	17	24	53	16.8	19.1	4	Next bunker	...do	6	143	...do	Next BRBH and top layer.
	...do...	17	24	52	16.8	19.2	5	Next ER and Tun	...do	(1)	122	...do	Along ERBH and tunnel.
	...do...	17	24	50	16.9	20.9	6	Tunnel	...do		61	Cool	
	...do...	17	24	48	17.2	18.6	7	...do	...do		61	...do	

[1] No data. [2] This cargo was discharged at two ports in Denmark and the corn in this hold was discharged at the first port.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 765

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ April 18, 1919

STRAINS OF WHITE BURLEY TOBACCO RESISTANT TO ROOT-ROT.

By JAMES JOHNSON, *Agent*, and R. H. MILTON, *Assistant, Office of Tobacco Investigations.*

CONTENTS.

RELATION OF ROOT-ROT TO THE CROPPING SYSTEM IN PRACTICAL TOBACCO CULTURE.

In the systems of tobacco culture prevailing in the United States there are two outstanding extremes in the management of the land. In one case tobacco is grown on the same soil year after year for indefinite periods, while in the other there is a rotation of crops in which only one or two crops of tobacco are grown on the land in a period of 8 to 10 years. The continuous-culture system is characteristic of the cigar-tobacco section of New England and to a considerable extent of Wisconsin and Ohio, while on the tobacco lands of Pennsylvania the systematic rotation of crops is the rule. In the southern tobacco-growing sections generally there is considerable variation in farm practice in this particular, but in most districts it is seldom that the system of continuous tobacco culture is attempted. The practice of growing only one or two crops of tobacco on the land and then allowing a period of 6 to 10 years to elapse before cropping to tobacco again is especially characteristic of the Burley section of Kentucky and the adjoining States.

These radically different practices have not developed without good reason on the part of the growers, and the cause is a matter which will be briefly considered at this time. In the Connecticut Valley tobacco growers have less area to exploit, and although the land is not naturally fertile heavy applications of commercial fertilizers are used with profit. Under the conditions there experience has shown that it is possible to grow tobacco commercially with more or less success by the continuous-culture system. In the Burley district there is as a rule no dearth of tobacco land and the soil is naturally quite fertile, so that practically no commercial fertilizers are used. Here experience has shown that tobacco can not be successfully grown on the same soil for more than two years in succession, although other crops following tobacco will grow very satisfactorily. Briefly, the accepted explanation for half a century has been that tobacco is very hard on the soil, in that it removes great quantities of plant food, and some growers have thought that the supply of certain kinds of this food which are essential for tobacco but not for other crops becomes exhausted, at least temporarily. In Connecticut, then, enormous applications of fertilizer have been resorted to in order to maintain production, while in the Burley district the soil which has grown tobacco for one or two years is given a 5 to 10 year "rest," usually in sod, to remedy the condition of "exhaustion."

The purpose of this bulletin is to show the incorrectness of the commonly accepted explanations, especially as applied to the Burley section. The cigar-tobacco sections have made equally incorrect interpretations of the special requirements of the tobacco crop, and the attempt has been made to maintain production by heavy applications of fertilizer rather than by crop rotation. Owing to the variety of tobacco grown, it will be shown that the Burley grower is at once forced to change his land, whereas, on the other hand, the cigar-tobacco grower, using other varieties, has been able to keep up continuous cropping with considerable success. It is now known that there is a root disease which has been an important factor in determining cropping methods used in tobacco culture.

DESCRIPTION OF ROOT-ROT.

In some sections many tobacco growers have become more or less acquainted with the disease of tobacco known as root-rot and realize its importance as related to crop production. Unfortunately, however, a great many growers are entirely unaware of the occurrence of the disease, even though it be the cause of a total failure of the tobacco crop on their soils. The primary reason for this is at once evident. Though growers as a rule are very keen in observing small diseased areas on the stems and leaves of plants, they rarely examine with care the roots, which are hidden in the soil. Many growers gain their first acquaintance with the root-rot while pulling plants from the seed beds. In some districts most tobacco growers, perhaps, have noticed in certain years or on some plants roots which are not only small in size and number but which are decayed and brown or black, instead of having normally abundant roots of pure-white color. No great attention is given to this, since it is known that such plants when set in the field send out new roots and may appear to start out almost as well as healthy plants. Nevertheless, this condition is frequently the source of future difficulties. The plants may or may not recover from this trouble, depending on a number of environmental factors. Fortunately, plants so affected often do not make a sufficiently vigorous growth in the beds to permit transplanting; hence they save some discouragement later. In passing, then, it may be said that the root disease is one of the common causes of plants turning yellow and failing to grow properly in the beds.

It has been found that the amount of damage done by the root disease is largely dependent upon the temperature of the soil, which is, of course, controlled largely by the temperature of the air. Low temperatures (60° to 75° F.) favor root-rot, while high soil temperatures (80° to 100° F.) practically prevent the disease from developing. Therefore, if the season is relatively warm, diseased plants may partially or wholly recover. However, all growing seasons have periods, sometimes extending over most of the season, when the weather is cool. Recovery then does not occur or is very slow. The plants refuse to grow, or make little headway as compared with neighboring fields on ground free from disease, and the crop prospects are much reduced. Frequently, however, after long cool periods a week or two of very warm weather starts the crop into a very rapid growth if sufficient moisture is present or if plenty of rainfall occurs.

A common occurrence, even in the Burley district, where a rotation system is practiced, is the transplanting of healthy (or diseased) plants into soils which already harbor the root trouble. These soils we will hereafter call "sick" soils. The result so far as crop production is concerned will depend largely on seasonal conditions, especially as to soil temperature, as previously described. A crop may or may not be produced. The situation as a whole, however, is much more serious, since this is by far the most common way in which the disease starts, and all the plants become involved. For all practical purposes it is safe to say that in the Burley district substantially all fields which have grown two or more crops of tobacco (and often those growing only one crop) are more or less "tobacco sick." This disease does not attack grains, corn, or hemp, and, in fact, affects no other agricultural crop except certain legumes, these sick tobacco soils being capable of growing such crops in a satisfactory manner so far as root-rot is concerned.

The symptom of this disease is, then, a decay of the root system, resulting in a stunting of the plants, roughly proportional to the extent of the decay in the roots. The effect of the disease on the root system and the growth of the plant is shown in figure 1. Very frequently the plants make no growth during the season, on account of this disease. Curiously enough, root-rot rarely kills the plants in the field. Aside from becoming stunted and yellow, they may show wilt-

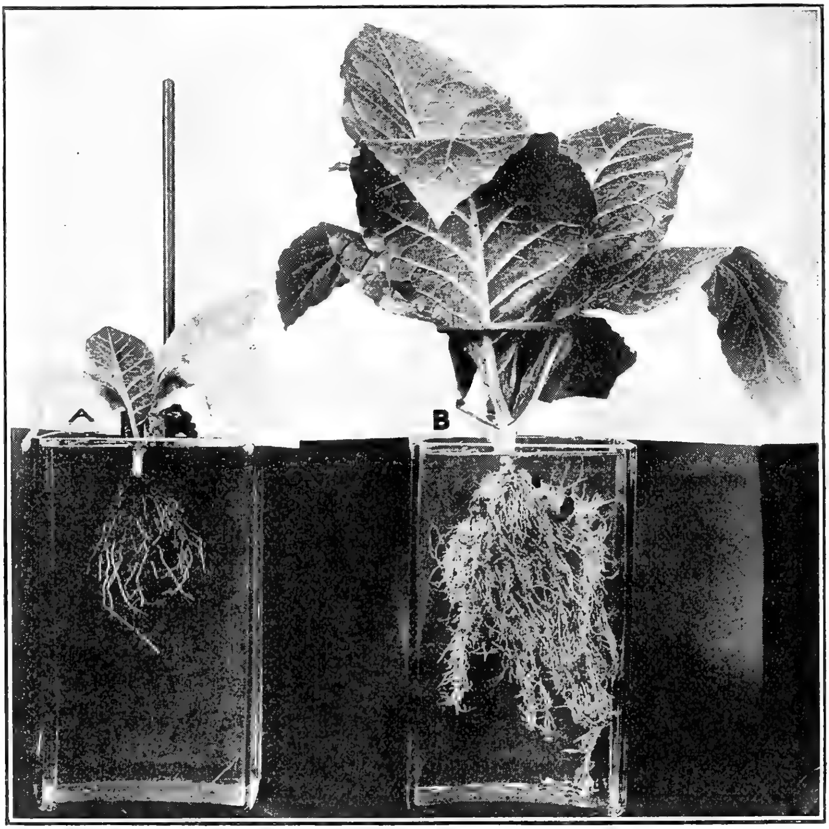

FIG. 1.—Plants of Burley tobacco grown on "tobacco-sick" soil (*A*) and in soil free from disease (*B*), showing the relative number of roots. These plants were grown under identical conditions, except that the soil in which plant *B* was grown was sterilized, so as to kill the parasites causing the disease.

ing, even in very moist soils, on days when tobacco in healthy soil and other crops show no wilting. The depleted root system is not able to take up water as fast as the leaves lose it, causing temporary wilting. It is not, however, a typical wilt disease, since the leaves do not remain wilted. Crops with root-rot suffer from "drought," therefore, very much more quickly than healthy crops.

The importance of this disease is shown by the fact that careful observations over a considerable part of the tobacco-growing sections of the United States in recent years have shown that the damage annually runs into millions of dollars. The loss in Kentucky alone must easily exceed on the average $2,000,000 yearly.

CAUSE OF THE DISEASE.

The root-rot is caused by a fungus which lives as a parasite on the roots of the plant. This organism, or germ, although so small that it can not be seen except with a high-power miscroscope, is still a very large organism as compared with other parasites which produce well-known diseases in plants and animals. This organism is called *Thielavia basicola*, and technically this disease should be called the Thielavia root-rot, since there are many other organisms which cause root diseases in other plants. This fungus can grow into the roots of the tobacco plant and feed on its tissues, which results in their decay. Moreover, it can live on dead organic material in the soil, though not as readily, and in the absence of the tobacco plant from the soil it gradually dies out, though this may require from 5 to 10 years or more. The exact time has not yet been determined, but it probably varies somewhat with different types of soil. The disease spreads very much in the same way as other diseases of plants and animals. It is sometimes very difficult to account for the first infection by the fungus. The most common means of spreading it is through the transference of sick soil, either by wind, water, or animals, to healthy soil or by the transplanting of diseased plants from infested seed beds.

With this description of the nature and cause of the disease, the skeptical grower has still the right to ask for proof that the root-rot is doing the amount of damage claimed and that it, and not depletion of soil fertility, is the reason why tobacco soils in the Burley section require several years of "rest" after having grown one, two, or three crops of tobacco. There exists, fortunately, a convenient and convincing proof of this fact. This lies in varietal differences in resistance and susceptibility to the disease.

VARIETAL RESISTANCE AND SUSCEPTIBILITY.

It is now a well-established fact that plants as well as animals differ in their degree of susceptibility to disease. This is now known to hold true for the tobacco plant as regards the Thielavia root-rot.

If two varieties of tobacco, Connecticut Havana and White Burley, for instance, are planted side by side on ground which has just grown two or three crops of Burley, the Havana seed in most instances will produce at the end of the season from two to a hundred times as much weight as the Burley. If, however, these two varieties are planted on ground on which tobacco has not been grown for several years and which is not "tobacco sick," the Burley tobacco will produce as great or a greater weight, plant for plant or acre for acre, than the Connecticut Havana. If we pull up and examine the roots of plants of both varieties grown on healthy ground, they are found to be large and white. On sick soil, however, a Burley plant will usually have only relatively few stubby black roots, as compared with the Havana tobacco, although the latter variety also may show some signs of the disease. The difference in yields between two varieties can be made even more striking, since we have varieties two and three times as resistant as the Connecticut Havana. No variety more susceptible than the ordinary White Burley strains grown in the Burley section has been found. Such a test can be made easily on any soil, and in connection with this study it has been repeated a great many times, with the expected results in nearly every instance. Where the expectations were not realized there has been good reason for suspecting disturbing factors other than the Thielavia root-rot.

The behavior of resistant and susceptible varieties on sick soils is regarded as positive proof of the extent of the injury attributed to the root-rot. It can be satisfactorily explained in no other way. The accumulation of data upon the subject over a period of five years in Wisconsin, Connecticut, Kentucky, and in Canada, together with field surveys in other States, has left no doubt of the widespread occurrence and economic importance of the disease.

With the marked differences in resistance to the root-rot manifested by different varieties of tobacco clearly in mind, it will be readily seen that these differences satisfactorily account for the marked contrast in methods of handling tobacco lands in some of the northern cigar-tobacco districts and in the Burley district. The extreme susceptibility of the Burley variety permits of no other system than a short cropping period for tobacco and a long "rest" for the land. In the northern cigar-tobacco districts tobacco culture has involved a struggle between old sick soils and the resistance of the varieties grown. The influence of this struggle upon agricultural practice has been threefold. First, the growers have applied enormous quantities of fertilizers, hoping thereby to remedy the worn-out condition of the soils, which has resulted in more or less wastage of fertility, since sick soils can not be benefited appreciably by fertilizers except under special conditions (by the use of resistant types, through prevailing high soil temperatures, etc.). In the second place, resistant strains apparently have been unknowingly selected and developed on account of their adaptability to these soils. In the third place, the disease in many instances has made such progress that growers have been compelled to change to new soils frequently, and in some northern districts tobacco has been given a definite and permanent place in rotation with other farm crops.

DEVELOPMENT OF BURLEY STRAINS RESISTANT TO ROOT-ROT.

Although a high measure of control of the root-rot in the Burley section is attained by the system of rotation in use it is evident that, on account of the extreme susceptibility of the Burley variety, considerable disease occurs annually. The susceptibility of this variety not only prevents continued culture when desired, but also makes the growing of second and third crops on the soil quite a game of chance. A type of Burley as resistant as some of the cigar varieties and still possessing the yield and quality of the ordinary Burley strains therefore would be extremely valuable in reducing the annual loss from disease. Two possible means of producing such a type are selection for disease resistance among commercial varieties now grown and crossing resistant green types, such as some of the cigar tobaccos, with White Burley, for the purpose of adding disease resistance to the White Burley characteristics. The first method, that is, selection for resistant strains in diseased fields, has been resorted to in obtaining the results presented here. All tobacco growers have seen fields in which the crop has made a very uneven growth, though all the plants apparently had an equal chance to start and develop. It sometimes happens that these fields behave in this manner because of the presence of the root-rot and the use of impure seed. Those plants which grow rapidly and stand out distinctly from their neighbors may be resistant to the disease. A large number of these have been selected and the seeds saved from the individual plants and grown in separate rows on sick soils the following year. A few of these selections have shown very distinct resistance when compared with ordinary Burley, and these strains propagated and tested over a period of several years under many varied conditions have continued to maintain their original degree of resistance. In some cases these strains have been tested on a rather large scale on both healthy and sick soils for the purpose of comparing the quality of the cured leaf produced with that of the ordinary White Burley. The results on the whole have been very encouraging, although the ideal in mind has not yet been reached. The resistant strains thus far produced and given commercial trial are all of the drooping-leaf type and not stand-up Burleys, which many growers prefer. Encouraging results have now been secured in developing resistance in the stand-up types also, and it is expected that these strains will soon be ready for testing commercially.

A more important feature, however, is the quality of the resistant Burleys obtained, as compared with the best strains of ordinary

Burley. Quality in Burley tobacco is largely a matter of the color and texture of the cured product. Several trials have shown that the resistant type is practically equal to the ordinary Burley varieties in these respects. The final criterion must be the relative prices brought on the warehouse floor. In this, the resistant Burley has so far shown itself to be equally as valuable as the ordinary Burleys. In the field, however, it seems that the top leaves do not color up as rapidly or as brightly as some of the best strains of ordinary Burley. The importance of this from a commercial standpoint is seemingly not great, although it is true that it may result in somewhat more "red leaf." The fact that the resistant Burley makes a more vigorous growth on partially sick soils, however, will generally result in a greater proportion of the higher priced grades, which, together with a larger total yield, may fully offset any disadvantage of slightly reduced color. Briefly stated, some of the best strains of the ordinary Burley may produce better quality on healthy soil, but on sick soil the resistant Burley will usually prove better in both yield and quality.

The results attained up to the present time warrant the recommendation of the resistant type for growing on all sick soils in the Burley section on which it is to be expected that the ordinary varieties of White Burley will give unsatisfactory yields. It is hoped that in the near future the resistant character will be introduced into the best strains of ordinary Burley, so that they may be grown successfully on diseased as well as on healthy soils.

EXPERIMENTS IN THE WHITE BURLEY DISTRICT OF KENTUCKY.

The resistant Burley strains have been tested on several farms in the Burley section of Kentucky during the past three years. These demonstrations have been made on the farms of Mr. E. F. Shropshire, Lexington; Dr. S. H. Halley, Paynes Depot; Mr. William Feck, Lexington; Mr. N. H. Witherspoon, Winchester; and Mr. J. Waller Rodes, Lexington. Several others also have grown some of the strains on trial. The progress of the work from the standpoint of the demonstration of disease resistance has been hampered somewhat by the difficulty of finding growers who were willing to put in third or fourth crops in succession on the same soil, since it was felt that a crop failure with Burley would be almost certain to follow. Such soils, however, have been obtained in a few instances. On the farm of Mr. E. F. Shropshire, Maysville Pike, Lexington, a plat which had already grown three crops of Burley was secured in 1916. Resistant and ordinary Burleys have been planted on this land for the last three years. The results each season have been striking. The ordinary Burleys have made practically no growth, while the resistant strains have made on the average a normal growth each year. This land, therefore, has been made to produce six crops in succession by the use of the resistant Burley variety. The comparative

FIG. 2.—Resistant White Burley and ordinary White Burley strains of tobacco grown on "sick" soil in alternate rows. The rows of ordinary Burley have made almost no growth since transplanting. Farm of E. F. Shropshire, Lexington, Ky., 1916.

growth of these resistant strains and the ordinary types of Burley is shown in figures 2 and 3. In northern tobacco districts, where old tobacco soils are more easily obtainable for such tests, fair crops of

FIG. 3.—Resistant White Burley and ordinary White Burley strains of tobacco grown on "sick" soil on the farm of E. F. Shropshire, Lexington, Ky., in 1917, showing the relative growth early in the season.

resistant Burley have been grown after 12 successive crops of tobacco. Results similar to those secured at the Shropshire farm have been obtained at several other places, indicating the general occurrence of sick land and the adaptability of resistant Burley to it. The behavior of the resistant strains as compared with the ordinary Burleys on the farm of Mr. William Feck is shown in figure 4. It does not follow, nor is it recommended, that continuous culture of Burley tobacco should be practiced in the Burley section. On small farms or where suitable soil is scarce it may be highly desirable to grow tobacco on the same land more frequently than hitherto has been possible. The important point, however, is that the number of tobacco crops which may be grown on a given piece of land usually is not sharply limited by lack of fertility, but rather by disease. The value of resistant strains, therefore, lies in reducing the chances of poor yields in second or third crops on soils gradually becoming sick.

FIG. 4.—Resistant White Burley tobacco (on the right) and ordinary White Burley strains (on the left) growing on the farm of William Feck, Lexington, Ky., in 1917. The tobacco was about half grown when the photograph was taken.

With respect to the quality of the resistant Burley, considerable evidence is at hand to show that so far as market value is concerned it has not proved to be inferior to the ordinary strains. Some of the growers who tried this seed in 1917 on a small scale planted as many as 10 or 15 acres in 1918. The final reports as to the quality of the 1918 crop are not yet obtainable, but there is no reason to believe that its average value will be less than that of ordinary Burley, i. e., the Kelly, Halley, Big Stand-up, and other strains.

RESISTANT BURLEY STRAINS RECOMMENDED FOR SICK SOILS IN WHITE BURLEY DISTRICTS.

Until stand-up Burleys of unquestionable perfection in quality are obtained it is believed that growers can very profitably plant the resistant drooping-leaved variety of Burley where it is desired to utilize sick soils. It is recommended that those who are putting in second or third crops of Burley or have reason to suspect that the root-rot is present try some of the resistant Burley seed. The grower will thus have an opportunity to determine to his own satisfaction the cause of tobacco-sick soil and at the same time to compare the type and quality of the resistant Burley with that of the ordinary strains. For a proper test it is necessary, of course, that some ordinary Burley be grown on the diseased soil alongside of the resistant strains and handled in the same way in all respects, for otherwise there will be no accurate basis for comparison. Two or three strains of the resistant Burley seed are available for distribution, and although one strain may be slightly better than another, few or no data on this point have yet been obtained. Where the land has had a long rest from tobacco the resistant type is not recommended, for it will not show any improvement over ordinary Burley on healthy soil. The value of these new strains lies in their resistance to root-rot; hence, there would be no purpose in growing them on land free from this disease except in so far as they reduce the injury from root-rot due to the transplanting of diseased plants from infested seed beds.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 766

Contribution from the Bureau of Entomology

L. O. Howard, Chief

Washington, D. C. PROFESSIONAL PAPER July 10, 1919

A STUDY OF COMPSILURA CONCINNATA, AN IMPORTED TACHINID PARASITE OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

By Julian J. Culver,[1]

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CONTENTS.

INTRODUCTION.

Compsilura concinnata Meigen (Pl. I, fig. 1), one of the imported tachinid parasites of the gipsy moth and the brown-tail moth, was introduced into Massachusetts first in 1906, at which time these moths were so abundant and destructive, particularly in eastern Massachu-

[1] The writer wishes to express his appreciation of the help given by the various assistants at the Gipsy Moth Laboratory as well as by the field men, both at the laboratory and in collecting host material; to Mr. A. F. Burgess and Dr. John N. Summers for their helpful suggestions and advice; to Mr. R. T. Webber for furnishing rearing records, the bulk of the native host list being the results of his experiments; to Mr. C. F. Muesebeck for assisting in the dissections and drawings of some of the figures in this bulletin; and to Mr. A. M. Wilcox, who furnished large quantities of parasite-free host material for use in the reproduction experiments on Compsilura.

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setts, that enormous areas of forest and shade trees were defoliated annually. In some residential sections life was rendered almost unbearable by the presence of enormous numbers of caterpillars. Although the history of the introduction and destructive work of these two pests has already been published,[1] few except eye witnesses could realize the serious conditions that existed at the time parasite introduction was begun.

Since 1891, when the gipsy moth covered an area of approximately 200 square miles, it has spread until in 1916 it involved 20,715 square miles, and is found in all of the New England States. In some localities in Massachusetts, where it was once accounted a plague, the severity of the infestation has been reduced to such an extent that the pest is more easily controlled.

The brown-tail moth was first regarded as a serious problem in 1897, when it was found in 15 towns close to Boston. Since then it has spread until now (1916) it covers a territory of 38,118 square miles, occurring in all of the New England States. Both sexes of the brown-tail moth are strong fliers. This important factor helps to explain why this insect is found over a larger area than the gipsy moth, the female of the latter species being unable to fly.

The life cycle of both the gipsy moth and the brown-tail moth is such that all stages, with the exception of the imago, are attacked by parasites. The internal-feeding parasite *Compsilura concinnata* is parasitic only upon the larvæ of these two hosts, and, while it has been reared occasionally from the pupæ, it will not complete its life cycle if the attack is delayed until the host pupates. These two hosts form an ideal combination for Compsilura, as the brown-tail moth larvæ occur in the field a short while after the parasite emerges from

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[1] "Insect Life," Vol. III, p. 297.

"Fifth Report of Entomological Commission," A. S. Packard, 1890, p. 138.

"The Gipsy Moth," Forbush and Fernald, 1896. State of Massachusetts.

"The Gipsy Moth in America," Bureau of Ent. Bull., New Series, No. 11, 1897.

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"The Gipsy Moth as a Forest Insect, with Suggestions as to its Control," W. F. Fiske, Bureau of Ent. Circ. No. 164, 1913.

"The Dispersion of the Gipsy Moth," A. F. Burgess, Bureau of Ent. Bull. No. 119, 1913.

"The Gipsy Moth and the Brown-tail Moth, with Suggestions for their Control," A. F. Burgess, Farmers' Bull. No. 564, 1914.

"Report on the Gipsy Moth Work in New England," A. F. Burgess, Dept. of Agri. Bull. No. 204, 1915.

hibernation. The gipsy-moth larvæ are a little later, and the bulk of the Compsilura reared at the gipsy-moth laboratory come from this host.

HISTORY OF COMPSILURA CONCINNATA MEIGEN.

DESCRIPTION.

Compsilura concinnata is larviparous, the eggs hatching in the uterus and the young being injected into the host by means of a larvipositor, which is inserted in an opening of the host integument made by a grooved, curved piercer, resembling a **V** in shape. When parasites were first imported there were among them certain tachinid puparia, some of which were not specifically identified at that time. It is probable that in this lot of unidentified puparia were some of the *Compsilura concinnata*, although, if such was the case, no record was kept.

Compsilura concinnata was first described in 1824 by Meigen, in "Systematische Beschreibung des bekannten europäischen zweiflügeligen Insekten," Volume IV, page 412, under the name of *Tachina concinnata*. Following is a translation of the original description:

Length 7½ mm. Face white, both sides to above the middle with vibrissæ; palpi orange. Vertex rather narrow, white, with a deep black stripe; bristles reaching up to the hypostoma. Antennæ somewhat shorter than the hypostoma, brown, with a larger bristle, which is thickened for about one-third of its length. Thorax whitish; the dorsum with blackish iridescence and four deep black stripes; the outer somewhat broader. Abdomen cone shaped; the first segment and a dorsal line and band on the hind edge of the next segment polished black; venter of abdomen carinate, black, with whitish incisions. Legs black, alulæ white; wings almost glossy transparent; apical cross vein straight, with rounded corners; the veins converge closely on the edge of the wing before its apex, the usual cross vein somewhat curved. The above description was from a female.

The larva and puparium (Pl. I, fig. 2) of Compsilura were both described in 1834 by Bouché in "Naturgeschichte der Insekten . . .", printed in Berlin, page 57. A translation of the descriptions follows:

The larva is elliptical, somewhat narrower anteriorly, roughish, fleshy, soft, variable, with swollen outlines and very finely grooved. The thoracic incision is black, as are also the articulation pieces of the abdomen, armed with little sharp points. The spines are arranged more or less in wavy rows. The black, short, and stout mouth hooks are almost straight. The antennae are wartlike, double, clear brown. The prothoracic stigmata are short, yellow, and parted. The hind part (last segment) is small, rounded, shallowly excavate posteriorly. In this depression are the two round, black stigmata bearers, provided on the inner side with white, round, transparent spots and brown three-divided stigma. Length 7½ mm.

The pupa is dark brown, elliptical-stout. Almost a smooth barrel. The segments are linked together, a little muricate at the abdomen. The prothoracic stigmata of the coming fly forms short blunt points. The blackish-brown posterior stigmata bearers are close together, and are provided with trifoliate stigmata. Length, 6½ mm.

In the description of the larva Bouché neglected to speak of a very important point, the anal hooks of the first-stage larvæ. This character has been found only in one other tachinid first-stage larva, that of the closely allied genus Dexodes. It is very easy to determine this stage by these hooks and to verify the fact that Compsilura parasitizes early-stage brown-tail moth larvæ in the fall, as has been found from various dissections. Pantel describes and illutrates these hooks in "La Cellule." (Fig. 1.) There are three of these peristigmatic hooks; two prestigmatic and one retrostigmatic. It is with these hooks that 'he larva attaches itself to the peritrophic membrane just previous to molting into the second stage. As the larva grows, the molt skins are pushed down on to this funnel until just previous to emerging, when the full-grown third-stage maggot breaks loose and forces itself out of the dead host. This is done in the following manner: The anterior end of the parasite, assisted by the mouth hooks, makes a small opening in the integument of the host and by a gradual process of extending and retracting the anterior part of the body the larva finally succeeds in passing out. If the host is one that has spun a cocoon, the parasite larva will pupate within this, but if not, it will drop to the ground or pupate near the host. The time between emergence of the larva and pupation is governed by such things as temperature and location, whether on a tree trunk, in soil, or elsewhere.

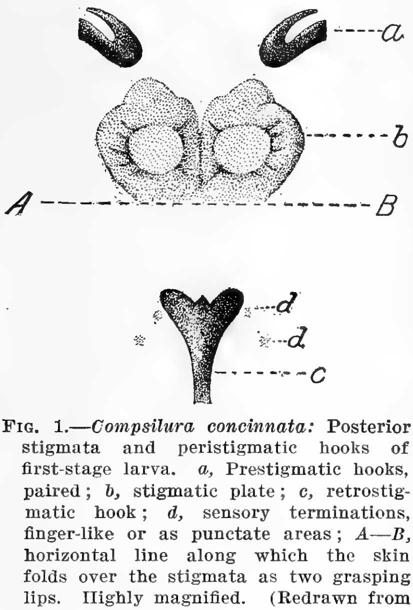

FIG. 1.—*Compsilura concinnata:* Posterior stigmata and peristigmatic hooks of first-stage larva. *a,* Prestigmatic hooks, paired; *b,* stigmatic plate; *c,* retrostigmatic hook; *d,* sensory terminations, finger-like or as punctate areas; *A—B,* horizontal line along which the skin folds over the stigmata as two grasping lips. Highly magnified. (Redrawn from Pantel.)

DISTRIBUTION IN EUROPE.

Compsilura concinnata is found in Europe in practically all of the territory covered by the brown-tail moth. It has been imported into the United States from 10 European countries and possibly from Japan. Very little work has been done with the parasite in Europe beyond Pantel's investigations. Compsilura has been described under a number of synonyms by various authors, and reference to these synonyms can be found in the "Katalog der Paläarktischen Dipteren," Volume III.[1]

[1] See also "Bibliography," pp. 25–26.

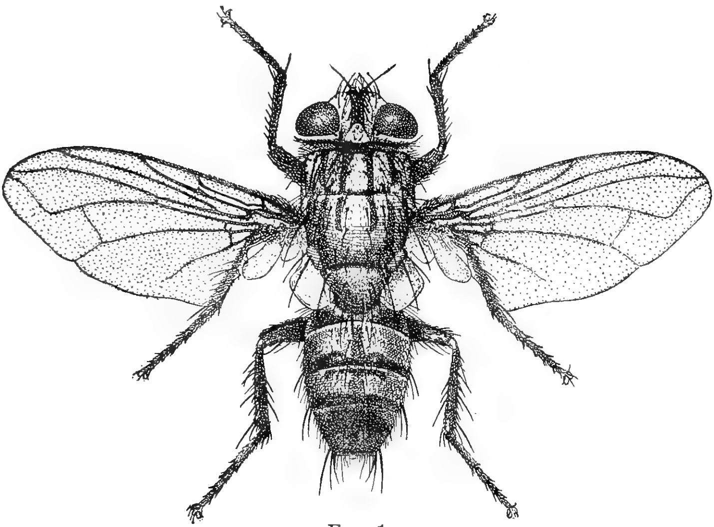

FIG. 1.

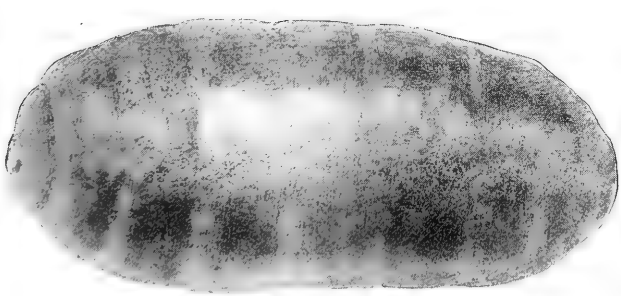

FIG. 2.

ADULT AND PUPARIUM OF COMPSILURA CONCINNATA.

FIG. 1.—Adult female. FIG. 2.—Laterial view of puparium. Fig. 1, 6½ times natural size; fig. 2, about 10 times natural size.

HOSTS, EUROPEAN AND AMERICAN.

This parasite attacks a large number of both nocturnal and diurnal hosts in Europe, the host list comprising 58 different species. In the United States it does not attack so many, probably due to its recent importation to this country. In time the host list for Compsilura in the United States will, no doubt, surpass that in Europe, for within the few years it has been established in New England a host list comprising 33 species already has been compiled,[1] and undoubtedly it attacks more than are known at the present time. All of the records given in the list of native hosts of Compsilura were secured at the gipsy moth parasite laboratory, Melrose Highlands, Mass. In a few instances these records have been duplicated by investigators at other places.

Table I gives the European host list.

TABLE I.—*Foreign hosts of Compsilura concinnata; records from the "Katalog der Paläarktischen Dipteren" and from the Bibliography.*

- *Abraxas grossulariata* L.
- *Acronycta aceris* L.
- *Acronycta alni* L.
- *Acronycta cuspis* Hübn.
- *Acronycta megacephala* F.
- *Acronycta rumicis* L.
- *Acronycta tridens* Schiff.
- *Araschinia levana* L.
- *Araschinia prorsa* L.
- *Arctia caja* L.
- *Attacus cynthia* L.
- *Catocala promissa* Esp.
- *Cimbex humeralis* Fourcr.
- *Craniophora ligustri* Fab.
- *Cucullia lactucae* Esp.
- *Acronycta verbasci* L.
- *Dasychira pudibunda* L.
- *Dilina tiliae* L.
- *Dipterygia scabriuscula* L.
- *Drymonia ruficornis* Hübn.
- *Euproctis chrysorrhoea* L.
- *Heteromorpha caeruleocephala* L.
- *Hyloicus pinastri* L.
- *Libytha celtis* Laich.
- *Macrothylacia rubi* L.
- *Mamestra brassicae* L.
- *Mamestra oleracea* L.
- *Mamestra persicariae* L.
- *Malacosoma neustria* L.
- *Oeonistis quadra* L.
- *Papilio machaon* L.
- *Phalera bucephala* L.
- *Pieris brassicae* L.
- *Plusia festucae* L.
- *Plusia gamma* L.
- *Poecilocampa populi* L.
- *Pontia rapae* L.
- *Porthetria dispar* L.
- *Porthetria monacha* L.
- *Porthesia similis* Fussl.
- *Melalopha anachoreta* Fab.
- *Pyrameis atalanta* L.
- *Smerinthus populi* L.
- *Spilosoma lubricipeda* L.
- *Stauropus fagi* L.
- *Stilpnotia salicis* L.
- *Taeniocampa stabilis* View.
- *Thaumetopoea processionea* L.
- *Thaumetopoea pityocampa* Schiff.
- *Timandra amata* L.
- *Trichiocampus viminalis* Fall.
- *Trachea atriplicis* L.
- *Vanessa antiopa* L.
- *Vanessa io* L.
- *Vanessa polychloras* L.
- *Vanessa urticae* L.
- *Vanessa xanthomelas* Esp.
- *Yponomeuta padella* L.

The following is the American host list:

TABLE II.—*American hosts of Compsilura concinnata.*

- *Apatela hasta* Guen.
- Arctiid sp.
- *Autographa brassicae* Riley.
- *Callosamia promethea* Dru.
- *Cirphis unipuncta* Haw.
- *Cimbex americana* Leach.
- *Deilephila gallii* Rott.
- *Diacrisia virginica* Fab.
- *Deidamia inscripta* Harris.
- *Ennomos subsignarius* Hübn.
- *Estigmene acraea* Dru.
- *Euchaetias egle* Dru.
- Geometrid sp.
- *Hemerocampa leucostigma* S. & A.
- *Hyphantria cunea* Dru.
- *Malacosoma americana* Fab.
- *Malacosoma disstria* Hübn.
- *Mamestra adjuncta* Boisd.
- *Mamestra picta* Harris.
- *Melalopha inclusa* Hübn.
- Noctuid sp.
- Notodontid sp.
- *Notolophus antiqua* L.
- *Papilio polyxenes* Fab.
- *Plusiodonta compressipalpis* Guen. (By Reiff, at Forest Hills, April 7, 1913.)
- *Pontia rapae* L.
- *Phlegethontius quinquemaculata* Haw.
- *Rhodophora florida* Guen. (By Reiff, at Forest Hills, Sept. 8, 1913.)
- *Schizura concinna* S. & A.
- *Vanessa antiopa* L.
- *Vanessa atalanta* L.
- *Vanessa huntera* Fab.
- *Xylina* sp. Ochs.

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[1] This covers all records, including those of the year 1916.

IMPORTATIONS TO UNITED STATES.

Compsilura was first imported into the United States in 1906, though it was not determined as such, being included in the general classification of Tachinidae. In 1907, from shipments of brown-tail moth larvæ and gipsy moth larvæ and pupæ there were secured 104 puparia which were determined as *Compsilura concinnata.* These came from France, Germany, and Austria. Most of the Compsilura imported in 1907 were found free in the boxes of brown-tail moth larvæ, and a few in the gipsy moth shipments. In 1908 an experiment was tried in shipping live puparia from Europe to Melrose Highlands, Mass., but it was not successful, as the puparia were nearly all broken. That year 220 Compsilura were received. The year 1909 was the banner year in importations of Compsilura, a total of 6,626 being secured from foreign shipments, about 50 per cent of these coming from gipsy-moth material. This was the first time that Compsilura was accepted as more than an occasional parasite of *Porthetria dispar.* During the year 1910 the majority of the 1,859 Compsilura received were secured from gipsy-moth shipments in the late larva and early pupa stages. No puparia shipped as such were received, as those sent the previous year came in such poor condition. The season of 1911 was the last during which Compsilura was imported. In this year 1,233 were received, about 75 of which came as puparia, practically all of the others being secured from brown-tail moth shipments. In the period between 1906 and 1911 Compsilura was received from nine European countries as well as a few possibly from Japan, a grand total of 10,042 being received at the Gipsy Moth Laboratory.

COLONIZATION.

There is no record of the number of Compsilura colonized in 1906 or 1907, but in Bulletin 91 of the Bureau of Entomology, page 220, reference is made to efforts along this line.

In 1907 a large colony was liberated at the location of one of the colonies of 1906, in the town of Saugus, Mass. No colonization was attempted in 1908, but in 1909 several colonies were established throughout eastern Massachusetts in the gipsy-moth area. Very little colonization was done in 1910 and 1911, a total of 1,304 being colonized during that time. It was in 1910 that a colony of this parasite was put out in Washington, D. C., to combat the white-marked tussock moth (*Hemerocampa leucostigma* S. & A.). In 1912 colonization of Compsilura in New England was again resumed on a larger scale than at any previous time, and this has been continued until the entire gypsy-moth area has been covered. This parasite does not appear to be so firmly established in the brown-tail moth area where the gypsy moth is not found, though colonization has been made there. It is true that it will perpetuate itself without the gypsy moth, but not in such large numbers, as collections made from these outlying towns have shown.

During the years 1912 to 1916 the entomological branch of the Dominion of Canada collected in New England and shipped for colonization to New Brunswick and Nova Scotia 32,824 Compsilura to combat the brown-tail moth. In 1914 and 1915 assistants of the branch of Cereal and Forage Insect Investigations of the United States Bureau of Entomology collected and sent Compsilura to Arizona and New Mexico to be used in the fight against the range caterpillar *Hemileuca oliviae* Ckll., a total of about 4,000 of these parasites being divided between the two States. During the years 1915 and 1916 about 3,000 Compsilura were sent to Florida to be used against the fall army worm (*Laphygma frugiperda* S. & A.). Compsilura has not proved as successful in the West and South as it has in New England up to the present time. In Arizona and New Mexico the conditions are so radically different from those in New England that even though the parasite becomes established it will take some time for it to became climatically adjusted. It has been too recently colonized in the South to justify predictions as to the results that will be accomplished. In Canada it more nearly approaches its standing, as an effective parasite, in the outskirts of the brown-tail moth infestation in New England and in time should prove a valuable aid in the control of this pest.

SPREAD.

The rate of spread of Compsilura has been determined in two ways: (1) By scouting, which consists of carefully examining gipsy moth and brown-tail moth infestations in localities just outside the area previously recorded as covered by Compsilura, and (2) by collections of various lepidopterous larvæ from towns beyond the known spread of the parasite. This rate of spread has been found to be approximately 25 miles per year, and this is taken into consideration in colonizing the parasites, the colonies having been put out in most cases about 25 miles apart in all directions. This proves that the insect is a strong flier, for there are no artificial means worth considering that will assist in its dispersion.

RECOVERY.

The first recovery of Compsilura was made in New England in 1907, a single specimen reared from a field collection of gipsy-moth larvæ. Attempts to recover this parasite failed in 1908, but in 1909, soon after colonization, several puparia were reared from collections of both brown-tail moth and gipsy-moth larvæ, which proved that the parasite had become established from the colonies of 1906 and 1907. It was in 1909 that assistants from the laboratory, in scouting for larvæ of *Calosoma sycophanta* L., found numbers of Compsilura puparia in the field. Since the first substantial recovery in 1909 the parasite has been recovered from 303 towns in New England. These towns are scattered throughout the entire gipsy-moth area, with very few outside. (See map, Pl. II.) An interesting recovery of Compsilura was made in 1915, from the Island of Nantucket, Mass., 25 miles from the mainland, where the nearest colony of the parasite is located.

Compsilura is scattered over so wide a territory that it is usually possible to collect it in almost any part of New England within the gipsy-moth area. This is especially so where the gipsy moth is abundant in a locality not far distant from where Compsilura has been colonized any length of time. The general method is to make trial collections of 100 fourth-stage larvæ and maintain them in feeding trays.[1] These trays are small and rectangular, the bottoms being covered with thin cloth and a narrow band of tanglefoot applied near the top to prevent the escape of larvæ. If this trial collection shows a parasitism of 8 to 10 per cent, the location is considered a good field for bulk collections to secure parasite material for colonization. In a few instances where both trial and bulk collections showed a very high percentage of parasitism the first year, it has not been considered necessary to make trial collections from a given locality the following year. This is not always relied upon, however, as Compsilura may be present in a locality in fairly large numbers one year, while the following year collections from the same locality will give a low percentage of parasitism. This is particularly true of places where the brown-tail moth is scarce and which may have a good infestation of gipsy moths. Compsilura seems to be more prevalent where there is a rather heavy infestation of both brown-tail moths and gipsy moths.

All of the collections are sent by mail or brought into the laboratory in wooden boxes 3½ by 5¼ by 9½ inches. These boxes have a hole in one end through which the larvæ are put as they are collected, about 350 to 400 larvæ in each box; this hole is then covered by a piece of tin or zinc, which is secured by four tacks. Fresh food is placed in the boxes as the larvæ are collected; this keeps them separated in transit. As soon as these boxes are received at the laboratory they are opened, the location recorded and filed under a number, and the larvæ counted and placed in a feeding tray, the size of which is governed by the number from a single locality.

[1] These trays have been described in Department of Agriculture Bull. No. 250, July, 1915.

Map Showing Distribution of Compsilura concinnata in New England. The Area Inclosed by the Heavy Line is the Territory Covered by Compsilura. The Crosses Show Where it Has Been Colonized Outside This Area, But Has Not Yet Been Recovered.

These trays are carefully examined and all of the Compsilura puparia removed and counted every two or three days, records being kept under the locality number. As these puparia are removed they are kept in a cool place until a sufficient number, 500, is secured, when they are ready to be sent to some point for colonization.

DISCUSSION OF CLASSIFICATION OF COMPSILURA CONCINNATA.

FIG. 2.—*Compsilura concinnata:* Ovariole of adult female at hatching. Greatly enlarged. (Pantel.)

The parasitic Diptera, which include Tachinidae, are classified according to structure and method of attack. Method of attack is governed by the structure of the insect, and J. Pantel, in "La Cellule," Volume I, has classified these parasites, grouping them in the form of a key, according to structure. As this entire classification is too lengthy for reproduction here, the writer will give merely an extract of the group containing Compsilura.

Group VII. Species which, by means of distinct perforating and laying instruments, insert hatched larvæ, or those about to hatch, in the body of the host.

Enumeration of species.	*General host index.*
Compsilura concinnata Meig. *Dexodes nigripes* Fall. *Vibrissina demissa* Rond.	A very long list of caterpillars and false caterpillars. (Pantel here notes that he has bred them from 12 (species) bombycid caterpillars (Townsend).)

While Compsilura is moderately fecund, each female deposits larvæ singly beneath the skin of the host. The ovaries, at the time of hatching, form an obconic bundle consisting, on an average, of 14 ovarioles or strings of developing eggs, and each ovariole containing, on an average, 8 developing eggs. (Fig. 2.) These averages were arrived at from dissections of 50 sexually mature females. This would make the reproductive capacity of Compsilura approach 225, but this total is not reached, as a general thing, as dissections of adults, which were three to four weeks old, have shown. A series of dissections have shown that the average reproductive capacity of Compsilura is from 90 to 110 larvæ.

The paired oviducts leading from the ovaries into the anterior uterus, the three spermathecæ, and the accessory glands are shown in the illustration of the reproductive system of an unfertilized female (fig. 3). The posterior uterus in an unfertilized female is a short, nearly straight passageway which is empty, but which, when the female becomes gravid, elongates, as the developing young descend, into a long intestine-like incubating organ leading to the larvipositor. These developing larvæ are arranged transversely for about halfway down the posterior uterus, causing this organ to resemble a flat, more or less coiled ribbon, gradually enlarging toward the external organs of reproduction. As the developing larvæ are forced downward their axes gradually change until the axis of the posterior uterus and the larvæ is the same. (Fig. 4.)

At the distal termination of the posterior uterus is the "laying organ" or larvipositor. This is slightly chitinized and has a small tubelike opening just large enough for the passage of one larva. This organ, as well as the anus, arises in the venter of the sixth abdominal segment and is curved forward when at rest, fitting into the carinate venter of the fifth abdominal segment. The larvipositor fits into a curved chitinous hook or piercer, which is grooved, reresembling a V in structure. Beneath this hook is a supporting organ arising from the fifth segment, which is strongly spined on both sides in such a manner that it reinforces the piercer while the female is in the act of attacking the host caterpillar. The parasite larvæ, as they are forced down the posterior uterus, are turned in some manner and are injected into the host, with the anterior end first. This was the conclusion the writer reached after making a number of dissections of females after they had deposited part of their young. In these dissections some of the larvæ were found to be inclosed in a very thin membranous sheath, which fitted the body very closely, while others were found naked. This leads to the inference that Compsilura deposits both bare and inclosed larvæ. Pantel suggests that this might be possible on account of a prolongation of the egg stage, due to the absence of an appropriate host.

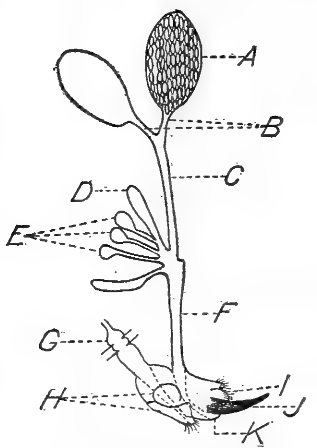

FIG. 3.—*Compsilura concinnata:* Reproductive system of unfertilized female. *A*, Ovary, showing ovarioles; *B*, paired oviducts; *C*, anterior uterus; *D*, accessory glands; *E*, spermathecæ; *F*, posterior uterus; *G*, rectum, showing rectal papillæ; *H*, lateral lobes of dorsum of sixth abdominal segment; *I*, reinforcement of piercer, from dorsum of fifth abdominal segment; *J*, piercer; *K*, larvipositor. Greatly enlarged. (Original.)

DISCUSSION OF LARVA STAGE OF COMPSILURA CONCINNATA.

Compsilura larvæ pass their entire life within the body of the host. The young larva is introduced generally into the intestines, where it is motile, floating free until just previous to molting into the second stage, when it becomes attached to one of the stigmata or vesicles of the branching trachea. This is done by means of the three anal hooks which are found in the first-stage Compsilura maggot. (Figs. 1 and 5.)

Respiration takes place through the anal stigmata of the larva, air being furnished by the stigma or trachea of the host. A tracheal funnel is formed by the maggot pushing itself backward against the

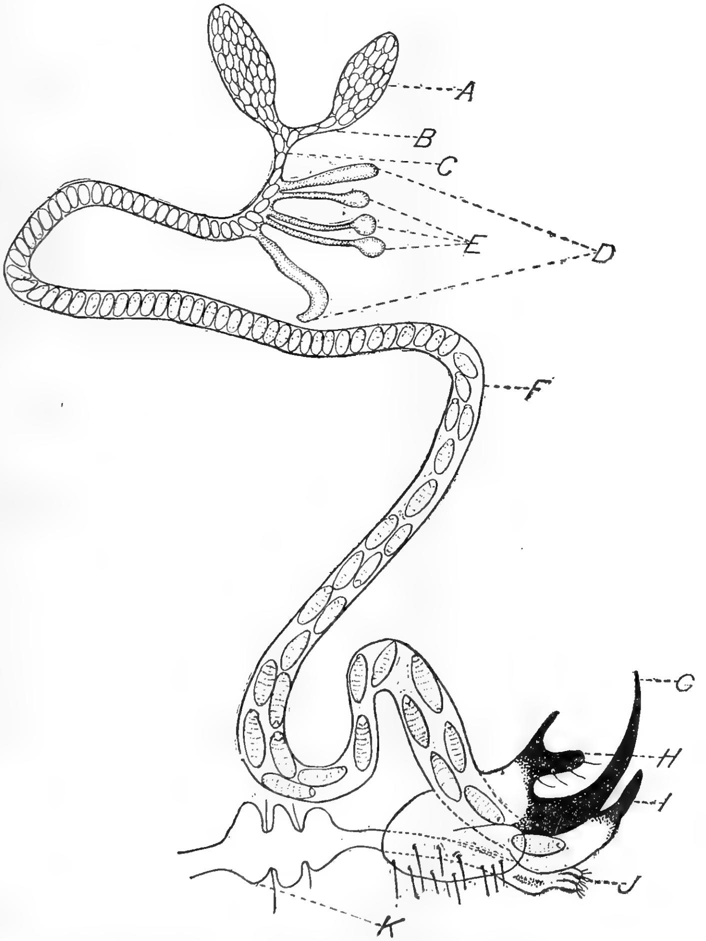

FIG. 4.—*Compsilura concinnata:* Reproductive system of fully developed fertilized female. *A*, Ovary; *B*, oviduct; *C*, anterior uterus; *D*, accessory glands; *E*, spermathecæ; *F*, posterior uterus; *G*, piercer; *H*, support for piercer; *I*, Larvipositor; *J*, anus; *K*, rectum, showing rectal papillæ. Greatly enlarged. (Original.)

place of attachment. This leaves the anterior end of the parasite larva free for feeding. As the larva molts, it pushes the exuvium down on the funnel, and it is possible to locate both the first and second stage mouth-hooks upon dissection of the host. The larva remains in this funnel until just previous to emergence from the host, when it breaks loose and emerges ready for pupation.

The larvæ differ somewhat in appearance in the three stages. In the first-stage larvæ the mouth-hook is single pointed, being heavily chitinized throughout with the exception of the inside areas of the divided posterior part. This posterior end is membranous and serves as a place of attachment to hold the hook in position, this being true of all three stages. The first segment has a row of heavy spines around its base, while the second segment is thickly studded with the same kind of spines. The ventral part of the remaining segments is also fitted with the same spiny structure, in this case the spines extending upward laterally along the anterior border of each segment. All of the segments are more or less covered with what, under the high-power microscope, appear to be very small granulations. On the last abdominal segment there is a peculiar set of hooks that make possible the determination of first-stage Compsilura. These are for the purpose of attachment to the stigma of the host. (Fig. 5.)

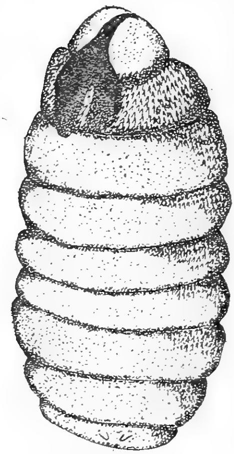

FIG. 5.—*Compsilura concinnata:* First-stage larva, right lateral view. Greatly enlarged. (Original.)

The second-stage larva of Compsilura differs from the first in three main points: (1) The mouth-hook is double throughout, the halves being jointed by a chitinous structure, and is jointed in one place (fig. 6); (2) the chitinous part of the hook extends farther basally, the whole outline of the hook being more uneven; and (3) the heavy spines on the integument are lost in this stage, while the anterior border of each abdominal segment has two or three rows of lighter spines, which extend completely around the body. The first segment is more contracted on the ventral surface, grading off at a gradual angle to its junction with the second segment. The anal hooks are wanting in this stage and the permanent structure of the anal stigmata is clearly shown.

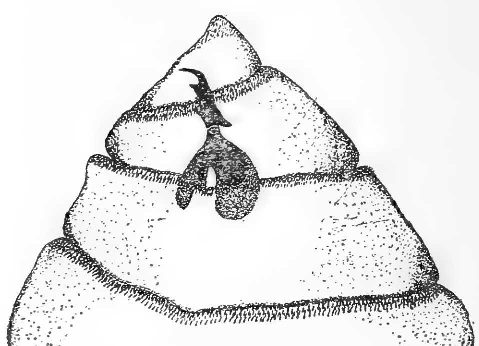

FIG. 6.—*Compsilura concinnata:* Anterior end of second-stage larva, left lateral view. Greatly enlarged. (Original.)

The third and last stage of the larva differs slightly from the second in the structure of the mouth-hook and spines on the body. The mouth-hook is still divided into two parts, but there are two joints in it. (Fig. 7.) The heavy chitinous structure does not extend so far basally, but the membranous portion is larger than in the second stage. The spiny armature is even less than in the second stage, only a thin sprinkling of spines being present on the anterior end of each segment. The anal stigmata are black and much larger than in the second stage, appearing as they will be found in the puparium (fig. 8).

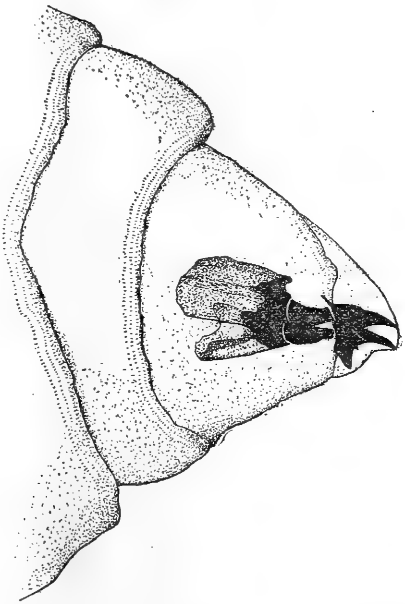

FIG. 7.—*Compsilura concinnata:* Anterior end of third-stage larva, right lateral view. Greatly enlarged. (Original.)

LIFE HISTORY.

METHOD OF HANDLING.

The collection and handling of host material in the laboratory has been referred to in the preceding pages. The methods of handling the parasite in determining its life history follow.

In the fall of 1914, when the life-history work on Compsilura was begun, the notes at the laboratory were thoroughly reviewed and all of the information concerning this parasite assembled. All of the available literature was studied, and, while several authors had written of Compsilura, very little could be found concerning the actual life history of the parasite. At this time experiments were being carried on to investigate the life history of *Apanteles lacteicolor* Vier., and it was from the type of tray then in use that the present "reproduction tray" (fig. 9) for Compsilura was evolved. This tray measured 12 by 12 by 5 inches, with a groove around three sides, in which a sliding glass cover could be fitted. The bottom of the tray was of muslin, which permitted of partial ventilation and could be replaced. In two opposed

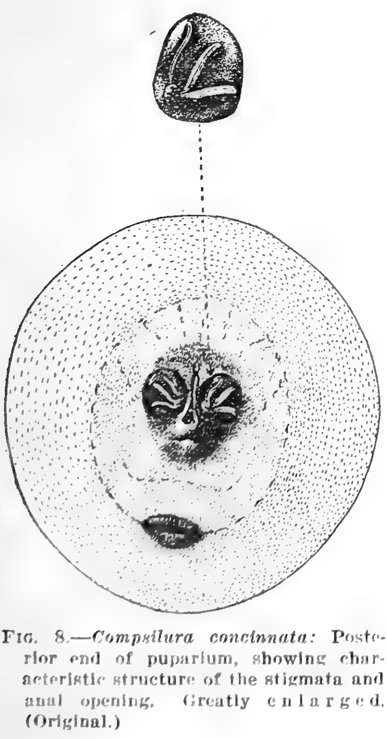

FIG. 8.—*Compsilura concinnata:* Posterior end of puparium, showing characteristic structure of the stigmata and anal opening. Greatly enlarged. (Original.)

sides were holes covered with fine copper screen, affording good ventilation. In the center of the front of the tray was a hole 3 inches in diameter, in which was fitted a round plug having a 1-inch hole through the center for inserting a vial containing foliage; by this arrangement the stem of the foliage could be kept in water. The experiment number label, with the number and species of hosts, number of both sexes of Compsilura, and the date begun, was also pasted on the front. In the right side of the tray was a smaller hole for the purpose of placing the parasites in the tray, this being closed with a cork.

During the summer of 1915 sugar water was used as food, being sprayed on the leaves and on the sides of the tray. This was found to be unsatisfactory, first, because sugar water was not heavy enough food for the flies and they did not live for any length of time, and, second, when this sticky substance was sprayed over the leaves and the sides of the tray the flies frequently would become stuck to it. During the season of 1916 honey water in the proportion of one part honey to three of water was used very satisfactorily. This was fed to the flies by the use of an atomizer, with which it was sprayed on a sponge placed in a watch glass. In the bottom of the tray was kept a small dish of sand, which was moistened each day, thus keeping the humidity constant. Temperature records were kept with a self-recording thermometer placed near the reproduction trays. The experiments were conducted in a house which had three screened windows on one side and the opposite side built so that about half of it was open and well screened. One end was closed and the other had a screen door in it. The three sides being thus open, good ventilation was afforded. The reproduction trays were arranged on two sides of this shed on shelves which were constructed of narrow strips to facilitate ventilation in the trays.

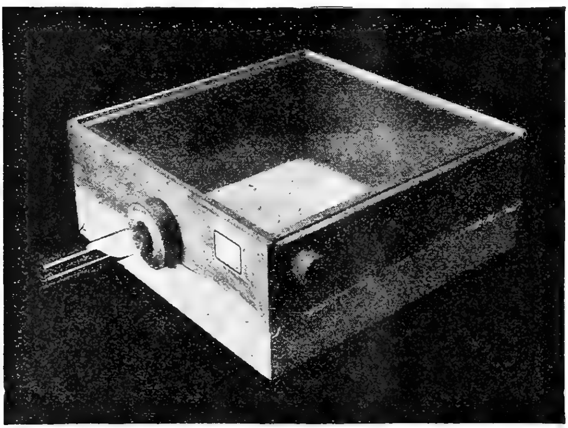

FIG. 9.—Reproduction tray used in life-history experiments on *Compsilura concinnata*. (Original.)

During the summer of 1915 difficulty was experienced in securing parasite-free hosts, the only material of this nature that could be had in large numbers being the brown-tail moth larvæ. These were reared from the hibernating webs collected the previous fall. A large number of gipsy-moth larvæ were hatched for this purpose, but owing to the high percentage of mortality, due to the so-called wilt disease, few survived long enough to be used in the experiments. In the spring of 1916 efforts were made to secure more of the parasite-free material, with the result that the writer was more successful than before. A large number of brown-tail moth larvæ were reared from the webs, and several thousand gipsy-moth larvæ were hatched out. These hosts were kept in large "tanglefooted" trays, which were covered with fine screen cloth, to prevent any possibility of parasitism being effected from outside sources. Through the cooperation of the assistants of the Bureau of Entomology at the Bussey Institution an abundance of parasite-free material was secured of the species *Bombyx mori* L., *Hemerocampa leucostigma* S. & A., and *Callosamia promethea* Drury, which had been reared in a greenhouse, where it was impossible for parasitism by Compsilura to take place.

LARVA AND PUPA STAGES.

The conditions under which the life history of Compsilura was studied were so different from the normal that no doubt it varies from that actually obtaining in the field. Nevertheless, as nearly the normal environment of the fly as was possible under laboratory conditions was simulated.

The length of the larva stage in Compsilura varies with the season, being unaffected by temperature to any appreciable extent. Tables III and VI indicate the length of the larva stage under laboratory conditions. As shown, the adult flies were of varying ages at the beginning of each experiment, this apparently affecting the length of the larva stage. The length of the stage for each larva was computed from the time the experiment was begun, for it was impossible to note the time at which each adult attacked the host larva. The length of the pupa stage is also shown in Tables III and VI. The puparia used in these experiments were removed from the various trays as soon as they had hardened and become the characteristic dark-brown color.

TABLE III.—*Length of larva and pupa stages of Compsilura concinnata under laboratory conditions, Melrose Highlands, Mass., 1916.*

Experiment begun.	Age of female Compsilura when experiment began.	Number of Compsilura larvæ secured.	Average number of days in larva stage of Compsilura.	Number of puparia that emerged.	Average length of pupa stage.	Proportion of sexes.		Number and stage of hosts.	Species and stage of host.
						Male.	Female.		
1916.	*Days.*				*Days.*				
July 13	3	28	16.64	24	12	13	11	100, fourth stage	Brown-tail moth, larvæ.
17	17	6	9.83	3	14.50	2	1	50, fourth stage.	Do.
6	6	19	13.57	15	10.40	7	8	60, third and fourth stages.	Gipsy-moth, larvæ.

The pupa stage of Compsilura is passed in two ways. In the field, puparia will be found both in the crevices of the bark and in the webs of prepupal brown-tail moth larvæ or "spin-ups." They will also be found about 1 inch beneath the surface of the soil at the base of trees. The average length of the pupa stage in the soil is from two to four days greater than above ground.

ADULT STAGE.

The length of the adult stage under laboratory conditions varies with the temperature and methods of handling. The methods of handling have been previously mentioned. The average length of the adult stage of Compsilura is shown in Table IV.

TABLE IV.—*Average length of adult stage of Compsilura concinnata, Melrose Highlands, Mass., 1916.*

22 days for 35 mated males in glass-covered trays.
18 days for 35 mated females in glass-covered trays.
13.5 days for 22 unmated males in glass-covered trays.
4.5 days for 22 unmated females in glass-covered trays.

GESTATION.

The period of gestation varies with the temperature, an increase in temperature tending to shorten the period. A new supply of hosts was added every two days and close watch for the emergence of Compsilura larvæ was maintained. The time required for the period of gestation was reckoned from the time of mating to the time the adults and hosts were separated; then, to get accurately the length of the larva stage, each maggot was isolated as it emerged from the host and the larva stage was reckoned from the end of the period of gestation. (See Table V.)

TABLE V.—*Gestation period of Compsilura concinnata: Single females in each experiment, Melrose Highlands, Mass., 1916.*

Date experiment began.	Age of fly at copulation.	Number of Compsilura larvæ secured.	Average length of larva stage.	Number and stage of hosts.	Host.	Gestation period.
	Days.		*Days.*			*Days.*
July 13	1	3	9.5	30, fourth stage	Brown-tail moth larvæ	4.5
14	2	13	7.42	70, fourth stage	do	5
16	2	8	7.23	60, fourth stage	do	3
31	2	1	10	70, fourth stage	do	6
Average						4.5

PARTHENOGENESIS.

Since it was thought that Compsilura might, at times, be parthenogenetic, a series of experiments was conducted to determine whether this is the case. In each case 5 unfertilized females were placed in trays with 25 third and fourth stage gipsy-moth larvæ which had been reared under screen from hatching. Attempted larviposition was noted, but in no case were Compsilura larvæ secured and none were found upon dissecting the hosts. This same false larviposition was noted with larvæ of *Bombyx mori*. The piercer punctured the integument of the host, for each time an attack was made the caterpillar bled at the point of attack. A number of the Compsilura used were dissected, but none showed uterine eggs or developing maggots in the uterus. In several of these females the posterior uterus had become lengthened as is the case after fertilization.

COPULATION.

When union was successfully accomplished, copulation lasted from 26 minutes to 1 hour and 50 minutes, and while a number of records were secured, the foregoing represents the extremes. Attempted coition was noted at times which occupied several seconds, but in cases of such short duration these attempts were unsuccessful. The results of observations on copulation seem to be more or less contradictory. In some cases Compsilura were confined in glass jars, screen cages, or glass-covered trays for several days, and did not copulate; whereas in one case a male, which was 16 days old and had been mated previously, copulated for 1 hour and 50 minutes with a female which was only 24 hours old. Another pair that were only 18 hours old copulated for $1\frac{1}{2}$ hours. In cases where copulation occurred soon after emergence from puparia the temperature and humidity were quite high. It was observed also that the flies will copulate more readily if the male is from 2 to 4 days older than the female.

LARVIPOSITION.

Compsilura will attempt larviposition in confinement when only one day old and before copulation takes place. It is physically impossible that this attempted larviposition can be effective, as Compsilura is viviparous and young larvæ have not had sufficient time to develop within the mother in that length of time.

The method of larviposition is as follows: The female approaches the host, stopping within about an inch of it and, after surveying the victim carefully, strikes quickly. The host makes a quick movement of the entire body and the Compsilura flies off, only to return immediately until she is finally satisfied. If larviposition is successful at the first attempt, the parasite seems satisfied for a few moments. Records were secured of Compsilura attacking one gipsy-moth larva as many as seven or more times in rapid succession, the whole occurring within $1\frac{1}{2}$ minutes. Larviposition will be attempted shortly after copulation, as records show that this occurs within 26 minutes after coition has been completed.

The host larva will be attacked in almost any portion of the body, as larviposition was attempted on the head capsule, the middle part of the body, and the posterior segments. Although the middle portion seems to be preferred, this may be due to the host's inability to disturb the parasite as easily in this portion as it does on either the anterior or posterior end.

ACTION ON HOSTS OTHER THAN THE GIPSY AND BROWN-TAIL MOTHS.

In working out the life history of Compsilura various hosts were used, all, with one exception, being indigenous to this country. Sixteen native species were utilized, and while Compsilura had been reared from most of these, attempts at reproduction in the laboratory failed on all but four. A matter of interest in connection with reproduction on *Callosamia promethea* and *Bombyx mori*, which had been reared parasite-free beneath screen, was the high percentage of superparasitism. This was particularly true of *Bombyx mori*, in several instances as many as 10 Compsilura puparia being secured from a single host; and of *Hemerocampa leucostigma*, it being a very common occurrence for from 3 to 4 Compsilura puparia to be reared from one host. In Table VI are given the results of reproduction upon these three hosts.

TABLE VI.—*Development of Compsilura concinnata in various hosts, Melrose Highlands, Mass., 1916.*

Date.	Age of flies when experiment began.	Number of Compsilura larvæ.	Average length of larva stage.	Number of puparia secured.	Length of pupa stage.	Proportion of sexes.		Number and stage of host.	Host.
						Male.	Female.		
	Days.		*Days.*		*Days.*				
July 19	3	30	14.76	26	12	19	6	50, third[1] and fourth stages.	H. leucostigma.
15	18	5	17.20	3	17.33	1	2	15, third stage....	C. promethea.
18	2	23	22.27	17	16.25	8	9	25, third and fourth stages.	Do.
19	2	5	19	5	15.80	3	2	25, fourth stage...	Do.
19	3	59	15.60	30	11.60	17	13	35, fourth stage...	Bombyx mori.
24	4	60	19.05	....	....	......	......	50, fourth stage...	Do.

[1] These stages refer to each molt of the host larva.

Pontia rapae is a splendid intermediate host for Compsilura, this pest being found in New England wherever cabbage is grown, and because of the overlapping of its broods, which makes it possible to find nearly all stages of larvæ in the field from spring until winter, Compsilura is assured of at least one host upon which to perpetuate itself. Fortunately, however, Compsilura is not compelled to rely solely upon *Pontia rapae* for existence, as a glance at the native host list will show.

EFFECT OF TEMPERATURE UPON VARIOUS STAGES OF COMPSILURA CONCINNATA.

Temperature, under laboratory conditions, appears to exert little influence in the development of larvæ within the host. This is particularly true during the summer season. In the late summer the larva stage is lengthened, but in averaging the whole season when Compsilura larvæ were secured, July 13 to August 24, it was found that the larva stage was lengthened at a time when there was very little variation in average temperature. (See Table VII.)

TABLE VII.—*Effect of temperature upon length of larva stage of Compsilura concinnata under laboratory conditions, Melrose Highlands, Mass., 1916.*

Number of individuals.	Larva stage.	Average temperature.	Number of individuals.	Larva stage.	Average temperature.
	Days.	° *F.*		*Days.*	° *F.*
1	6	72	2	11	71
4	7	74	1	14	74
4	8	73	1	15	71
8	9	72	1	16	71
2	10	72			

This average temperature, as noted in Table VII, was secured by taking four readings a day and averaging the whole.

The effect of temperature upon the pupa stage is shown in Table VIII.

TABLE VIII.—*Effect of temperature upon length of pupa stage of Compsilura concinnata under laboratory conditions, Melrose Highlands, Mass., 1916.*

Number of individuals.	Pupa stage.	Average temperature.	Number of individuals	Pupa stage.	Average temperature.
	Days.	° *F.*		*Days.*	° *F.*
3	7	71	9	15	66
2	9	67	4	16	64
13	10	72	4	17	64
5	11	71	2	18	66
46	12	72	3	19	63
13	13	69	1	20	63
7	14	68			

Temperature averages shown in Table VIII were secured in the same way as for the larva stage. The shorter pupal periods were observed in the middle of the summer and those of longer duration in the late summer and early fall. All of these records were made from puparia above ground, the length of the pupa period in those below the surface of the soil being from two to four days greater.

The effects of temperature on adult Compsilura are shown in figure 10. The temperature was determined by readings at noon each day, when observations were made on the activity of the adults. It is practically impossible to rate terms of activity in either degrees or percentages, so the following terms were adopted: (1) *Very active.*

Constantly flying; copulating; larvipositing freely and feeding. (2) *Active.* Flying a little; larvipositing some; crawling around and feeding. (3) *Inactive.* Crawling around; no copulation or larviposition; very little feeding. (4) *Very inactive.* Practically dormant, sluggish.

SEASONAL HISTORY.

PRESENCE IN FIELD AND NUMBER OF GENERATIONS.

Compsilura occurs in the field, as shown by collections of adults in 1915, on May 1. It was on this date that two male specimens were collected. The latest that adults were taken in the field was October 28 and 29, 1915. This represents the extremes of collections of adults of this parasite. The earliest collections of puparia in the field were made June 16, 1915, from brown-tail moth "spin-ups," and the latest record, from a collection of *Pontia rapae*, made September 30, 1915. Among collections of host material for Compsilura is that of brown-tail moth "spin-ups" and the time of occurrence of these in the field varies from year to year, the average being about June 25. Immediately following these is begun the collection of gipsy-moth larvæ for this parasite. Figuring on the foregoing basis of collections, and allowing a range of 28 to 30 days for completion of life history in the field, it will be found that three full generations are passed during the season.

In the laboratory the period from adult to adult averages 24 days, and with a "gestation period" of 4.5 days, the life cycle involves about the same length of time as is required under natural conditions in the field. It was found possible to secure more than three generations annually in the laboratory by supplying hosts later than they could be found in the field.

The most accessible host in the spring is the brown-tail moth larva, which is attacked soon after emergence from the hibernating web. The growth of the parasite in this host during the early part of the larval period is more or less retarded owing to the slow spring development of the young brown-tail moth larvæ. Just previous to pupation of the host, while the brown-tail moth larva is spinning its cocoon, the parasite larva emerges and pupates within the loosely woven web. A short time after this the appearance of adult Compsilura is noted, and puparia are to be found in the early gipsy-moth larvæ, some few coming from the late fourth and early fifth stage hosts. These are evidently part of the same generation as those from the brown-tail moth larvæ. The early issuing adults emerge from the brown-tail moth hosts in time to attack the later stages of the gipsy-moth larvæ together with native hosts, which are prevalent at this time, and this constitutes the beginning of the second generation of Compsilura. Those issuing from this second generation the last of August and first of September constitute the third generation and furnish the adults which attack the hosts in which the Compsilura larvæ later hibernate.

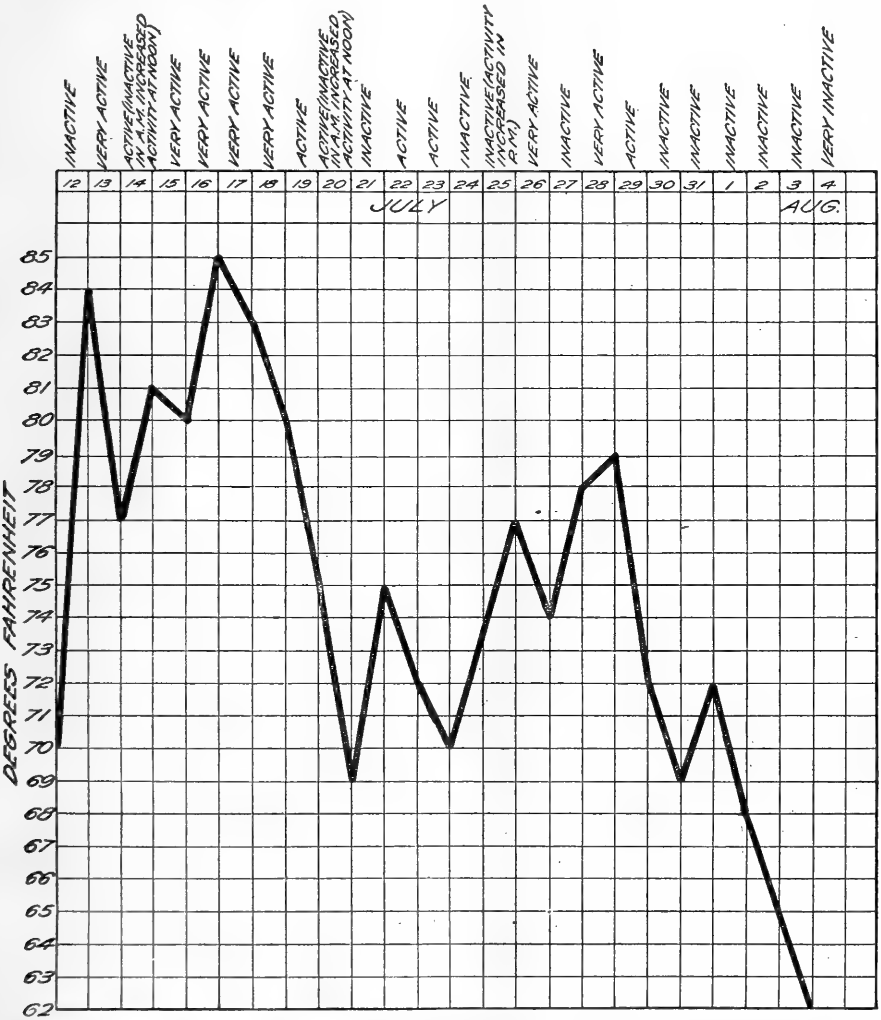

FIG. 10.—Diagram illustrating relation of temperature to activity of adult *Compsilura concinnata*, July and August, 1916. (Original.)

HIBERNATION.

Hibernation of Compsilura is the point in the life history of the parasite which has not been completely worked out, although enough has been accomplished in this line to warrant its discussion here. Several cases of hibernation of Compsilura have been recorded, but only six hosts have given absolute records. These are

Papilio polyxenes Fab., *Diacrisia virginica* Fab., *Deilephila gallii* Rott., *Deidamia inscriptum* Harris, *Callosamia promethea* Drury, and an unidentified geometrid. In all of these cases the parasites passed the winter as larvæ, emerging and pupating in the spring. No doubt when the host material lately in hibernation at the laboratory is fully examined the list of hosts in which Compsilura passes the winter will be materially increased. A single record of hibernation was noted in a chrysalid of *Pontia rapae* that was kept inside during the winter, the Compsilura emerging January 18, 1915. While it would seem that this host is ideal for the hibernation of Compsilura, in no other case has the parasite been recorded as passing the winter in it, although several thousand chrysalids of *Pontia rapae* have been collected from localities where Compsilura has been recovered in the fall and placed in hibernating quarters.

Attempts which have been made to carry Compsilura through the winter in the adult and pupa stages, under laboratory conditions, have proved unsuccessful. In the early fall of 1916 a number of puparia were divided into two lots, one of which was placed in an ordinary glass vial and the other in a box of leaf mold and loam. Both lots were then put in an ice chest where the temperature varied from 40° to 42° F., and where the humidity was high and constant. A month later some of the puparia were taken from the vial and opened, disclosing well-developed, healthy nymphs. A few were opened from time to time until November 15, when the last were found dead. The last puparia found alive had been confined in the ice chest for 49 days, and it would appear that under natural conditions the puparia might hibernate, although attempts made in this direction have failed.

In Bulletin 91 of the Bureau of Entomology, published in 1910, is found the only plausible explanation of the failure of Compsilura to hibernate within the overwintering brown-tail moth larvæ. On pages 219 and 220 is the following paragraph:

> Larvæ, which are almost certainly *Compsilura concinnata*, have been occasionally found in living brown-tail moth caterpillars during the winter months. It is presumed if these larvæ were able to mature under these circumstances, that they would have been reared before now from some among the hundreds of thousands of brown-tail caterpillars which have been carried through their first three or four spring stages in the laboratory. None having been reared under these circumstances, the only logical conclusion is that they start into activity so early and develop so rapidly as to cause the death of the host before they are sufficiently advanced to pupate successfully.

This, no doubt, is true, for the writer conducted experiments under ideal conditions for the hibernation of Compsilura, if this were possible, in hibernating brown-tail moth larvæ. From several places where Compsilura was prevalent during the summers of 1914 and 1915, hibernating webs of brown-tail moth larvæ were collected during the following fall and spring, and when the season began they were placed in feeding trays which were kept covered with fine mosquito screening. These were fed until the hosts pupated, and although this experiment was repeated for two years, the trays being carefully examined at least once a week during the time of feeding, no Compsilura were secured.

The results of these experiments substantiate the statement referred to in the foregoing bulletin, that it is impossible for Compsilura larvæ to hibernate in overwintering brown-tail moth larvæ. Dissections during the fall of 1915 showed conclusively that Compsilura attacks the young brown-tail moth larvæ and will live through part of the first larval instar in this host, but that the small size of the host prevents the parasite larva from maturing sufficiently to pupate.

SECONDARY PARASITISM.

Secondary parasites of Compsilura play an important part in the spread and effectiveness of the tachinid parasite. These secondaries attack the Compsilura maggot immediately following its emergence from the host, or the fresh puparia, and before it has hardened. From no puparia secured from beneath the surface of the soil have secondary parasites emerged, only those found above ground being attacked. During the seasons of 1915 and 1916 1,164 Compsilura puparia were collected in various parts of New England over the entire area covered by this parasite, and from 10.31 per cent of them secondary parasites issued.

SUPERPARASITISM.

To ascertain the effectiveness of Compsilura, a series of experiments was conducted from 1912 to 1916, with gipsy-moth larvæ collected on the border towns of Compsilura dispersion for the years 1909 to 1913, five towns being selected in which the parasites were first recovered in the five-year period mentioned. These border towns have furnished the host material each year for the last four years, and the collections yielded an average parasitism of 10.21 per cent. These results were secured by making collections of from 10 to 20 fifth-stage gipsy-moth larvæ and feeding them singly, either in small trays or in screened boxes, care being exercised to safeguard them from any parasitism after reaching the laboratory.

It was from these same experiments that the highest parasitism by Compsilura was gained, and in several cases three puparia were secured from a single host larva. Data were also obtained from the foregoing experiments on the effect of wilt on Compsilura parasitism. If the parasite larva is ready to molt into the last larval instar, although the death of the host occurs from wilt, it will not prevent further development of the parasite larva, but pupation will be accelerated. The larva can not remain in its tracheal funnel after the body contents of the host become flaccid, but it will be seen moving slowly about, and will emerge from two to five days after the death of the host.

Similar experiments were conducted during the years 1915 and 1916 with brown-tail moth larvæ, treated in the same manner as were the gipsy-moth larvæ, with the average result of two parasites per larva, at times as many as four puparia being secured from one host.

SUPERNUMERARY PARASITISM.

The fight for ascendancy between some of the tachinid and hymenopterous parasites is well illustrated by a study of Compsilura parasitizing brown-tail moth larvæ. When two internal feeding parasites of different orders occur in a single host larva and complete that part of their existence which is passed within the host, parasitism is described as "supernumerary." This is illustrated by Compsilura and *Meteorus versicolor* Vier. in their occurrence in brown-tail moth larvæ. It was noted, in an experiment where brown-tail moth larvæ were isolated and fed in single boxes, that *Meteorus versicolor* was present to quite an appreciable extent. The hosts did not die immediately after emergence of this hymenopterous parasite, and in from two to four days, in some cases, Compsilura would emerge. In no case were any Compsilura secured previous to emergence of Meteorus.

ECONOMIC IMPORTANCE.

The white-marked tussock moth, *Hemerocampa leucostigma*, which a few years ago was a serious pest in many localities in New England, has practically disappeared since Compsilura was established. The saturniid *Callosamia promethea*, which in past years was very common in the area covered by Compsilura, is now quite rare. While the cabbage worm, *Pontia rapae*, is still a serious pest, its numbers have been materially lessened in some sections, Compsilura, no doubt, playing an important part in this decrease. The celery worm, *Papilio polyxenes*, is not so common now as it was previous to the importation of Compsilura. The fall webworm, *Hyphantria cunea*, which could be found in eastern Massachusetts in large numbers in 1910, is scarcely noticed now. The writer does not claim that Compsilura is the sole cause of the disappearance of these pests, but this parasite has been reared from all of them, and it is significant that the decrease has occurred since the advent of Compsilura. Outside of the area in which this parasite occurs, many of these caterpillars will be found in considerable abundance. The gipsy moth and brown-tail moth infestation has been materially lessened in sections where this parasite has been firmly established for some time, but spraying, hand-suppression work, and the effects of predacious enemies, disease, and other parasites have all had their parts to play in causing the decrease, not only of the gipsy moth and the brown-tail moth, but of other native pests as well.

From the foregoing it will be seen that *Compsilura concinnata* is the most important tachinid parasite brought into this country for combatting the gipsy moth and the brown-tail moth, and that it attacks both freely. Judging from its increasing list of native hosts in the United States, it bids fair to become one of the most important economic parasites in this country. Compsilura has been established in the United States only 10 years, and during that time it has been recorded from a large number of native hosts, and no doubt this host list is much longer than is known at the present time.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 767

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief.

Washington, D. C. **PROFESSIONAL PAPER** **April 28, 1919**

OAK-LEAF POISONING OF DOMESTIC ANIMALS.

By C. Dwight Marsh, Physiologist in Charge of Poisonous-Plant Investigations, A. B. Clawson, Physiologist, and Hadleigh Marsh, Veterinary Inspector, Bureau of Animal Industry.

CONTENTS.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

Although the literature on poisoning by acorns is extensive, publications on poisoning by oak leaves are comparatively few. The earliest recorded statement regarding the injurious properties of oak leaves is by Mascal, 1662, page 243,[1] who says "Again oak leaves, if sheep eat thereof green, it is evil for them, especially for young lambs, which will kill them; and likewise of other cattel."

Apparently there was no other reference to this subject until 1893, when Cornevin treats of it quite fully. As this is the only extended account in the literature and as his work is not common in libraries, his statement is quoted in full (by translation) as follows:

There are no less than 300 species of the genus Quercus. For our purpose we consider only one, the most common. Moreover what is said about this will apply to the others.

Quercus robur, L. (Chène rouvre).—According to many botanists we should unite under this Linnean species the two varieties *Q. pedunculata* Thrh. and *Q. sessiflora* Smith as well as the forms derived from them, especially *Q. Cerris* and *Q. pubescens* Wills.

[1] For complete titles of works cited see list of literature on page 36.

The oak is so common that it is unnecessary to give a botanical description in this place. We may recall the fact that the fruit at its base is placed in a cup, which is pedunculated in the variety under consideration, but sessile in *Q. sessiflora*, while the opposite condition exists in the leaves of the two forms.

Independently of the wood and the tan bark which it furnishes for manufacture and fuel, the oak annually provides for the food of animals its acorns, and, in some regions, its leaves.

It is to the leaves exclusively that it is necessary to call attention; they occasion in the live stock which consume them, under some special conditions, accidents of serious importance.

In the early spring in the low country, and a little later in the plateaux, when the buds of the trees of our forests are opening and the young leaves have still the light-green color which tints the country so beautifully in the spring, it happens that the farmers whose supplies of forage are exhausted pasture their animals in the forests. This is the custom of the inhabitants of the forests, of the charcoal burners, of the woodmen who work the cuttings, and is frequently a necessity for the small farmers of the wooded country. The cattle, for a long time accustomed to dry feed and finding little grass on the soil of the forest, eagerly eat the fresh twigs and young leaves upon them. If they are grazing in a thick coppice, their eagerness has no limit at first.

After some days of this feeding, there appears, at first only on young animals, and especially it has been noticed on those with a thin skin and white hair, then later in the milch cows and the rest of the herd, the symptoms of a disease observed and described for a long time under the characteristic name of "mal de brou" or of "maladie des bois." In the South it has been observed following grazing in lands where different shrubs grow, and especially the Spanish broom (Genêt D'Espagne) whence it is commonly called genestade.

Symptoms.—The animals, with a full appetite at first, eat less and less, they ruminate only a little, and apparently with difficulty; they are eventually affected with constipation, which increases and their excrement becomes hard and coated. They remain a long time lying down, and from time to time look at their flanks as in cases of dull colic, then get up and urinate. The liquid is emitted in jets and is then of a dark-red color. The secretion of milk in the females is lessened and eventually fails entirely. There is some fever, trembling of the muscles, and weakness of the hind legs, the coat is rough, the dorsolumbar region more sensitive than normal, the mouth cold, and the saliva reduced.

Three or four days after the onset of the disease the rumination is completely stopped, the patients stamp, exhibit colic, and have the abdomen drawn up; the pulse is hard, the heart action agitated, the respiration accelerated and labored, the shaking of the muscles violent, and they attempt to urinate frequently.

Always a striking symptom is the color of the urine; it is constantly dark, but with variations of shade which pass from a clear red to the deep dark color of Malaga wine, with the brown shade predominating.

If the animal is withdrawn from the cause of its illness and receives the necessary care for its condition it will most generally recover.

The prognosis is bad when the constipation is succeeded by a foamy dysentery with very fetid and abundant feces. Then the patients very quickly become feeble, and die in a condition of marasmus.

In the great majority of cases the "mal de brou" does not make rapid progress; nevertheless, there occurs, exceptionally, a kind of sudden explosion of illness. There is a sudden and abundant expulsion of bloody urine with violent colic and sometimes intestinal hemorrhage; under these conditions the patients have succumbed in 24 hours.

Lesions.—They are those of gastroenteritis and of nephrocystitis. The first are generally closely related to the intensity and progress of the disease. The second are more accentuated. The kidneys are doubled or tripled in volume, show ecchymotic spots on their surface, hemorrhagic foci in their parenchyma, inflammation of the pelvis and the destruction of the uriniferous tubules or their obstruction by fibrinous coagulum. The bladder is almost always turned back upon itself and is nearly empty or contains a small quantity of dark urine; the mucous membrane is inflamed.

The study of the urine, which is the more interesting part in the history of hematuria, has been much neglected up to the last years. Only the most evident physical characters have been noted, and there has been established only one essential point, the presence of or absence of blood corpuscles in the urine. Stockfleth denies their existence in this liquid, while most French authors admit it. M. A. Robin has made a thorough study of the urology, and we can not do better than to quote a résumé of his observations.

"The urine is viscous, with alkaline reaction, with an ox-house odor, rich in sediment formed largely of coagulated albuminoid matter and tinted brown. The blood corpuscles are rare, but one finds crystals of urate of ammonia, a very little carbonate of calcium, some drops of oil, some leucocytes, no oxalate of calcium, a little urea in a normal condition, a considerable diminution of the hippurates and a notable increase of the chlorids, a little phosphoric acid, albumen in considerable quantity and also some urohematin and hemoglobin. No trace of sugar."

From his analysis, M. Robin concludes that during the course of the disease "the organism loses heavily in urea and especially in the chlorids, losses which become more evident as the animals eat less, that the uric acid replaces the hippuric, the urine of the sick animals approaching temporarily the condition of that in carnivores; that the salts of calcium diminish in the liquid and disappear in the sediment; that the free oil and the casts increase and appear in connection with the defervescence; lastly that the affection appears to be a hemoglobinuria rather than a true hematuria."

What is the substance producing this hemoglobinuria? It must be found in the young shoots and new leaves of the oak, but it is to be noticed that those of the hornbeam, ash, alder, hazel, privet, cornel, spruce, pitch fir, gorze, and broom under the same conditions are capable of producing similar results. All these shoots and leaves are rich in tannin, and investigators have been led to consider this body as the one producing the harm. We will discuss this opinion.

To sustain it, it can be argued that the tannin is in much larger proportion in the accused plants, and especially in the oak in the spring than in the winter, and that it is more abundant in the young oaks than in the old since in the latter the tannin is transformed to gallic acid and then little by little into brown extractives.

It is learned that the content of tannin in the plants containing tannin has relation to the physiological activity of the tissues in such a way that its maximum is found in the young organs, like the sprouts, young branches, and the first leaves, the forming tissues, the cambium and the phellogen.

Does it follow that it is a greater introduction of tannin into the economy which occasions the "mal de brou?" I do not think so. As a matter of fact animals are given food which is just as rich in tannin and which, nevertheless, occasions no accidents in spite of the continuance of such treatment. We may mention the acorns which in the wooded districts, in France and elsewhere, are given to all animals, horses, fattening animals, and swine, without ever bringing on hematuria, but with excellent results. The leaves of the vine are, among foliaceous organs, especially rich in tannin—from time immemorial these have been collected and preserved in silos as food for animals in winter. Who has ever known the "mal de brou" to follow their consumption? In the Scandinavian country, in the north of Russia and of Asia, especially among the Baskir tribes, they use the bark of the birch, pine, spruce, elm, wild cherry, linden and willow, having an equal content of tannin, for feeding the animals during the winter, and no inconvenience or accident results.

The experiments, partly with tannin, partly with tannic acid made by the pharmacologists, no more prove the harmfulness of these substances or the production of hemoglobinuria. Gohier has performed in this line an experiment often quoted. He fed large quantities of oak bark to horses, which came out with good results; he proved an arrest of digestion with obstinate constipation, but without hematuria. Their blood, far from having a tendency to lose its hemoglobin, became more red, more coagulable, and much slower in putrefying.

Moreover the therapeutic investigations made with tannic acid employed as pure as possible have not disclosed hematuria following its use for a long time.

Finally we may add that the consumption of the leaves of oak, ash, etc., in summer, autumn, and winter at a time when they contain a much smaller proportion of tannin than in the spring, it is true, but still in large quantity, does not bring on the "maladie des bois." In the mountain region of the southeast and center, especially in the high and low Alps, the Lozère, the Ardèche, the Haute-Loire, the Rhône, etc., they cut in autumn the leafy branches of the oak growing from the pollards, and with these they feed the sheep for a long time without accident.

If the tannin of the bark, fruit, and leaves of summer and autumn can not be blamed, two hypotheses are presented; there may exist in the young leaves along with the tannin an ephemeral poisonous substance, which soon disappears, or the tannin itself may come into a special condition which may give it the harmful properties which have been described.

The first hypothesis is hardly tenable for it would be very singular if this poison should have, up to the present time, escaped the notice of the chemists and botanists, who have studied tannin so thoroughly. We can not deny it absolutely, for we can not pledge the future, and can not foresee what may ultimately be discovered, but we expect the facts will support this belief.

Let us look at the second. It is admitted nowadays that plants hold the tannin under the form of a polygallic glucoside which is easily changed. The varieties of this are many, following the plant species which furnish them. It is probable that in the same species many of these varieties, derived one from the other, appear and disappear to make way finally for the specific variety. It will be very desirable that the chemists should study this point, commencing their analyses with the opening of spring. The check of its plant histology should not be neglected. We possess, actually, many good reagents which can furnish useful information: the perchlorid which colors green or blue, according to the character of the tannin; the bichromate of potassium which forms a compact reddish-brown compound and the solution of molybdate of ammonia in a concentrated solution of chlorhydrate of ammonia, which colors the tannin red and has the advantage of making it possible to distinguish the glucosides of tannin from the tannic acid, for an excess of the chlorhydrate of ammonia produces in the first voluminous precipitate, while the last remains colored red.

These varieties of tannin, very changeable as has been said, may suffer modifications in the plant economy and furnish sometimes acids, sometimes special bodies like pyrocatechin.

Now, some very interesting investigations of M. C. Hayem have shown that the blood of animals submitted to the action of pyrogallic acid and pyrocatechin shows special modifications. The blood corpuscles are attacked and a certain proportion of hemoglobin extravasated. There is a formation of methemoglobin at the same time in the red corpuscles and in the plasma and more or less intense degeneration of the corpuscles. On the other side it has been established that in hematuric fever and in paroxysmal hemoglobinuria, the urine contains methemoglobin.

Do not all these ideas combine to make us admit the possibility of a particular state of the tannin in the young tissues and the modification of this tannin in the animal economy?

However this may be, the farmer should see from this and what precedes that if feeding with gathered leaves in the summer and in autumn raises no objection because it brings no inconvenient consequences, it is not the same when the collection is made in the beginning of spring and contains shoots and very young leaves. The better way will be not to subject the animals to it.

Before closing we should say that the employment of sawdust of oak wood as a litter is not to be recommended. It furnishes an acid manure that can only be usefully employed after being corrected by phosphates. This litter is also accused of attacking in time the udders of milch cows and of occasioning inflammations.

Harting, 1901, says that goats eat oak twigs without injury, but deer and cows are fatally poisoned.

Mackie, 1903, published a paper on the value of oak leaves for forage. He gives chemical analyses of a number of species and discusses their comparative value as forage. His general conclusion is that the oaks have a fairly high nutritive value, deciduous species being better than the live oaks. He does not intimate that the leaves have any poisonous properties.

In the Breeder's Gazette of September 1, 1909, page 362, occurs the following short article:

OAK LEAF KILLS CATTLE.

Stockmen grazing cattle in the national forests in the southwest, especially in Colorado and New Mexico, have suffered serious losses during the present summer through the cattle eating oak leaves. In that section of the country the season has been unusually dry and grass extremely scarce. To eke out the scanty forage supply the cattle have browsed on the scrub oak which covers large portions of the range. Ordinarily the stock does not browse much on the oak and the little they do get, taken with the other food, is not injurious, but when, as in the present season, the oak browse furnishes a large proportion of the daily food of the cattle, the results are serious.

The oak leaves and sprouts contain a large percentage of tannic acid. The action of this acid on the stomach is extremely injurious and the losses have been unusually severe. The symptoms of the disease are staring eyes, feverish and blistered lips and nose, the animal ceases to graze or seek for food, standing in one place for hours at a time. The coat becomes rough and the hair is all turned the wrong way, as in cases of loco poisoning. The animal does not chew its cud and in a comparatively short time it becomes too weak to remain on its feet and death rapidly follows. So far as is known the only remedy available for this trouble is linseed oil given as a drench in amounts from 1 to 2 quarts. The oil appears to overcome the injurious effects of the tannic acid, and if the disease is not advanced too far and the animal can be furnished sufficient food so it will not be forced to eat the oak, it will generally recover. The best method, of course, in handling the trouble is, if possible, to get the cattle away from the range where the oak is found and furnish them with plenty of fresh green feed to build up again.

Lander, 1912, page 270, makes a brief statement which is evidently based on Cornevin.

Barnes, 1913, pages 268 and 278, treats of the subject, making practically the same statements which were made earlier in the Breeder's Gazette.

Glover and Robbins, 1915, page 25, speak of the subject as follows:

> Scrub oak is considered poisonous by many stockmen. They will take the pains to keep their stock from the oak thicket. It is very likely that most cases of poisoning resulting from cattle grazing in scrub-oak thickets are due to larkspur which grows therein.

The foregoing covers all the literature that has been found on the subject of poisoning by oak leaves. It may be noted that the bibliography is surprisingly small, and that even the somewhat extended account of Cornevin contains much theoretical matter and is not supported by experimental evidence.

POISONING BY OAK LEAVES IN NORTH AMERICA.

Throughout the grazing region of the West there is a very general belief in the poisonous properties of oak leaves, more particularly with regard to their supposed toxic properties for cattle. Heavy losses are said to have been caused in certain localities, and many inquiries have been addressed to the Department of Agriculture for information concerning the disease and its treatment. In connection with the investigations of poisonous plants and their effects there has been an attempt to collect all available information on the subject, and feeding experiments have been carried on during four summers.

As has already been indicated, the published statements with regard to poisoning by oak leaves in America are very few. The Department of Agriculture, however, has received by correspondence considerable information on the subject which may be summarized as follows:

Localities of supposed poisoning.—The States from which most of the complaints have come are Colorado, Utah, New Mexico, and Texas. Many of the reports have come through forest supervisors, the following national forests being represented: San Isabel, Las Animas, Nebo, Fillmore, La Sal, Wasatch, Manti, and Fishlake. It may be noted that the Utah national forests are largely represented, and more detailed complaints have come from that State than from the others.

Species supposed to be poisonous.—Of course, the reports ordinarily do not connect the disease with any one species. It is evident, however, from our knowledge of the local flora in the places from which the complaints come, that most of the trouble is ascribed to two species, *Quercus gambellii* Nutt. and *Q. havardi* Ryd. The latter species is popularly known in Texas and New Mexico as the "shinnery" oak, and the plant is said to "shinnery" cattle.

Season when poisoning occurs.—While many of the reports are indefinite as to whether poisoning is more likely to occur at particular seasons of the year, there is a general agreement that most cases occur in the spring. Some say that all cases are in the spring. Most observers say that the harmful effects are produced by eating the buds and young leaves. Some say that these are most harmful after being frosted. It has been noted by many that cattle in poor condition in the spring of the year are most liable to be affected, and that if well fed they are not harmed.

Symptoms.—The symptoms described by Cornevin included loss of appetite, cessation of rumination and lactation, fever, trembling of muscles, dark-red urine, and constipation followed by dysentery; the autopsies showed gastroenteritis and acute nephritis.

The reports from supposed oak-brush poisoning in the United States do not agree very closely with Cornevin's description. Barnes, 1913, gives the prominent symptoms as fever, scabby sore nose, deep-set eyes, hair turned the wrong way, difficult breathing, and contents of stomach compacted, the material being dry and burned.

From the reports of different stockmen may be added as characteristic symptoms, constipation, dark or bloody feces, and emaciation; it is said by some that an examination of the stomach contents shows masses of oak leaves, and that the material in the third stomach is dry and hard. Some of the cases are said to be acute but many linger along for weeks and months.

Animals poisoned.—The principal complaint is of cattle, although sheep have been reported as affected by oak. It may be noted that the European authors, Cornevin more particularly, apparently consider cattle the principal sufferers, though sheep and deer are mentioned. Harting says that goats are not injured.

EXPERIMENTAL WORK WITH SCRUB OAK.

A considerable number of so-called oak-brush cases have been seen upon the range in Utah and Texas. These animals exhibit the common symptoms of emaciation, sunken eyes, weakness, and bloody feces. Autopsies have shown a gastroenteritis and sometimes a pathological condition of the liver which might be explained by parasitism. The temperature in observed cases was subnormal rather than one indicating fever. The general condition of the animals closely resembled that exhibited by locoed animals. This condition in Utah is known as "summer sickness" as well as "oak-brush poisoning."

During four summers, 1915, 1916, 1917, and 1918, feeding experiments were conducted with cattle at the Salina experiment station, Utah, to determine whether feeding upon oak leaves is harmful. All these experiments were with the scrub oak of Utah, *Quercus gambellii.*

The table following gives a summarized statement of the feeding experiments:

Summary of four years' feeding experiments of cattle with scrub oak (Quercus gambellii) at Salina Experiment Station, Utah, 1915 to 1918.

Cattle No.	Weight of animal	Date of feeding.	Part of plant used.	Weight of plant fed. Total.	Weight of plant fed. Per 1,000 pounds of animal.	Number of days of feeding.	Average daily feed per 1,000 pounds of animal.	Severity of sickness.	Remedy.	Result.	Remarks.
	Pounds.	1915.		*Pounds.*	*Pounds.*	*Days.*	*Pounds.*				
674	600(?)	June 23 to 25	Leaves	27	45(?)	3	15?	Not sick	None		
692	300(?)	June 23 to July 2.	Leaves and twigs	104.5	348(?)	10	34.8	Became thin and weak	do	Recovery	Refused to eat oak just before turned out.
674		June 27 to 30	Leaves			4		Not sick	do		
676		July 4 to Aug. 24.	do			52		Constipation	do	Recovery	On 2 days received about 10 pounds of weighed leaves.
679		do	do			52		do	do	do	Do.
685		Aug. 24 to Sept. 20.	do			28		do	do	do	
691		do	do			28		do	do	do	
		1916.									
712	432 to 466	May 31 to June 16.	Twigs and buds	211.25	489	17	28.8	do	do	do	Fed alfalfa hay June 1, 6, 8, 10, and 16.
712	466 to 486	June 17 to 19	Small leaves	36.75	78.8	3	26.3	do	do	do	Fed alfalfa hay June 18 and 19.
702	448 to 502	June 7 to 16	Twigs and buds	133	296.9	10	29.69	Constipation, bloody feces.	do	do	Fed 2½ to 3½ pounds alfalfa hay June 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19.
702	500	June 17 to 19	Small leaves	33.5	67	3	22.3	do	do	do	
732	520 to 465	June 21 to 27	Leaves			7		Loss of weight			Ate very little.
715	360 to 332	do	do			7		Not sick			Do.
703	636 to 614	June 21 to Aug. 4	do			45		Constipation			In pasture 8 times.
704	662 to 615	June 28 to Aug. 4	do			38		do			In pasture 8 times; fed alfalfa hay once.
731	539 to 580	June 28 to Sept. 9	do			74		Constipation, bloody feces.	None	Recovery	From Aug. 11 fed daily 3 pounds alfalfa hay; in pasture 8 times.
722	506 to 538	Aug. 5 to Sept. 9.	do			36		Not sick			From Aug. 11 fed daily 3 pounds alfalfa hay.
723	493 to 580	Aug. 5 to Sept. 17	do			44		do			Do.
703	812 to 812	Sept. 10 to 17	do			8		do			Fed daily 3 pounds alfalfa hay.
704	760 to 765	do	do			8		do			Do.
		1917.									
758	435 to 482	June 11 to July 26.	Buds, leaves, and flowers.			46		Mucus in feces	None	Recovery	

770	372 to 377	June 11 to July 19.	....do			39		Constipation, feces with mucus and blood.	Linseed oil	Death	
772	456 to 396	July 10 to 22	Leaves			13		....do	None	....do	
765	426 to 350	July 10 to 26	....do			17		Constipation, bloody feces, loss of weight.	....do	Recovery	
751	438 to 472	Aug. 2 to Sept. 9	....do			39		Not sick			Fed daily 3 pounds of alfalfa hay.
760	374 to 409	....do	....do			39		....do			Do.
		1918.									
760	540 to 590	June 5 to July 4	Buds, leaves, and flowers.			30		....do			Do.
763	482 to 552	....do	....do			30		....do			Do.
808	622 to 604	July 11 to 24	Leaves			14		Feces, with mucus and blood.	Epsom salt	Recovery	Recovery not due to the remedy.
814	354 to 347	July 12 to 24	....do			13		Bloody feces, dry nose.	....do	....do	Do.
761	758 to 718	Aug. 15 to Sept. 10	....do			27		Constipation, bloody feces.	None	....do	

EXPERIMENTAL FEEDING OF CATTLE IN 1915.

In 1915 oak leaves were fed to seven head of cattle. To two of these, Nos. 674 and 692, weighed amounts of the leaves were fed. Unfortunately there were no facilities at the experiment station at that time for weighing the cattle, so that the weights of the animals were estimated and the ratios of the quantity fed to the weights of the animals are only approximate.

Cattle No. 674 received from June 23 to June 25, 27 pounds of leaves with no effect. This was probably in the ratio of about 15 pounds daily to 1,000 pounds of animal.

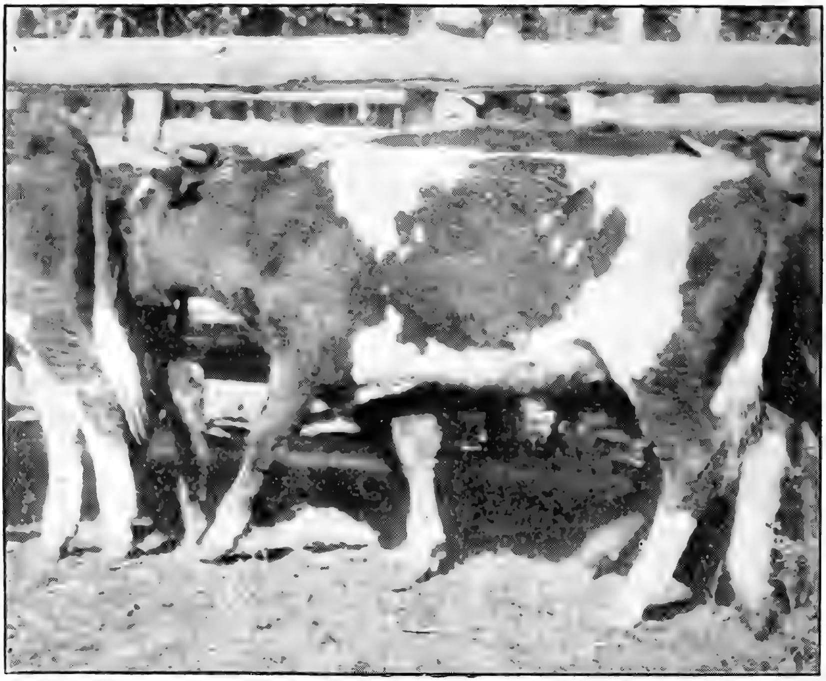

FIG. 1.—Cattle No, 676. June 20, 1915, to which oak leaves were fed experimentally.

Cattle No. 692, commencing with June 23, was fed leaves and twigs for 10 days, receiving a total of 104.5 pounds. This was probably not far from 35 pounds daily to 1,000 pounds of live weight. The animal lost flesh and remained thin and weak after being turned out in the pasture.

Five cattle, Nos. 674, 676, 679, 685, 691, received oak-brush leaves, the branches being thrown into the corrals and the animals picking off the leaves. This method was used partly to avoid the labor of gathering the leaves for feeding, but more particularly because in this way the animals ate a larger quantity. In this way, too, there was an approach to the natural conditions of grazing. The animals were fed on oak leaves exclusively and for periods varying from 4 days in the case of No. 674 to 52 days in the cases of Nos. 676 and 679. Inasmuch as the cattle could not be weighed the records do not show exactly the effect of the feeding on the weights. It was evident, however, that all lost in flesh. This might be expected even if the oak had no injurious properties, for it does not have the nutritive value of the grasses, and then the cattle would not do so well on any one form of forage as they would if their feed offered some variety. All were somewhat constipated but showed no other undesirable symptoms; this constipation was not a serious matter

FIG. 2.—Cattle No. 676, August 24, 1915, to which oak leaves were fed experimentally.

and while the animals lost some flesh, all presented a fair appearance at the close of the experiment. The photographs of the two animals, Nos. 676 and 679, figures 1, 2, 3, and 4, taken June 20 and August 24, show that they did not suffer materially from the experiment.

The results of the cattle feeding in 1915 left the whole subject in much doubt. Some of the cattle were constipated and did not thrive, but this in part might be explained away. It seemed clear that feeding on oak browse might be continued for a considerable period without necessarily producing injurious results but that possibly in some cases more or less injury might follow.

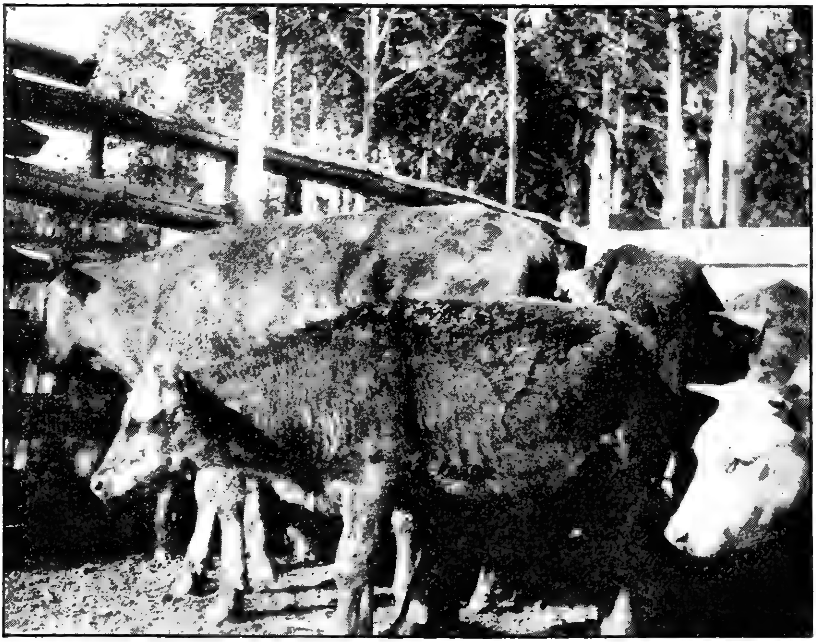

FIG. 3.—Cattle No. 679, June 20, 1915, to which oak leaves were fed experimentally.

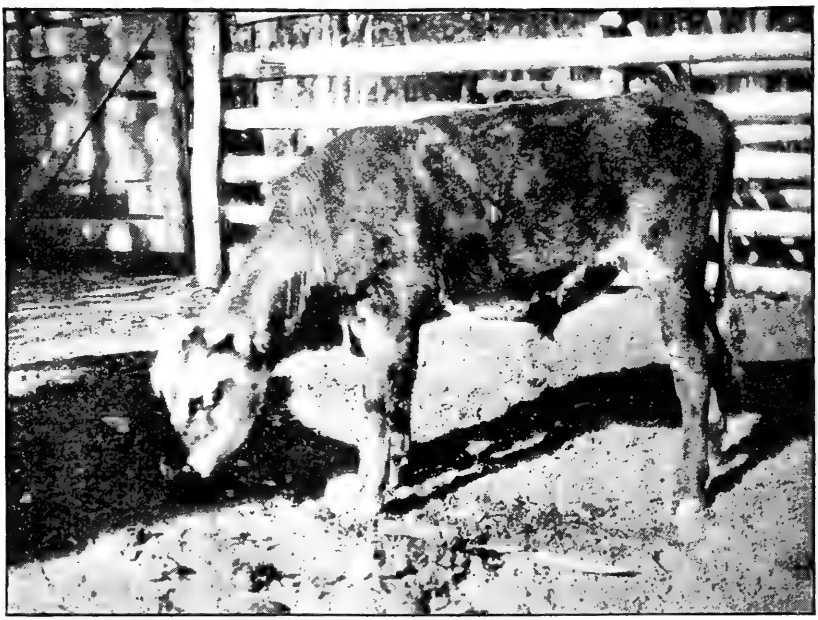

FIG. 4.—Cattle No. 679, August 24, 1915, to which oak leaves were fed experimentally.

EXPERIMENTAL FEEDING OF SHEEP IN 1915.

An attempt was made to feed four sheep, but three refused to eat the oak. The experiment was continued with one, No. 327, for 30 days. This one received an average of 2 pounds daily per hundredweight of animal. The oak was fed with chopped hay one day at the beginning of the experiment, but with this exception it received oak leaves exclusively. Its weight fell from 74.5 pounds to 66.5 pounds, but no other bad effect was noted.

EXPERIMENTAL FEEDING OF CATTLE IN 1916.

Two experiments on the feeding of buds and twigs were conducted with cattle Nos. 702 and 712. No. 702 received buds and twigs from June 7 to June 16, and small leaves from June 17 to June 19. No. 712 received buds and twigs from May 31 to June 16 and small leaves from June 17 to June 19. Both animals were treated in the same way, the only difference being that No. 712 was fed for a longer time. During the experiment they were kept in the corrals and were fed exclusively upon the oak, except that on 12 days each was given 3 pounds of alfalfa hay daily.

Careful clinical observations were made, the temperature and pulse being taken at stated times three or four times daily, and they were weighed frequently. The temperature and pulse showed no deviations from what might be expected in normal animals and followed a strikingly regular rhythm from day to day. The increase in weight was continuous. No. 702 weighed at the beginning of the experiment 448 pounds, and at the end 502 pounds. No. 712 during the same time, from June 7 to June 19, increased from 432 pounds to 486 pounds. Reduced to percentages of the original weight, No. 702 gained 12 per cent and No. 712, 12.5 per cent.

It is interesting to compare these gains with those of 23 other animals which were kept on pasture during the same period and which were weighed June 7 and June 22, thus covering nearly the same time as Nos. 702 and 712. The gain in these animals varied from 10.68 per cent to 25 per cent. One other animal that was in pasture was weighed June 7 and June 19 and had lost 8.4 per cent. The average gain of the 24 animals in pasture was 15.64 per cent. While the experiment animals Nos. 702 and 712 gained as much as the minimum of those on pasture, they did not come up to the average and it is probably fair to presume that they would have done better in pasture, yet this is by no means certain, as only two animals are concerned and it is possible that they would have fallen into the number of those with comparatively small gains. Moreover, this deflection from the average is not enough to indicate any serious effect on the cattle feeding upon oak. Figures 5 and 6 show the weight curves of Nos. 702 and 712. Both animals were constipated and once bloody feces were noticed in No. 702. No other symptoms were noted.

Six other cattle were fed on oak-brush leaves during the summer of 1916, the feeding being conducted, as in 1915, by throwing freshly cut oak brush into the corrals, where the animals picked off the leaves.

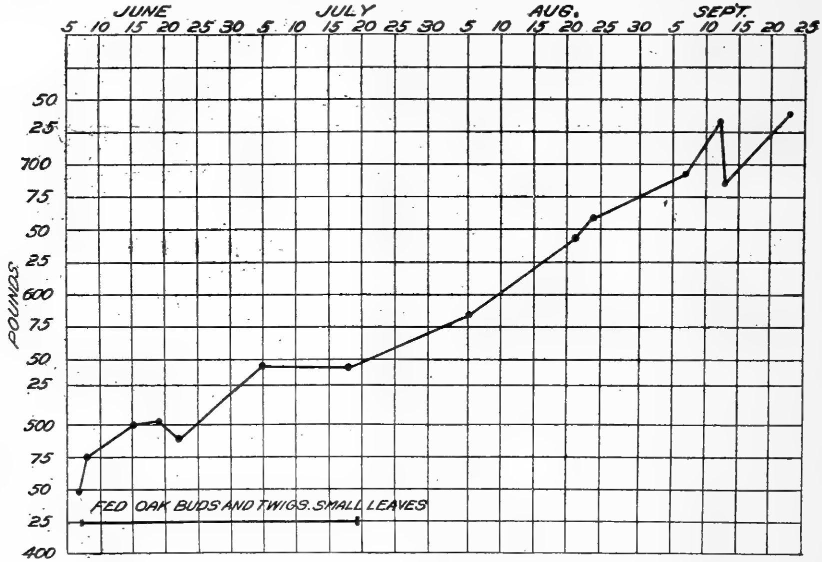

FIG. 5.—Weight curve of cattle No. 702, fed with 3 pounds of alfalfa hay per day from June 7 to July 19, 1916.

Nos. 715 and 732 were fed in this way from June 21 to June 27. Although nothing but oak was furnished them, both of these animals ate very little. They lost weight during the feeding, but showed no other ill effects. No. 732 did not make a normal gain during the rest of the summer, but there was no reason to think that this lack of gain was a result of the oak feeding.

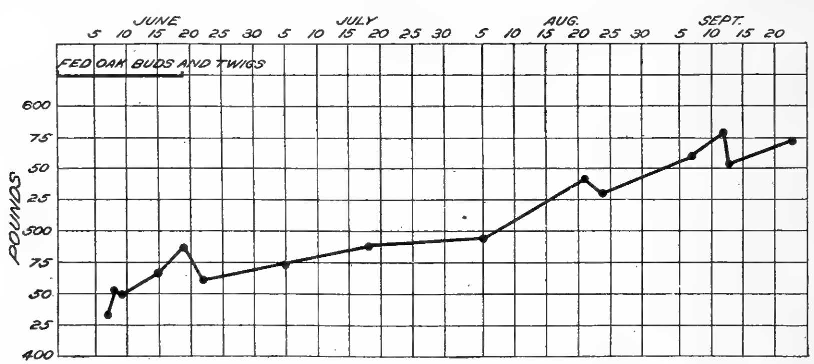

FIG. 6.—Weight curve of cattle No. 712, fed oak from May 31 to June 19, 1916, with 3 pounds of alfalfa hay per day on 12 days.

Nos. 703 and 704 received oak brush—703 from June 21 to August 4 and 704 from June 28 to August 4—and these animals were given oak brush with 3 pounds of alfalfa hay each, from September 10 to September 17. During the first period there was a loss of weight in No. 704, followed by a sharp gain. No. 703 during this period maintained its weight, on the average, and also showed a marked

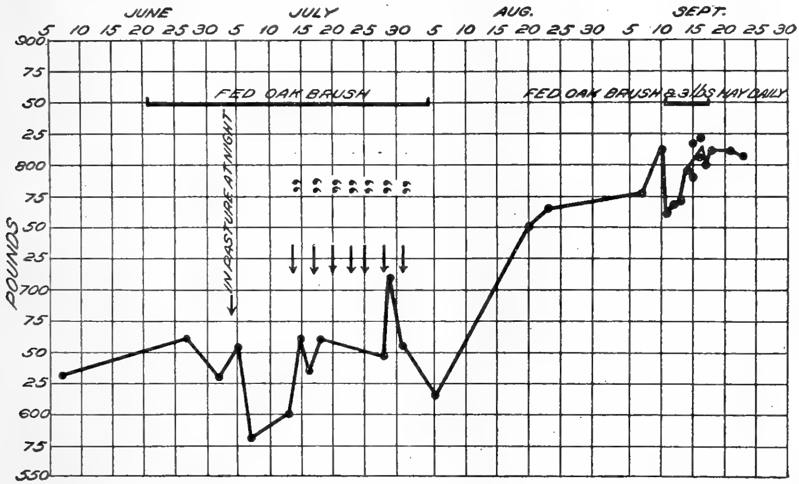

FIG. 7.—Weight curve of cattle No. 703, fed oak from June 21 to Aug. 4, 1916, and oak with alfalfa hay from Sept. 10 to 17, 1916.

gain when turned into the pasture. During the second period, when 3 pounds of alfalfa hay were given daily to each animal in addition to the oak, both animals maintained their weight. Presumably,

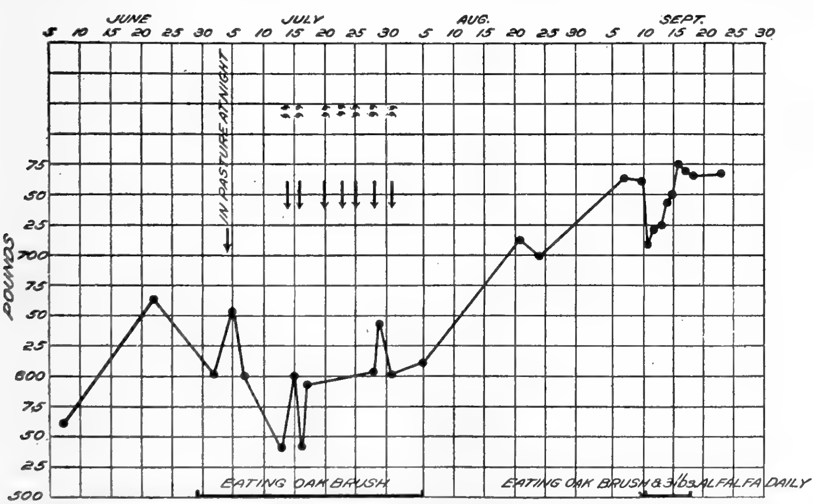

FIG. 8.—Weight curve of cattle No. 704, fed oak from June 28 to Aug. 4, 1916, and oak with alfalfa hay from Sept. 10 to 17, 1916.

judging from the recorded weights of cattle in the pasture, Nos. 703 and 704 would have made distinct gains if they had been kept in the pasture. Figures 7 and 8 show the weight curves of Nos. 703 and 704.

It may be noted that No. 704 was under observation in 1917 and made normal gains.

No. 723 received oak brush from August 5 to August 10, and from August 11 to September 13 received oak brush and 3 pounds of alfalfa hay daily. This proved to be a maintenance ration. No 723 had been gaining during the season, but during the feeding remained at a standstill, while under favorable conditions it probably would have continued to make gains.

No. 722 received oak brush from August 5 to August 10 and oak brush with a daily ration of 3 pounds of alfalfa hay from August 11 to September 9. The result was almost identical with that in the case of No. 723. In both cases, while the gain continued for some days after the oak feeding was commenced, the result of the whole period was to stop the gain.

No. 731 received oak brush from June 28 to August 10, and oak brush with a daily ration of 3 pounds of alfalfa hay from August 11 to September 9. It lost weight up to about August 5 and then made a continuous gain through the remainder of the period of feeding. No. 731 was constipated, and at one time during the feeding exhibited bloody feces.

Most of the sheep fed on oak brush were constipated, but showed no other symptoms. Moreover, the constipation was not of a serious character.

The work of 1916 modified the results of 1915 by showing definitely that feeding upon oak browse may produce constipation and bloody feces, but it could not be inferred that so-called oak-brush poisoning is a very serious matter. It also appeared that probably a daily ration of hay, in addition to the oak, would prevent ill results. It should also be noticed that all the animals fed on oak exclusively were fed for a comparatively short time.

EXPERIMENTAL FEEDING OF CATTLE IN 1917.

In 1917 six head of cattle were used in the experimental feeding. In all cases the animals were fed in the corrals, cut branches of the oak being brought in, as in 1916, and the cattle ate the buds, flowers, and leaves from the branches much as they would when grazing upon the range.

Two cattle, Nos. 758 and 770, were fed early in the season and received at first buds, flowers, and small leaves, and later the mature leaves. As the season of 1917 was late, these animals were fed as soon as the foliage had started on the oaks.

No. 758, a steer, was fed from June 11 to July 26, 46 days, having nothing but oak, until June 25 the feeding was buds, flowers, and small leaves; after that date full-grown leaves were used. On June 24 the animal was somewhat constipated and at this time and at intervals during the remainder of the feeding the feces contained more or less mucus, indicating intestinal irritation. The steer made no gain in weight during the time it was eating oak, but after being put on pasture at the termination of the experiment, July 27, gained rapidly. (Fig. 9.)

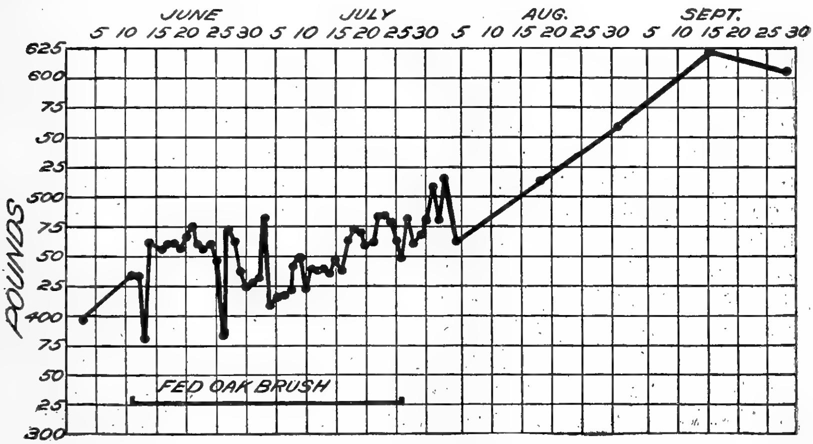

FIG. 9.—Weight curve of cattle No. 758, fed oak from June 11 to July 26, 1917.

No. 770, a steer, was fed with No. 758, having the same course of treatment. Early in the experiment the animal became much constipated, this condition being very marked by June 19. The feces contained much mucus and more or less blood. As the experiment proceeded, the animal ceased to eat freely of the oak and on

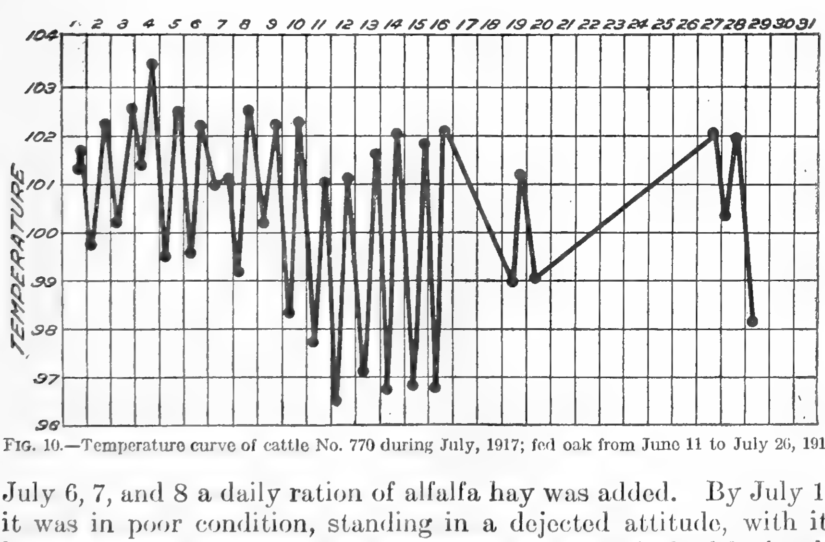

FIG. 10.—Temperature curve of cattle No. 770 during July, 1917; fed oak from June 11 to July 26, 1917.

July 6, 7, and 8 a daily ration of alfalfa hay was added. By July 13 it was in poor condition, standing in a dejected attitude, with its head extended in a position that seems to be typical of bad oak-brush cases. Much of the time it was lying down. The pulse became slow and weak and the variation between morning and afternoon temperature greater than in a normal animal, the morning temperature being very low (see fig. 10). On July 17 it was turned into pasture to graze, but was brought in again July 19 and given feedings of oak brush. July 20 it was returned to pasture and brought into the corral on July 27. At this time it was very weak and the feces were composed largely of bloody mucus. It was given 500 cubic centimeters of raw linseed oil. On July 28 its eyes were sunken, and in the afternoon its pulse became almost imperceptible. On the morning of July 29 it was lying upon its side, groaning, pulse imperceptible, breathing with difficulty, and died at 11.30 a. m.

At the autopsy deep congestion was found in the duodenum, jejunum, ileum, cecum, anterior part of the colon, and about 5 inches

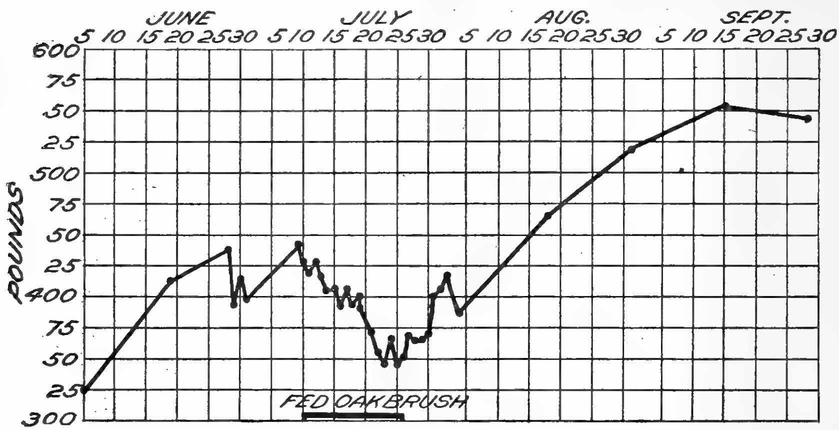

FIG. 11.—Weight curve of cattle No. 765, fed oak from July 10 to July 26, 1917.

of the rectum. In the epidermal space of the spinal column there was an excess of serous coagulum. Otherwise the organs were normal.

On July 10 feeding of oak leaves was commenced with cattle Nos. 765 and 772. These animals were kept in the corral and fed upon oak exclusively.

No. 765 was fed from July 10 to July 26. On July 21 it was noted that the feces were hard and bloody, and from this time the animal was very much constipated and showed marked depression. The coat was rough and the nose dry. From the beginning of the feeding it progressively lost weight, as shown in figure 11. There was nothing abnormal about the pulse and respiration rates. The difference between morning and afternoon temperature was rather greater than normal. July 26 it was fed some alfalfa hay with the oak, and on the next day it was kept in pasture. From this time until August 4 it was kept in pasture part of the time and part of the time fed in the corral with hay. On August 4 it was turned into pasture, where it was kept under observation until September 28. During this time it gained in weight and regained its normal condition.

No. 772, a steer, was fed with No. 765. By July 22 it had lost its appetite and was much constipated, its feces being not only hard but also containing blood and mucus. It had progressively lost weight from the beginning of the feeding. Its pulse became weak in the succeeding days, its eyes sunken, the nose dry, and the animal became very weak and was lying down most of the time. A little hay was given it, but it gradually grew worse, the feces became more liquid, and contained much blood and mucus. The pulse became indistinguishable, and it died on the morning of July 27.

At the autopsy dark, hemorrhagic areas were found on the pericardium and the surface of the heart. There was some peritoneal

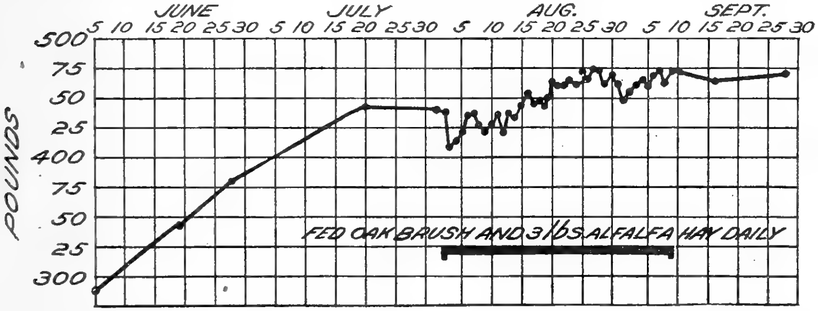

FIG. 12.—Weight curve of cattle No. 751, fed oak and 3 pounds of alfalfa hay per day from Aug. 21 to Sept. 9, 1917.

inflammation but no adhesions. Congestion was present in the duodenum, the anterior part of the jejunum, the ileum, and the rectum. The large intestine showed slight congestion. The liver appeared abnormally fibrous, the gall bladder was filled with gelatinous bile; apparently the bile was dammed up, as there was no evidence of bile in the duodenum. The history of the animal showed no marked abnormalities in the temperature or the rates of the pulse and respiration. It should be noted that this animal died after feeding upon oak only 13 days.

Two steers, Nos. 751 and 760, were fed oak leaves from August 2 to September 9. With the oak each was given 3 pounds of alfalfa hay daily. These feedings were to check up the 1916 experiments with cattle Nos. 703, 704, 722, 723, and 731, in which alfalfa hay was fed with the oak, with no resulting ill effects from the oak feeding. Figures 12 and 13 show the curves of weight of Nos. 751 and 760. It will be seen that they were practically at a standstill during the period of the experiment. No symptoms of ill effect were noted, however, other than failure to make the gain which would be expected at that time of the year.

The inference from this experiment and the one of the preceding year is that a small hay ration will prevent such ill effects as follow an exclusive diet of oak leaves. The cases of 1917 supplemented the work of the preceding years by furnishing positive evidence of the possibility of oak poisoning and in giving fairly clear pictures of the symptoms and pathology.

EXPERIMENTAL FEEDING OF CATTLE IN 1918.

The work of the three preceding years at the Salina station, with the investigations at Monahans, Tex., which are described on pages 21–29, was considered to have proved definitely the possibility of oak poisoning, showed the symptomatology and pathology, and made it probable that a comparatively small quantity of other forage would prevent the ill effects of the oak. The experiments of 1918 were intended to clear up certain matters that were still in doubt.

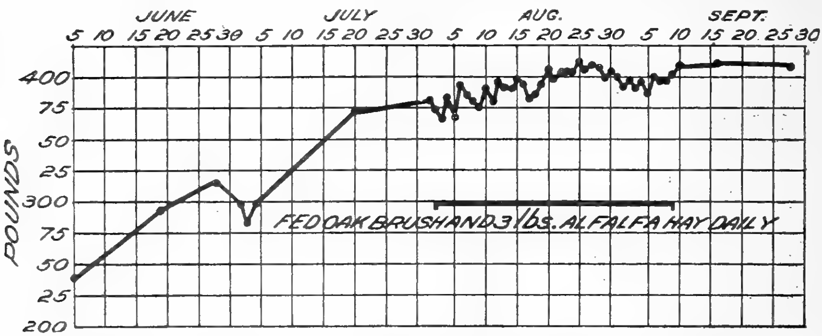

FIG. 13.—Weight curve of cattle No. 760, fed oak and 3 pounds of alfalfa hay per day from Aug. 2 to Sept. 8, 1917.

EPSOM SALT AS A REMEDY.

From the fact that oak-poisoned animals are constipated it was thought possible that treatment which would relieve this condition might prevent the illness. Cattle Nos. 808 and 814 were fed upon oak leaves in the corrals from July 12 to July 24 and each was drenched twice daily with 2 ounces of epsom salt. This remedy kept the bowels in a loose condition, but both animals exhibited blood and mucus in the feces, and showed other distinct symptoms of poisoning. It was evident from this that constipation was not the main factor in oak-brush poisoning.

POSSIBLE LOSS OF TOXICITY IN MATURE LEAVES.

The positive cases of the preceding years had been produced early in the season, and it is generally believed among stockmen that it is the young leaves and buds that produce poisoning. Moreover the experiments of feeding hay with the oak, which resulted in the continued well being of the animals, were carried on late in the season. It was possible that the fact that these animals were not poisoned was due to the lack of toxicity of the mature leaves rather than to the beneficial effects of the hay. Therefore it was determined to try this experiment early in the season. Cattle Nos. 760 and 763 were fed on oak buds, flowers, and leaves from June 5 to July 4, and to each was given 3 pounds of alfalfa hay daily. Neither of these animals showed any ill effects from the oak. No controls were used with these animals, but the results of exclusive oak feeding at this season in preceding years make it reasonably certain that Nos. 760 and 763 would have shown symptoms of poisoning if they had not received the hay rations. This supplemented the work of the preceding years and made it probable that cattle would not suffer from oak poisoning at any season if other forage were provided. It should be added that experience at Monahans, Tex., indicated clearly that hay was equally beneficial in the early stages of the oak.

Cattle No. 761 was fed entirely on oak from August 15 to September 10; lost weight, became constipated, and showed mucus in the feces. It was not badly affected, but was a clear case of incipient oak-brush poisoning. This was positive evidence of the possibility of oak poisoning by mature leaves. While probably more cases of oak-brush poisoning occur in the spring, due probably to the lack of other forage, they may happen at any season when the conditions are favorable.

EXPERIMENTAL WORK WITH "SHINNERY" OAK.

From March 20, 1917, to May 20, 1917, Mr. Clawson was stationed at Monahans, Tex., to study so-called "shinnery" oak (*Quercus havardi*) poisoning. Arrangements had been made by Mr. W. N. Waddell, of Fort Worth, Tex., by which corrals and pastures could be used on the ranch of Estes and Brantley.

The soil near Monahans is sandy, with areas of gypsum rock, and the vegetation consists largely of shinnery oak, mesquite, bear grass (Nolina), some sage, some grama grass, and a few weeds, the grass and weeds appearing in rather small numbers after rains. In the early spring the vegetation consists essentially of oak, mesquite, bear grass, and sage. As seen over most of the range, the oak is a low-spreading shrub a foot or two in height. Where it has been protected from grazing it may grow from 3 to 6 feet in height.

Figure 14 shows the condition of the shinnery on a grazed pasture March 27, 1917, and figure 15 the plants April 15, 1917, when they were in flower. Figure 16 shows a group of cattle April 3, 1917, grazing on a sandhill covered with shinnery, and in figure 17, taken on the same date, a 2-months-old calf is shown in the foreground eating shinnery. In the early spring the cattle eat very largely of the oak, as there is very little other forage.

It was found that the conditions of the locality were such as to make corral feeding impracticable. The cattle, however, are grazed in large, fenced pastures, with fixed watering places, at which wind-

FIG. 14.—*Quercus havardi*, shinnery oak, Mar. 27, 1917.

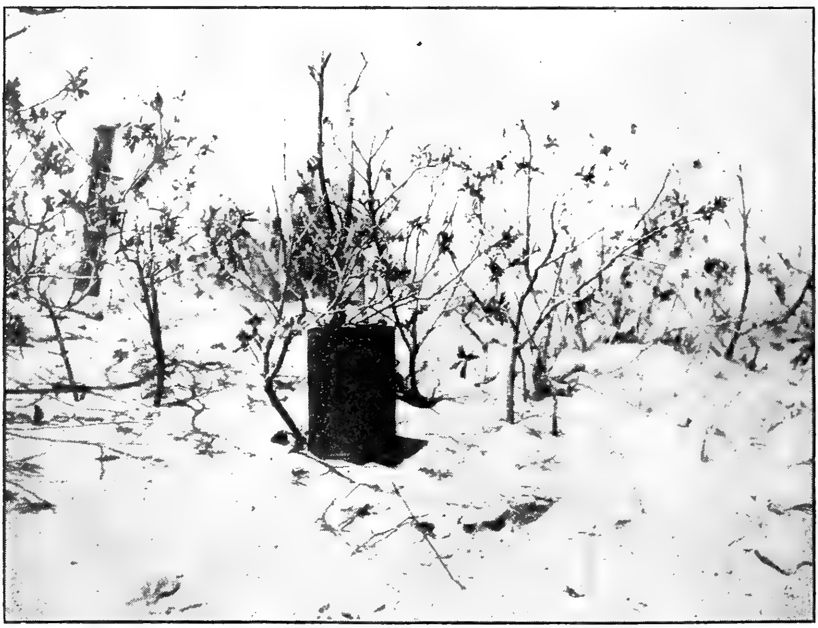

FIG. 15.—*Quercus havardi*, shinnery oak, in flower, Apr. 15, 1917.

FIG. 16.—Group of cattle feeding on shinnery oak, Apr. 3, 1917.

FIG. 17.—Cattle feeding on shinnery; a 2-months-old calf in the foreground.

mill pumps are installed, and it was possible by constant observation to get fairly accurate information as to what the cattle were eating and the effect of the feed upon them.

The pastures under observation included a "trap pasture" of about a section (640 acres) of land in which were kept some animals which were the special objects of investigation; a 5-section pasture containing an abundance of shinnery oak; a similar pasture of about 16 sections; and another large pasture containing none of the shinnery.

The general plan of the experiment, as outlined, was as follows:

1. Fifteen head of cattle which had been on pasture and had received in addition more or less cottonseed cake, were to be kept in the 5-section pasture where there was shinnery oak, and fed hay from time to time.

2. In the same pasture a large number of cattle were to be observed which had received no cottonseed cake, but would be given hay with the first bunch.

3. A still larger lot were in the 16-section pasture; they had received no cottonseed cake and would be allowed to graze, receiving no hay.

4. A bunch in the oak-free pasture which were to receive no other forage than that which could be picked up by grazing, and, of course, would eat no oak.

5. A few head were to be taken from the other pastures and put in the trap pasture, where they would be obliged to eat oak if they ate anything, and given no other feed.

The experiment was commenced sufficiently early in the season to follow the cattle from the time the buds began to swell, and was continued until well after the maturity of the leaves.

RESULTS ON 15 MARKED CATTLE IN 5-SECTION PASTURE.

The 15 animals were a part of a small bunch of cattle, mostly cows, which had been picked up in the pastures and put into a small trap pasture near the ranch house, because they were in poor condition. Besides what these animals picked up in the pasture, they had been fed daily from about February 25 to March 26 on cottonseed cake. On March 26, 1917, these animals were turned into the 5-section pasture and fed hay at frequent intervals as they came to water. At times they were driven to water and fed. To get data on individuals 15 of these animals were numbered and marked.

From March 27 to May 6 almost daily trips were made over the 5-section pasture, and observations made on the numbered animals found. Because of the size of the pasture it was not possible to see all of them each time. From April 8 to April 29 these cattle were given an opportunity to get a little alfalfa hay every two or three days or oftener, and most of them took advantage of it. One, No. 784, probably got much less hay than the others. By May 7 all danger of "oak-brush poisoning" was considered to be past by the ranch owners, and the cattle were run into the 16-section pasture.

None of these cattle were injured by the oak eaten, though observation showed them to be eating a large quantity of it. No. 784 was especially fond of the oak. Between March 31 and April 23 she was seen almost daily either eating oak or lying in the best oak patches. At times she ate the oak very greedily. April 1 she was fed alfalfa, and from April 14 on, it was noticed that she ate other things with the oak, such as bear-grass buds and grass. She was very fond of the bear-grass buds.

On April 4 she was thin and gaunt, a condition which continued until April 16, when she began to look better. It was thought during this period that she might develop into an oak-brush case. From April 16 on, her condition improved.

RESULTS ON OTHER CATTLE IN 5-SECTION PASTURE.

Besides the lot mentioned as having been fed cottonseed cake, something over 200 head of cattle were being run in the 5-section pasture. Of these, 38 were bulls and about 75 were yearlings, the remainder being old cows and calves. The bulls and yearlings had been fed to some extent, the other cattle had not. While making the almost daily rides about the 5-section pasture, close watch was kept of these animals to see what they were eating, and to catch any possible cases of "oak-brush poisoning."

The main diet of practically all these cattle was oak. This was determined by observing the animals grazing, and noting where they were feeding, as shown by tracks. Most of the pastures being drifting sand which filled old tracks almost daily, this observation was easy. The oak in this pasture was kept grazed down while in an adjoining pasture with no cattle it showed good growth.

The buds began swelling first on the higher sandhills and last on the flats. From about March 29, when the buds first began showing to any extent on the sandhills, until near the middle of April, the cattle grazed mostly on the sandhills. By this time the buds had begun to swell on the flats. Some little grass also appeared on the flats at this time, and the cattle began leaving the hills, and were more and more seen feeding on the flats. In other words, they went where they could get the oak buds and young leaves on which they did the main part of their grazing. When grasses and weeds began to show up, however, about the middle of April, they took what they could get of them.

From April 8 on, an opportunity was given these cattle to get a little alfalfa hay every two or three days. Some days they were rounded up at one of the wells and fed, and some days hay was thrown out so that they could get it when they came in to water. Most of them took advantage of it. From the time the observations began until about the middle of April, these cattle were badly constipated, the feces as observed being in small, hard, dry lumps.

It is significant that none of the cattle in this pasture showed typical symptoms of shinnery poisoning, though their main diet, aside from the hay, was oak. Two or three animals (old cows) were at one time suspected of being affected, as their feces became stringy. This condition soon passed off, however, and they became normal.

RESULTS ON CATTLE IN 16-SECTION PASTURE.

The 16-section pasture lying to the north and northwest of the five sections showed practically the same vegetation, excepting that some of the oak started a little earlier in a few places along its eastern edge. The western half of this pasture, too, was different in that the land was harder and contained no oak. About 400 cattle were here. They had all "rustled" for feed during the winter and were not fed hay at any time.

The grazing habits were exactly the same as those of the cattle in the 5-section pasture. They grazed almost entirely in the shinnery hills, eating the oak from the time the buds began to swell until late in April, when the oak began to show growth on the flats. By the last of April they were working toward the western half of the pasture, where they could get some grass and weeds.

In this pasture seven cattle were seen that showed typical symptoms of "oak-brush poisoning," and five were known to have died of this trouble.

Note should be made here of two other pastures which were examined from time to time. These are a 12-section pasture to the north, and a 40-section pasture to the east, called the Cowden pasture. The 12-section pasture was very similar to the 16-section pasture, and contained about 150 cattle. The Cowden pasture was a typical shinnery pasture and differed from the others only in having a greater abundance of the oak, much of which started growth somewhat before that in the other pastures. This was due to the great abundance of white sandhills.

Two typical cases of shinnery poisoning, both of which died, were seen in the 12-section pasture and seven cases were observed in the Cowden pasture, at least three of which died. Some of the others also doubtless died, as they were in bad condition. The size of the pasture made it impossible to follow up these cases. It is very probable, too, that there were cases which were never seen, in both the Cowden and in the 12-section pastures.

RESULTS ON CATTLE IN OAK-FREE PASTURE.

Just to the west of the 5-section pasture is a 7-section tract spoken of as the hard-land pasture. The sands here are more compact and the pasture contains no shinnery. In other respects, it compares with the other pastures.

Thirty-eight heifers were kept in this pasture during the winter and spring, and allowed to rustle for their living. The feed in this pasture was very short, but the animals managed to get along. They were seen very frequently. No cases of sickness occurred.

RESULTS ON CATTLE IN TRAP PASTURE (OAK ONLY).

Eight cattle were selected for close observation. They were put into a small trap pasture where the only available feed was oak with a small amount of grass and over most of the period a very few weeds. These cattle were followed and notes made on what the individuals were eating and doing, to get as complete a history as possible under the conditions. Three of them had been taken from the 5-section pasture April 8. They were No. 789, a long yearling steer, weight about 600 pounds, and Nos. 790 and 791, both long yearling heifers weighing about 400 pounds each. On April 9, three long yearling heifers, Nos. 792, 793, and 794, were taken from the hard-land pasture and placed with the others. On May 1 two calves about 5 months old, which had been raised by hand, were turned in with the above-mentioned six head, and kept with them.

From the time these cattle were put into the trap pasture until May 16 they were watched closely. Each day, with very few exceptions, they were observed during a good portion of the time they were grazing, and notes taken, special attention being paid to just what each one was eating. Between April 13 and 17 they were herded during the forenoon in a pasture adjoining the trap pasture where the oak was especially abundant. The other days they were watched in the trap pasture.

Cattle Nos. 789, 790, 791, 792, 793, and 794 are of the greatest interest in this experiment, as they were herded on the oak for a longer time than the other two and were held there from the time the oak began to develop until it was in full leaf, or during the period when the shinnery trouble in this region is experienced. No. 793 was the best oak eater in the little bunch, and developed a typical case of shinnery poisoning. Nos. 789 and 790 ate considerable oak, but after a few days' feeding managed to find other things to eat with it. Both kept in good condition except for severe constipation, which was especially marked while they were eating the most oak. Nos. 792 and 794 ate very little oak at any time. Though both were poor because of lack of food, they showed no symptoms of poisoning. They were at times somewhat constipated but much less so than the other cattle.

Nos. 804 and 805 were run with this bunch from May 1 to May 16. During this time they ate considerable oak but got grass and weeds along with it and were fed a little cottonseed cake daily. They were not harmed by the oak, but steadily gained in flesh, and their feces remained nearly normal.

No. 793, above mentioned, is the most interesting case. On April 9 she was brought in from the hard-land pasture, having had no chance to eat oak, and she was in fair condition. She was marked and turned into the trap pasture to graze and was watered at the house daily. From April 10 to April 25 she ate the oak freely, showing a preference for the buds and young leaves. During this time she ate very little besides oak. She was badly constipated all of the time so far as observed, defecating seldom, and the feces were small in quantity and in small, hard lumps. From April 11 to 14 the attempt was made to get her to drink water containing a small quantity of epsom salt, but as she objected to it the attempt was abandoned and straight well water was given the same as to the others.

The constipation grew worse during the oak feeding. On April 20 the feces were very dry and dark in color; April 22 they were in very dry, hard lumps; April 24 they were in small, hard, ball-like lumps. On April 25 she came in for water by herself about noon. The abdomen was noticed to be drawn up. At 1.30 p. m. she was seen to defecate, passing only four very small balls, each about the size of a walnut. They were at least as hard and dry as a sheep's feces, and contained considerable gelatinous, tough mucus and some blood. She drank considerable water. When walking she moved slowly and had a tendency to drag her hind feet. She was somewhat humped up. She was turned back into the trap pasture but at 5.50 p. m. was again found at the gate of the watering corral. At this time her nose was noticed to be dry, and there was some trembling of the lips and grating of the teeth.

She seemed about the same the next morning, at which time her temperature was 98.8° F., pulse 60 and weak, the mucous membranes of the mouth and nostrils were pale, there was marked trembling of the muzzle, and her nose was somewhat parched. While being driven out to the pasture she passed six or seven very hard lumps of feces, each about the size of a big hickory nut, and these were covered with dry, gluelike mucus and some blood. While in the pasture she showed little inclination to eat anything. During the forenoon she acted as though trying to defecate, but without result until 11.20, when she managed to pass about a quart of hard, lumpy, and dry feces which were bound together with stringy mucus and contained some blood. A hemoglobin test in the afternoon showed 75 per cent, and the blood contained 5,280,000 red corpuscles per cubic millimeter.

On April 27 and 28 her general condition remained the same, and she often acted as though thirsty. There was frequent grating of the teeth. In drinking she would stand about sipping a little water often. She was much depressed, and at times acted somewhat as if nauseated.

On April 29 and up to May 10 when being driven she had a tendency to wander away from the other animals, and had to be urged along. She had a strong tendency to get into the brush and stand until driven out. On the whole she acted much like a "loco."

From April 25, when she first began to show marked symptoms, until April 30 she ate almost nothing. From then until May 8 she ate a little grass and now and then took a very little oak. When she did eat it was in a listless manner. On May 9 she ate better and continued to improve daily, eating mainly grass and weeds with a little oak now and then.

On May 6 at 5 p. m. she was observed to pass about a quart of brownish liquid feces containing neither blood nor mucus. Though she had been watched closely this was the first defecation noted since May 1. At the time, May 6, her temperature was 103° F., the pulse was imperceptible, and her skin was dry and hard.

On May 10 her pulse was still too weak to feel, her hemoglobin tested 80 per cent.

From this time on her condition slowly improved. On May 14 her feces were nearly normal. On May 16 she was still very poor, but her general condition and action were much improved, and she was thought to be on the road to recovery and the experiment was terminated.

Comparing this animal (No. 793) with No. 794, which fed along with it but spent her time hunting grass and weeds, we see a marked difference. No. 793 became very sick with typical symptoms, while No. 794 showed no symptoms, though she remained poor from lack of feed.

In the shinnery country the statement is often made that as soon as the shinnery starts growth in the spring cattle will leave all other feed, even refusing hay, and eat the oak. This idea is erroneous. The oak is the first thing to start growth in the spring, and comes at a time when other feed is practically exhausted. The cattle, too, have existed for a long time on dry, hard feed, and are hungry for something green.

Careful observation shows that the cattle will eat grass and weeds whenever they can find them, and often spend considerable time hunting for them. If held without feed for a few hours they will take the first thing handy, which in this region is oak. After taking the edge off their appetites, they usually keep a lookout for grass and weeds, often refusing the oak. If they have an opportunity to get hay they take it.

The cattle observed showed a very marked preference for oak in certain stages of growth. They obviously liked the swelling buds and minute leaves and flowers, but did not care for three-quarters to fully grown leaves. Usually they would refuse to eat oak at this stage. After the leaves become somewhat older they are said to like them again.

GENERAL RESULTS OF THE EXPERIMENTAL WORK.

SYMPTOMS.

The first symptom, though not always the first one which is noticed by stockmen, is pronounced constipation. The feces are passed very infrequently, are small in quantity, and very hard and lumpy. These lumps may be no larger than a large marble and as dry as the feces passed by sheep. Within a few days, stringy, gluelike mucus is passed with the feces, and this may be somewhat bloody. As the condition develops, the mucus forms a greater proportion of the defecated material, until in late stages, clear mucus may be passed in lumps. In some cases the feces appear at first sight normal in color, but inspection usually shows that they contain a large proportion of mucus. At this time a diarrheal condition may exist.

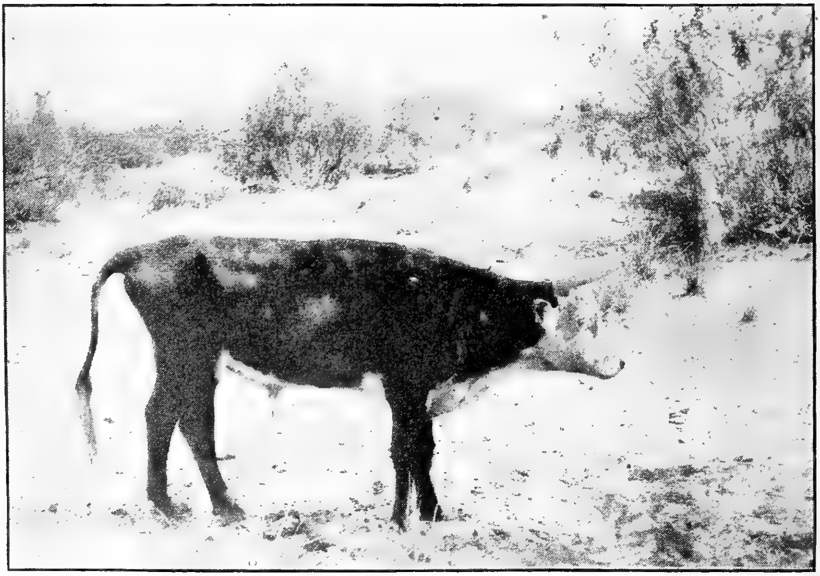

FIG. 18.—A shinneried bull.

Early in the history of the sickness the animal looks gaunt, the coat is rough, and the nose becomes dry and cracked. The attitude, both standing and walking, is peculiar; the head is extended forward and the animal shows depression, discomfort, and sometimes evidence of pain, this pain doubtless being due to the irritated and inflamed condition of the alimentary canal. (Figs. 18 and 19.)

The animal gradually grows weaker and may die at any time from a few days to two weeks or more.

As a rule animals lose their appetites early in the disease, refusing food, but appear thirsty. They will stand about watering places, taking frequent sips of water. This, together with the dry, parched nose, has given stockmen the idea that they have a fever, but ordinarily, at least, the fever does not exist. They are anemic and often have upon the body swellings containing an accumulation of serum.

The respiration remains about normal during the course of the sickness, but the pulse is weak and slower than in healthy animals. In fatal cases the pulse may become more rapid just before the end.

The temperature in sick animals has a wider variation between morning and afternoon than in healthy cattle, the morning temperature being unusually low. This results in a lower average temperature. This is well shown in figure 10, which gives the curve of temperature of cattle No. 770.

FIG. 19.—A shinneried cow, showing a typical attitude.

It may be noted that the symptoms, in many respects, resemble those of hemorrhagic septicemia, and it seems probable that sometimes the two conditions have been confused. They can be distinguished, ordinarily, however, without laboratory examination, by the fact that the high temperature and pneumonic conditions of hemorrhagic septicemia are absent in the oak cases.

AUTOPSY FINDINGS.

The characteristic pathological condition of the animals which die of oak poisoning is one of severe enteritis or gastroenteritis followed by an edematous stage. The mucosa of the small intestines and abomasum is usually badly inflamed and sometimes swollen, and areas and patches of congestion are usually present in the cecum and rectum. This congestion may even extend to the serous membrane of the intestines.

The animals are anemic, and pronounced accumulations of serum are usually found beneath the skin and in connection with the serous surfaces. This in the cases autopsied was especially pronounced in the mesentery, which was much thickened and contained a jellylike deposit which in some cases forced the serous layers apart. The swelling ruptures numerous blood vessels, causing hemorrhagic spots.

The heart had many petechiæ or small hemorrhages on its surfaces, and there was sometimes a serous accumulation on its surface or on the pericardium.

The abdominal cavity of one animal was distended with a serous accumulation. The kidneys may show small hemorrhages.

One animal autopsied appeared to have passed by the acute stage of congestion. The intestines were darkened from an old congestion, and the thickened mesentery was adherent in places to the body wall, as were the liver and kidneys. In this case no serous deposits were found under the skin, but the skin was unusually adherent to the flesh.

MICROSCOPIC PATHOLOGY.

The most prominent lesions in cattle killed by oak-brush poisoning occur in the alimentary tract and the kidneys. The abomasum and the intestines show a condition of gastroenteritis, often in a very severe form. The part of the alimentary canal where this inflammation is exhibited in the greatest intensity varies in different animals. The intestines are inflamed or show changes which follow this condition, such as degeneration of epithelial lining and glandular tissue, increase in connective tissue especially in the mucosa, and edema of the intestinal walls, which are often thickened. Both small and large intestines are involved.

The abomasum or fourth stomach in most cases shows changes similar to those found in the intestines.

The kidneys are inflamed and show a pronounced edema, which is indicated by shrunken glomeruli, enlarged tubules, and numerous casts in the tubules. In some cases the epithelial cells lining the tubules appear stretched and flattened, but in most cases they are more or less degenerated. The epithelium in many tubules is sloughed off from the basement membrane. The enlarged tubules give the kidney sections a cystic appearance. There is an increase in the connective tissue between the tubules.

Most of the other tissues may be edematous. This condition is frequently seen in the heart, liver, pancreas, and various serous tissues. In connection with these edematous swellings hemorrhagic spots often occur.

LENGTH OF TIME NECESSARY TO PRODUCE HARM FROM OAK FEEDING.

Observation on the range and experimental feeding both show that some cattle may eat oak brush for a long time with no definitely bad effect. Some will even eat oak exclusively with no harm. Generally speaking, those that are injured show the results only after eating a considerable quantity through a rather prolonged period. The observations on the shinnery oak showed that symptoms resulted after the animals had been feeding from 16 to 35 days.

In the experimental animals, which were fed exclusively upon oak, constipation was noted in 2 cases in 6 days, and in the others definite symptoms appeared in from 8 to 13 days. In the 2 fatal cases one died in 39 days and one in 17 days. Of course, under ordinary circumstances, it would not be expected that range animals would show symptoms so soon as the subjects of these experiments, for the feeding of the animals in the corrals was intensive, and of oak exclusively.

Permanent injury may not follow from oak. Some animals injured by oak feeding may linger a long time, and eventually die. In some cases, however, favorable conditions may bring about recovery with no evidence of permanent injury. No. 704, which was the subject of experiment in 1916, was observed through the summer of 1917, and made normal gains.

EFFECT OF EATING OAK WITH OTHER FEEDS.

The experimental work at the Salina experiment station in 1916, 1917, and 1918 showed conclusively that oak could be eaten not only with no harm but also with apparently distinct benefit if other additional forage was provided. As small a quantity as 3 pounds of alfalfa hay daily, with the oak, prevented injury and maintained the weight of the animals. Range experience in Utah clearly indicated the same thing. Observations in the handling of cattle on the "shinnery" ranges near Monahans, Tex., also demonstrated the beneficial effects of comparatively small feedings of hay.

In this connection it may be mentioned that W. R. Morley, of Datil, N. Mex., told Assistant Botanist Eggleston that although the cattlemen of that region had heavy losses from oak poisoning, he himself had avoided them by feeding hay and a small quantity of cottonseed meal as long as his cattle returned to the corrals.

ACTIVE PRINCIPLE OR PRINCIPLES CAUSING OAK-BRUSH POISONING.

Very little chemical or pharmacological work has been done to determine the fundamental cause of the injurious effects of oak-brush forage; this matter is still under investigation, but the results are not sufficiently definite to report.

It has been assumed by some that tannin or the tannates might be responsible for the trouble. On this account it seemed best to perform some experiments with tannic acid. Two animals were used, cattle Nos. 755 and 815. It was impossible to estimate the quantity of tannin obtained by an animal feeding upon oak brush, for it was found impracticable to handle the animals in such a way as to know how much oak they were eating. It was planned to give to one animal 25 grams (0.055 pound) and to the other 50 grams (0.11 pound) daily per 1,000 pounds of animal.

The 25-gram dose was given to No. 755, being administered by drench daily in 3 doses of 8.33 grams each. This was continued from August 4 to September 2, producing no effect upon the animal.

The 50-gram dose was given to No. 815. This, as in the case of No. 755, was divided into 3 daily doses, and was continued from September 5 to September 10; September 11 only 2 of the doses were given, and September 12 only 1. From September 13 to September 17 the 3 daily doses were resumed, and on September 18 and 19 only 1 dose was given. During the experiment the animal was fed upon hay. No symptoms were noticed, but on the morning of September 20 it was found dead. It was very much bloated and it was evident that it had vomited profusely. In the autopsy there were found hemorrhages in the trachea. The lungs were congested, there were hemorrhages and infiltrations of serum in the muscular coats of the esophagus, the first and second stomachs were distended with gas, there were hemorrhagic patches in the duodenum, and congested spots in the jejunum, ileum, cecum, and rectum. There were hemorrhages on the surface and interior of the thymus. The superficial blood vessels of the brain were fuller than normal and there was a possible excess of spinal fluid.

The animal had not shown general symptoms which could be considered comparable with oak poisoning, but possibly died from the effect of the tannic acid.

These experiments indicated that the cause of oak-brush poisoning could not be tannic acid, and made it very doubtful whether the tannin in the oak was the fundamental cause of the trouble.

SUMMARY OF CONCLUSIONS FROM EXPERIMENTAL WORK.

1. Continuous feeding on oak leaves may produce sickness which sometimes has a fatal termination. Only a small percentage of the animals in a given range are injured.

2. The specially marked symptoms are constipation, feces containing mucus and blood, emaciation, and edema.

3. A diet composed exclusively of oak leaves does not form a sufficiently nutritious diet to permit normal gains in weight.

4. Oak leaves with a small quantity of other feed may provide a maintenance ration. It has been found experimentally that as small a quantity of alfalfa hay as 3 pounds daily will supplement the oak for this purpose.

5. Oak leaves may produce injurious effects at any season. Most of the cases, however, occur in the spring because on the range at that time there is a scarcity of other forage and the young oak leaves are attractive. While cattle later in the season may eat largely of oak, more or less other forage is available and no harmful results are experienced.

6. The "summer sickness" of the Utah ranges is identical with so-called oak-brush poisoning.

DISCUSSION OF RESULTS WITH RELATION TO PRECEDING INVESTIGATIONS.

The conclusions stated above are derived entirely from the results of range investigations and experimental feeding in the western part of the United States. As has already been stated, very little has been published with regard to oak poisoning. The statements of Barnes, 1913, and of The Breeder's Gazette, 1909, cover about all that has been published concerning oak poisoning in the United States, except newspaper notices. The study of oak leaves by Mackie, 1903, gave results that are in entire harmony with those obtained in the feeding experiments at the Salina experiment station, reported in this bulletin.

The extended account by Cornevin is the only detailed statement of oak poisoning that has ever been published. A comparison of his statements with the results obtained in our experiments shows a general agreement, but with certain marked differences. Cornevin states that the animals, in addition to the constipation with hard feces, which is so marked a symptom in our experimental work, exhibit colic, trembling, and bloody urine. These symptoms did not appear in the experimental animals in Utah and Texas; the microscopic examination, however, showed marked nephritis. Cornevin states that the pulse is "hard" and that the animals have fever. In the Salina cases the pulse was weak rather than hard and there was no fever, but, on the contrary, the temperature was somewhat lower than normal. It may reasonably be questioned, however, whether Cornevin's statement in regard to fever was based on any exact observations, as the use of the clinical thermometer was not very common at that time. Apparently the European animals were affected in a much more acute and severe manner; this is also shown in what Cornevin says of the "lesions," which correspond very well to those observed in Utah and Texas, but are more marked in the French cases.

A large part of Cornevin's description is taken up by an account of the condition of the urine and a discussion, largely theoretical, of the probable relation of the tannic acid in the plants to the hemoglobinuria. This phase of the subject is reserved for a later consideration, after some unfinished experimental work has been completed. So far as the work has gone there appears to be no marked discrepancy between Cornevin's account and the results obtained.

PRACTICAL CONSIDERATIONS FOR RANGE GRAZING.

So far as these investigations have gone the following statements appear to be justified:

1. During the summer and fall the oak-brush ranges of Utah can be used for grazing, not only with no harm to cattle, but with positive benefit.

2. The admission of cattle to oak-brush ranges before grass has started practically compels the cattle to eat oak, as that is the only forage available. To make certain that there is no loss from oak brush at this time, it is important that an examination of the condition of the range should precede the admission of cattle, rather than that they should be admitted on a fixed date, inasmuch as seasons differ markedly in the advancement of the vegetation. After the grass has started so that the cattle have an opportunity to get something in addition to the oak, there is little danger of oak poisoning.

3. On the shinnery ranges, as on the oak ranges in Utah, the danger to cattle is from an exclusive diet of oak. The shinnery ranges can be used without loss provided a comparatively small quantity of other feed is available.

4. The loss from oak on an oak range is estimated at from 2 to 3 per cent. Considering the handling of range cattle from a cold-blooded business standpoint it may, under some circumstances, be more profitable to stand the loss rather than to provide the additional feed. It should be remembered in this connection, however, that underfeeding tends to injure cattle permanently and prevent normal gains in weight, so that the tendency among many stockmen to gamble on the chance of getting cattle through the winter and spring on short feed is liable to lead to disastrous results.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 768

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER April 5, 1919

PRODUCTION OF LUMBER, LATH, AND SHINGLES IN 1917.

By Franklin H. Smith and Albert H. Pierson, *Statisticians in Forest Products.*

CONTENTS.

INTRODUCTION.

In this bulletin, which is one of an annual series covering the period 1904 to 1917, inclusive, with the exception of 1914,[1] are detailed statistics of the 1917 production of lumber, lath, and shingles in the continental United States,[2] with comparative figures from previous annual reports.

The collection and compilation of the statistics for the Western States was done through the district offices of the Forest Service at Missoula, Denver, Albuquerque, Ogden, San Francisco, and Portland. The figures for New York State were furnished by the New York Conservation Commission. The work in all of the other States east of the Rocky Mountains was done by the Office of Industrial Investigations of the Forest Service, Washington, D. C.[3]

[1] A detailed summary of the 1914 lumber production is given in Bulletin 506, which contains the figures for 1915.

[2] The production statistics for 1917 were summarized in a preliminary statement issued in May, 1918.

[3] Acknowledgment is made for assistance in the compilation and review of this bulletin to A. B. Strough, New York Conservation Commission; and to J. E. Keach, Miss Ina M. Jenkins, Miss Frances R. Waters, Miss Frances Veitch, D. M. Lang, Quincy Randles, E. H. Hall, C. L. Hill, Miss Alice M. Gray, Thornton T. Munger, and A. G. Jackson, of the Forest Service.

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As in former years the census was carried on in cooperation with the National Lumber Manufacturers' Association, which contributed financial assistance, and aided, through its affiliated organizations, in securing reports from the mills.

TOTAL LUMBER PRODUCTION.

The quantity of lumber reported cut in 1917 by 16,420 mills was 33,192,911,000 board feet. The output of 2,652 mills cutting less than 50,000 board feet each is not included in the reported cut. An additional 2,470 mills were reported idle. The estimated total lumber production in 1917 was 36,000,000,000 board feet. The reported cut shows a decrease of 4.6 per cent from the 1916 figures; the number of mills reporting, a decrease of 4.9 per cent; and the estimated total production, a decrease of 10 per cent.

The conditions in and out of the lumber industry which contributed to the decreased production in 1917 are obvious. War demands almost completely disrupted the usual channels of trade distribution. The softwoods which ordinarily are utilized for construction purposes in city and country were diverted to a large extent to Government war preparations—to the building of ships and the erection of buildings for men and stores and to other types of emergency structures.

Advanced prices of all material and high labor costs discouraged private building throughout the country; statistics covering 101 of the principal cities show that the estimated cost of buildings for which permits were issued was 29 per cent less in 1917 than in 1916, and that the number of permits fell off 23 per cent. Factories consuming hardwoods to a marked extent in nonessential products curtailed their output or changed their line, and the decreased demand was not altogether offset by Government purchases and manufactures. A scarcity of cars for long periods, combined with general railroad freight congestion and prolonged embargoes in the East, made it difficult to ship lumber for other than Government use. Exports, as during 1916, were small because of the limited tonnage available. High wages paid skilled and common labor and the constant bidding for labor by construction companies in the war industries tended toward reduced output through depleting the crews in the woods and mills. Hundreds of small mill operators were unable to cope with the labor situation and did not operate, while hundreds of others found it more profitable to engage in other occupations. In 1916, 67.38 per cent of the lumber reported cut was produced by mills cutting 5,000,000 feet or more annually; in 1917 the per cent was 71.19.

The reported lumber cut, the number of active mills reporting, and the estimated annual total cut are given in Table 1 for each year since 1899 for which data have been compiled. The statistics for all of the years are not directly comparable, since the intensiveness of the individual annual canvass made must be taken into consideration. The enumerations for 1899 and 1909 were made practically complete through the employment of field agents of the Bureau of the Census in the decennial censuses for those years, which permitted the output of nearly all, if not all, mills being recorded. The reported cut for 1917 was smaller than for any year since 1905, with the exception of 1915, while the estimated total cut for 1917 was the smallest for any year since 1899.

TABLE 1.—*Quantity of lumber reported, number of active sawmills reporting, and estimated total cut, 1899–1917.*

Year.	Reported cut of lumber.	Active mills reporting.	Estimated total cut of lumber.
1899	35,084,166,000	31,833	35,084,166,000
[1] 1904	34,135,139,000	[2] 18,277	43,000,000,000
1905	30,502,961,000	11,666	43,500,000,000
1906	37,550,736,000	22,398	46,000,000,000
[3] 1907	40,256,154,000	28,850	46,000,000,000
[3] 1908	33,224,369,000	31,231	42,000,000,000
1909	44,509,761,000	[4] 46,584	44,509,761,000
[3] 1910	40,018,282,000	[2] 31,934	44,500,000,000
[3] 1911	37,003,207,000	[2] 28,107	43,000,000,000
1912	39,158,414,000	[2] 29,005	45,000,000,000
1913	38,387,009,000	[2] 21,668	44,000,000,000
[1] 1914	37,346,023,000	[2] 27,506	40,500,000,000
1915	31,241,734,000	[2] 16,815	38,000,000,000
1916	34,791,385,000	[2] 17,269	40,000,000,000
1917	33,192,911,000	[2] 16,420	36,000,000,000

[1] Custom mills excluded.
[2] Mills cutting under 50,000 feet excluded.
[3] Including mills which manufacture lath and shingles exclusively (1,500 estimated).
[4] Includes 4,543 mills cutting less than 50,000 feet, and all cooperage, veneer, millwork, box, furniture, and other factories cutting any lumber at all in 1909.

TABLE 2.—*Reported production of lumber 1909, 1912, 1914, and computed totals, 1915, 1916, and 1917, by classes of mills.*

Classes.	Year.	Mills.		Quantity reported.	
		Number reporting.	Per cent.	Feet B. M.	Per cent.
All classes	[1] 1909	42,041	100.00	44,384,795,000	100.00
	1912	29,005	100.00	39,158,414,000	100.00
	1914	27,506	100.00	37,346,023,000	100.00
	[2] 1915	29,951	100.00	37,011,656,000	100.00
	[2] 1916	30,081	100.00	39,807,251,000	100.00
	[2] 1917	24,815	100.00	35,831,239,000	100.00
Class 5: 10,000,000 feet and over per year	1909	888	2.11	19,126,223,000	43.09
	1912	926	3.19	21,259,274,000	54.29
	1914	867	3.15	20,934,446,000	56.06
	[2] 1915	846	2.82	20,669,746,000	55.84
	[2] 1916	925	3.08	23,310,137,000	58.56
	[2] 1917	899	3.62	22,148,570,000	61.81
Class 4: 5,000,000 to 9,999,000 feet per year	1909	783	1.86	5,291,606,000	11.92
	1912	608	2.10	4,311,063,000	11.01
	1914	547	1.99	3,910,370,000	10.47
	[2] 1915	453	1.51	3,224,448,000	8.71
	[2] 1916	484	1.61	3,513,767,000	8.82
	[2] 1917	459	1.85	3,360,502,000	9.38
Class 3: 1,000,000 to 4,999,000 feet per year	1909	5,443	12.95	10,068,592,000	22.69
	1912	3,747	12.92	7,009,608,000	17.90
	1914	3,291	11.97	6,078,730,000	16.28
	[2] 1915	3,191	10.65	6,201,864,000	16.76
	[2] 1916	3,041	10.11	5,858,675,000	14.72
	[2] 1917	2,352	9.48	4,615,941,000	12.88
Class 2: 500,000 to 999,000 feet per year	1909	6,468	15.39	4,315,636 000	9.72
	1912	4,420	15.24	2 951 068 000	7.54
	1914	4,261	15.49	2 780 184 000	7.44
	[2] 1915	4,198	14.02	2 941 264 000	7.95
	[2] 1916	4,594	15.27	3 096 760 000	7.78
	[2] 1917	3,689	14.87	2 460 685 000	6.87
Class 1: 50,000 to 499,000 feet per year	1909	28,459	67.69	5 582,738,000	12.58
	1912	19,304	66.55	3,627,401,000	9.26
	1914	18,540	67.40	3,642,293,000	9.75
	[2] 1915	21,263	70.99	3,974,334,000	10.74
	[2] 1916	21,037	69.93	4,027,912,000	10.12
	[2] 1917	17,416	70.18	3,245,541,000	9.06

[1] The total for 1909 differs from that shown in the other tables because 4,543 mills cutting 124,966,000 feet or less than 50,000 feet each, are omitted above.
[2] The data here shown for 1915, 1916, and 1917 are computed totals by classes of mills.

LUMBER PRODUCTION BY CLASSES OF MILLS.

The policy of arbitrarily dividing the reporting mills into classes according to the quantity of lumber cut was followed as in previous years. Table 2 shows, by classes, the computed[1] number of mills reporting and the computed total production for 1909 and for 1912

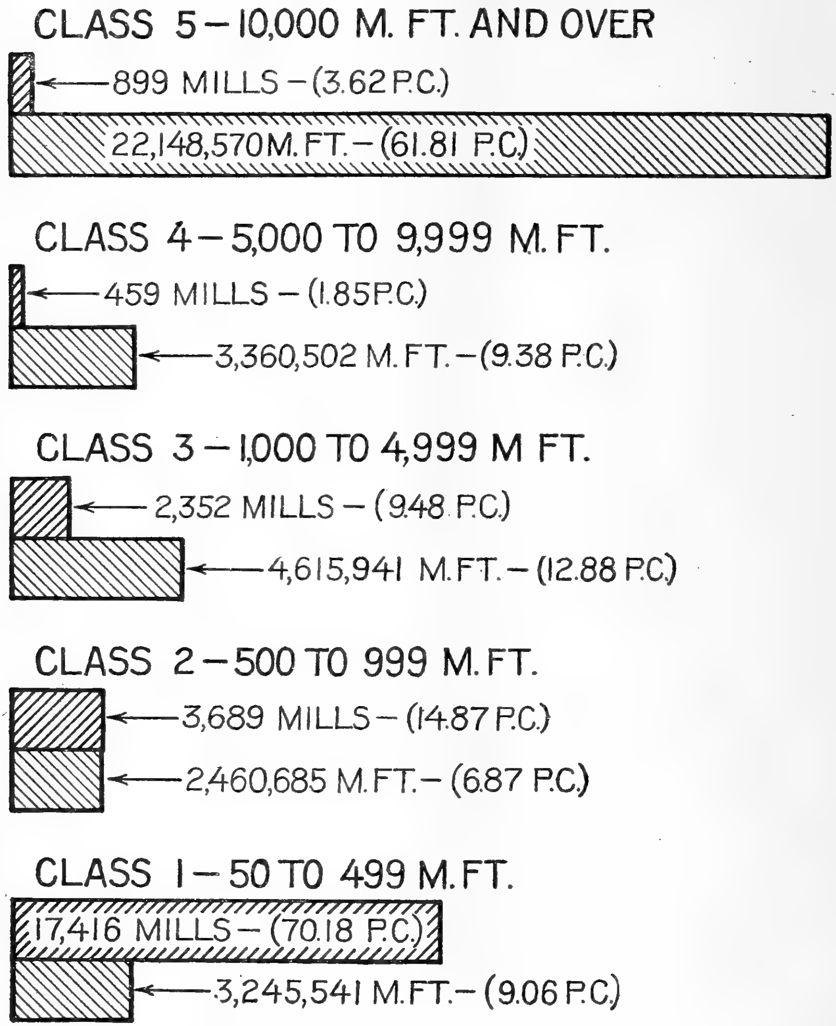

FIG. 1.—Relation of mill classes to production in 1917.

to 1917, inclusive. The figures for 1909 are given for comparative purposes because of the exceptionally complete census obtained for that year and the belief held by many lumbermen that that year marked the high point in lumber production in this country.

[1] "Computed," as used in this bulletin, expresses results obtained by the extension of figures based on actual returns so as to show totals for approximately all sawmills whether or not reports were received from them.

Attention is directed to the increasingly large per cent of the total production contributed by the bigger operations. In 1909, mills cutting 10,000,000 feet and over produced 43.09 per cent of the total cut for the year, while in 1917 this same class of mills cut 61.81 per cent of the total. Though special efforts are made to secure a report for each big operation, which makes the figures for the two larger classes of mills more complete than for those of the three lower classes, the concentration of production among the larger mills is undoubtedly on the increase.

Figures on sawmill production and sawmill capacity, arranged by classes of mills and by States, are contained in Table 3. The bases for these data were the answers to a question on the lumber cut schedule as to how much lumber the reporting mill could produce in a 10-hour shift if demand and price were very favorable. While the question was more or less hypothetical, a sufficient number of replies was received to indicate the condition. A considerable variation is noted in the average number of 10-hour days operated by the mills in different States, and also in the average yearly output per mill. The table shows that the mills in the fifth class operate closer to capacity than do the mills in the lower classes, which bears out a theory held by operators generally. No attempt has been made to compute average figures for the country as a whole, since conditions governing the industry are so divergent as to render a computed average misleading.

The cut by classes of mills arranged by States is given in Table 4, which shows not only the importance of the industry of each State but the concentration of large mills in certain regions. Of the 894 class 5 mills reporting their output for 1917, 124 were located in Louisiana, 69 in Mississippi, 55 in Texas, 45 in Arkansas, and 39 in Alabama. In the Lake States group 50 were in Wisconsin, 36 in Michigan, and 24 in Minnesota. In the western States 124 were in Washington, 58 in Oregon, and 39 in California and Nevada.

These 12 States have an aggregate of 663 class 5 mills, or 75 per cent of the total reporting for all the States. By contrast they contain only 21 per cent of the total number of class 1 mills reporting or 2,199 class 1 mills; whereas three other States—Virginia, North Carolina, and South Carolina—have 1,937 class 1 mills, or nearly as many as the 12 States.

TABLE 3.—*Reported number of days operated, yearly output, cut per 10-hour day, and estimated daily capacity, for average mill, by States and classes, 1917.*

State.	Class 5.				Class 4.				Class 3				Class 2.				Class 1.			
	Average number of 10-hour days operated.	Average yearly output per mill.	Average cut per 10-hour day per mill.	Estimated daily capacity per mill.	Average number of 10-hour days operated.	Average yearly output per mill.	Average cut per 10-hour day per mill.	Estimated daily capacity per mill.	Average number of 10-hour days operated.	Average yearly output per mill.	Average cut per 10-hour day per mill.	Estimated daily capacity per mill.	Average number of 10-hour days operated.	Average yearly output per mill.	Average cut per 10-hour day per mill.	Estimated daily capacity per mill.	Average number of 10-hour days operated.	Average yearly output per mill.	Average cut per 10-hour day per mill.	Estimated daily capacity per mill.
		Feet B. M.	Feet B. M.	Feet B. M.		Feet B. M.	Feet B. M.	Feet B. M.		Feet B. M.	Feet B. M.	Feet B. M.		Feet B. M.	Feet B. M.	Feet B. M.		Feet B. M.	Feet B. M.	Feet B. M.
Alabama	320	30,461,000	95,200	96,700	228	6,759,000	29,600	32,800	199	2,052,000	10,300	15,800	138	676,000	4,800	9,800	60	180,000	2,900	6,400
Arizona	218	18,312,000	84,000	94,000									144	768,000	5,300	12,000	60	198,000	3,100	7,500
Arkansas	292	22,790,000	78,100	99,400	273	7,246,000	26,500	35,700	154	1,976,000	12,800	19,400	128	617,000	4,800	11,400	61	189,000	3,000	7,400
California and Nevada	302	39,432,000	123,000	168,000	178	7,281,000	41,000	69,000	94	1,888,000	23,500	32,000	82	657,000	10,700	19,000	78	234,000	6,800	9,800
Colorado									205	2,086,000	10,100	19,500	129	686,000	5,300	12,400	57	158,000	3,300	17,700
Connecticut									166	1,174,000	7,100	14,800	180	580,000	3,200	10,000	56	163,000	2,800	5,800
Delaware													150	750,000	5,000	9,700	46	156,000	3,400	4,900
Florida	363	25,259,000	69,700	75,600	200	6,468,000	32,300	43,100	212	2,267,000	10,700	15,700	197	678,000	3,400	7,700	93	207,000	2,200	6,000
Georgia	286	21,361,000	74,800	88,000	254	6,147,000	24,200	40,000	196	2,147,000	10,900	15,900	149	647,000	4,300	8,900	64	185,000	2,900	6,600
Idaho	244	30,012,000	123,000	131,000	148	9,028,000	61,000	73,000	116	1,972,000	17,000	28,000	79	553,000	7,000	17,000	36	216,000	6,000	10,000
Illinois									223	1,500,000	6,700	13,500	150	730,000	4,900	10,000	47	117,000	2,500	5,300
Indiana									226	1,886,000	8,400	13,700	167	630,000	3,800	7,600	76	193,000	2,500	5,300
Iowa																	34	130,000	3,800	5,900
Kentucky									198	1,381,000	6,900	11,500	137	672,000	4,900	8,600	62	200,000	3,200	6,100
Louisiana	331	27,518,000	83,000	92,500	238	7,916,000	33,200	38,700	157	1,992,000	12,700	23,300	107	718,000	6,700	12,400	84	211,000	2,500	9,100
Maine	244	22,968,000	94,300	109,500	186	7,206,000	38,700	53,800	184	2,273,000	12,300	20,300	102	677,000	6,100	12,900	73	197,000	2,700	10,200
Maryland									225	1,025,000	4,600	10,000	180	706,000	3,900	6,700	76	201,000	2,700	6,300
Massachusetts									190	1,551,000	8,100	15,500	132	630,000	4,800	9,400	70	199,000	2,900	7,600
Michigan	325	16,764,000	51,500	63,300	239	7,029,000	29,400	35,600	143	2,423,000	16,900	25,400	94	738,000	7,800	11,600	42	168,000	3,900	10,200
Minnesota	422	91,166,000	216,000	229,100	280	6,133,000	22,000	30,000					70	636,000	9,100	13,600	31	175,000	5,500	8,800
Mississippi	288	25,166,000	87,200	93,900	199	7,177,000	36,100	49,000	165	1,861,000	11,300	18,200	130	694,000	4,100	10,400	72	217,000	3,000	6,900
Missouri	261	13,628,000	52,200	65,000					183	1,457,000	7,900	13,800	118	630,000	5,300	8,800	66	187,000	2,800	5,800
Montana	280	32,480,000	116,000	129,000	177	7,257,000	41,000	48,000	98	2,058,000	21,000	31,000	76	684,000	9,000	18,000	34	170,000	5,000	9,200
New Hampshire									194	1,789,000	9,200	12,900	104	618,000	5,900	10,300	78	261,000	3,300	9,600
New Jersey																	111	178,000	1,600	3,700

New Mexico	231	15,015,000	65,000	67,000	183	9,150,000	50,000	58,000	170	1,870,000	11,000	17,000	112	784,000	7,000	10,300	67	268,000	4,000	7,200
New York									185	1,613,000	8,700	10,300	139	649,000	4,700	9,000	54	151,000	2,800	6,900
North Carolina	254	12,372,000	48,800	63,100	225	6,852,000	30,500	42,000	209	1,816,000	8,700	14,800	130	656,000	5,000	8,200	69	221,000	3,200	6,900
Ohio									222	1,654,000	7,400	9,800	196	703,000	3,600	6,500	76	214,000	2,800	5,700
Oklahoma	452	38,089,000	84,200	106,300					200	3,000,000	15,000	20,000	150	510,000	3,400	15,000	73	156,000	2,100	6,800
Oregon	243	27,216,000	112,000	133,000	167	7,849,000	47,000	60,000	122	2,196,000	18,000	28,000	84	756,000	9,000	20,000	51	306,000	6,000	12,000
Pennsylvania	297	18,292,000	61,600	65,000	295	7,388,000	25,000	30,000	193	1,558,000	8,100	16,700	150	638,000	4,300	7,400	67	182,000	2,700	6,400
Rhode Island													110	702,000	6,300	10,400	40	160,000	4,000	6,000
South Carolina	267	18,326,000	68,500	87,500	254	6,652,000	26,200	30,000	219	1,722,000	7,800	11,100	165	654,000	4,000	6,800	57	181,000	3,200	6,800
South Dakota																	37	188,000	5,100	8,600
Tennessee	255	13,544,000	53,000	68,300	247	8,248,000	33,500	49,100	177	2,128,000	12,100	17,300	106	666,000	6,300	10,200	62	197,000	3,200	5,800
Texas	312	25,776,000	82,700	90,600	204	7,341,000	35,900	40,000	161	1,974,000	12,300	25,200	139	601,000	4,300	12,800	68	165,000	2,400	8,300
Utah													101	535,000	5,300	8,300	55	125,000	2,300	5,400
Vermont									178	1,576,000	8,900	18,000	124	670,000	5,400	10,900	91	204,000	2,200	8,400
Virginia	268	18,517,000	69,000	79,000	228	7,581,000	33,300	36,600	176	1,897,000	10,800	18,700	139	671,000	4,800	8,100	71	220,000	2,200	5,800
Washington	240	26,160,000	109,000	138,000	189	8,127,000	43,000	52,000	136	2,720,000	20,000	30,000	86	774,000	9,000	21,000	61	305,000	5,000	14,000
West Virginia	295	19,435,000	65,900	80,000	249	8,145,000	32,700	40,900	211	3,092,000	14,700	21,100	138	750,000	5,400	8,100	60	180,000	3,000	6,800
Wisconsin	323	26,639,000	63,900	83,500	186	6,634,000	66,600	43,800	118	2,389,000	20,300	31,000	71	651,000	9,200	16,900	31	189,000	6,100	11,400
Wyoming																	49	141,000	2,900	6,900

TABLE 4.—*Sawmills classified by States, according to reported quantity of lumber cut, 1917.*

State.	Aggregate.		Class 5: Mills cutting over 10,000,000 feet.		Class 4: Mills cutting from 5,000,000 to 9,999,000 feet.		Class 3: Mills cutting from 1,000,000 to 4,999,000 feet.		Class 2: Mills cutting from 500,000 to 999,000 feet.		Class 1: Mills cutting from 50,000 to 499,000 feet.	
	Number of active mills reporting.	Quantity.	Number of mills.	Quantity.	Number of mills.	Quantity.	Number of mills.	Quantity.	Number of mills.	Quantity.	Number of mills.	Quantity.
		Feet B. M.		*Feet B. M.*		*Feet B. M.*		*Feet B. M.*		*Feet B. M.*		*Feet B. M.*
United States	16,420	33,192,911,000	894	22,021,914,000	452	3,310,304,000	2,178	4,274,653,000	2,460	1,640,980,000	10,436	1,945,060,000
Alabama	772	1,409,618,000	39	762,222,000	24	166,484,000	155	321,339,000	119	79,905,000	435	79,668,000
Arizona	22	79,022,000	4	70,142,000			1		3	[1] 6,851,000	14	2,029,000
Arkansas	674	1,591,952,000	45	987,610,000	30	216,044,000	119	251,961,000	99	64,595,000	381	71,742,000
California and Nevada	169	1,417,068,000	39	1,249,520,000	9	67,725,000	29	69,968,000	22	15,165,000	70	14,690,000
Colorado	100	71,312,000			2		15	[2] 46,764,000	18	12,356,000	65	12,192,000
Connecticut	136	61,236,000					18	27,467,000	22	16,343,000	96	17,426,000
Delaware	35	8,409,000							3	2,250,000	32	6,159,000
Florida	212	1,127,359,000	38	784,394,000	27	211,163,000	42	96,876,000	28	18,420,000	77	16,506,000
Georgia	613	671,528,000	14	238,567,000	18	128,840,000	90	167,546,000	105	69,501,000	386	67,074,000
Idaho	181	749,764,000	22	652,554,000	3	27,322,000	21	40,327,000	16	9,630,000	119	19,931,000
Illinois	114	42,182,000			2		5	[2] 22,726,000	8	5,305,000	99	14,151,000
Indiana	439	218,712,000			2		48	[2] 111,631,000	61	41,884,000	328	65,197,000
Iowa	65	13,143,000					1		2	[1] 4,772,000	62	8,371,000
Kansas	4	4,255,000					1				3	[1] 4,255,000
Kentucky	579	329,203,000	4	64,235,000	9	64,428,000	42	79,780,000	59	39,208,000	465	81,552,000
Louisiana	335	3,861,860,000	124	3,405,708,000	36	271,073,000	65	143,345,000	39	26,773,000	71	14,961,000
Maine	530	705,014,000	12	201,451,000	14	97,192,000	136	285,981,000	91	61,639,000	277	58,751,000
Maryland	184	61,720,000			1		8	21,573,000	19	12,343,000	156	27,804,000
Massachusetts	243	138,233,000					49	77,597,000	50	33,707,000	144	26,929,000
Michigan	301	975,648,000	36	617,236,000	28	199,884,000	47	111,654,000	29	19,332,000	161	27,542,000
Minnesota	198	999,476,000	24	907,962,000	6	34,776,000	9	18,144,000	24	14,946,000	135	23,648,000
Mississippi	671	2,221,010,000	69	1,512,164,000	28	215,235,000	185	361,723,000	115	79,358,000	274	52,530,000
Missouri	357	257,712,000	6	97,271,000	7	44,436,000	30	45,753,000	35	22,975,000	279	47,277,000
Montana	122	347,496,000	7	253,817,000	5	36,514,000	17	34,203,000	14	9,325,000	79	13,637,000
New Hampshire	263	263,511,000	1				104	[3] 207,868,000	48	32,709,000	110	22,934,000

New Jersey	92	21,117,000					3	3,830,000	6	4,115,000	83	13,172,000
New Mexico	56	88,625,000	2		3	[4] 58,257,000	6	13,159,000	6	3,626,000	39	13,583,000
New York	1,172	335,016,000	3	31,733,000	1		38	[5] 76,105,000	105	69,069,000	1,025	158,109,000
North Carolina	1,482	1,316,307,000	31	44,322,000	28	184,501,000	194	311,991,000	287	187,028,000	942	188,465,000
Ohio	511	202,349,000			3	17,812,000	26	42,493,000	91	63,121,000	391	78,923,000
Oklahoma	96	226,711,000	5	176,356,000	1		12	[5] 29,255,000	16	11,872,000	62	9,228,000
Oregon	409	2,485,783,000	58	2,147,479,000	12	88,905,000	71	162,967,000	65	43,352,000	203	43,080,000
Pennsylvania	851	501,359,000	10	219,086,000	3	20,699,000	37	61,094,000	110	71,483,000	691	128,997,000
Rhode Island	20	10,570,000							15	9,980,000	5	590,000
South Carolina	412	672,852,000	16	325,928,000	16	122,425,000	75	135,969,000	76	50,762,000	229	37,768,000
South Dakota	28	29,045,000	1				2	[3] 23,217,000	2		23	[6] 5,828,000
Tennessee	815	582,003,000	9	122,885,000	15	118,804,000	68	138,748,000	146	94,470,000	577	107,096,000
Texas	299	1,592,119,000	55	1,322,100,000	12	89,705,000	62	121,914,000	58	36,649,000	112	21,751,000
Utah	59	8,567,000							3	1,612,000	56	6,955,000
Vermont	314	157,258,000	2		1	[4] 37,407,000	21	30,213,000	58	40,130,000	232	49,508,000
Virginia	1,168	942,879,000	23	309,186,000	16	117,888,000	120	190,973,000	243	163,370,000	766	161,462,000
Washington	438	4,304,449,000	124	3,678,985,000	45	337,086,000	107	232,776,000	47	30,900,000	115	24,702,000
West Virginia	430	810,458,000	21	370,809,000	31	233,531,000	49	117,829,000	53	37,073,000	276	51,216,000
Wisconsin	398	1,271,069,000	50	969,979,000	14	104,893,000	50	120,832,000	42	29,100,000	242	46,265,000
Wyoming	51	7,932,000							2		49	[6] 7,932,000

[1] Includes the cut of 1 mill in class 3.
[2] includes the cut of 2 mills in class 4.
[3] Includes the cut of 1 mill in class 5.
[4] Includes the cut of 2 mills in class 5.
[5] Includes the cut of 1 mill in class 4.
[6] Includes the cut of 2 mills in class 2.

TABLE 5.—*Total number of active sawmills reporting and quantity of lumber reported or computed, by States, 1908–1917.*

State.	Computed totals.			Reported totals.							
	1917 (24,815 mills).	1916 (30,081 mills).	1915 (29,951 mills).	1914 [1] (27,506 mills).	1913 (21,668 mills).	1912 (29,005 mills).	1911 [2] (28,107 mills).	1910 [2] (31,934 mills).	1909 (46,584 mills).	1908 [2] (31,231 mills).
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
Total	[3] 35,831,239,000	[3] 39,807,251,000	[3] 37,011,656,000	[3] 37,346,023,000	[3] 38,387,009,000	[3] 39,158,414,000	[3] 37,003,207,000	[3] 40,018,282,000	44,509,761,000	33,224,369,000
Washington	4,568,500,000	4,494,000,000	3,950,000,000	3,946,189,000	4,592,053,000	4,099,775,000	4,064,754,000	4,097,492,000	3,862,916,000	2,915,928,000
Louisiana	4,210,000,000	4,200,000,000	3,900,000,000	3,956,434,000	4,161,560,000	3,876,211,000	3,566,456,000	3,733,900,000	3,551,918,000	2,722,421,000
Oregon	2,585,000,000	2,222,000,000	1,690,000,000	1,817,875,000	2,098,467,000	1,916,160,000	1,803,698,000	2,084,633,000	1,898,995,000	1,463,158,000
Mississippi	2,425,000,000	2,730,000,000	2,300,000,000	2,280,966,000	2,610,581,000	2,381,898,000	2,041,615,000	2,122,205,000	2,572,669,000	1,861,016,000
Arkansas	1,765,000,000	1,910,000,000	1,800,000,000	1,796,780,000	1,911,647,000	1,821,811,000	1,777,303,000	1,844,446,000	2,111,300,000	1,656,991,000
Texas	1,735,000,000	2,100,000,000	1,750,000,000	1,554,005,000	2,081,471,000	1,902,201,000	1,681,080,000	1,884,134,000	2,099,130,000	1,524,008,000
Alabama	1,555,000,000	1,720,000,000	1,500,000,000	1,494,732,000	1,523,936,000	1,378,151,000	1,226,212,000	1,465,623,000	1,691,001,000	1,152,079,000
North Carolina	1,460,000,000	2,100,000,000	2,090,000,000	2,227,854,000	1,957,258,000	2,193,308,000	1,798,724,000	1,824,722,000	2,177,715,000	1,136,796,000
California	[4] 1,417,068,000	[4] 1,420,000,000	[4] 1,130,000,000	1,303,183,000	1,183,380,000	1,203,059,000	1,207,561,000	1,254,826,000	1,143,507,000	996,115,000
Wisconsin	1,385,000,000	1,600,000,000	1,210,000,000	1,391,001,000	1,493,353,000	1,498,876,000	1,761,986,000	1,891,291,000	2,025,038,000	1,613,315,000
Florida	1,230,000,000	1,425,000,000	1,110,000,000	1,073,821,000	1,055,047,000	1,067,525,000	983,824,000	992,091,000	1,201,734,000	730,906,000
Minnesota	1,075,000,000	1,220,000,000	1,100,000,000	1,312,230,000	1,149,704,000	1,436,726,000	1,485,015,000	1,457,734,000	1,561,508,000	1,286,122,000
Michigan	1,065,000,000	1,230,000,000	1,100,000,000	1,214,435,000	1,222,983,000	1,488,827,000	1,466,754,000	1,681,081,000	1,889,724,000	1,478,252,000
Virginia	1,060,000,000	1,335,000,000	1,500,000,000	1,488,070,000	1,273,953,000	1,569,997,000	1,359,790,000	1,652,192,000	2,101,716,000	1,198,725,000
West Virginia	890,000,000	1,220,000,000	1,100,000,000	1,118,480,000	1,249,559,000	1,318,732,000	1,387,786,000	1,376,737,000	1,472,942,000	1,097,015,000
Maine	770,000,000	935,000,000	1,000,000,000	992,594,000	834,673,000	882,128,000	828,417,000	860,273,000	1,111,565,000	929,350,000
Idaho	760,000,000	849,600,000	777,000,000	763,508,000	652,616,000	713,575,000	765,670,000	745,984,000	845,800,000	518,625,000
South Carolina	745,000,000	857,000,000	800,000,000	701,540,000	752,184,000	816,930,000	584,872,000	706,831,000	897,660,000	560,888,000
Georgia	740,000,000	1,000,000,000	1,000,000,000	1,026,191,000	844,284,000	941,291,000	801,611,000	1,041,617,000	1,342,249,000	904,668,000
Tennessee	630,000,000	700,000,000	800,000,000	885,035,000	872,311,000	932,572,000	914,579,000	1,016,475,000	1,223,849,000	790,642,000
Pennsylvania	565,000,000	750,000,000	950,000,000	864,710,000	781,547,000	992,180,000	1,048,606,000	1,241,199,000	1,462,771,000	1,203,041,000
New York	360,000,000	400,000,000	475,000,000	486,195,000	457,720,000	502,351,000	526,283,000	506,074,000	681,440,000	781,391,000
Kentucky	360,000,000	525,000,000	560,000,000	596,392,000	541,531,000	641,296,000	632,415,000	753,556,000	860,712,000	658,539,000
Montana	350,000,000	383,900,000	328,000,000	317,842,000	357,974,000	272,174,000	228,416,000	319,089,000	308,582,000	311,533,000
New Hampshire	290,000,000	385,000,000	500,000,000	482,744,000	309,424,000	479,499,000	388,619,000	443,907,000	649,606,000	606,760,000
Missouri	275,000,000	260,000,000	350,000,000	370,571,000	416,608,000	422,470,000	418,586,000	501,691,000	660,159,000	458,938,000
Oklahoma	240,000,000	240,000,000	230,000,000	200,594,000	140,284,000	168,806,000	143,869,000	164,663,000	225,730,000	158,756,000
Indiana	240,000,000	270,000,000	350,000,000	298,571,000	332,993,000	401,017,000	360,613,000	422,963,000	556,418,000	411,868,000
Ohio	225,000,000	280,000,000	400,000,000	286,063,000	414,943,000	499,834,000	427,161,000	490,039,000	542,904,000	459,259,000
Vermont	170,000,000	200,000,000	260,000,000	249,608,000	194,647,000	235,983,000	239,254,000	284,815,000	351,571,000	304,017,000

Massachusetts	155,000,000	210,000,000	250,000,000	143,094,000	224,580,000	259,329,000	273,317,000	239,206,000	361,200,000	384,526,000
New Mexico	93,000,000	91,600,000	65,787,000	57,167,000	65,818,000	82,650,000	83,728,000	83,544,000	91,987,000	79,439,000
Arizona	79,022,000	92,270,000	75,915,000	78,667,000	77,363,000	76,287,000	73,139,000	72,655,000	62,731,000	43,287,000
Colorado	71,500,000	77,580,000	74,500,000	102,117,000	74,602,000	88,451,000	95,908,000	121,398,000	141,710,000	117,036,000
Maryland	68,000,000	90,237,000	165,000,000	162,097,000	140,469,000	174,320,000	144,078,000	154,554,000	267,939,000	168,534,000
Connecticut	66,000,000	75,000,000	90,000,000	81,883,000	93,730,000	109,251,000	124,661,000	126,463,000	168,371,000	137,855,000
Illinois	45,000,000	60,000,000	110,000,000	66,227,000	102,902,000	122,528,000	96,651,000	113,506,000	170,181,000	123,319,000
South Dakota	29,045,000	29,650,000	22,562,000	18,744,000	19,103,000	20,986,000	13,046,000	16,340,000	31,057,000	25,859,000
New Jersey	25,000,000	40,000,000	45,000,000	48,748,000	27,248,000	34,810,000	28,639,000	36,542,000	61,620,000	34,930,000
Iowa	13,436,000	20,000,000	35,000,000	11,443,000	21,676,000	46,593,000	59,974,000	75,446,000	132,021,000	97,242,000
Rhode Island	10,646,000	18,000,000	15,000,000	15,902,000	14,984,000	14,421,000	9,016,000	14,392,000	25,489,000	30,528,000
Wyoming	8,700,000	18,495,000	17,000,000	11,852,000	12,940,000	13,560,000	33,309,000	30,931,000	28,602,000	18,822,000
Utah	8,567,000	9,385,000	10,892,000	8,680,000	5,403,000	9,055,000	10.573,000	11,786,000	12,638,000	15,059,000
Delaware	8,500,000	12,000,000	25,000,000	25,000,000	18,039,000	28,285,000	23,853,000	46,642,000	55,440,000	41,184,000
Kansas	4,255,000	534,000								
All other States				[5] 15,672,000	[5] 19,461,000	[5] 22,525,000	[5] 11,786,000	[5] 12,594,000	[5] 15,946,000	[5] 10,627,000

[1] Custom mills excluded.
[2] Includes also exclusive lath and shingle mills reporting (1,500 estimated).
[3] Mills cutting less than 50,000 feet per year excluded.
[4] Includes cut of mills in Nevada.
[5] Includes Kansas, Nebraska, and Nevada.

LUMBER PRODUCTION BY STATES.

Table 5 shows for 10 years—1908 to 1917, inclusive—the total number of sawmills in operation and the total quantity of lumber

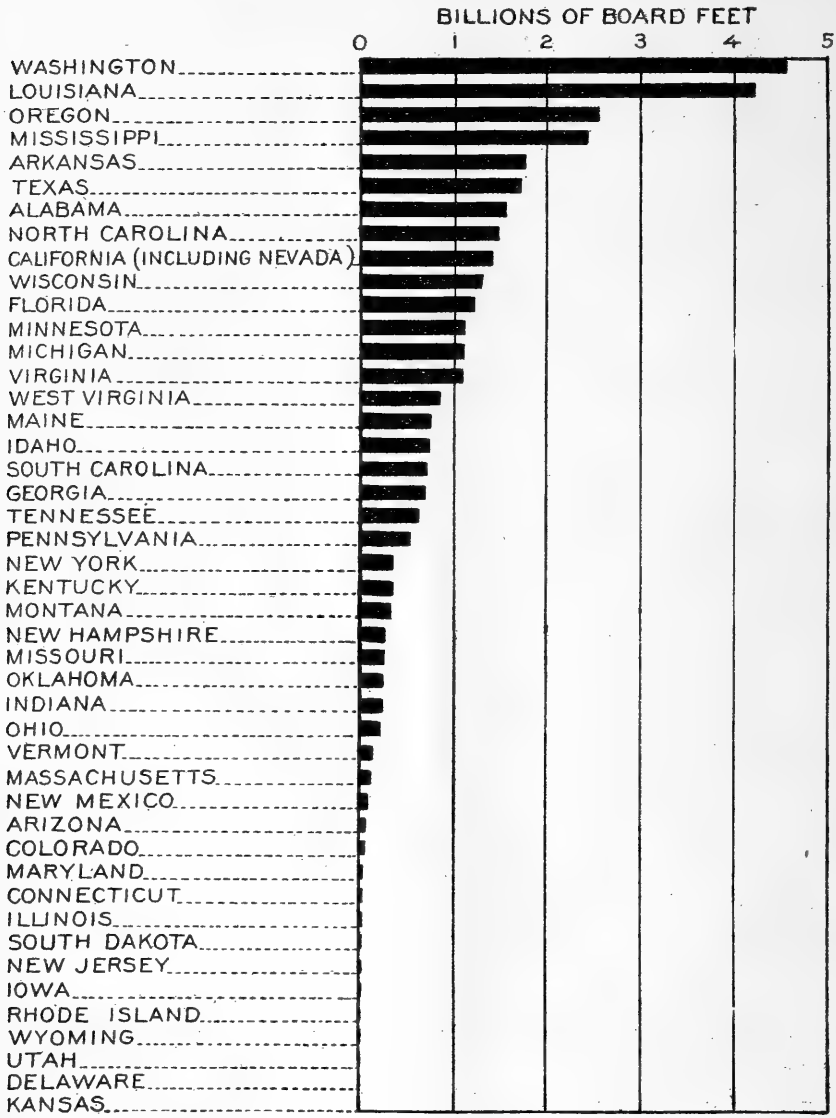

FIG. 2.—Computed total lumber production in 1917, by States.

reported sawed in each State. These statistics indicate clearly the growth or decline of the industry in each State.

It is significant that only Washington, Louisiana, and Oregon, the three States ranking highest in production for 1917, and Missouri, New Mexico, and Kansas show a larger cut than in 1916. In the other States, with the exception of Oklahoma, where the total cut is the same for both years, the output decreased. None of the gains were of much importance except that in Oregon, which was approximately 16 per cent. Serious declines are noticeable in the figures for some of the larger producing States, such as that of 30 per cent in the North Carolina cut, 27 per cent in West Virginia, 21 per cent in Virginia, 18 per cent in Maine, 26 per cent in Georgia, 25 per cent each in Pennsylvania and New Hampshire, and 31 per cent in Kentucky. The decreased cut extends through the figures for the other States in a varying degree, the 10 per cent, or 89,600,000 feet, decrease in Idaho being of relatively greater importance than the 20 per cent, or 55,000,000 feet decrease in Ohio.

The trend of production over a period of years is shown in Table 6 by groups of States which constitute more or less natural units.

TABLE 6.—*Lumber cut by groups of States in per cent of the total.*

	1850	1860	1870	1880	1890	1900	1909	1917
Northeastern group	54.8	37.0	37.8	25.8	19.8	16.3	11.7	7.0
Central group	18.6	21.1	20.0	18.4	13.1	16.1	12.3	7.4
Southern group	8.5	13.0	6.9	9.7	15.6	24.0	33.3	38.8
North Carolina pine group	5.1	4.8	2.5	4.1	4.7	7.7	11.6	9.1
Lake States group	6.3	13.6	24.4	34.7	34.6	24.9	12.3	9.9
Pacific group	5.9	6.4	4.0	3.6	8.5	8.3	15.5	23.9
Rocky Mountain group		.1	.9	.9	1.1	1.6	2.9	3.8
All other States	.8	4.0	3.5	2.8	2.6	1.1	.4	.1

LUMBER PRODUCTION BY KINDS OF WOOD.

Arranged in Table 7 is the computed cut of the different woods for the last 10 years. As the figures in Table 5 disclose a decreased cut in most of the States, the figures in Table 6 show a corresponding decline in the quantity of many of the species manufactured. The computed cut of only three softwoods was greater in 1917 than during the preceding year: Douglas fir with an increase of 3 per cent, western yellow pine 16 per cent, and white fir with 15 per cent.

Among the softwoods the decrease in the output from the year before amounted to 10 per cent in yellow pine, 17 per cent in white pine, 6 per cent in hemlock, 10 per cent in spruce, 5 per cent in cypress, 1 per cent in redwood, 20 per cent in larch, and 7 per cent in sugar pine. The maximum decrease for any one wood was 59 per cent in lodgepole pine. Hardwood production also fell off appreciably, the decrease reaching 32 per cent in oak, 6 per cent in birch, 22 per cent in chestnut, 38 per cent in yellow poplar, 13 per cent in beech, 15 per cent in elm, and 26 per cent in basswood.

The several woods which go to make up the bulk of the lumber cut in the United States are treated individually in the following pages. The tabulation for each species shows by States the number of active mills reporting, the quantity reported cut, the proportion of the total reported cut, the average value per thousand feet f. o. b. mill, and the computed total cut. The average values given in the tables are the weighted averages of about 55 per cent of the 16,420 mills which reported their cut, and accurately reflect the true value of the several species of lumber at the mill. The variation in values for the same

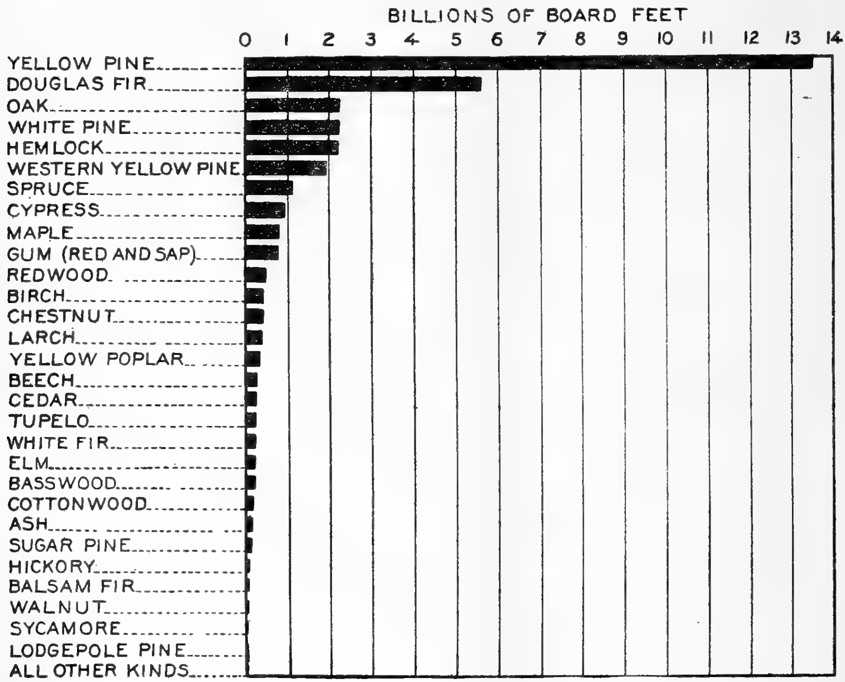

FIG. 3.—Computed total lumber production in 1917, by kinds of woods.

wood in different States is caused by character of timber, type of manufacture, and distance from market.

The question is frequently asked in connection with lumber production figures as to what part shortleaf pine forms of the total quantity of yellow pine reported, or the per cent of white oak cut to the total. It is not practicable in the lumber census work to do more than group the figures for all of the yellow pines together, and treat the oaks, gums, cedars, and other woods in the same way since no standard classification is found among the lumbermen. Producers in one section frequently apply a local name to a given species and only confusion would follow an attempt to segregate the figures.

TABLE 7. —*Quantity of each kind of lumber reported 1908–1914, and computed total production of each kind of lumber, 1915–1917.*

Kind of wood.	Computed totals.			Reported totals.						
	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
Total	35,831,239,000	39,807,251,000	37,011,656,000	37,346,023,000	38,387,009,000	39,158,414,000	37,003,207,000	40,018,282,000	44,509,761,000	33,224,369,000
Yellow pine	13,539,464,000	15,055,000,000	14,700,000,000	14,472,804,000	14,839,363,000	14,737,052,000	12,896,706,000	14,143,471,000	16,277,185,000	11,236,372,000
Douglas fir	5,585,000,000	5,416,000,000	4,431,249,000	4,763,693,000	5,556,096,000	5,175,123,000	5,054,243,000	5,203,644,000	4,856,378,000	3,675,114,000
Oak	2,250,000,000	3,300,000,000	2,970,000,000	3,278,908,000	3,211,718,000	3,318,952,000	3,098,444,000	3,522,098,000	4,414,457,000	2,771,511,000
White pine	2,250,000,000	2,700,000,000	2,700,000,000	2,632,587,000	2,568,636,000	3,138,227,000	3,230,584,000	3,352,183,000	3,900,034,000	3,344,921,000
Hemlock	2,200,000,000	2,350,000,000	2,275,000,000	2,165,728,000	2,319,982,000	2,426,554,000	2,555,308,000	2,836,129,000	3,051,399,000	2,530,843,000
Western yellow pine	1,960,000,000	1,690,000,000	1,293,985,000	1,327,365,000	1,258,528,000	1,219,444,000	1,330,700,000	1,562,106,000	1,499,985,000	1,275,550,000
Spruce	1,125,000,000	1,250,000,000	1,400,000,000	1,245,614,000	1,046,816,000	1,238,600,000	1,261,728,000	1,449,912,000	1,748,547,000	1,411,992,000
Cypress	950,000,000	1,000,000,000	1,100,000,000	1,013,013,000	1,097,247,000	997,227,000	981,527,000	935,659,000	955,635,000	743,247,000
Maple	860,000,000	975,000,000	900,000,000	909,743,000	901,487,000	1,020,864,000	951,667,000	1,006,637,000	1,106,604,000	874,983,000
Gum, red and sap	788,000,000	800,000,000	655,000,000	675,380,000	772,514,000	694,260,000	582,967,000	610,208,000	706,945,000	589,347,000
Redwood	487,458,000	490,850,000	420,294,000	535,199,000	510,271,000	496,796,000	489,768,000	543,493,000	521,630,000	404,802,000
Birch	415,000,000	450,000,000	415,000,000	430,667,000	378,739,000	388,272,000	432,571,000	420,769,000	452,370,000	386,367,000
Chestnut	415,000,000	535,000,000	490,000,000	540,591,000	505,802,000	554,230,000	529,022,000	535,049,000	663,891,000	539,341,000
Larch	360,000,000	455,000,000	375,000,000	358,561,000	395,273,000	407,064,000	368,216,000	383,514,000	421,214,000	382,466,000
Yellow poplar	350,000,000	560,000,000	464,000,000	519,221,000	620,176,000	623,289,000	659,475,000	734,926,000	858,500,000	654,122,000
Beech	296,000,000	360,000,000	360,000,000	376,464,000	365,501,000	435,250,000	403,881,000	437,325,000	511,244,000	410,072,000
Cedar	265,000,000	410,000,000	420,000,000	499,903,000	358,444,000	329,000,000	374,925,000	415,039,000	346,008,000	272,764,000
Tupelo	265,000,000	275,000,000	170,000,000	124,480,000	120,420,000	122,545,000	98,142,000	92,071,000	96,676,000	69,170,000
White fir	218,200,000	190,000,000	125,048,000	112,627,000	88,109,000	122,613,000	124,307,000	132,327,000	89,318,000	98,120,000
Elm	205,000,000	240,000,000	210,000,000	214,294,000	214,532,000	262,141,000	236,108,000	265,107,000	347,456,000	273,845,000
Basswood	203,000,000	275,000,000	260,000,000	264,656,000	257,102,000	296,717,000	304,621,000	344,704,000	399,151,000	319,505,000
Cottonwood	190,000,000	200,000,000	180,000,000	195,198,000	208,938,000	227,477,000	198,629,000	220,305,000	265,600,000	232,475,000
Ash	175,000,000	210,000,000	190,000,000	189,499,000	207,816,000	234,548,000	214,398,000	246,035,000	291,209,000	225,367,000
Sugar pine	132,600,000	169,250,000	117,701,000	136,159,000	149,926,000	132,416,000	117,987,000	103,165,000	97,191,000	99,809,000
Hickory	95,000,000	125,000,000	100,000,000	116,113,000	162,980,000	278,757,000	240,217,000	272,252,000	333,929,000	197,372,000
Balsam fir	88,900,000	125,000,000	100,000,000	125,212,000	93,752,000	84,261,000	83,375,000	74,580,000	108,702,000	69,956,000
Walnut	62,000,000	90,000,000	90,000,000	25,573,000	40,565,000	43,083,000	38,293,000	36,449,000	46,108,000	43,681,000
Sycamore	32,000,000	40,000,000	25,000,000	22,773,000	30,804,000	49,468,000	42,836,000	45,063,000	56,511,000	43,332,000
Lodgepole pine	12,500,000	30,800,000	26,486,000	18,374,000	20,106,000	22,039,000	33,014,000	26,634,000	23,733,000	(1)
All other kinds	56,117,000	40,351,000	47,893,000	55,624,000	85,366,000	82,145,000	69,548,000	68,428,000	62,151,000	47,873,000

[1] Not separately reported.

YELLOW PINE.

Yellow pine produces nearly 38 per cent of the aggregate cut of all woods. In the yellow-pine cut are included the figures for the longleaf pine produced in the Southern and Gulf States, the shortleaf pine from the same region as well as from Arkansas, and the shortleaf and loblolly pine of the North Carolina pine region.

The computed cut for 1917 was 10 per cent under that for 1916 and is the smallest cut recorded since 1911. The decrease in output was generally distributed among the several States, that of 24 per cent in North Carolina being the most noticeable and resulting in the State's dropping from fourth to seventh place in the relative rank of producing States. Alabama's total output was 9 per cent greater than for the preceding year, making the one exception of any note to the widespread reduction in cut.

Not only was the production of yellow pine smaller than for several previous years, but the character of material likewise changed considerably through the urgent demand for heavy material needed in ship construction. No statistics are available as to the increase in the per cent of timbers and large-dimension cut, but it was large. Reports were received from 6,217 active mills in 1917, whereas 6,592 mills reported in 1916.

The average value of yellow pine f. o. b. mill for the year was $19 per 1,000 feet, an advance from $14.33 the year before, and the highest average value ever recorded for that wood since the collection of prices was undertaken in connection with the lumber census work. The advance is equivalent to 33 per cent over the 1916 value, and the figure is based upon the reports made by 4,260 mills.

TABLE 8.—*Reported production of yellow-pine* [1] *lumber in 1917.*

[Computed total production in the United States, 13,539,464,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill
		Feet B. M.		
United States	6,217	12,483,410,000	100.0	$19.00
Louisiana	238	2,982,638,000	23.9	20.40
Mississippi	536	1,814,928,000	14.5	18.84
Texas	272	1,520,286,000	12.2	19.92
Alabama	721	1,285,604,000	10.3	17.34
Arkansas	397	956,316,000	7.7	20.10
Florida	204	946,096,000	7.6	18.34
North Carolina	1,266	940,972,000	7.5	17.19
Virginia	831	586,293,000	4.7	17.94
South Carolina	409	558,194,000	4.5	19.22
Georgia	597	547,870,000	4.4	16.59
Oklahoma	57	196,677,000	1.6	19.84
Tennessee	255	55,550,000	.4	15.16
Missouri	85	31,118,000	.2	15.58
Maryland	120	23,386,000	.2	18.80
Kentucky	70	13,875,000	.1	22.39
All other States (see Summary, p. 39)	159	23,607,000	.2	17.76

[1] Longleaf pine (*Pinis palustris*), also known as Georgia pine and hard pine and exported as pitch pine; cut mostly in the Gulf States.

North Carolina pine (*Pinus tæda*), also called shortleaf, loblolly, old field, rosemary, and Virginia pine; cut mostly in Virginia, North and South Carolina, Arkansas, and Texas.

Shortleaf pine (*Pinus echinata*); cut mostly in Virginia, North and South Carolina, Arkansas, Louisiana, and Mississippi.

Slash (or Cuban) pine (*Pinus cariboea*); cut mostly in Georgia and the Gulf States east of the Mississippi River.

Scrub pine (*Pinus virginiana*), also called Jersey pine; cut in the Middle Atlantic States.

Pitch pine (*Pinus rigida*); Middle Atlantic and Northern States.

Spruce pine (*Pinus glabra*); Gulf States.

Pond pine (*Pinus serotina*); South Atlantic States.

Sand pine (*Pinus clausa*); Florida and Alabama.

Table-mountain pine (*Pinus pungens*); Appalachian Mountains.

DOUGLAS FIR.

The reported Douglas-fir [1] production, 5,351,025,000 feet, was 3 per cent greater than that of the preceding year. The computed total production of 5,585,000,000 feet is the largest recorded annual cut for any year for which there are figures. The cut reported was for 1,024 mills; 1,175 mills reported in 1916. A change took place in the relative proportion produced by the mills of the two leading States, Washington's total being 6 per cent less than in 1916 and Oregon's total 12 per cent more than in 1916.

The average value of $16.28 per 1,000 feet is an advance of 51 per cent over the 1916 value and a 15 per cent advance over the former record price of $14.12 in 1907.

TABLE 9.—*Reported production of Douglas-fir [1] lumber, 1917.*

[Computed total production in the United States, 5,585,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	1,024	5,351,025,000	100.0	$16.28
Washington	337	3,320,044,000	62.0	16.15
Oregon	326	1,759,044,000	32.9	16.44
California	88	156,083,000	2.9	18.00
Idaho	131	66,663,000	1.3	14.78
Montana	73	38,600,000	.7	16.40
All other States (see Summary, p. 39)	69	10,591,000	.2	16.24

[1] Douglas fir (*Pseudotsuga taxifolia*) is the principal commercial species.

OAK.

There has been an almost unbroken annual decline in oak production in the United States during the last ten years, and 1917 proved no exception to this tendency. The reported cut of 1,967,694,000 feet was 9 per cent smaller than the 1916 output, with reports from 8,839 mills in 1917 and 9,400 in 1916. The decreasing cut can be ascribed to the fact that oak stumpage is not so plentiful as it was a decade ago and that the use of a wider variety of hardwoods has affected the demand for oak.

Several changes in the relative positions of the States in order of production occurred in 1917. Tennessee rose to second from third place in the amount cut because of an increased cut over 1916 amounting to 5 per cent, displacing Arkansas. Mississippi dropped from sixth into eighth place, North Carolina moving into the former position. Missouri advanced to seventh from tenth place, owing to an increased cut amounting to 18 per cent over the previous year. The figures for Tennessee, Missouri, and Indiana are the only ones

[1] *Pseudotsuga taxifolia.*

showing an increased cut for 1917. It is worthy of note that Indiana, where the manufacture of oak has been carried on for generations and where a decreased output could logically be looked for, reported a cut of 85,210,000 feet, as compared with 83,674,000 feet in 1916.

The average value of oak rose from $20.06 per 1,000 feet in 1916 to $24.49 in 1917, an increase of 22 per cent.

TABLE 10.—*Reported production of oak [1] lumber, 1917.*

[Computed total production in the United States, 2,250,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	8,839	1,967,694,000	100.0	$24.49
West Virginia	420	242,415,000	12.3	25.37
Tennessee	759	237,574,000	12.1	26.07
Arkansas	421	235,763,000	12.0	24.05
Kentucky	553	170,469,000	8.6	25.80
Virginia	834	169,725,000	8.6	19.98
North Carolina	854	115,749,000	5.9	19.27
Missouri	320	112,897,000	5.7	20.87
Mississippi	262	111,751,000	5.7	25.00
Ohio	476	90,561,000	4.6	29.17
Pennsylvania	680	85,779,000	4.3	26.10
Indiana	412	85,210,000	4.3	34.81
Louisiana	96	70,538,000	3.6	23.48
Alabama	347	38,363,000	1.9	17.84
Texas	86	36,829,000	1.9	21.06
New York	621	22,592,000	1.3	28.66
All other States (see Summary, p. 39)	1,698	141,179,000	7.2	24.03

[1] Commercially the oaks are classed as white and red. The principal commercial oaks are listed below:

White oaks:

- White oak (*Quercus alba*) is the white oak common throughout the eastern half of the United States.
- Chestnut (or rock) oak (*Quercus prinus*) is found in the Appalachian region.
- Post oak (*Quercus minor*) and bur oak (*Quercus macrocarpa*) are common throughout the eastern half of the country.
- Overcup oak (*Quercus lyrata*) and cow (or basket) oak (*Quercus michauxii*) are the principal southern white oaks.

Red oaks:

- Red oak (*Quercus rubra*) is the red oak common to the eastern part of the United States.
- Texan red oak (*Quercus texana*) is the principal red oak sawed in the lower Mississippi Valley.
- Pin oak (*Quercus palustris*) is found in the Eastern and Central States.
- Scarlet oak (*Quercus coccinea*) is the northern and northeastern red oak.
- Yellow (or black) oak (*Quercus velutina*) is common to most States east of the Rocky Mountains.
- Willow oak (*Quercus phellos*) is cut mostly in the Southern States.

WHITE PINE.

The output of white pine in 1917, like that of other softwoods, was smaller than for the previous year. The total reported production of 2,050,360,000 feet showed a decrease of 12 per cent. The cut was the smallest of which there is record. The reduced cut is consistently shown by all of the States, the greatest reduction for any one State being that shown for Idaho of 110,651,000 feet, or 36 per cent. Minnesota's mills put out 41 per cent of all the white pine reported cut in 1916 and 44 per cent in 1917; Idaho's share was 13 per cent in the 1916 total and 9 per cent in 1917. Maine, where many generations of lumbermen have developed the white pine industry, displaced Idaho in second place in the rank of producing

States, and New Hampshire moved into fourth place, which was occupied by Wisconsin in 1916.

The average value of white pine for the year was $24.81 per 1,000 feet, an advance of $5.65 per 1,000, or 29 per cent, over the year before.

TABLE 11.—*Reported production of white-pine [1] lumber, 1917.*

[Computed total production in the United States, 2,250,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	2,984	2,050,360,000	100.0	$24.81
Minnesota	148	901,941,000	44.0	25.86
Maine	408	256,014,000	12.5	22.68
Idaho	36	193,404,000	9.4	25.56
New Hampshire	246	171,547,000	8.4	21.83
Wisconsin	234	160,630,000	7.8	28.34
Massachusetts	211	90,797,000	4.4	20.87
New York	698	57,924,000	2.8	26.89
Washington	37	56,955,000	2.8	19.39
Michigan	131	47,571,000	2.3	29.47
Pennsylvania	297	25,756,000	1.3	26.99
North Carolina	96	20,190,000	1.0	22.13
Vermont	114	18,884,000	.9	21.04
Connecticut	54	10,043,000	.5	23.11
Virginia	74	9,144,000	.5	19.20
West Virginia	57	8,461,000	.4	20.89
All other States (see Summary, p. 39)	143	21,099,000	1.0	19.62

[1] White pine (*Pinus strobus*) is the white pine cut in the Lake States, the Northeastern States, and the Appalachian region.
Norway (or red) pine (*Pinus resinosa*), though botanically a yellow pine, is cut in the Lake States and largely marketed with white pine.
Jack pine (*Pinus banksiana*) is cut in the Lake States.
Western white pine (*Pinus monticola*) is cut in Idaho, Montana, Washington, and Oregon.

HEMLOCK.

The curtailment in production in 1917 was less for hemlock than for any other one of the principal construction woods. The total reported production of 1,968,217,000 feet was smaller by only approximately 18,000,000 feet, or less than 1 per cent, than the 1916 cut. The output of the mills in Wisconsin, the leading State in hemlock production, was enlarged by 7 per cent over that of 1916, which may be attributed to the exceptionally heavy demands made by the Government for lumber for construction work. Michigan mills likewise increased their output, though less than 1 per cent of the total. Wisconsin and Michigan combined to produce in 1917 more than 45 per cent of the hemlock cut of the country, as compared with 43 per cent in 1916. Washington's increased output was 19 per cent, amounting to nearly 50,000,000 feet. Slightly increased production also took place among the New York and the Tennessee mills, and in the shifting of figures New York supplanted Maine in the sixth position in the relative rank of States.

The average value of hemlock rose from $15.35 per 1,000 feet in 1916 to $20.78 in 1917, an increase of 35 per cent.

TABLE 12.—*Reported production of hemlock* [1] *lumber, 1917.*

[Computed total production in the United States, 2,200,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	3,359	1,968,217,000	100.0	$20.78
Wisconsin	240	563,946,000	28.7	23.27
Michigan	200	327,651,000	16.6	19.80
Washington	103	317,243,000	16.1	16.30
Pennsylvania	409	242,628,000	12.3	23.10
West Virginia	135	134,060,000	6.8	21.81
New York	940	84,193,000	4.3	23.72
Maine	355	66,583,000	3.4	19.91
Oregon	33	49,479,000	2.5	16.33
North Carolina	108	36,688,000	1.9	17.85
Virginia	82	32,954,000	1.7	18.68
Tennessee	69	31,182,000	1.6	15.75
New Hampshire	186	26,059,000	1.3	20.85
Vermont	242	18,192,000	.9	20.69
Kentucky	50	13,489,000	.7	21.54
Massachusetts	115	10,201,000	.5	20.23
All other States (see Summary, p. 39)	92	13,669,000	.7	20.36

[1] Hemlock (*Tsuga canadensis*) is cut in the Lake States, Northeastern States, and the Appalachian region. Western hemlock (*Tsuga heterophylla*) is manufactured in Washington and Oregon.
Black (or western mountain) hemlock (*Tsuga mertensiana*) is cut in small quantities. Carolina hemlock (*Tsuga caroliniana*) is occasionally cut in the Appalachian region.

WESTERN YELLOW PINE.

Stimulated cutting in practically all of the producing States resulted in a total production of 1,865,282,000 feet of western yellow pine, an increase of 11 per cent over the 1916 cut. While the output in the chief State of production, California, was less by 3 per cent than the year before, the output in Oregon was 18 per cent, in Idaho 31 per cent, and in Washington 15 per cent greater than in 1916. Oregon's cut was 25.2 per cent of the total production of western yellow pine in 1917; in 1916 it was 23.7 per cent. California's cut was 25.6 per cent of the whole in 1917 and 29.4 per cent in 1916. Through changes in operations New Mexico took sixth place in rank of production, which was occupied by Arizona last year.

The average mill value for western yellow pine in 1916 was $14.52 per 1,000; in 1917 it was $19.59, an advance of $5.07, or 35 per cent, during the year.

TABLE 13.—*Reported production of western yellow-pine* [1] *lumber, 1917.*

[Computed total production in the United States, 1,960,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	747	1,865,282,000	100.0	$19.59
California (including Nevada)	110	478,565,000	25.6	22.50
Oregon	118	469,408,000	25.2	19.66
Idaho	116	315,019,000	16.9	18.51
Washington	113	217,353,000	11.6	16.29
Montana	87	150,905,000	8.1	18.80
New Mexico	55	83,426,000	4.5	16.11
Arizona	22	78,107,000	4.2	19.42
Colorado	53	35,328,000	1.9	17.11
South Dakota	28	29,045,000	1.6	25.04
All other States (see Summary, p. 39)	45	8,126,000	.4	17.80

[1] Western yellow pine (*Pinus ponderosa*) is the one species cut as such.

SPRUCE.

The immense demand for spruce for airplane material is not reflected in the lumber production figures for 1917, since the accelerated production did not take place until late in the year. Much spruce gotten out in the woods was in the form of rived bolts, and was not the product of the sawmill.

The total reported cut, 978,265,000 feet, was 13 per cent smaller than in 1916. Maine, which has contributed annually about one-third of the total spruce milled, sawed only 79,000,000 feet, or 21 per cent less in 1917 than in 1916; even with the reduced cut the State maintained first rank among the producing States. The cut in Vermont, New Hampshire, and New York also was reduced, and this reduction, as in Maine, is directly attributable to the higher price obtainable for spruce as pulp material than as lumber. Oregon ranked seventh in 1915 among the spruce producing States, jumped into fourth place in 1916, and assumed third place in 1917. Oregon cut 65,000,000 feet in 1915, 96,000,000 feet a year later, and 121,000,000 feet in 1917. Washington's cut was slightly smaller in 1917 than for the preceding year. North Carolina, Minnesota, Colorado, California, and Idaho enlarged their total for 1917.

The average value reported for spruce lumber was $24.41 per 1,000 feet, though from $100 to $250 per 1,000 feet was paid for the highest grade procurable for airplane construction. The average value in 1916 was $17.58, so that the 1917 value represents a rise of 39 per cent.

TABLE 14.—*Reported production of spruce*[1] *lumber, 1917.*

[Computed total production in the United States, 1,125,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	1,320	978,265,000	100.0	$24.41
Maine	298	297,949,000	30.4	23.43
Washington	66	198,271,000	20.3	22.34
Oregon	26	120,647,000	12.3	28.28
West Virginia	18	68,895,000	7.0	30.30
Vermont	244	48,630,000	5.0	24.28
North Carolina	17	47,360,000	4.8	28.33
Minnesota	67	40,999,000	4.2	24.28
New Hampshire	112	36,057,000	3.7	23.47
New York	184	27,215,000	2.8	28.51
Colorado	47	22,896,000	2.3	17.14
California	4	20,659,000	2.1	17.50
Idaho	23	19,171,000	2.0	22.49
Wisconsin	42	7,852,000	.8	25.78
Michigan	68	6,703,000	.7	24.06
Montana	11	6,437,000	.7	18.22
All other States (see Summary, p. 39)	93	8,524,000	.9	19.79

[1] Red spruce (*Picea rubra*) is the principal species cut in the northeastern States and the Appalachian region.
Sitka spruce (*Picea sitchensis*) is the principal species cut in Oregon and Washington.
Black spruce (*Picea mariana*) is cut in limited quantities in the northeastern States.
White spruce (*Picea canadensis*) is cut in the Lake States.
Engelmann spruce (*Picea engelmanni*) is cut in the Rocky Mountain region.

CYPRESS.

Cypress was less seriously affected by the general slump in production than many other woods and the cut of 917,445,000 feet was but 3 per cent, or 28,000,000 feet, under that for 1916. In Louisiana, which milled 56 per cent of all the cypress cut in 1917, the output of 509,659,000 feet was 17,766,000 feet, or 3 per cent, less than in 1916; and in Florida the cut of 166,857,000 feet was 21,942,000 feet, or 12 per cent, under that of 1916. In South Carolina the total cut was enlarged and the State displaced Georgia in third place among the producing States. The cut reported in Arkansas and Missouri also was slightly more in 1917 than the year before.

The average value of cypress for 1917, $23.92, is an advance of $3.07, or 15 per cent, over the preceding year, and the spread is noticeably less than for many of the other woods.

TABLE 15.—*Reported production of cypress*[1] *lumber, 1917.*

[Computed total production in the United States, 950,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	654	917,445,000	100.0	$23.92
Louisiana	97	509,659,000	55.6	24.48
Florida	36	166,857,000	18.2	24.51
South Carolina	37	59,107,000	6.5	25.90
Georgia	31	51,219,000	5.6	26.05
Arkansas	135	43,969,000	4.8	21.88
Missouri	44	26,981,000	2.9	19.68
Mississippi	91	16,537,000	1.8	24.14
North Carolina	73	15,958,000	1.7	20.69
Tennessee	44	10,003,000	1.1	25.63
Virginia	15	9,539,000	1.0	21.87
All other States (see Summary, p. 39)	51	7,616,000	.8	21.32

[1] Bald cypress (*Taxodium distichum*) is the one species cut as such.

MAPLE.

The quantity of maple reported sawed was less by approximately 1 per cent than in 1916. The three principal producing States, Michigan, Wisconsin, and West Virginia, produced within 11,000,000 feet as much as in 1916, and slight increases in output occurred among the mills in Ohio, Indiana, and Missouri. The production of maple has not varied to any marked degree during the last 10 years.

The average value of $23.16 per 1,000 feet is an increase above the average of $18.24 obtained in 1916 of $4.92 per 1,000 feet, or 27 per cent.

TABLE 16.—*Reported production of maple [1] lumber, 1917.*

[Computed total production in the United States, 860,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	3,944	802,089,000	100.0	$23.16
Michigan	249	349,688,000	43.6	24.11
Wisconsin	264	154,570,000	19.3	21.10
West Virginia	193	67,471,000	8.4	25.90
New York	786	45,024,000	5.6	23.91
Pennsylvania	427	42,903,000	5.3	20.68
Ohio	328	26,244,000	3.3	22.34
Indiana	340	23,324,000	2.9	27.50
Vermont	206	16,870,000	2.1	21.50
Missouri	91	14,135,000	1.8	19.93
All other States (see Summary, p. —)	1,060	61,860,000	7.7	21.02

[1] Sugar (or hard) maple (*Acer saccharum*) is cut principally in the Northern States.
Silver (or soft) maple (*Acer saccharinum*) is also cut in the Northern States.
Red (or soft) maple (*Acer rubrum*) is the principal species cut in the Southern States.
Mountain maple (*Acer spicatum*) and striped maple (*Acer pennsylvanicum*) are cut in the Eastern States.
Oregon maple (*Acer macrophyllum*) is cut in the Pacific Coast States.

RED GUM.

One of the few woods for which a gain in production was made in 1917 was red gum, the total output reaching 730,662,000 feet, or a 12 per cent increase over the 1916 total of 651,879,000 feet. The cut in 1916 was 36 per cent greater than for the preceding year. Organization of the efforts of the operators in finding new markets and in handling their product is responsible for the enlarged output and consumption of red gum. The quantity cut in Arkansas, Mississippi, and Louisiana was slightly in excess in each instance of the 1916 output, the total for the three States amounting to 68 per cent of all the gum reported cut. Tennessee's production almost trebled in 1917, being 64,356,000 feet. The 1916 cut was 23,917,000 feet. It is significant that the number of mills which reported cutting red gum in 1917 was 1,949, while but 1,845 reported in 1916.

A higher average mill value was obtained in 1917 than in 1916, the average value of $19.56 in 1917 being an increase of $4.92 per 1,000 feet, or 34 per cent.

TABLE 17.—*Reported production of gum [1] lumber, 1917.*

[Computed total production in the United States, 788,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	1,949	730,662,000	100.0	$19.56
Arkansas	284	230,964,000	31.6	19.92
Mississippi	204	169,847,000	23.2	19.96
Louisiana	89	94,671,000	13.0	19.22
Tennessee	212	64,356,000	8.8	24.42
Texas	49	26,342,000	3.6	16.80
Alabama	117	25,147,000	3.4	15.06
Missouri	60	24,981,000	3.4	17.23
South Carolina	32	19,883,000	2.7	17.93
North Carolina	116	12,866,000	1.8	15.78
Georgia	48	12,392,000	1.7	16.75
Kentucky	163	10,084,000	1.4	16.80
Virginia	122	9,165,000	1.3	15.91
All other States (see Summary, p. 39)	453	29,964,000	4.1	19.19

[1] Red (or sweet) gum (*Liquidambar styraciflua*) is the only species that goes into red gum lumber. Commercial sap gum is the sapwood of the red gum.

REDWOOD.

Redwood production was maintained in 1917 on the same scale as for the preceding year, the reported total output of 487,458,000 feet being less than 1 per cent smaller than that for 1916. The production figure given is believed to cover approximately all of the redwood cut.

An exceptional advance of 51 per cent is noted in the average mill value over the previous year. The value reported was $21 per 1,000 feet in 1917, a jump of $7.07 from 1916.

TABLE 18.—*Reported production of redwood [1] lumber, 1917.*

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	36	487,458,000	100.0	$21.00
California	36	487,458,000	100.0	21.00

[1] Redwood (*Sequoia sempervirens*) is the species chiefly cut. Bigtree (*Sequoia washingtoniana*) furnishes a minor part of the redwood production.

BIRCH.

The reported total cut of birch, amounting to 387,283,000 feet, was an increase of 6 per cent over the 1916 cut, and was occasioned by the heightened war demands. Wisconsin and Michigan, the two principal birch-producing States, increased their output over the preceding year by 16 per cent and 4 per cent, respectively. The combined output of the two States formed 65.3 per cent of all birch reported cut in 1916 and 69.9 per cent in 1917. The number of mills which reported cutting birch in Wisconsin and Michigan in 1917 was 367 and for the preceding year 410. Vermont's increase in cut from 22,980,000 feet in 1916 to 30,882,000 feet in 1917 puts that State in third instead of fifth place in the rank of producing States.

The average value of $24.07 per 1,000 feet reported for birch is $4.48, or 23 per cent, over the 1916 value.

TABLE 19.—*Reported production of birch [1] lumber, 1917.*

[Computed total production in the United States, 415,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	1,836	387,283,000	100.0	$24.07
Wisconsin	226	208,864,000	53.9	24.21
Michigan	141	61,768,000	16.0	24.74
Vermont	202	30,882,000	8.0	25.98
Maine	150	21,713,000	5.6	21.44
West Virginia	107	18,960,000	4.9	25.02
New York	358	17,628,000	4.6	24.93
Pennsylvania	196	7,535,000	1.9	20.09
New Hampshire	98	6,344,000	1.6	20.86
Minnesota	48	4,395,000	1.1	18.26
All other States (see Summary, p. 39)	310	9,194,000	2.4	20.92

[1] Yellow birch (*Betula lutea*) is the principal species cut in the Lake States, New England, and New York. Paper birch (*Betula papyrifera*) and white (or gray) birch (*Betula populifolia*) are also cut to a limited extent in New England.
Sweet (or cherry) birch (*Betula lenta*) is cut in West Virginia and Pennsylvania.
River (or red) birch (*Betula nigra*) is cut in the Southern States.

CHESTNUT.

The chestnut-lumber production of 382,652,000 feet was a slump of 9 per cent from the total of the year before. The cut in West Virginia of 107,410,000 feet was 24,782,000 feet, or 19 per cent less than that of 1916. A slight increase occurred among the mills in North Carolina, Virginia, Connecticut, Tennessee, and New York. A decreased cut in Pennsylvania dropped that State from second to fourth rank in order of State production.

The average value of chestnut was $21.54 in 1917, an increase over the 1916 value of $4.49, or 26 per cent.

TABLE 20.—*Reported production of chestnut* [1] *lumber, 1917.*

[Computed total production in the United States, 415,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	3,061	382,652,000	100.0	$21.54
West Virginia	295	107,410,000	28.1	22.87
North Carolina	223	47,277,000	12.3	20.76
Virginia	292	42,073,000	11.0	19.38
Pennsylvania	602	40,149,000	10.5	21.49
Connecticut	134	33,149,000	8.7	21.50
Tennessee	281	32,738,000	8.6	20.35
New York	410	17,153,000	4.5	23.28
Massachusetts	126	16,863,000	4.4	21.53
Kentucky	263	13,231,000	3.5	20.27
Maryland	75	9,337,000	2.4	19.99
Ohio	184	6,795,000	1.8	23.29
New Jersey	68	5,405,000	1.4	23.66
New Hampshire	37	4,778,000	1.2	20.29
Rhode Island	20	4,718,000	1.2	24.70
All other States (see Summary, p. 39)	51	1,576,000	.4	18.64

[1] Chestnut (*Castanea dentata*) is the only species included in chestnut lumber.

LARCH.

Larch production declined 11 per cent from 1916, the total cut being 336,640,000 feet in 1917 and 376,731,000 feet the year before. In Montana the decrease amounted to 17 per cent and in Idaho to 7 per cent. These two States cut 72 per cent of the total in 1916 and 70 per cent in 1917. Wisconsin's output was 40 per cent and that of Michigan 11 per cent under the 1916 figures. The quantity milled in Washington was 12 per cent greater than the year before; in Oregon it was 63 per cent greater. Minnesota's total showed an increase of 17 per cent from the year before.

The fact that larch shared in the advance in price with other of the western woods explains, in part, the greater output in Washington and Oregon. The tamarack, or larch, of the Lake States has always returned the operators a higher average value, as will be noted from the figures shown in the accompanying tabulation, than the western product.

The average mill value for all larch was $12.49 in 1916; in 1917 it was $16.21, an increase of 30 per cent.

TABLE 21.—*Reported production of larch [1] (tamarack) lumber, 1917.*

[Computed total production in the United States, 360,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	537	336,640,000	100.0	$16.21
Montana	41	135,734,000	40.3	16.38
Idaho	56	99,950,000	29.7	14.60
Washington	48	34,242,000	10.2	13.74
Wisconsin	135	19,410,000	5.8	20.71
Minnesota	96	18,217,000	5.4	20.56
Michigan	98	14,680,000	4.3	21.01
Oregon	21	13,793,000	4.1	14.94
All other States (see Summary, p. 39)	42	614,000	.2	21.18

[1] Western larch (*Larix occidentalis*) is the species cut in the Inland Empire and the Pacific Northwest. Tamarack, or larch (*Larix laricina*), is cut in the Lake States and New England States.

YELLOW POPLAR.

The reported total output of yellow poplar of 325,968,000 feet was smaller by nearly 70,000,000 feet, or 17 per cent, than the 1916 cut. The decrease is consistent with the general trend of poplar production during the last 10 years. West Virginia's cut alone fell off 23,480,000 feet, or 23 per cent, from the year before; and a decreased cut took place in most of the other States producing poplar except in Tennessee and Kentucky, where slight gains are recorded.

The average mill value of $27.17 per 1,000 feet is $5.28 per 1,000, or 24 per cent, above the 1916 value.

TABLE 22.—*Reported production of yellow-poplar [1] lumber, 1917.*

[Computed total production in the United States, 350,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	2,779	325,968,000	100.0	$27.17
West Virginia	255	79,035,000	24.2	30.78
Tennessee	429	48,425,000	14.9	28.61
Kentucky	333	42,205,000	12.9	30.84
Virginia	355	37,213,000	11.4	25.00
North Carolina	305	29,311,000	9.0	21.77
Georgia	87	28,252,000	8.7	22.43
Alabama	164	21,519,000	6.6	19.87
Ohio	179	13,252,000	4.1	31.56
South Carolina	138	7,014,000	2.1	20.86
Indiana	198	6,094,000	1.9	35.48
Pennsylvania	161	4,348,000	1.3	26.44
Mississippi	89	4,181,000	1.3	22.56
All other States (see Summary, p. 39)	186	5,119,000	1.6	22.98

[1] Yellow poplar (*Liriodendron tulipifera*) is the only species that goes into poplar lumber.

BEECH.

The production of beech was less than 2 per cent smaller in 1917 than in the preceding year, the figures being 278,345,000 feet for 1917 and 283,363,000 feet for 1916. Michigan's cut was 10 per cent less than for the previous year. In Indiana the cut was increased slightly and that State moved into second from third place among the producing States; while Pennsylvania, which occupied second, dropped into fourth place. Beech is one of the woods which has shown a steady decrease annually for 10 years past.

The average mill value for beech in 1917 was $19.58 per 1,000 feet; in 1916 it was $16.20, so that there was a rise of 21 per cent during the year.

TABLE 23.—*Reported production of beech[1] lumber, 1917.*

[Computed total production in the United States, 296,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	3,095	278,345,000	100.0	$19.58
Michigan	182	59,573,000	21.4	21.01
Indiana	345	40,919.000	14.7	20.16
West Virginia	207	35,584,000	12.8	19.74
Pennsylvania	336	34,049,000	12.2	18.50
New York	620	28,503,000	10.2	19.87
Ohio	358	24,376,000	8.8	19.27
Kentucky	284	20,136,000	7.2	16.26
Tennessee	181	8,379,000	3.0	18.75
Vermont	157	7,698,000	2.8	20.84
Wisconsin	29	3,335,000	1.2	24.29
Virginia	71	3,143,000	1.1	17.46
New Hampshire	57	3,046,000	1.1	18.87
All other States (see Summary, p. 39)	268	9,604,000	3.5	17.41

[1] Beech (*Fagus atropunicea*) is the only species that goes into beech lumber.

CEDAR.

The output of cedar lumber in the United States does not represent the drain on the cedar timber, since millions of feet are used annually in the manufacture of shingles and thousands of poles, posts, ties, and pencil slats are also produced. The cut of cedar lumber in 1917 was 258,005,000 feet, 70 per cent smaller than the year before. While the production fell off 13 per cent in Washington and 9 per cent in Oregon, the combined output of these States was 68.9 per cent of that reported for the entire country in 1917, as compared with 62.6 per cent in 1916. California's output increased 28 per cent and the State moved past Idaho and Virginia from fifth into third place.

Considerable variation is shown in the average value compiled for the different States, which reflects the difference in the species cut. The average value of cedar per 1,000 feet for the country as a whole took an upward turn from $15.24 for 1916 to $19.40 for 1917, an advance of 27 per cent.

TABLE 24.—*Reported production of cedar*[1] *lumber, 1917.*

[Computed total production in the United States, 265,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	573	258,005,000	100.0	$19.40
Washington	96	135,820,000	52.6	18.16
Oregon	46	42,088,000	16.3	22.85
California	46	21,310,000	8.3	17.50
Idaho	16	15,319,000	5.9	14.29
Virginia	20	9,017,000	3.5	15.44
Tennessee	78	7,713,000	3.0	33.44
North Carolina	34	7,462,000	2.9	22.98
Maine	51	6,821,000	2.7	20.85
Michigan	26	5,954,000	2.3	17.14
All other States (see Summary, p. 39)	160	6,501,000	2.5	26.70

[1] Western red cedar (*Thuja plicata*) is cut in Washington, Oregon, and Idaho.
Port Orford cedar (*Chamæcyparis lawsoniana*) is cut in Oregon.
Yellow cedar (*Chamaecyparis nootkatensis*) is cut in Washington.
Incense cedar (*Libocedrus decurrens*) is cut in California.
Northern white cedar (or arborvitæ) (*Thuja occidentalis*) is cut in the Lake States and the Northeastern States.
White cedar (or juniper) (*Chamæcyparis thyoides*) is cut in the Atlantic Coast States.
Red cedar (*Juniperus virginiana*) and southern red juniper (*Juniperus barbadensis*) is cut in Tennessee, Florida, and Alabama.

TUPELO.

Nearly all of the leading tupelo-producing States, the exception being Virginia, reported a heavier cut in 1917 than the year before, the total for the country being 249,992,000 feet, or 17 per cent in excess of the 1916 figures. The cut was larger in Louisiana by 12 per cent than the year before, 14 per cent in Alabama, nearly three times as large in Mississippi, and more than twice as large in North Carolina and South Carolina. Forty more mills reported cutting tupelo in 1917 than in 1916. In each one of the last 10 years there has been a growth in the output of tupelo.

There was a decided upward tendency in the average value, which reached $18.06 per 1,000 feet, an increase of 39 per cent over the 1916 average value of $13.

TABLE 25.—*Reported production of tupelo*[1] *lumber, 1917.*

[Computed total production in the United States, 265,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	658	249,992,000	100.0	$18.06
Louisiana	55	127,210,000	50.9	18.30
Alabama	43	25,528,000	10.2	19.26
Mississippi	54	21,974,000	8.8	18.68
North Carolina	51	18,179,000	7.3	16.16
South Carolina	18	16,933,000	6.8	18.28
Virginia	42	9,009,000	3.6	15.22
Missouri	29	7,746,000	3.1	17.54
Tennessee	80	5,115,000	2.0	17.69
Arkansas	56	4,788,000	1.9	15.76
All other States (see Summary, p. 39)	230	13,510,000	5.4	18.06

[1] Tupelo (or cotton gum) (*Nyssa aquatica*) is cut in the Gulf States.
Black gum (or pepperidge) (*Nyssa sylvatica*) is cut in the Atlantic and Central States and is sold both as tupelo and black gum.
Water gum (*Nyssa biflora*) is cut to a small extent in the Southern Atlantic States.

ELM.

Compared with the quantity of elm reported cut in 1916, the 1917 total cut of 191,853,000 feet is but 2 per cent smaller. The cut was lower by 11 per cent than the year before in Wisconsin, 15 per cent in Michigan, and 9 per cent in Indiana. The mills in Arkansas, Tennessee, Mississippi, and Missouri cut more than in 1916. The annual production of this wood has not varied much during the last few years.

The average mill value of elm was $23.89 in 1917, an increase of 23 per cent over the 1916 average of $19.46.

TABLE 26.—*Reported production of elm [1] lumber, 1917.*

[Computed total production in the United States, 205,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	2,562	191,853,000	100.0	$23.89
Wisconsin	271	46,077,000	24.0	24.14
Michigan	204	36,107,000	18.8	27.35
Arkansas	103	21,748,000	11.3	23.55
Indiana	276	17,244,000	9.0	25.27
Tennessee	141	12,809,000	6.7	25.54
Mississippi	86	11,443,000	6.0	20.41
Missouri	126	9,959,000	5.2	21.23
Ohio	270	9,653,000	5.0	22.97
New York	420	6,015,000	3.1	21.88
Louisiana	37	4,786,000	2.5	22.93
All other States (see Summary, p. 39)	628	16,012,000	8.4	18.70

[1] White (or soft) elm (*Ulmus americana*) is cut in all of the States east of the Rocky Mountains.
Slippery (or red, or soft) elm (*Ulmus pubescens*) is cut in the same region as white elm.
Cork (or true rock) elm (*Ulmus racemosa*) is cut in the Lake States.
Wing elm (*Ulmus alata*) and cedar elm (*Ulmus crassifolia*) are occasionally cut in the lower Mississippi Valley.

BASSWOOD.

The cut of basswood has shown an almost unbroken yearly decrease since 1908, and the 1917 figure of 190,757,000 feet is 9 per cent less than the reported cut of the year preceding. With the exception of Michigan, where an increase of about 5 per cent over the 1916 manufacture is noted, the six leading producing States show a decreased cut from the year before ranging from a maximum of 27 per cent in West Virginia to a minimum of 1 per cent in Virginia.

The average mill value for basswood in 1917 was $25.96; in 1916 it was $21.05. The increase is 23 per cent.

TABLE 27.—*Reported production of basswood*[1] *lumber, 1917.*

[Computed total production in the United States, 203,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	2,548	190,757,000	100.0	$25.96
Wisconsin	273	67,787,000	35.5	26.60
Michigan	197	38,427,000	20.1	27.74
West Virginia	161	21,098,000	11.1	25.43
New York	638	12,240,000	6.4	25.48
Virginia	73	6,925,000	3.6	25.65
North Carolina	87	6,570,000	3.4	22.96
Tennessee	82	6,251,000	3.3	25.21
Ohio	174	5,231,000	2.7	25.84
Indiana	128	4,859,000	2.6	27.49
Kentucky	82	4,698,000	2.5	23.41
Vermont	174	4,530,000	2.4	23.68
Pennsylvania	196	4,391,000	2.3	23.69
Minnesota	70	3,832,000	2.0	19.45
All other States (see Summary, p. 39)	213	3,918,000	2.1	21.70

1 Basswood (or linn) (*Tilia americana*) is cut in the Lake States.
White basswood (*Tilia heterophylla*) is cut in the Appalachian Mountain region.
Downy basswood (*Tilia pubescens*) is cut in limited quantity in the Southern States.

WHITE FIR.

White fir is of ever growing importance commercially, and its production increases each year. The 1916 production was 56 per cent greater than the 1915 output. The total output of 213,427,000 feet reported for 1917 is 13 per cent in excess of the 1916 cut. The quantity made by the California and Nevada mills was 40 per cent more than the year before. The combined cut of the two States was 56.6 per cent of the country's total in comparison with 45.3 per cent in 1916. The cut of the Washington mills increased 32 per cent and that of the Montana mills was nearly trebled; on the other hand, Idaho mills cut 38 per cent and Oregon mills 3 per cent less than in 1916.

A 40 per cent increase in the average value of white fir took place during the year. The 1916 value was $12.25; the 1917 value, $17.16.

TABLE 28.—*Reported production of white-fir*[1] *lumber, 1917.*

[Computed total production in the United States, 218,200,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	233	213,427,000	100.0	$17.16
California (including Nevada)	63	120,661,000	56.6	18.00
Idaho	51	37,416,000	17.5	17.83
Washington	41	23,736,000	11.1	15.36
Oregon	41	19,847,000	9.3	13.79
Montana	9	9,645,000	4.5	15.28
All other States (see Summary, p. 39)	28	2,122,000	1.0	17.91

1 White fir (*Abies concolor*) is cut only in the West.
Marketed as white fir are:
Grand fir (*Abies grandis*), cut mostly in Idaho and Montana.
Silver fir (*Abies amabilis*), cut chiefly in Washington.
Noble fir (*Abies nobilis*), cut chiefly in Oregon.
Red fir (*Abies magnifica*), cut chiefly in California.
Alpine fir (*Abies lasiocarpa*), cut chiefly in California.

COTTONWOOD.

Cottonwood production totaling 178,985,000 feet reflected stimulated manufacture in 1917, for it was a 33 per cent addition to the 1916 reported cut. A large part of the cottonwood produced is utilized in the manufacture of boxes, and the demand for boxes during the year was exceptionally strong. Production in Mississippi was 35 per cent over that of 1916, in Louisiana 17 per cent, in Missouri 62 per cent, and in Arkansas 68 per cent. Cottonwood output during the last ten years has remained nearly stationary.

The average mill value for cottonwood increased 33 per cent, or from $17.42 in 1916 to $23.19 in 1917.

TABLE 29.—*Reported production of cottonwood*[1] *lumber, 1917.*

[Computed total production in the United States, 190,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	928	178,985,000	100.0	$23.19
Mississippi	55	47,725,000	26.7	23.57
Arkansas	55	46,163,000	25.8	26.04
Louisiana	32	21,494,000	12.0	23.85
Minnesota	65	10,986,000	6.1	15.73
Missouri	64	8,655,000	4.8	23.15
Tennessee	48	7,664,000	4.3	26.38
Michigan	55	5,042,000	2.8	19.83
New York	66	4,750,000	2.7	20.24
Wisconsin	40	4,090,000	2.3	19.08
All other States (see Summary, p. 39)	448	22,416,000	12.5	20.60

[1] Common cottonwood (*Populus deltoides*) is the species most commonly cut east of the Rocky Mountains and more particularly in the lower Mississippi Valley.
Swamp cottonwood (*Populus heterophylla*) is cut in the Mississippi Valley States.
Aspen (or popple) (*Populus tremuloides*) is cut in the Lake States and the Northeastern States, and to a limited extent in the Rocky Mountains and farther west.
Large-toothed aspen (*Populus grandidentata*) is cut in the Lake States and Northeastern States.
Balm of Gilead (*Populus balsamifera*) is cut in the Lake States and Eastern States.
Black cottonwood (*Populus trichocarpa*) is cut in the Pacific Coast States.

ASH.

Of the eight States leading in the production of ash all but one slightly increased their respective outputs and contributed to the 2 per cent increase over the 1916 cut. The total reported quantity milled was 159,175,000 feet. The exception noted above was in Arkansas, where the decreased output amounted to 10 per cent. Louisiana by an increased cut of 33 per cent over 1916 became the leading producing State, supplanting Arkansas in the position. The demand for ash in 1917 became insistent because of specific uses to which it was put in war-preparation work.

Ash has next to the highest average value of any domestic wood. The average for 1917 was $30.01 per 1,000 feet, an increase of 26 per cent from $23.85 in 1916.

TABLE 30.—*Reported production of ash[1] lumber, 1917.*

[Computed total production in the United States, 175,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	3,259	159,175,000	100.0	$30.01
Louisiana	59	21,492,000	13.5	27.33
Arkansas	108	20,768,000	13.0	31.21
Wisconsin	209	13,676,000	8.6	25.22
Tennessee	176	13,649,000	8.6	34.97
Indiana	219	12,295,000	7.7	38.16
Mississippi	87	8,649,000	5.4	30.95
New York	586	7,955,000	5.0	29.14
Michigan	166	7,350,000	4.6	27.12
Ohio	267	7,100,000	4.5	33.06
All other States (see Summary, p. 39)	1,382	46,241,000	29.1	28.48

[1] Lumber trade practice specifies white ash and brown ash. The former is cut from the white ash tree and the latter from the black ash tree.
Green ash (*Flaxinus lanceolata*) is cut in the Southern States.
White ash (*Flaxinus americana*) is cut in the Central States.
Black ash (*Flaxinus nigra*) is cut in the Lake States and Northeastern States.
Red ash (*Flaxinus pennsylvanica*) is cut in limited quantity in the Eastern States.
Oregon ash (*Flaxinus oregona*) is cut in the Pacific Northwest.

SUGAR PINE.

The cut of sugar pine totaled 132,568,000 feet in 1917, a decrease of 22 per cent from the year before. A slightly larger quantity was sawed in Oregon than the year before, with an addition of two mills to the number reporting.

The average value of sugar pine was $24.69 per 1,000 feet. In 1916 the average was $16.77. The difference represents an increase of 47 per cent. A material difference exists between the average value reported for the two States, Oregon and California.

TABLE 31.—*Reported production of sugar-pine[1] lumber, 1917.*

[Computed total production in the United States, 132,600,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	68	132,568,000	100.0	$24.69
California	55	127,951,000	96.5	25.00
Oregon	13	4,617,000	3.5	16.15

[1] Sugar pine (*Pinus lambertiana*) is the only species cut as such and is found only in California and southern Oregon.

HICKORY.

Hickory lumber production in 1917 declined 12 per cent from the year before, the total being 82,512,000 feet. Production has shown a decrease for almost every year of the last ten, emphasizing the scarcity of this important wood; much hickory, however, is made into vehicle dimension stock and is not reported in the lumber cut. Of the ranking 10 States the only one which exceeded its cut for 1916 is Mississippi, which increased its output by 10 per cent.

An increase in the average value from $23.84 to $29.48 per 1,000 feet, or 24 per cent, took place from 1916 to 1917.

TABLE 32.—*Reported production of hickory*[1] *lumber, 1917.*

[Computed total production in the United States, 95,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	2,396	82,512,000	100.0	$29.48
Arkansas	110	12,511,000	15.2	32.57
Tennessee	232	11,054,000	13.4	29.08
West Virginia	197	9,237,000	11.2	25.51
Mississippi	63	7,338,000	8.9	33.35
Indiana	264	7,276,000	8.8	35.28
Ohio	297	6,276,000	7.6	30.87
Kentucky	208	6,056,000	7.3	25.01
Louisiana	28	3,229,000	3.9	24.89
Pennsylvania	202	3,848,000	4.7	34.79
Missouri	85	2,767,000	3.4	34.18
North Carolina	114	2,383,000	2.9	21.85
Virginia	113	2,337,000	2.8	19.98
All other States (see Summary, p. 39)	483	8,200,000	9.9	26.08

[1] Several species of hickory are cut, the principal ones being:
Shagbark (*Hicoria ovata*).
Shellbark (*Hicoria laciniosa*).
Pignut (*Hicoria glabra*).
Bitternut (*Hicoria minima*).
Mockernut (*Hicoria alba*).

BALSAM FIR.

The reported balsam-fir output, 75,491,000 feet, was 22 per cent smaller than in 1916. A part of the timber cut was diverted from the sawmill to the pulp mill because of its relatively higher value as pulp wood than saw logs. The production in Wisconsin was more than double that of the year before. The cut for the other States fell off in various proportions from 20 per cent in Maine to 49 per cent in New Hampshire.

The average mill value of balsam fir of $20.02 per 1,000 feet was 21 per cent more than the corresponding figure for 1916.

TABLE 33.—*Reported production of balsam-fir*[1] *lumber, 1917.*

[Computed total production in the United States, 88,900,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	485	75,491,000	100.0	$20.02
Maine	197	42,839,000	56.8	20.95
Minnesota	65	11,234,000	14.9	14.86
Michigan	41	7,899,000	10.4	20.85
Wisconsin	33	5,884,000	7.8	19.87
Vermont	89	4,228,000	5.6	21.62
New Hampshire	30	2,473,000	3.3	21.18
All other States (see Summary, p. 39)	30	884,000	1.2	23.18

[1] Balsam fir (*Abies balsamea*) is the only species cut as such.

WALNUT.

Despite the urgent call for black-walnut lumber, made largely by rifle manufacturers, production was 53,676,000 feet, or 12 per cent, below that of the year previous. Veneer producers were active in the market and many of the best logs went to these plants instead of to sawmills. In Missouri and in Ohio the output was greater by 10 per cent than in the previous year, but the figures for the other States show a decline.

A noteworthy jump of 72 per cent over the 1916 average value of walnut took place. In 1916 the value was $42.38 per 1,000 feet; in 1917 it was $72.99. The importance attached to walnut is shown by the fact that its value is greater than that of any other domestic species.

TABLE 34.—*Reported production of walnut*[1] *lumber, 1917.*

[Computed total production in the United States, 62,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	1,001	53,676,000	100.0	$72.99
Missouri	61	13,373,000	24.9	117.77
Kentucky	122	8,112,000	15.1	44.05
Indiana	189	7,872,000	14.7	61.92
Ohio	126	6,656,000	12.4	44.51
Tennessee	115	4,828,000	9.0	55.82
Iowa	31	3,719,000	6.9	58.91
Illinois	23	2,269,000	4.2	115.21
West Virginia	77	887,000	1.7	37.70
Arkansas	27	532,000	1.0	51.06
Virginia	52	450,000	4.8	31.53
Pennsylvania	50	255,000	.5	41.55
North Carolina	43	230,000	.4	32.85
All other States (see Summary, p. 39)	85	4,493,000	8.4	79.86

[1] Black walnut (*Juglans nigra*) is the only species cut as such.

SYCAMORE.

Sycamore production has run along rather evenly for 10 years. The 1917 cut of 28,548,000 feet was but 2 per cent more than that of the previous year. The Arkansas output was 17 per cent and the Tennessee output 32 per cent greater than in 1916.

From 1916 to 1917 the average value of sycamore advanced from $14.65 to $18.68 per 1,000 feet, or 28 per cent.

TABLE 35.—*Reported production of sycamore [1] lumber, 1917.*

[Computed total production in the United States, 32,000,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	904	28,548,000	100.0	$18.68
Arkansas	59	8,455,000	29.6	16.28
Tennessee	93	4,869,000	17.0	20.97
Indiana	198	3,964,000	13.9	22.01
Kentucky	88	1,796,000	6.3	16.64
Missouri	87	1,535,000	5.4	16.55
Illinois	43	1,501,000	5.3	23.62
Ohio	109	1,423,000	5.0	21.13
Virginia	37	1,364,000	4.8	15.69
Mississippi	32	824,000	2.9	16.94
Louisiana	14	774,000	2.7	19.08
All other States (see Summary, p. 39)	144	2,043,000	7.1	17.36

[1] Sycamore (*Platanus occidentalis*) is the only species cut as such.

LODGEPOLE PINE.

The output of lodgepole pine in 1917, amounting to 12,415,000 feet, was less than one-half of the quantity reported sawed the year before and was very much smaller than for any one of the last 10 years.

The average value for lodgepole pine was $18.34, compared with $15.13 in 1916, an advance of 21 per cent.

TABLE 36.—*Reported production of lodgepole-pine [1] lumber, 1917.*

[Computed total production in the United States, 12,500,000 feet.]

	Number of active mills reporting.	Quantity reported.	Per cent.	Average value per 1,000 feet f. o. b. mill.
		Feet B. M.		
United States	94	12,415,000	100.0	$18.34
Colorado	18	7,673,000	61.8	18.35
Wyoming	27	1,818,000	14.7	18.60
Montana	11	986,000	7.9	18.03
Idaho	22	898,000	7.2	17.81
Utah	10	702,000	5.7	20.35
All other States (see Summary, p. 39)	6	338,000	2.7	14.75

[1] Lodgepole pine (*Pinus contorta*) is the only species cut as such.

MINOR SPECIES.

In Table 37 is shown the quantity reported sawed of a number of woods, both domestic and imported, which have more or less special uses and which are in themselves not important enough to be tabulated and discussed separately. The tabulation also indicates the average value reported and the States in which the several woods were sawed. The quantity of mahogany cut is nearly twice as much as that reported for the preceding year, while the cut of willow was five times larger in 1917 than in 1916.

TABLE 37.—*Reported production of lumber of minor species, 1917.*

[Computed total production in the United States, 56,117,000 feet.]

Kind of wood.	Quantity reported.	Average value per 1,000 feet f. o. b. mill.	States reporting.
	Feet B. M.		
Total	52,712,000	$75.11	
Mahogany	25,832,000	128.06	Louisiana, Kentucky, Indiana, Illinois, Ohio.
Willow	8,033,000	15.78	Louisiana, Mississippi, Arkansas, Tennessee, Illinois, Iowa, New York, Indiana, Missouri.
Cherry	5,768,000	37.10	West Virginia, Pennsylvania, Tennessee, New York, North Carolina, Indiana, Michigan, Ohio, Kentucky, Virginia, New Hampshire, Vermont, Wisconsin, Arkansas, Connecticut, Louisiana.
Buckeye	4,317,000	20.32	Tennessee, Virginia, North Carolina, West Virginia, Kentucky, Ohio, Iowa.
Magnolia	2,133,000	18.95	Louisiana, Texas, Mississippi, Florida.
Locust	1,022,000	29.01	Pennsylvania, West Virginia, Arkansas, Tennessee, Missouri, North Carolina, Virginia, Iowa, Louisiana, New York, Illinois, Mississippi, Indiana.
Pecan	979,000	21.85	Louisiana, Arkansas, Mississippi, Oklahoma, Illinois, Tennessee.
Hackberry	967,000	17.26	Arkansas, Tennessee, Alabama, Indiana, Illinois, Missouri, Iowa, Mississippi.
Cucumber	865,000	21.87	West Virginia, Pennsylvania, New York.
Butternut	742,000	27.57	Indiana, West Virginia, Wisconsin, Virginia, North Carolina, Massachusetts, Vermont, Kentucky, New York, Iowa, Pennsylvania, Ohio, Tennessee, Michigan.
Eucalyptus	420,000	[1] 33.00	California.
Laurel	294,000	[1] 42.00	California.
Red bay	269,000	17.95	Georgia, South Carolina.
Spanish cedar	225,000	65.27	Louisiana, Kentucky, California.
Apple	200,000	[1] 43.00	New York.
Alder	173,000	15.14	Washington, Oregon.
Box elder	163,000	21.38	North Carolina, Illinois.
Japanese oak	163,000	[1] 67.00	California.
Horn beam	54,000	29.63	Massachusetts, New Hampshire.
Persimmon	38,000	17.82	South Carolina, Arkansas, Georgia, Illinois, Mississippi, Missouri.
Sassafras	32,000	17.28	Tennessee, South Carolina, Arkansas.
Holly	23,000	24.43	Oklahoma. Louisiana.

[1] Arbitrary value assigned.

PRODUCTION OF LATH.

Lath production in the country as a whole responded to the lighter demand in 1917, incident to restricted building. The product has but one principal use, and anything that interferes with the utilization in the direct consuming channel results in a lessened output. Reports were received from 1,456 mills, which scheduled a total of 2,281,738,000 pieces, a decrease of 17 per cent from the year before. The output decreased in all of the States except Arkansas, Florida, and Texas. Table 38 shows the number of active mills reporting and the production of each for the last three years.

TABLE 38.—*Reported production of lath, 1915–1917, inclusive.*

	Number of active mills reporting.			Quantity reported (number of pieces).		
	1917	1916	1915	1917	1916	1915
United States	1,456	1,770	1,689	2,281,738,000	[1] 2,754,683,000	2,745,134,000
Louisiana	68	69	66	348,806,000	354,551,000	418,554,000
Washington	58	64	71	230,194,000	264,690,000	389,995,000
Minnesota	45	53	54	213,092,000	267,788,000	230,686,000
Wisconsin	113	121	116	185,074,000	218,598,000	179,193,000
Arkansas	31	30	48	147,578,000	78,157,000	97,185,000
Maine	106	139	122	142,488,000	[1] 215,112,000	172,346,000
Mississippi	33	30	29	133,925,000	162,689,000	123,011,000
Oregon	32	46	28	132,418,000	142,352,000	95,801,000
Florida	27	28	23	97,954,000	85,187,000	89,860,000
Idaho	22	24	29	86,264,000	117,365,000	85,672,000
Michigan	62	80	74	84,352,000	[1] 109,323,000	124,543,000
Texas	18	20	19	47,654,000	42,686,000	40,698,000
Georgia	25	46	36	46,889,000	49,316,000	34,969,000
West Virginia	54	80	70	44,233,000	96,665,000	82,561,000
Pennsylvania	158	187	196	43,928,000	63,016,000	70,877,000
All other States (see Summary, p. 39)	604	753	708	296,889,000	487,188,000	509,183,000

[1] Corrections have caused a reduction from the figures previously shown.

PRODUCTION OF SHINGLES.

With building operations throughout the country adversely affected in 1917 it was to be expected that the production of shingles would decrease. The reported cut was 8,696,513,000 pieces, a decrease of 7 per cent from the 1916 total manufacture. Washington, in which State are made 73 per cent of all the shingles reported cut, produced 6 per cent less than in 1916. Oregon, Louisiana, and Michigan totals are larger for 1917 than for the preceding year. On the other hand, California's output was diminished by 25 per cent. Other details of production are given in Table 39, which shows the number of mills operating and the cut in each of the last three years in the leading producing States.

TABLE 39.—*Reported production of shingles, 1915–1917, inclusive.*

	Number of active mills reporting.			Quantity reported (number of pieces).		
	1917	1916	1915	1917	1916	1915
United States	1,619	1,932	1,648	8,696,513,000	[1] 9,371,333,000	8,459,378,00
Washington	230	238	239	6,313,364,000	6,739,388,000	6,313,335,000
Oregon	42	50	48	481,353,000	471,762,000	336,652,000
Louisiana	55	53	45	453,819,000	404,263,000	385,610,000
California	41	52	25	261,434,000	348,622,000	200,755,000
Michigan	69	69	63	203,907,000	201,171,000	250,640,000
Maine	150	200	187	166,101,000	[1] 217,543,000	268,004,000
Wisconsin	73	73	77	151,726,000	175,455,000	122,882,000
Florida	49	51	31	143,792,000	131,795,000	116,054,000
Georgia	116	148	111	112,430,000	131,763,000	69,308,000
North Carolina	110	135	125	73,703,000	123,959,000	74,773,000
Texas	39	42	33	61,011,000	32,749,000	22,245,000
Arkansas	44	42	31	59,927,000	45,411,000	20,501,000
Alabama	94	113	82	54,735,000	[1] 81,414,000	67,629,000
Idaho	7	9	11	52,631,000	79,960,000	49,512,000
Mississippi	32	29	18	39,261,000	25,196,000	11,950,000
All other States (see Summary, p. 39)	468	628	522	67,319,000	160,882,000	149,528,000

[1] Corrections have caused a slight reduction from the figures previously shown.

LUMBER VALUES.

The average values for lumber shown in Table 40 were determined for each species from the individual reports from mills representing every variation incident to the logging, transportation, manufacture, and sale of lumber. More than one-half of the mills in reporting their cut furnished values at which sales were made f. o. b. mill. These reports were carefully scrutinized and the figures are undoubtedly representative.

The table shows the average value of the different woods for specified years from 1899 to 1916 and indicates the good, bad, and indifferent years of the lumber industry. The 1917 average value of $20.32 per 1000 feet established a record. It is 33 per cent higher than the 1916 figure and 23 per cent higher than the figure obtained for the profitable year of 1907. Every wood listed in the table shared in the advance, some to a much greater degree than others, as is revealed in the individual species tables.

TABLE 40.—*Average value of lumber per thousand feet, b. m., by kinds of wood, for specified years, 1899–1917.*

Kind of wood	1917	1916	1915	1911	1910	1909	1907	1904	1899
All kinds	$20.32	$15.32	$14.04	$15.05	$15.30	$15.38	$16.56	$12.76	$11.13
Softwoods:									
Yellow pine	19.00	14.33	12.41	13.87	13.29	12.69	14.02	9.96	8.46
Douglas fir	16.28	10.78	10.59	11.05	13.09	12.44	14.12	9.51	8.67
White pine	24.81	19.16	17.44	18.54	18.93	18.16	19.41	14.93	12.69
Hemlock	20.78	15.35	13.14	13.59	13.85	13.95	15.53	11.91	9.98
Spruce	24.41	17.58	16.58	16.14	16.62	16.91	17.26	14.03	11.27
Western yellow pine	19.59	14.52	14.32	13.62	14.26	15.39	15.67	11.30	9.70
Cypress	23.92	20.85	19.85	20.54	20.51	20.46	22.12	17.50	13.32
Redwood	21.00	13.93	13.54	13.99	15.52	14.80	17.70	12.83	10.12
Cedar	19.40	15.24	16.10	13.86	15.53	19.95	19.14	14.35	10.91
Larch (tamarack)	16.21	12.49	10.78	11.87	12.33	12.68	13.99	11.39	8.73
White fir	17.16	12.25	10.94	10.64	11.52	13.10	15.54	(1)	(1)
Sugar pine	24.69	16.77	17.40	17.52	18.68	18.14	19.84	(1)	12.30
Balsam fir	20.02	16.49	13.79	13.42	14.48	13.99	16.16	(1)	(1)
Lodgepole pine	18.34	15.13	13.57	12.41	14.88	16.25	(1)	(1)	(1)
Hardwoods:									
Oak	24.49	20.06	18.73	19.14	18.76	20.50	21.23	17.51	13.78
Maple	23.16	18.24	15.21	15.49	18.16	15.77	16.84	14.94	11.83
Gum, red and sap	19.56	14.64	12.54	12.11	12.26	13.20	14.10	10.87	9.63
Chestnut	21.54	17.05	16.17	16.63	16.23	16.12	17.04	13.78	13.37
Yellow poplar	27.17	21.89	22.45	25.46	24.71	25.39	24.91	18.99	14.03
Birch	24.07	19.59	16.52	16.61	17.37	16.95	17.37	15.44	12.50
Beech	19.58	16.20	14.01	14.09	14.34	13.25	14.30	(1)	(1)
Basswood	25.96	21.05	18.89	19.20	20.94	19.50	20.03	16.86	12.84
Elm	23.89	19.46	16.98	17.13	18.67	17.52	18.45	14.45	11.47
Ash	30.01	23.85	22.15	21.21	22.47	24.44	25.01	18.77	15.84
Cottonwood	23.19	17.42	17.36	18.12	17.78	18.05	18.42	14.92	10.37
Tupelo	18.06	13.00	12.25	12.46	12.14	11.87	14.48	(1)	(1)
Hickory	29.48	23.84	23.35	22.47	26.55	30.80	29.50	23.94	18.78
Walnut	72.99	42.38	48.37	31.70	34.91	42.79	43.31	45.64	36.49
Sycamore	18.68	14.65	13.86	13.16	14.10	14.77	14.58	(1)	11.04

[1] Data not obtained.

DETAILED SUMMARY.

In Table 41 are summarized the data presented in the individual species tables, showing, by States, the number of active sawmills reporting and their cut of each wood, and in addition the production of lath and shingles for 1917.

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917.*

SOFTWOODS.

State.	Number of active mills reporting.	Aggregate softwoods and hardwoods.	Total softwoods.	Yellow pine.	Douglas fir.
		Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
United States	16,420	33,192,911,000	27,130,008,000	12,483,410,000	5,351,025,000
Alabama	772	1,409,618,000	1,291,066,000	1,285,604,000	
Arizona	22	79,022,000	79,022,000		510,000
Arkansas	674	1,591,952,000	1,000,295,000	956,316,000	
California and Nevada	169	1,417,068,000	1,416,141,000		156,083,000
Colorado	100	71,312,000	71,164,000		3,756,000
Connecticut	136	61,236,000	14,531,000	403,000	
Delaware	35	8,409,000	6,345,000	6,303,000	
Florida	212	1,127,359,000	1,113,194,000	946,096,000	
Georgia	613	671,528,000	600,756,000	547,870,000	
Idaho	181	749,764,000	749,165,000		66,663,000
Illinois	114	42,182,000	1,437,000		
Indiana	439	218,712,000	115,000	10,000	
Iowa	65	13,143,000	14,000		
Kansas	4	4,255,000			
Kentucky	579	329,203,000	30,270,000	13,875,000	
Louisiana	335	3,861,860,000	3,492,297,000	2,982,638,000	
Maine	530	705,014,000	671,141,000	668,000	
Maryland	184	61,720,000	27,597,000	23,386,000	
Massachusetts	243	138,233,000	107,918,000	4,424,000	
Michigan	301	975,648,000	410,458,000		
Minnesota	198	999,476,000	972,679,000		
Mississippi	671	2,221,010,000	1,831,465,000	1,814,928,000	
Missouri	357	257,712,000	58,382,000	31,118,000	
Montana	122	347,496,000	347,306,000		38,600,000
New Hampshire	263	263,511,000	236,878,000	689,000	
New Jersey	92	21,117,000	6,474,000	6,020,000	
New Mexico	56	88,625,000	88,625,000		4,587,000
New York	1,172	335,016,000	171,474,000	401,000	
North Carolina	1,482	1,316,307,000	1,068,630,000	940,972,000	
Ohio	511	202,349,000	1,587,000	109,000	
Oklahoma	96	226,711,000	198,241,000	196,677,000	
Oregon	409	2,485,783,000	2,480,036,000		1,759,044,000
Pennsylvania	851	501,359,000	270,742,000	2,251,000	
Rhode Island	20	10,570,000	3,964,000		
South Carolina	412	672,852,000	617,353,000	558,194,000	
South Dakota	28	29,045,000	29,045,000		
Tennessee	815	582,003,000	111,065,000	55,550,000	
Texas	299	1,592,119,000	1,520,801,000	1,520,286,000	
Utah	59	8,567,000	8,431,000		497,000
Vermont	314	157,258,000	90,019,000		
Virginia	1,168	942,879,000	648,697,000	586,293,000	
Washington	438	4,304,449,000	303,814,000		3,320,044,000
West Virginia	430	810,458,000	213,746,000	2,329,000	
Wisconsin	398	1,271,069,000	759,697,000		
Wyoming	51	7,932,000	7,931,000		1,241,000

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917*—Continued.

SOFTWOODS—Continued.

State.	White pine.	Hemlock.	Western yellow pine.	Spruce.	Cypress.	Redwood.
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
United States	2,050,360,000	1,968,217,000	1,865,282,000	978,265,000	917,445,000	487,458,000
Alabama		10,000			3,553,000	
Arizona			78,107,000	405,000		
Arkansas					43,969,000	
California and Nevada		3,379,000	478,565,000	20,659,000		487,458,000
Colorado			35,328,000	22,896,000		
Connecticut	10,043,000	4,061,000		5,000		
Delaware					25,000	
Florida					166,857,000	
Georgia	1,575,000	80,000			51,219,000	
Idaho	193,404,000	1,325,000	315,019,000	19,171,000		
Illinois					1,437,000	
Indiana	1,000					
Iowa	14,000					
Kansas						
Kentucky	2,121,000	13,489,000		21,000	442,000	
Louisiana					509,659,000	
Maine	256,014,000	66,583,000		297,949,000		
Maryland	288,000	3,835,000			80,000	
Massachusetts	90,797,000	10,201,000		2,264,000		
Michigan	47,571,000	327,651,000		6,703,000		
Minnesota	901,941,000			40,999,000		
Mississippi					16,537,000	
Missouri					26,981,000	
Montana	4,974,000		150,905,000	6,437,000		
New Hampshire	171,547,000	26,059,000		36,057,000		
New Jersey		51,000				
New Mexico			83,426,000	612,000		
New York	57,924,000	84,193,000		27,215,000		
North Carolina	20,190,000	36,688,000		47,360,000	15,958,000	
Ohio	558,000	918,000				
Oklahoma					1,564,000	
Oregon	1,000,000	49,479,000	469,408,000	120,647,000		
Pennsylvania	25,756,000	242,628,000		100,000		
Rhode Island	3,951,000	10,000				
South Carolina					59,107,000	
South Dakota			29,045,000			
Tennessee	6,617,000	31,182,000			10,003,000	
Texas					515,000	
Utah			4,448,000	2,283,000		
Vermont	18,884,000	18,192,000		48,630,000		
Virginia	9,144,000	32,954,000		1,750,000	9,539,000	
Washington	56,955,000	317,243,000	217,353,000	198,271,000		
West Virginia	8,461,000	134,060,000		68,895,000		
Wisconsin	160,630,000	563,946,000		7,852,000		
Wyoming			3,678,000	1,084,000		

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917*—Continued.

SOFTWOODS—Continued.

State.	Larch.	Cedar.	White fir.	Sugar pine	Balsam fir.	Lodgepole pine.
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
United States	336,640,000	258,005,000	213,427,000	132,568,000	75,491,000	12,415,000
Alabama		1,899,000				
Arizona						
Arkansas		10,000				
California and Nevada		21,310,000	120,661,000	127,951,000		75,000
Colorado			1,511,000			7,673,000
Connecticut		19,000				
Delaware		17,000				
Florida		241,000				
Georgia		12,000				
Idaho	99,950,000	15,319,000	37,416,000			898,000
Illinois						
Indiana	4,000	100,000				
Iowa						
Kansas						
Kentucky		322,000				
Louisiana						
Maine	217,000	6,821,000			42,889,000	
Maryland		8,000				
Massachusetts	15,000	157,000			60,000	
Michigan	14,680,000	5,954,000			7,899,000	
Minnesota	18,217,000	288,000			11,234,000	
Mississippi						
Missouri		283,000				
Montana	135,734,000	25,000	9,645,000			986,000
New Hampshire	4,000	49,000			2,473,000	
New Jersey	5,000	398,000				
New Mexico						
New York	325,000	592,000			824,000	
North Carolina		7,462,000				
Ohio	2,000					
Oklahoma						
Oregon	13,793,000	42,088,000	19,847,000	4,617,000		113,000
Pennsylvania		7,000				
Rhode Island		3,000				
South Carolina		52,000				
South Dakota						
Tennessee		7,713,000				
Texas						
Utah			501,000			702,000
Vermont	42,000	43,000			4,228,000	
Virginia		9,017,000				
Washington	34,242,000	135,820,000	23,736,000			150,000
West Virginia		1,000				
Wisconsin	19,410,000	1,975,000			5,884,000	
Wyoming			110,000			1,818,000

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917*—Continued.

HARDWOODS.

State.	Total hardwoods.	Oak.	Maple.	Gum, red and sap.	Birch.	Chestnut.
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
United States	6,062,903,000	1,967,694,000	802,089,000	730,662,000	387,283,000	382,652,000
Alabama	118,552,000	38,363,000	334,000	25,147,000	118,000	387,000
Arizona						
Arkansas	591,657,000	235,763,000	7,878,000	230,964,000	1,000	
California	927,000	44,000				
Colorado	148,000					
Connecticut	46,705,000	9,126,000	895,000	5,000	833,000	33,149,000
Delaware	2,064,000	1,535,000	78,000	297,000	10,000	45,000
Florida	14,165,000	527,000		5,735,000	1,000	
Georgia	70,772,000	18,936,000	531,000	12,392,000	3,000	331,000
Idaho	599,000					
Illinois	40,745,000	17,891,000	2,297,000	4,161,000	78,000	1,000
Indiana	218,597,000	85,210,000	23,324,000	4,678,000	259,000	520,000
Iowa	13,129,000	3,084,000	524,000		51,000	
Kansas	4,255,000	125,000	5,000			
Kentucky	298,933,000	170,469,000	6,387,000	10,084,000	438,000	13,231,000
Louisiana	369,563,000	70,538,000	137,000	94,671,000	61,000	
Maine	33,873,000	3,717,000	3,037,000		21,713,000	2,000
Maryland	34,123,000	17,318,000	3,129,000	1,183,000	302,000	9,337,000
Massachusetts	30,315,000	6,612,000	1,377,000		2,493,000	16,863,000
Michigan	565,190,000	6,416,000	349,688,000		61,768,000	
Minnesota	26,797,000	3,028,000	156,000		4,395,000	
Mississippi	389,545,000	111,751,000	2,532,000	169,847,000		
Missouri	199,330,000	112,897,000	14,135,000	24,981,000	202,000	
Montana	190,000					
New Hampshire	26,633,000	6,700,000	4,000,000		6,344,000	4,778,000
New Jersey	14,643,000	6,899,000	510,000	409,000	41,000	5,405,000
New Mexico						
New York	163,542,000	22,592,000	45,024,000	27,000	17,628,000	17,153,000
North Carolina	247,677,000	115,749,000	7,333,000	12,866,000	1,751,000	47,277,000
Ohio	200,762,000	90,561,000	26,244,000	1,946,000	48,000	6,795,000
Oklahoma	28,470,000	14,931,000	18,000	9,104,000	2,000	
Oregon	5,747,000	1,022,000	2,318,000			
Pennsylvania	230,617,000	85,779,000	42,903,000	641,000	7,535,000	40,149,000
Rhode Island	6,606,000	1,437,000	262,000	10,000	10,000	4,718,000
South Carolina	55,499,000	7,184,000	968,000	19,883,000		
South Dakota						
Tennessee	470,938,000	237,574,000	8,586,000	64,356,000	1,408,000	32,738,000
Texas	71,318,000	36,829,000		26,342,000		
Utah	136,000					
Vermont	67,239,000	2,185,000	16,870,000		30,882,000	290,000
Virginia	294,182,000	169,725,000	8,443,000	9,165,000	1,084,000	42,073,000
Washington	635,000		125,000			
West Virginia	596,712,000	242,415,000	67,471,000	1,768,000	18,960,000	107,410,000
Wisconsin	511,372,000	12,761,000	154,570,000		208,864,000	
Wyoming	1,000	1,000				

ALASKA LUMBER PRODUCTION.

Figures are presented herewith covering the cut of lumber, by species, in Alaska in 1917. Production data for this Territory have not heretofore been compiled. Table 42, at the bottom of page 43, shows the quantity of each kind of wood sawed, the number of mills cutting each species, the number of mills cutting, and the production by classes, and the average value per thousand feet of each species.

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917*—Continued.

HARDWOODS—Continued.

State.	Yellow poplar.	Beech.	Tupelo.	Elm.	Basswood.	Cottonwood.	Ash.
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
United States..	325,968,000	278,345,000	249,992,000	191,853,000	190,757,000	178,895,000	159,175,000
Alabama..........	21,519,000	455,000	25,528,000	375,000	176,000	1,947,000	2,911,000
Arizona..........	....	....	....	....	....	....	....
Arkansas..........	243,000	175,000	4,788,000	21,748,000	229,000	46,163,000	20,768,000
California..........	....	....	....	....	....	....	....
Colorado..........	....	....	....	....	....	148,000	....
Connecticut..........	440,000	582,000	2,000	63,000	111,000	185,000	554,000
Delaware..........	25,000	24,000	20,000	....	....	5,000	5,000
Florida..........	1,314,000	....	1,917,000	....	8,000	2,468,000	2,185,000
Georgia..........	28,252,000	206,000	2,125,000	196,000	....	622,000	5,361,000
Idaho..........	....	....	....	....	....	599,000	....
Illinois..........	575,000	1,092,000	3,103,000	2,438,000	103,000	786,000	2,222,000
Indiana..........	6,094,000	40,919,000	610,000	17,244,000	4,859,000	916,000	12,295,000
Iowa..........	....	....	1,000	1,872,000	896,000	2,490,000	304,000
Kansas..........	....	....	....	25,000	....	50,000	5,000
Kentucky..........	42,205,000	20,136,000	1,064,000	1,076,000	4,698,000	1,875,000	3,473,000
Louisiana..........	429,000	950,000	127,210,000	4,786,000	126,000	21,494,000	21,492,000
Maine..........	....	1,603,000	....	828,000	807,000	667,000	1,499,000
Maryland..........	842,000	297,000	211,000	13,000	393,000	....	93,000
Massachusetts..........	122,000	1,357,000	....	50,000	276,000	55,000	875,000
Michigan..........	162,000	59,573,000	11,000	36,107,000	38,427,000	5,042,000	7,350,000
Minnesota..........	....	6,000	....	3,674,000	3,832,000	10,986,000	713,000
Mississippi..........	4,181,000	967,000	21,974,000	11,443,000	....	47,725,000	8,649,000
Missouri..........	405,000	70,000	7,746,000	9,959,000	253,000	8,655,000	2,286,000
Montana..........	....	....	....	....	....	190,000	....
New Hampshire....	40,000	3,046,000	....	486,000	536,000	105,000	586,000
New Jersey..........	327,000	115,000	18,000	418,000	4,000	1,000	98,000
New Mexico..........	....	....	....	....	....	....	....
New York..........	115,000	28,503,000	....	6,015,000	12,240,000	4,750,000	7,955,000
North Carolina....	29,311,000	1,674,000	18,179,000	587,000	6,570,000	356,000	2,029,000
Ohio..........	13,252,000	24,376,000	207,000	9,653,000	5,231,000	783,000	7,100,000
Oklahoma..........	....	1,000	108,000	565,000	....	2,473,000	407,000
Oregon..........	....	....	....	....	....	1,170,000	1,204,000
Pennsylvania..........	4,348,000	34,049,000	73,000	1,326,000	4,391,000	214,000	4,331,000
Rhode Island..........	60,000	10,000	....	25,000	....	....	35,000
South Carolina....	7,014,000	....	16,933,000	254,000	....	124,000	2,956,000
South Dakota..........	....	....	....	....	....	....	....
Tennessee..........	48,425,000	8,379,000	5,115,000	12,809,000	6,251,000	7,664,000	13,649,000
Texas..........	....	20,000	1,804,000	762,000	....	1,652,000	2,151,000
Utah..........	....	....	....	....	....	136,000	....
Vermont..........	20,000	7,698,000	....	774,000	4,530,000	848,000	3,107,000
Virginia..........	37,213,000	3,143,000	9,009,000	86,000	6,925,000	1,169,000	1,068,000
Washington..........	....	....	....	....	....	290,000	80,000
West Virginia..........	79,035,000	35,584,000	2,236,000	119,000	21,098,000	92,000	5,703,000
Wisconsin..........	....	3,335,000	....	46,077,000	67,787,000	4,090,000	13,676,000
Wyoming..........	....	....	....	....	....	....	....

TABLE 42.—*Number of mills cutting, quantity of lumber cut by species and by classes of mills, and average value of lumber in Alaska, 1917.*

Species	Number of mills cutting each species.	Total cut.	Average value per 1,000 feet.	Class 4: Number of mills, 3.	Class 3: Number of mills, 2.	Class 2: Number of mills, 4.	Class 1: Number of mills, 21.
		Feet B. M.		*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*
Total..........	....	33,160,000	$21.19	20,540,000	5,200,000	2,500,000	4,920,000
Spruce..........	30	31,773,000	21.23	19,473,000	5,000,000	2,500,000	4,800,000
Hemlock..........	6	1,117,000	19.61	942,000	150,000	....	25,000
Cedar..........	6	260,000	21.76	125,000	50,000	....	85,000
Yellow cypress..........	1	10,000	50.00	....	....	....	10,000

TABLE 41.—*Active sawmills (cutting 50,000 feet and over) reporting, and reported production of each kind of lumber and of lath and shingles, by States, 1917*—Continued.

HARDWOODS—Continued.

State.	Hickory.	Walnut.	Sycamore.	Minor species.	Lath.	Shingles.
	Feet B. M.	*Feet B. M.*	*Feet B. M.*	*Feet B. M.*	*Pieces.*	*Pieces.*
United States	82,512,000	53,676,000	28,548,000	52,712,000	2,281,738,000	8,696,513,000
Alabama	1,077,000	58,000	107,000	50,000	39,685,000	54,735,000
Arizona					19,878,000	180,000
Arkansas	12,511,000	532,000	8,455,000	1,439,000	147,578,000	59,927,000
California				883,000	37,651,000	261,434,000
Colorado					491,000	35,000
Connecticut	746,000	11,000	2,000	1,000	736,000	555,000
Delaware	20,000				568,000	20,000
Florida	5,000			5,000	97,954,000	143,792,000
Georgia	1,317,000	35,000	275,000	190,000	46,889,000	112,430,000
Idaho					86,264,000	52,631,000
Illinois	1,650,000	2,269,000	1,501,000	578,000	5,000	
Indiana	7,276,000	7,872,000	3,964,000	2,557,000	415,000	
Iowa	101,000	3,719,000	39,000	48,000		
Kansas	30,000	4,010,000	5,000			
Kentucky	6,056,000	8,112,000	1,796,000	7,833,000	7,153,000	1,601,000
Louisiana	3,848,000		774,000	23,047,000	348,806,000	453,819,000
Maine					142,488,000	166,101,000
Maryland	492,000	67,000	446,000		208,000	751,000
Massachusetts	133,000	30,000		72,000	583,000	533,000
Michigan	324,000	42,000	107,000	173,000	84,352,000	203,907,000
Minnesota	5.000	2,000			213,092,000	1,498,000
Mississippi	7,338,000	1,000	824,000	2,313,000	133,925,000	39,261,000
Missouri	2,767,000	13,373,000	1,535,000	66,000	5,485,000	2,362,000
Montana					23,332,000	3,259,000
New Hampshire	2,000			10,000	8,865,000	1,731,000
New Jersey	379,000	14,000	5,000		4,504,000	7,797,000
New Mexico					9,546,000	1,500,000
New York	740,000	35,000	14,000	751,000	10,478,000	8,302,000
North Carolina	2,383,000	230,000	100,000	1,282,000	36,287,000	73,703,000
Ohio	6,276,000	6,656,000	1,423,000	211,000	3,004,000	15,000
Oklahoma	205,000	71,000	499,000	86,000	18,866,000	338,000
Oregon				33,000	132,418,000	481,353,000
Pennsylvania	3,229,000	255,000	120,000	1,274,000	43,928,000	3,924,000
Rhode Island	22,000	17,000			30,000	70,000
South Carolina	29,000	20,000	20,000	114,000	21,934,000	13,610,000
South Dakota					100,000	336,000
Tennessee	11,054,000	4,828,000	4,869,000	3,233,000	10,318,000	5,167,000
Texas	908,000	5,000	65,000	780,000	47,654,000	61,011,000
Utah					333,000	1,295,000
Vermont		5,000		30,000	6,170,000	2,894,000
Virginia	2,337,000	450,000	1,364,000	928,000	30,244,000	9,000,000
Washington				140,000	230,194,000	6,313,364,000
West Virginia	9,237,000	887,000	239,000	4,458,000	44,233,000	481,000
Wisconsin	15,000	70,000		127,000	185,074,000	151,726,000
Wyoming					20,000	65,000

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UNITED STATES DEPARTMENT OF AGRICULTURE

SUPPLEMENT TO

BULLETIN No. 769

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. ▼ October 29, 1919

THE PRODUCTION AND CONSERVATION OF FATS AND OILS IN THE UNITED STATES.

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Since Department of Agriculture Bulletin 769 was issued new statistics on the production, importation, and exportation of fats and oils in the United States have become available. The following tables, which contain the most recent figures on the fat and oil situation, have therefore been prepared to supersede the tables originally printed. They have been compiled from data collected by the Fats and Oils Division of the United States Food Administration, and turned over by that division to the United States Department of Agriculture. This publication completes the report of the fats and oils survey conducted by the Government during 1917 and 1918. Unless otherwise stated, all figures cover the calendar year.

TABLE 1.—*Production of vegetable oils in the United States.*

Oil.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Castor	23,359,000	20,423,000	22,766,000	22,902,000	14,184,000
Coconut [1]	31,729,000	38,272,000	104,727,000	188,488,000	341,235,000
Coquito	....	....	803,000	....	....
Corn [2]	72,832,000	91,810,000	109,963,000	118,021,000	111,065,000
Cottonseed [3]	1,435,401,000	1,789,777,000	1,492,430,000	1,343,849,000	1,283,823,000
Linseed	461,656,000	507,422,000	531,586,900	482,199,000	375,452,000
Mustard seed	360,000	306,000	729,000	1,098,000	1,296,000
Olive	966,000	1,128,000	1,462,000	963,000	618,000
Palm kernel [2]	3,200,000	402,000	8,619,000	6,453,000	3,784,000
Peanut [2]	454,000	1,006,000	28,534,000	50,499,000	95,934,000
Raisin seed	320,000	435,000	752,000	667,000	586,000
Rapeseed	90,000	19,000	223,000	232,000	139,000
Sesame	....	30,000	129,000	304,000	299,000
Shea nut	....	....	3,974,000	81,000	....
Soy bean [2]	....	2,764,000	9,920,000	42,074,000	79,861,000
Miscellaneous	1,114,000	1,568,000	2,249,000	1,268,000	409,000
Total	2,031,481,000	2,455,362,000	2,318,866,000	2,259,098,000	2,308,685,000

[1] Figures represent total production of edible and inedible oil. As the edible oil is made from the inedible oil, there may be some duplication in these figures.
[2] Figures represent total production of edible and inedible oil.
[3] Figures represent total production of crude oil only.

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TABLE 2.—*Production of animal and fish fats and oils in the United States.*

Product.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Bone grease	29,528,000	42,264,000	34,389,000	31,020,000	24,817,000
Cod and cod liver oil	372,000	394,000	367,000	439,000	712,000
Garbage grease	30,411,000	44,688,000	60,212,000	65,250,000	53,476,000
Herring oil	1,888,000	1,512,000	1,476,000	1,637,000	774,000
Lard [1]	727,744,000	887,580,000	1,086,581,000	868,389,000	1,008,757,000
Lard, neutral	51,414,000	51,303,000	76,163,000	52,548,000	81,289,000
Menhaden oil	33,009,000	16,265,000	20,598,000	18,640,000	12,370,000
Neats foot oil	5,181,000	5,158,000	7,239,000	8,317,000	9,764,000
Oleo stock	122,568,000	143,247,000	152,982,000	153,188,000	145,929,000
Sperm oil	4,083,000	2,495,000	4,560,000	3,567,000	743,000
Tallow [1]	202,946,000	227,339,000	275,511,000	268,825,000	304,891,000
Whale oil	931,000	632,000	1,691,000	1,193,000	431,000
Wool grease and recovered grease	7,206,000	9,370,000	14,137,000	13,839,000	21,020,000
Miscellaneous animal oils	1,980,000	1,470,000	2,649,000	2,049,000	7,559,000
Miscellaneous fish oils	1,001,000	1,333,000	1,931,000	3,078,000	954,000
Miscellaneous greases	95,277,000	133,195,000	129,571,000	113,748,000	165,509,000
Total	1,315,539,000	1,568,245,000	1,870,057,000	1,605,727,000	1,838,995,000

[1] Figures include edible and inedible product

TABLE 3.—*Estimated production of fats and oils in the United States.*[1]

Product.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Vegetable oils	2,031,481,000	2,455,362,000	2,318,866,000	2,259,098,000	2,308,685,000
Animal fats and oils	1,315,539,000	1,568,245,000	1,870,057,000	1,605,727,000	1,838,995,000
Total	3,347,020,000	4,023,607,000	4,188,923,000	3,864,825,000	4,147,680,000
Butter fat (farm) [2]	1,660,000,000	1,613,736,000	879,610,000	733,222,000	777,000,000
Butter fat (factory)	581,000,000	652,382,000	630,825,000	637,503,000	669,492,000
Total	2,241,000,000	2,266,118,000	1,510,435,000	1,370,725,000	1,446,492,000
Grand total	5,588,020,000	6,289,725,000	5,699,358,000	5,235,550,000	5,594,172,000

[1] None of the derivatives reported in Table 11 are included here.
[2] The figures for farm butter fat are based on reports from various sources, and are believed by the authors to be at least 90 per cent correct.

TABLE 4.—*Importation of fats and oils into the United States.*[1]

Product.	1912	1914	1916	1917	1918
Vegetable:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Chinese nut oil	42,787,000	30,139,000	57,649,000	41,190,000	42,717,000
Coconut oil	46,720,000	58,012,000	64,349,000	163,091,000	356,089,000
Cottonseed oil	2,160,000	16,016,000	16,598,000	13,826,000	18,373,000
Linseed oil	2,135,000	4,350,000	711,000	633,000	196,000
Olive oil, edible	43,460,000	50,857,000	55,435,000	51,055,000	1,284,000
Olive oil, inedible	5,794,000	5,609,000	6,335,000	4,476,000	3,000
Olive foots	15,804,000	13,045,000	14,246,000	8,308,000	159,000
Palm oil	52,671,000	49,092,000	29,270,000	34,257,000	20,993,000
Palm kernel oil	27,680,000	21,089,000	4,324,000	306	34,000
Peanut oil	7,626,000	7,365,000	15,674,000	27,405,000	68,466,000
Rapeseed oil	10,266,000	11,172,000	20,181,000	10,132,000	23,079,000
Soy bean oil	24,959,000	12,555,000	145,409,000	264,926,000	335,984,000
Animal and fish:					
Cod and cod liver oil	....	14,198,000	10,973,000	16,618,000	8,939,000
Oleo stearin	9,178,000	4,030,000	649,000	5,555,000	1,557,000
Tallow	609,000	12,690,000	13,087,000	73,619,000	51,885,000
Miscellaneous greases	14,901,000	11,665,000	9,580,000	13,551,000	29,711,000
Miscellaneous oils	[2] 21,727,000	10,943,000	23,375,000	23,426,000	20,984,000
Total	328,477,000	332,827,000	487,845,000	752,068,000	980,453,000

[1] The figures in this table are taken from the Monthly Summary of Foreign Commerce of the United States, issued by the Bureau of Foreign and Domestic Commerce, of the United States Department of Commerce.
[2] Reported as "All fish and animal oils."

Table 5.—*Exportation of fats and oils from the United States.*[1]

Product.	1912	1914	1916	1917	1918
Vegetable:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Chinese nut (tung) oil	80,000	106,000	132,000	244,000	1,105 000
Coconut oil	358,000	506,000	478,000	1,830,000	926,000
Corn oil	22,870,000	16,199,000	9,119,000	4,709,000	171,000
Cottonseed oil	355,973,000	216,410,000	188,214,000	124,730,000	119,090,000
Linseed oil	3,151,000	1,995,000	6,180,000	11,485,000	5,806,000
Olive oil, edible	59,000	52,000	392,000	436,000	155,000
Olive foots	71,000	74,000	79,000	9,000	....
Palm oil	112,000	133,000	57,000	31,000	10
Palm kernel oil	75,000	358,000	5,000	200	1,000
Peanut oil	7,000	96,000	171,000	145,000	75,000
Soy bean oil	184,000	3,000	2,063,000	3,977,000	545,000
Stearin	(2)	(2)	1,411,000	1,262,000	1,020,000
Animal and fish:					
Fish oils (except whale)	9,375,000	1,340,000	1,059,000	956,000	4,281,000
Lard	495,093,000	438,016,000	426,660,000	372,721,000	548,818,000
Lard, neutral	57,556,000	21,798,000	27,265,000	9,423,000	6,307,000
Lard oil	1,224,000	767,000	2,679,000	1,852,000	349,000
Oleo oil	94,345,000	85,145,000	83,892,000	33,400,000	69,106,000
Stearin	1,524,000	3,239,000	13,217,000	8,295,000	10,550,000
Tallow	28,989,000	9,980,000	15,338,000	7,510,000	4,223,000
Miscellaneous greases	119,000	3,000	11,000	34,000	18,000
Miscellaneous oils	11,026,000	4,793,000	4,377,000	2,314,000	6,060,000
Lard compound	73,724,000	63,356,000	49,822,000	49,300,000	43,976,000
Oleomargarine	3,500,000	2,293,000	6,309,000	3,523,000	8,909,000
Total	1,159,415,000	866,662,000	838,930,000	638,186,000	831,491,000

[1] The figures in this table are taken from the Monthly Summary of Foreign Commerce of the United States, issued by the Bureau of Foreign and Domestic Commerce, of the United States Department of Commerce.
[2] Not reported as a separate item.

Table 6.—*Comparison of production with importation and exportation of fats and oils in 1918.*[1]

Product.	Produced.	Imported.	Exported.
Vegetable:	*Pounds.*	*Pounds.*	*Pounds.*
Chinese nut oil	....	42,717,000	1,105,000
Coconut oil	341,235,000	356,089,000	926,000
Corn oil	111,065,000	....	171,000
Cottonseed oil	1,283,823,000	18,373,000	119,090,000
Linseed oil	375,452,000	196,000	5,806,000
Olive oil	618,000	1,287,000	155,000
Palm oil	....	20,993,000	10
Palm kernel oil	3,784,000	34,000	1,000
Peanut oil	95,934,000	68,466,000	75,000
Rapeseed oil	139,000	23,079,000	....
Soy bean oil	79,861,000	335,984,000	545,000
Stearin	9,096,000	....	1,020,000
Animal and fish:			
Cod and cod liver oil	712,000	8,939,000	30,000
Fish oil, miscellaneous	14,098,000	....	4,251,000
Lard	1,008,757,000	....	548,818,000
Lard, neutral	81,289,000	....	6,307,000
Lard oil	44,586,000	....	349,000
Oleo oil	147,866,000	....	69,106,000
Stearin	95,433,000	1,557,000	10,550,000
Tallow	304,891,000	51,885,000	4,223,000
Miscellaneous greases	....	29,711,000	18,000
Miscellaneous oils	....	20,984,000	6,060,000
Lard compound	1,146,236,000	....	43,976,000
Oleomargarine	332,898,000	....	8,909,000

[1] This table includes only those items for which comparable figures are obtainable.

TABLE 7.—*Monthly production of fats and oils and their derivatives in the United States during 1918.*

Products.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
VEGETABLE OILS.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Castor [1]	1,442,000	600,000	599,000	565,000	441,000	678,000	770,000	492,000	569,000	268,000	104,000	188,000
Coconut, edible	6,840,000	11,327,000	15,092,000	11,368,000	12,756,000	7,922,000	6,736,000	7,232,000	7,348,000	9,483,000	5,873,000	9,327,000
Coconut, inedible	15,401,000	15,377,000	19,329,000	20,268,000	21,832,000	18,310,000	23,294,000	22,178,000	15,114,000	15,074,000	27,505,000	16,249,000
Corn, edible	7,519,000	6,230,000	7,950,000	6,946,000	6,782,000	5,697,000	6,396,000	6,283,000	4,993,000	5,334,000	4,897,000	5,313,000
Corn, inedible	1,992,000	2,701,000	2,749,000	2,758,000	2,832,000	2,439,000	2,709,000	2,727,000	2,679,000	3,242,000	2,335,000	7,562,000
Cottonseed, crude	180,560,000	154,134,000	138,618,000	101,106,000	60,593,000	26,341,000	14,726,000	12,793,000	80,634,000	160,970,000	187,035,000	166,313,000
Cottonseed, refined	144,152,000	134,870,000	166,168,000	141,376,000	86,920,000	57,739,000	36,870,000	13,738,000	26,739,000	117,475,000	143,692,000	148,819,000
Linseed	29,084,000	26,704,000	33,562,000	33,979,000	36,119,000	36,511,000	28,824,000	28,003,000	27,206,000	33,242,000	30,977,000	31,241,000
Mustard seed [1]	76,000	100,000	87,000	84,000	140,000	135,000	104,000	78,000	85,000	103,000	64,000	141,000
Olive	273,000	132,000	10,000	75,000	5,000	722			200	1,000	9,000	112,000
Palm kernel, edible	569,000	47,000		28,000								
Palm kernel, inedible	199,000	603,000	137,000		549,000	93,000	493,000	594,000	21,000			451,000
Peanut, edible	12,905,000	5,973,000	8,775,000	6,200,000	5,993,000	2,374,000	4,194,000	6,476,000	5,574,000	1,423,000	3,761,000	6,856,000
Peanut, inedible	2,035,000	1,507,000	725,000	1,196,000	847,000	715,000	1,272,000	1,301,000	1,490,000	1,454,000	4,651,000	8,237,000
Raisin seed				37,000	14,000	35,000	49,000	79,000	97,000	70,000	90,000	115,000
Rapeseed			6,000			10,000	1,000	7,000	62,000	52,000	750	
Sesame							48,000	132,000	16,000	103,000		
Soy bean, edible [2]	3,789,000	4,792,000	6,608,000	4,971,000	6,089,000	2,470,000	8,663,000	7,042,000	8,119,000	6,726,000	14,125,000	5,524,000
Soy bean, inedible	144,000	161,000	267,000	107,000		16,000	117,000	68,000	52,000	11,000		
Miscellaneous	8,000	27,000	69,000				12,000			155,000		138,000
ANIMAL FATS AND OILS.												
Cod and cod liver oil	47,000	8,000	14,000	22,000	23,000	26,000	30,000	21,000	31,000	79,000	96,000	315,000
Herring oil	11,000			1,000	20,000	75,000	82,000	226,000	250,000	106,000		3,000
Horse oil	8,000	19,000	71,000	88,000	14,000	25,000	40,000	30,000	239,000	250,000	41,000	48,000
Lard, edible	84,491,000	80,358,000	87,607,000	93,329,000	87,841,000	72,131,000	85,392,000	64,462,000	53,047,000	83,709,000	86,287,000	114,346,000
Lard, inedible	2,710,000	2,898,000	2,783,000	2,146,000	467,000	505,000	227,000	396,000	1,780,000	401,000	345,000	1,099,000
Lard, neutral	5,019,000	9,557,000	9,170,000	5,812,000	6,551,000	6,633,000	7,779,000	4,960,000	3,943,000	3,633,000	6,402,000	11,830,000
Menhaden oil	26,000	3,000	68,000	100,000	466,000	3,204,000	1,108,000	2,118,000	2,051,000	763,000	1,604,000	859,000
Neats foot oil and stock	746,000	676,000	613,000	581,000	692,000	776,000	773,000	864,000	721,000	916,000	718,000	1,688,000
Oleo stock	10,923,000	9,246,000	12,121,000	13,042,000	10,544,000	9,248,000	11,410,000	9,348,000	11,442,000	16,831,000	15,780,000	15,994,000
Sperm oil	338		166,000	119,000	175,000	124,000	159,000					
Tallow, edible [1]	3,900,000	4,241,000	3,820,000	2,683,000	2,467,000	2,390,000	5,038,000	4,197,000	4,850,000	5,991,000	4,834,000	4,050,000
Tallow, inedible [1]	19,427,000	18,693,000	21,686,000	23,064,000	18,540,000	18,465,000	19,913,000	17,684,000	19,784,000	26,455,000	22,743,000	23,679,000
Whale oil			57,000	89,000	98,000		154,000	2,000	4,000	6,000	14,000	7,000
Miscellaneous animal oils		543,000	170,000		6,000	882,000	1,206,000	35,000	492,000	748,000	1,585,000	1,019,000
Miscellaneous fish oils [1]	72,000	64,000	21,000	13,000	43,000	19,000	40,000	101,000	127,000	124,000	96,000	186,000

GREASES.												
Bone	2,925,000	3,106,000	2,520,000	2,347,000	2,260,000	1,808,000	2,003,000	2,336,000	1,800,000	1,605,000	959,000	1,148,000
Brown	196,000	158,000	1,074,000	1,377,000	1,382,000	1,220,000	1,403,000	1,407,000	1,448,000	1,721,000	1,389,000	2,048,000
Curriers'	148,000	54,000	18,000	25,000	88,000	19,000	3,000	39,000	38,000	38,000	44,000	33,000
Garbage	3,907,000	4,630,000	5,197,000	4,909,000	5,902,000	4,923,000	4,584,000	4,286,000	4,399,000	3,456,000	3,710,000	3,573,000
Sewer	....	39,000	30,000	40,000	44,000	55,000	45,000	57,000	48,000	64,000	61,000	60,000
Tankage	8,011,000	8,779,000	5,728,000	5,843,000	4,576,000	4,339,000	4,598,000	4,131,000	3,976,000	4,285,000	4,406,000	6,172,000
White	406,000	1,559,000	4,026,000	4,281,000	3,396,000	2,961,000	3,447,000	2,365,000	3,429,000	3,704,000	4,379,000	5,982,000
Wool and recovered	1,589,000	1,588,000	1,744,000	1,972,000	1,999,000	1,814,000	1,757,000	2,083,000	2,034,000	1,758,000	1,086,000	1,596,000
Yellow	550,000	559,000	2,545,000	3,197,000	2,507,000	2,578,000	4,027,000	2,465,000	2,329,000	3,240,000	3,373,000	4,746,000
Miscellaneous	103,000	349,000	1,871,000	726,000	1,286,000	1,427,000	1,478,000	474,000	1,106,000	855,000	2,541,000	485,000
DERIVATIVES.												
Acidulated soap stock	3,671,000	3,435,000	3,605,000	3,975,000	3,445,000	1,867,000	2,147,000	1,049,000	1,599,000	1,178,000	3,350,000	4,336,000
Animal stearin	1,900,000	1,368,000	1,668,000	2,621,000	2,060,000	2,029,000	2,116,000	3,088,000	3,671,000	1,626,000	1,327,000	2,200,000
Coconut olein, refined	....	....	....	384,000	212,000	168,000	....	153,000	....	....	....	....
Cottonseed foots	14,407,000	11,078,000	13,294,000	12,517,000	9,307,000	7,255,000	4,077,000	2,388,000	3,677,000	8,216,000	11,625,000	15,751,000
Cottonseed foots (distilled)	3,536,000	3,582,000	4,824,000	5,140,000	4,424,000	2,277,000	2,278,000	2,132,000	1,038,000	3,035,000	3,467,000	2,206,000
Fatty acids	2,531,000	5,805,000	6,227,000	6,768,000	6,795,000	6,471,000	6,567,000	6,074,000	6,545,000	3,533,000	6,253,000	5,543,000
Fatty acids (distilled)	2,280,000	2,567,000	3,229,000	3,689,000	3,120,000	3,437,000	2,799,000	3,659,000	4,413,000	9,258,000	3,795,000	4,673,000
Hydrogenated fat and oil	....	2,830,000	4,559,000	2,752,000	3,499,000	6,818,000	2,290,000	2,690,000	3,224,000	4,585,000	6,531,000	5,994,000
Lard oil	5,259,000	2,935,000	3,685,000	1,756,000	2,483,000	2,203,000	4,242,000	4,434,000	3,987,000	4,653,000	4,210,000	4,739,000
Lard stearin	242,000	336,000	898,000	730,000	675,000	352,000	566,000	892,000	360,000	351,000	366,000	409,000
Mutton oil	5,000	25,000	28,000	25,000	16,000	9,000	19,000	24,000	52,000	62,000	21,000	62,000
Oleo oil, edible	12,888,000	11,442,000	12,774,000	17,285,000	13,202,000	12,256,000	10,297,000	8,932,000	10,864,000	13,112,000	11,972,000	11,264,000
Oleo oil, inedible	622,000	....	....	45,000	1,000	3,000	60,000	204,000	....	248,000	99,000	296,000
Red oil	1,691,000	2,709,000	3,828,000	4,233,000	4,166,000	3,521,000	3,272,000	2,280,000	2,604,000	3,286,000	3,389,000	3,471,000
Stearic acid	299,000	730,000	2,502,000	2,434,000	2,120,000	1,799,000	1,532,000	965,000	1,086,000	1,791,000	1,703,000	1,610,000
Tallow and oleo stearin, edible	7,195,000	5,900,000	6,767,000	9,556,000	4,588,000	6,216,000	6,809,000	4,862,000	6,062,000	8,412,000	7,624,000	8,176,000
Tallow and oleo stearin, inedible	600,000	602,000	1,389,000	1,003,000	5,259,000	427,000	1,350,000	1,084,000	533,000	220,000	549,000	259,000
Tallow oil	....	517,000	94,000	130,000	116,000	71,000	73,000	93,000	69,000	27,000	31,000	18,000
Vegetable stearin	57,000	357,000	308,000	395,000	1,289,000	1,164,000	1,184,000	114,000	1,335,000	1,013,000	1,530,000	350,000
Miscellaneous foots	30,000	206,000	837,000	1,676,000	1,280,000	985,000	1,593,000	793,000	941,000	763,000	1,176,000	1,498,000
Miscellaneous soap stock	319,000	154,000	2,797,000	210,000	66,000	191,000	322,000	796,000	566,000	1,128,000	1,384,000	1,235,000

[1] Figures incomplete.

[2] This is largely imported crude oil which has merely been refined in the United States.

TABLE 8.—*Consumption of fats and oils by the lard substitute industry.*

Products consumed.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Vegetable:					
Cottonseed oil	866,696,000	1,053,142,000	919,447,000	1,069,214,000	1,015,051,000
Coconut oil				5,545,000	13,408,000
Corn oil			13,105,000	4,166,000	2,288,000
Peanut oil	1,687,000	2,144,000	17,869,000	12,209,000	27,912,000
Soy bean oil		1,585,000	14,247,000	34,351,000	56,517,000
Stearin	180,000	611,000	4,007,000	17,140,000	14,904,000
Miscellaneous oils	6,418,000	5,464,000	13,421,000	12,742,000	6,350,000
Animal:					
Pork fat and lard	1,200,000	1,290,000	1,069,000	1,004,000	1,850,000
Stearin	57,644,000	64,926,000	49,493,000	54,959,000	54,598,000
Tallow, edible	10,834,000	13,945,000	9,852,000	9,953,000	11,361,000
Hydrogenated oil [1]		83,000	778,000	833,000	18,172,000
Total [2]	944,659,000	1,143,190,000	1,043,288,000	1,222,116,000	1,222,413,000
Lard substitute produced [2]	876,927,000	1,136,522,000	1,027,133,000	1,173,446,000	1,146,236,000

[1] These figures do not represent the total amount of hydrogenated oil used in the manufacture of lard substitutes, for the reason that in many instances manufacturers who do their own hydrogenating reported the amounts of oils thus treated, rather than the amounts of the hardened product. The figures here given represent largely the amount of hydrogenated oil purchased by the smaller substitute makers for combining with the other ingredients.

[2] The discrepancy between the amount of the total substitutes reported and that of the ingredients used is probably due to the fact that some manufacturers included in their reports the weight of the crude oil instead of the refined oil.

TABLE 9.—*Consumption of fats and oils by the soap industry.*

Products consumed.	1912	1914	1916	1917
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Vegetable:				
Chinese vegetable tallow	2,013,000	3,485,000	5,273,000	6,417,000
Chinese nut oil			118,000	115,000
Coconut oil	78,816,000	77,959,000	111,084,000	168,602,000
Corn oil	9,822,000	11,368,000	12,821,000	15,997,000
Cottonseed oil	132,312,000	119,254,000	194,916,000	126,390,000
Linseed oil	1,390,000	1,034,000	803,000	1,006,000
Olive oil	690,000	748,000	1,184,000	1,731,000
Palm oil	7,546,000	71,896,000	14,938,000	27,345,000
Palm kernel oil	20,579,000	31,376,000	5,804,000	4,762,000
Peanut oil	31,000	76,000	1,181,000	15,126,000
Rapeseed oil	6,532,000	6,664,000	7,224,000	5,972,000
Sesame oil	1,110,000	11,000	8,000	5,000
Shea nut oil			1,058,000	2,487,000
Soy bean oil	1,182,000	4,499,000	57,373,000	124,058,000
Miscellaneous oils	9,097,000	6,637,000	7,020,000	9,692,000
Total	271,120,000	335,007,000	420,805,000	509,705,000
Animal and fish:				
Bone grease	17,526,000	16,832,000	19,535,000	37,032,000
Garbage grease	12,619,000	13,627,000	28,719,000	63,118,000
Herring oil	56,000	10,339,000	2,705,000	4,104,000
Lard	8,469,000	10,484,000	8,294,000	7,481,000
Menhaden oil	116,000	882,000	330,000	2,279,000
Neats foot oil and stock	29,000	77,000	329,000	118,000
Recovered grease	2,858,000	10,627,000	8,531,000	12,680,000
Sperm oil	9,000	7,000	14,000	17,000
Tallow	238,685,000	270,713,000	338,931,000	362,297,000
Tankage grease	28,566,000	31,822,000	35,769,000	38,303,000
Whale oil	9,927,000	4,023,000	8,126,000	5,732,000
Miscellaneous oils	4,639,000	10,909,000	11,130,000	9,490,000
Total	323,499,000	380,342,000	462,413,000	542,651,000
Derivatives: [1]				
Acidulated soap stock	20,135,000	32,075,000	20,473,000	25,086,000
Cottonseed foots	77,975,000	88,667,000	103,868,000	107,070,000
Cottonseed foots (distilled)	11,152,000	19,474,000	8,410,000	8,872,000
Fatty acids	16,735,000	20,896,000	33,720,000	35,050,000
Fatty acids (distilled)	12,765,000	14,946,000	28,195,000	39,465,000
Grease stearin	1,461,000	944,000	5,144,000	19,146,000
Lard oil	1,134,000	1,265,000	2,143,000	2,148,000
Olive oil foots	5,457,000	7,298,000	9,411,000	10,500,000
Red oil	8,723,000	10,275,000	10,230,000	12,812,000
Miscellaneous soap stock	25,000,000	25,000,000	25,000,000	25,000,000
Total	180,537,000	220,840,000	246,594,000	285,149,000
Grand total	775,156,000	936,189,000	1,129,812,000	1,337,505,000

[1] The fact that no reports for hydrogenated oil are included in this table does not mean that none is used in the soap industry. Large amounts of hydrogenated oil were substituted for tallow and other hard fats, which were abnormally high during the recent great war. The soap makers using hydrogenated oil, however, are largely producers of their own hardened fats, and have reported the oils hardened rather than the hydrogenated product.

TABLE 10.—*Consumption of fats and oils by the oleomargarine industry.*

Products consumed.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Vegetable:					
Coconut oil	293,000	112,000	563,000	19,763,000	61,773,000
Corn oil			147,000	859,000	60,000
Cottonseed oil	17,837,000	21,205,000	49,960,000	63,652,000	36,454,000
Mustard seed oil	197,000	373,000	169,000	46,000	158,000
Peanut oil	2,453,000	3,137,000	5,335,000	10,498,000	21,593,000
Soy bean oil	708,000	486,000	2,123,000	6,614,000	5,921,000
Vegetable stearin					42,000
Miscellaneous oils					124,000
Animal:					
Butter	645,000	600,000	2,152,000	3,303,000	4,548,000
Lard and neutral lard	14,794,000	19,439,000	33,446,000	42,401,000	45,702,000
Mutton oil				149,000	14,000
Oleo oil	28,145,000	46,445,000	68,989,000	96,652,000	96,378,000
Oleo stearin	906,000	2,620,000	2,036,000	2,494,000	3,427,000
Oleo stock	92,000	161,000	397,000	3,458,000	7,526,000
Tallow	16,000	329,000		77,000	982,000
Hydrogenated oil					66,000
Total	66,086,000	94,907,000	165,317,000	249,966,000	284,768,000
Other ingredients:					
Milk	11,856,000	12,799,000	21,331,000	24,410,000	61,128,000
Salt	2,096,000	2,537,000	4,088,000	6,115,000	18,279,000
Oleomargarine produced [1]	95,397,000	123,843,000	184,889,000	271,874,000	332,898,000

[1] The manufacture of the so-called nut margarines has increased greatly during the past few years. The makers of this product used a large amount of dried milk, and in some cases they have reported the weight of the dried milk instead of its equivalent in whole milk. It must also be remembered that when ready for the market oleomargarine contains from 14 to 16 per cent of water, introduced as such or with the milk and salt which are among the ingredients of this product. This in part accounts for the discrepancy between the amount of oleomargarine reported and the amount of ingredients entering into its composition.

TABLE 11.—*Production of fat and oil derivatives in the United States.*

Product.	1912	1914	1916	1917	1918
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Acidulated soap stock	32,702,000	33,025,000	26,199,000	16,151,000	33,657,000
Animal stearin	17,726,000	20,075,000	31,811,000	31,607,000	25,674,000
Coconut olein					917,000
Cottonseed foots	142,812,000	195,461,000	123,326,000	112,847,000	113,592,000
Cottonseed foots (distilled)	79,342,000	86,910,000	32,786,000	33,900,000	37,939,000
Fatty acids	15,618,000	23,463,000	20,431,000	25,446,000	69,112,000
Fatty acids (distilled)	28,476,000	32,436,000	50,016,000	55,373,000	46,919,000
Lard oil	19,812,000	22,034,000	45,413,000	37,931,000	44,586,000
Lard stearin		378	3,000	4,000	6,177,000
Mutton oil	573,000	687,000	430,000	405,000	348,000
Oleo oil	118,939,000	142,367,000	150,794,000	142,559,000	147,866,000
Red oil	27,494,000	38,109,000	38,300,000	40,160,000	38,450,000
Stearic acid	3,773,000	6,176,000	10,311,000	6,351,000	18,571,000
Tallow and oleo stearin	77,490,000	80,735,000	79,828,000	83,025,000	95,442,000
Tallow oil	5,010,000	8,103,000	6,702,000	3,761,000	1,239,000
Vegetable stearin			5,398,000	5,801,000	9,096,000
Miscellaneous foots	385,000	1,258,000	2,210,000	2,417,000	11,778,000
Miscellaneous soap stocks	10,076,000	18,095,000	11,629,000	7,457,000	9,168,000
Total	580,228,000	708,934,378	635,587,000	605,195,000	710,531,000

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 770

Contribution from the Bureau of Markets

CHARLES J. BRAND, Chief

Washington, D. C. January 29, 1919

MOTOR TRANSPORTATION FOR RURAL DISTRICTS.*

By J. H. Collins, *Investigator in Market Surveys.*

CONTENTS.

A FIELD FOR THE MOTOR TRUCK.

The motor truck as a medium for the carriage of farm products is now assuming a permanent place in the general scheme of transportation. It was to be expected that the motor truck would find its greatest usefulness in solving the problem of the "short haul," one of the most difficult problems which has confronted transportation experts during the last decade. The steady growth of our larger centers of population and their increasing demands for larger quantities of food have stimulated the development of producing areas adjacent

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to these consuming centers. These producing areas have been pushed further and further from the centers of population by the encroachment of the city proper. Gardeners and dairy farmers who, a few years ago, were faced with a short haul to the nearby market, now find the horse-drawn vehicle of other days entirely inadequate to cover the increased distance to market. Here the motor truck has offered itself as a transportation medium capable of working effectively within a much wider radius than the horse and wagon. The development of rail facilities for the short haul has not kept pace with the development of crop producing districts near the larger centers of population. The rapid growth of the truck manufacturing business during the past five years in itself would have directed the attention of manufacturers to rural territory as a profitable sales field.

Summing up, it will be seen that three general causes have contributed to the exploitation of the motor truck industry in rural territory. These causes, as we have noted above, are substantially as follows: (1) the growth of our larger cities and the consequent development of nearby producing areas to provide for part of the food needs of these cities; (2) the failure of the railroads to keep pace with the expansion of their short haul business; (3) the development of the motor truck manufacturing interests and the consequent extension of their sales campaigns. The crisis in the transportation field, brought about by the national war emergency, has afforded stimulus to the development of rural motor transportation more powerful than any other general influence. Doubtless the motor truck, in any event, would have established itself as a factor in the rural field. Ordinarily this establishment would have been a slow process, involving the many preliminary steps customary in introducing a new method of transportation. War conditions precipitated action by creating a very unusual demand for transportation facilities of all kinds. Persons interested in the motor truck found the field made ready by emergency conditions over which no individual or group of individuals had control. It has been necessary only to develop the field of action properly. Such development necessitates or presupposes a certain familiarity with the problem as a whole. A suspicion that such familiarity did not exist among those interested in developing rural motor routes was borne out by preliminary investigations, initiated by the Bureau of Markets. An attempt was made to conduct a general preliminary survey of rural motor routes established or in process of establishment. The general purpose of the survey was to secure basic information regarding the desirability of establishing such routes, the methods undertaken by the beginners in this field, and the measure of success which had been attained during the early period of operation.

Material collected in the survey mentioned above shows considerable differences in the plans adopted by the average inexperienced operator. The word "inexperienced" is used advisedly in view of the fact that the motor truck is a newcomer in the field of transportation and there has not yet been time for many of the important preliminary problems to be worked out and a general understanding of possibilities secured. Investigations show that there are five general classes engaged in rural hauling on a schedule basis. This classification is about as follows:

(1) The farmer who hauls for his neighbor or for the community as well as for himself. In many cases such persons have purchased motor trucks and have afterwards found that their own business was not sufficient to justify the maintenance of such equipment. By arranging to care for part of the haulage needs of their neighbors,

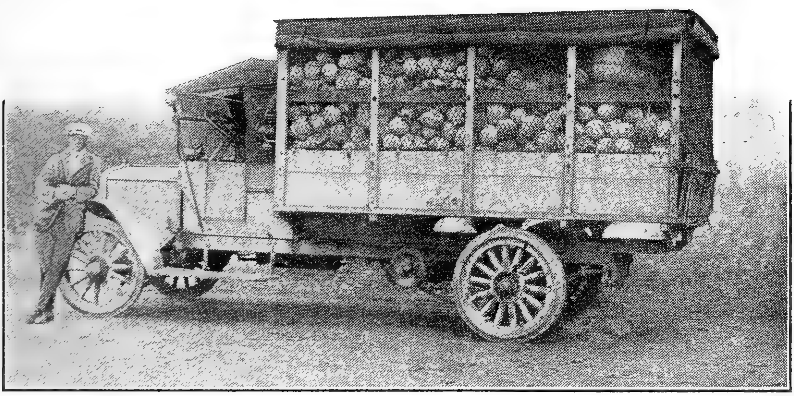

FIG. 1.—The cabbages and cucumbers in this truck load will travel 20 miles to Buffalo, N. Y., and arrive in good condition. The wire netting all around holds a large load in place.

they have made their investment a profitable one, and unconsciously have materially helped the local transportation problem of their communities.

(2) The regular local truck operators with limited capital, whose income is derived largely from their motor trucking business. Some of these persons are small farmers who have embarked in a new business and are willing to devote exclusive attention to the development of local motor routes.

(3) The local automobile or truck agencies that have initiated a motor route as a side line. In some cases the establishment of these routes has been for advertising purposes, the dealers feeling that a practical demonstration of the possibilities of the motor truck would result in increased sales. Often these ventures have proven so successful that they have become a permanent part of the farmers' business and would be conducted for profit even if the advertising value were nil.

(4) The city transfer companies, whose business permits them to undertake rural hauling. Most routes so developed are built on a sound basis. The companies, in most instances, develop their routes in districts familiar to them, where the opportunities for business are fairly well-known in advance.

(5) The large corporation operating a fleet of trucks and commanding considerable capital. There has been an increasing number of this class of operators, and the field has seemed attractive to many men of large capital. Profits during the war period have been such as to make it worth while for men of considerable means to devote serious attention to the building up of motor routes as a regular business.

There are many and varied modifications of the above classifications of operators. Motor hauling during the emergency has been very miscellaneous in character, and conditions do not permit general statements to be made covering the field as a whole. With such an array in the field of motor hauling, it would naturally be expected that there would be a very wide range of operating conditions. Investigations have shown that this is actually the case. Certain weaknesses in the rural motor truck industry have been noticed in connection with these studies, and it is the purpose of this publication to call to the attention of operators and prospective operators those features of the industry which apparently are not understood or appreciated. It is hoped that some of the suggestions contained in this publication may assist in avoiding loss and in helping in the development of the rural motor route on a sound business basis. That rural motor routes in general are not being so developed is evidenced by the unbusinesslike methods adopted by many new operators, including both farmer-operators and the strictly commercial organizations. Present efforts to stimulate the motor trucking industry on the part of those who would profit more by its expansion evidently are not a part of a systematic or well-conceived plan. It is easy to call to mind conditions under which motor truck operation in certain rural districts as a regular business proposition has not proven profitable. These limiting conditions have not received the attention that their importance would warrant. The suggestions on the following pages are designed not so much to give specific instructions on the formation of new rural routes as to call to mind those business arrangements which must in all cases be considered carefully if a venture is to prove profitable. It is hoped that this publication will assist in developing the proper sort of thinking among prospective operators and call up in definite order those basic considerations which must be given attention. The suggestions and conclusions included herein have resulted from a careful study of a large number of typical motor express routes in various sections of the country. In addition, the Bureau of Markets has been instrumental in establishing motor service in various districts during the early part of 1918 and the methods adopted and the difficulties encountered have furnished material for a fairly comprehensive viewpoint on the entire problem.

Inquiries are constantly being received regarding the practices and methods of successful operators of rural truck routes. It is a regrettable fact that there are practically no rural truck operators whose general plans are worthy of study by less experienced operators. Most rural routes are in the formative stage. For this reason it is felt that a summary of the problems of all will be of mutual interest both to the present operator and to the prospective one. The usefulness of the motor truck for the individual farmer will not be dwelt upon in this bulletin, but we will concern ourselves entirely with the possibilities of the motor truck as a community transportation feature.

PRELIMINARY SURVEY OF THE FIELD OF OPERATION.

Too many beginners delay a canvass of their field of operation until they are definitely committed to the establishment of a motor route by an investment of funds. Such a beginning is decidedly an unwise one. Many an optimistic viewpoint has been changed by a closer scrutiny of the business essentials which must be considered when a rural route is established. It is very desirable, in fact almost necessary, that a thorough business survey be made in advance by the prospective operator. In the first place, an investigation may disclose the fact that it is unnecessary or undesirable to start the route at all. Secondly, a proper investigation may materially modify preliminary plans, particularly with respect to the investment of funds and the selection of equipment. Enthusiastic but inaccurate reports which have been given wide circulation in many districts, have been responsible for some amateur beginnings which should never have been undertaken. The motor route which has a chance for success must be founded on a careful business analysis of the field of operations.

There are four important factors which must be given consideration by the beginner in the field of rural motor transportation. These four factors are: (1) The volume of farm products produced along the contemplated route; (2) the volume of miscellaneous hauling which could be secured to supplement regular loads; (3) competition from other carriers which would be encountered; (4) the character of the highways over which the trucks must run. It may safely be said that the features mentioned above will ultimately determine the success or failure of any rural route.

A motor route established in a sparsely settled or non-productive region is foredoomed to failure. A little thought will make it clear that a potential supply of commodities must be available for hauling if there is to be sufficient business to make the route a paying one. Secondary only to the total supply is the question of the character of production. A region devoted to the production of a few staple crops moving to market during a comparatively brief season each year will not furnish business for a permanent route. A necessary prerequisite for successful operation is a reasonably dependable tonnage throughout the year. For this reason it follows that the range of the shipping season is of primary interest to the truck operator. Regions of diversified farming, particularly those regions devoted to truck farming, offer the most fertile fields for rural motor transportation. In such districts shipping starts early in the season; new crops are periodically available for market, and the productive season usually extends to the limit set by climatic conditions. Districts devoted to the dairy industry are also potentially rich fields for the motor truck operator since dairying furnishes a dependable and reasonably uniform supply throughout the year. This permits the establishment of a fairly regular routine on the part of the truck operator and to that extent renders easy an efficient and economical conduct of his business.

Consideration should also be given to the nature of the products that will be hauled. Low-priced, bulky staples may not stand the transportation charges necessary to maintain a motor route. For example, it is rather unlikely that hay can be transported by motor truck for long distances except under unusual conditions with respect to price. Perishables may stand the motor truck tariff if the transportation service to market is speedier than the customary means of transportation. Commodities like cream, milk and eggs which are high in price as compared to bulk may bear a reasonably high transportation charge if more satisfactory facilities are offered.

The question of supplementary business for rural truck operators is often an important one. The return load is discussed in a subsequent section of this publication. It is desired merely to take occasion at this point to direct attention to possible side lines of operation which have been responsible for the final financial success of some routes. Arrangements for special hauling outside of the regular schedule are often an important source of income to the rural motor truck operator. Some have found it profitable to care for the tonnage offered by industrial enterprises in their districts. Others do special hauling for farmer patrons outside of regular hours. Usually the operator of a general route secures some profitable business from merchants along the route. These possibilities should be canvassed in advance as their presence or absence may determine the feasibility of the route. Above all, attention should be concentrated on the problem of arranging for loads so that there is a profitable load on all trucks whenever they are operated.

Competition is as important a feature as in other business. The motor operator may find it necessary in some cases to compete with express companies, railroads, electric interurban lines, boat lines, or other truck operators. It is a very unwise policy to ignore the competitor who is already in the field. Every producing district in the country has some sort of arrangement to provide for transportation to market. The wise beginner in the motor truck field will make a survey of existing transportation facilities in advance. He will make

Fig. 2.—Celery in crates is easily carried in most kinds of trucks.

a special effort to foresee the conditions under which the motor truck would fit into existing schemes of transportation. In considering competition, particular attention should be given to rates, schedules and delivery arrangements. These are the factors on which the motor truck must stand or fall so far as concerns competition with other transportation agencies. Some operators have found it possible to compete successfully with rail service and to charge rates rather higher than were charged by the customary carriers. Such a condition is possible only where the truck operator is able to afford a superior service and in districts where patrons are willing to pay a premium for such superior service. Delivery arrangements have always offered a certain amount of trouble to rail carriers and by effecting direct delivery from shipper to consignee with no intermediate delivery charges, the motor truck has been enabled to compete successfully with rail carriers whose rates are slightly less than those of the motor truck. Freight and express schedules in some districts have been unsatisfactory to the shippers and by offering a more prompt and speedy service, operators have often secured for themselves a very satisfactory tonnage that ordinarily would move by rail.

Good roads are a prerequisite to successful motor truck operation. It is believed that few motor truck operators realize the increased expense which results from travel on poor roads. The prospective operator who plans to move his truck along roads which are virtually impassable or at any rate unsatisfactory, will find that his daily operating costs are far in excess of normal costs of operation, and this one fact alone will seriously affect his profits. A careful road survey will be made in advance by the businesslike operator.

Enough has been said in the preceding paragraphs to indicate the general scope of the preliminary canvass which every prospective motor truck operator should make. The Bureau of Markets has made a fairly complete study of a large number of typical rural routes and has assisted in the establishment of several such routes. The points considered by investigators of this Bureau in making a preliminary canvass of the field of operation may be helpful to operators who contemplate such a study in their own territory. The following outline was placed in the hands of each investigator, and the final report on the feasibility of establishing motor service in any district covered complete reports on each of the items in this outline.

ROADS.
- Character of surface.
- Grades. (As affecting motor hauling.)

LOCATION AND LENGTH OF PROPOSED ROUTES.
- Terminals.
- Towns to be covered. (Distance apart, size, etc.)
- Total distance covered.
- Logical location for route headquarters.

PRINCIPAL COMMODITIES TO BE CARRIED EACH WAY.
- Nature of agriculture along route.
- Commodities to be hauled each way in summer. In winter.

AMOUNT OF BUSINESS WHICH WOULD BE PLEDGED.
- What business would be pledged in summer? In winter?
- Estimated quantity of business by months.
- Of what would return load consist?
- Who would furnish bulk of business—farmers or country merchants?
- Do prospective patrons seem inclined to pledge business?

SERVICE NOW GIVEN BY OTHER CARRIERS.
- What other carriers serve the territory?
- The maximum, minimum and average farm haul to loading stations.
- Schedule maintained by present carriers.
- How do present delivery arrangements compare with proposed arrangements if a motor route should be established?
- Rates charged at present. (Freight and express.)

SCHEDULE WHICH SHOULD BE MAINTAINED.

Number and capacity of trucks which probably would be needed.
When would trucks leave terminals to best serve the territory?
Probable running time over the route.
How many stops should be made and where?

PROPOSED METHODS OF COLLECTING AND DELIVERING.

At how many and at what points would loads be collected?
How would transportation charges probably be collected?
What delivery should be effected both at city and country points?

LOCAL INTEREST IN THE ENTERPRISE.

What persons or concerns are most interested? Why?
Could private capital be induced to contribute toward an experimental service?

PERMANENCE OF PROPOSED ROUTE.

Will territory support the proposed route when rail service is normal?
Is there any reason why the route should not be permanently profitable?

It is manifestly impossible completely to outline an ideal investigation which would be satisfactory for all districts. It is necessary to correlate the preliminary canvass with local conditions. The items enumerated in the above outline, however, may offer some suggestions which will be helpful to those interested in the establishment of rural motor transportation routes.

ADVANCE ESTIMATE OF OPERATING COSTS.

One of the first questions to arise in the mind of the prospective motor truck operator is: "What will it cost to operate a truck?" Loads will be arranged, rates will be established, the route will be planned and the truck purchased on the basis of this estimated cost. If the business is to be intelligently planned, it is essential that some idea be secured in advance as to prospective operating costs. The importance of having an idea of these costs in advance can not be over-emphasized.

There are several sources of information which may be helpful to the man contemplating the purchase of a motor truck. Previous personal experience of the operator is exceedingly valuable. Experiences of other operators may often be secured for the asking. Motor truck manufacturers will be glad to furnish prospective purchasers with such information of this nature as may be available. Data secured from truck manufacturers very often do not indicate the conditions under which the figures were secured. Information thus offered is usually an honest attempt to aid buyers but almost invariably there is too much generalization to make such figures a very valuable basis of estimation. Many cost statements issued by truck companies do not take into consideration the varying classes of highways over which trucks run, variations in the load, total monthly or yearly mileage and other important factors. There is a tendency to submit data secured under unusual or ideal circumstances and thus rendered valueless to the operator who must run his trucks under conditions over which he has little or no control.

Several factors must be considered in arriving at reasonable cost estimates. Among them are: (1) size of truck, (2) probable loads, (3) daily mileage, (4) condition of roads, (5) cost of gas, oil and repairs. Large trucks necessarily involve increased expenditures for operation. The cost of operation per unit of load, however, may be less with the large truck than with the small one. The operator whose prospective daily mileage will be unusually large must expect that his operating costs will be correspondingly large. Where the roads are smooth and hard, costs of operation will necessarily be much less than

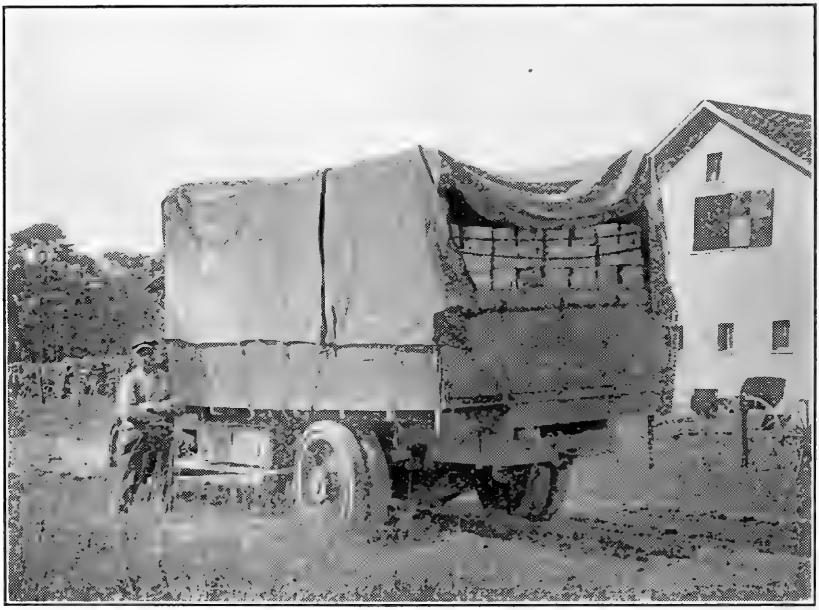

Fig. 3.—An open-top stake body, with loose canvas cover, carries a large load of grapes, but is not the best type of body for hauling perishable products.

where the roads are in a poor state of repair or so soft as to be nearly impassable at certain seasons of the year. Gasoline, oil and repair bills will vary in different sections of the country. It is impossible to generalize on these expenses at this point. The prospective operator must examine his local conditions, however, and adapt his ideas to the prevailing scale of prices.

In view of the fact that no two individuals operate motor trucks under identical conditions, it is necessary that there be some basis of calculation applicable under all conditions. Calculations bearing on costs of operating motor trucks are customarily based on the "ton-mile." This expression refers to the transportation of a one-ton load for a distance of one mile, or the equivalent thereof. The use of such a basis is more nearly accurate than an estimation of costs on a mileage basis where no consideration is given to the load. It is obvious that the truck operating with no load, costs less per mile for operation than one that is loaded. The wise operator will keep this basis well in mind in considering his costs of doing business.

Few motor truck owners foresee all of the cost items which will arise under actual operating conditions. Still fewer farmers, who have embarked in the motor trucking industry either as an individual enterprise or as part of a community effort, have a clear understanding of what factors must be considered in estimating costs of motor truck operation. Attention will be directed, therefore, to some of the more important items of cost. No attempt has been made to arrange these items in order of importance.

GASOLINE, OIL AND GREASE.

The costs of gasoline, oil and grease represent the first expense items which naturally occur to the mind of the prospective operator. The customary error made in considering them is shown in a tendency to emphasize unduly this character of expense. The cost of gasoline, oil and grease, of course, is dependent directly upon local prices. In some districts prices for these supplies are invariably higher than in other districts, and the prospective operator will naturally investigate his local market. The cost of these supplies is of course heavier when the motor truck is loaded and is one of the variable items of expense in motor truck operation which can be estimated with considerable accuracy. Most operators have a fair idea of the consumption of gasoline, oil, and grease by their own trucks. Operators who have had some experience in truck operation will find little difficulty in arriving at a reasonably close estimate of these costs. The data collected by the Bureau of Markets show a very wide range in the gasoline mileage for trucks of different sizes under varying conditions. A study of about 60 typical motor routes showed a mileage of from 5 miles to 9 miles per gallon of gasoline for two-ton trucks, 4 miles to 6 miles for three-ton trucks, and 3 miles to 5 miles for five-ton trucks. These figures are not conclusive but will serve to indicate a range which was found under actual operating conditions.

DRIVERS' WAGES.

The wages paid drivers vary in different sections of the country and for trucks of different sizes. In districts where the cost of labor is high, operators have found it necessary to pay relatively high wages for drivers. Information gathered by the Bureau of Markets on a number of routes indicates a daily wage range of from $2.75 to $7.50. The higher wages were paid for expert drivers of heavy motor trucks in industrial regions where the general scale of wages was high. Drivers of small trucks in general farming districts were content with the smaller wage. Where the truck owner expects to act as his own driver, it is only fair that a reasonable wage for this service be entered on the books before an attempt is made to calculate profits.

DEPRECIATION.

Depreciation as a feature of expense is little understood by the average small operator, and there is an almost universal tendency to accord too little consideration to this important item. Investigations disclose the fact that this constitutes one of the heaviest items of cost per mile of operation. Most operators who consider this item at all are inclined to set aside from 20 per cent to 33 1-3 per cent of the cost of the truck each year to cover depreciation. This is a very simple arrangement but it is not entirely a sound one. It is obvious that depreciation will be greatest on the truck which makes the greatest annual mileage. It will be seen, therefore, that unless the annual mileage, or prospective annual mileage, is considered, the preliminary estimate of depreciation is apt to be incorrect. Depreciation under actual working conditions varies considerably with different makes of trucks and is correspondingly less on better makes. It is impossible to set forth a formula which will enable the prospective purchaser of a motor truck to estimate in advance his depreciation with any considerable degree of accuracy. It will be necessary for each owner to consider carefully his own conditions and on the basis of past performance of trucks of the same size and make as his own, draw his own conclusions. The operator who is just considering the route will do well to study very seriously the importance of this item of cost. If he will tentatively estimate depreciation in terms of dollars and cents per year, estimate his prospective yearly mileage, and divide his annual depreciation cost by the annual mileage, he will be surprised at the cost of depreciation per mile of operation.

INTEREST ON INVESTMENT.

While interest on investment is a matter of controversy in corporation accounting there can be no doubt that the motor truck operator must give serious consideration to the fact that he will have invested considerable money in the motor truck that can not be used for other purposes. Most operators are content to estimate six per cent as a fair rate of interest per year, but few of them take into consideration the depreciating value of the truck. During its second year of operation, it is obvious that the motor turck is not worth as much as during its first year. For this reason, a charge of six per cent for interest on the purchase price of the car is not a just one during the second year of operation.

A simple formula has been devised by a conference of truck owners for calculating the average annual interest to be charged against a motor truck. This formula is as follows: $\frac{A+1}{A} \times \frac{C \times B}{2} =$

average yearly interest. In this formula A represents the estimated life of the truck in years under actual operating conditions; B represents the original investment; and C represents the rate of interest. To illustrate the use of this formula let it be assumed that a truck is purchased for $3000 which the operator estimates will last for 4 years under his operating conditions. Six per cent may be considered a fair rate of interest. Inserting the necessary values in the equation given above, we have: $\frac{4+1}{4} \times \frac{.06 \times \$3000}{2} = \$112.50$ (average yearly interest). The use of such a formula makes it possible to estimate, with a reasonable degree of accuracy, the amount which should be set aside each year as interest on the investment.

REPAIRS.

The regular repair bill, when coupled with the annual cost of overhauling, is often a serious one. The experience of motor truck operators in various sections of the country show that this is an important item of expense. Naturally it is impossible to make an advance estimate of these costs with any reasonable degree of accuracy. The annual repair bill will bear a practical relation to operating conditions. Where care is used in handling the truck, the cost of repairs will be much less than where no attempt is made to exercise reasonable supervision over operation. The cost of repairs increases with the age of the truck. Those operators who have purchased used equipment have found their repair bills relatively higher. Repairs during the first year of life of the new truck are not a very serious consideration. When the motor truck is in more or less continuous use throughout the year, it is usually laid up once each year and given a complete overhauling. The cost of this overhauling depends on the age of the truck, the care which it has received, and its size. Data collected by the Bureau of Markets show annual costs of overhauling ranging from about $100 to as high as $800 or $900. Those truck operators who make it a point to keep their trucks in a constant state of repair have relatively small charges to meet for annual overhauling. Those who operate their trucks as long as possible with no regular repairs must often face an extremely heavy charge for overhauling at the end of each year.

TIRES.

Tire cost is another heavy item of expense. This item varies directly with the use of the truck. Road conditions are a prime consideration in determining tire cost per mile of operation. It is often found that there is a very wide variation in tire cost of different trucks operating with varying loads and under changing conditions. Data in the possession of the Bureau of Markets show a range of tire costs of from one cent to four cents per mile where solid tires are used. These figures cover a large number of trucks of different sizes, operating with different loads. They are offered as illustrative rather than as authoritative. It must be remembered that while the actual tire cost of the large truck heavily loaded may be relatively high per mile of operation, the cost per ton may be small, and in the final analysis the latter comparison is the only fair one. Where pneumatic tires have been used, it usually has been found that the actual tire cost is rather in excess of the cost where solid tires are used, but in such cases the annual depreciation and the cost of repairs are usually less.

GARAGE RENT.

Garage rent is an item of expense which is often not incurred directly by the rural operator. Where the operator finds it necessary to rent garage space it is, of course, easy to calculate the cost. It is not so easy to make such an estimate, however, where no actual cash outlay is incurred. Where the operator is using garage facilities of his own, which might be valuable for other purposes, the rental value of these facilities should be entered on the books. Where no attempt is made to house the truck when not in use, the operator may save on garage cost only to lose a still greater amount due to increased depreciation.

TAXES, LICENSE AND INSURANCE.

Taxes and the costs of a license and insurance vary greatly in different states. The prospective owner of a motor truck should look into the matter in advance and be in a position to meet these liabilities as they come due. Insurance of various kinds must be considered. Theft, accident, and fire insurance should be taken out on the motor truck itself. Reliable operators now find it desirable to take out insurance covering the load which is being carried.

OVERHEAD EXPENSES.

The item of overhead expenses includes office rent, office equipment, clerical and other salaries, advertising, etc. They are often of minor importance to the farmer operator, but constitute a considerable expense for the larger operator who finds it necessary to maintain a business headquarters.

The above enumeration of operating costs may serve to call to the attention of some beginners in the field of motor truck transportation the need for carefully considering the business elements in advance of actual operation. The most common error of the beginner is to underestimate some of the cost items. Many beginners either underestimate or fail to estimate at all such an important item as depreciation. Such operators have been known to conduct their business for several months under the assumption that they were making money, only to find that their apparent net profit was being absorbed by the lessening value of their rolling stock. Other operators have been inclined to accept cost figures determined under widely different conditions, or under conditions which were not all comparable to those in the operator's own territory. Few operators realize that costs are directly related to the plan of operation, and the final costs of operating a given route will depend almost entirely on the local conditions under which the route must be maintained.

SELECTION OF OPERATING EQUIPMENT.

The problem of selecting proper operating equipment is one that ordinarily is not given the consideration its importance deserves. Too few operators have a sufficient knowledge of the mechanical operation of motor vehicles, so that many a promising route has proven unprofitable because of improper or insufficient mechanical equipment. In making their first purchases, some operators rely exclusively upon the statements of sales agents for motor truck companies. Often this procedure has proven satisfactory in the long run because as a rule the sales agent is anxious to see that his customer is supplied with the proper equipment, so that other orders may be expected in the future. It will be well, however, for the beginner in this industry to confer with owners and operators of motor trucks in his vicinity, who will be able to give him unbiased and unprejudiced advice.

SIZE OF TRUCK.

The size of the truck to be purchased will, of course, depend very largely on the estimated tonnage to be hauled. Not only must the operator purchase trucks of sufficient size to care for the business at the outset, but he must plan for a normal increase in tonnage, so that at a later date he will not find it necessary to purchase other equipment more suited to his needs. It must be remembered that there is a very definite relationship between the size of the truck and its upkeep cost. The cost of operation per mile of a large truck is greater than is that of a small truck. If a large truck is purchased and the average load carried is well below the rated capacity of the truck, the operator will find that his cost per unit of load is high. On the other hand, where regular loads are uniformly heavy, the cost per unit of load is much less with the larger truck. One five-ton truck will transport a five-ton load much more economically than will two trucks of half that capacity. In some cases, consideration must be given to the character of the load to be hauled. If the load is perishable by nature and the truck is not loaded to capacity, the comparatively heavy springs of the larger trucks may cause a deterioration of the load. If the load promises to vary considerably during different periods of the year, it may be advisable to consider the use of a trailer in connection with a truck of smaller rated capacity than the maximum load. The trailer seems to have been successfully used by a large number of commercial operators, but the Bureau of Markets has no data regarding the advisability of using trailers when the load is uniformly greater than the rated capacity of the truck.

Road conditions bear a direct relation to the size of truck to be selected. Roads having a light surface or country roads having a soft surface may not permit the operation of heavy trucks. In some states bridges in rural districts have not been designed to care for heavy modern traffic, and in these districts it is necessary to use lighter vehicles. Some States and some municipalities have placed legal restrictions on the weight of rolling vehicles passing over the roads. In most cases these restrictions are so worded as practically to forbid the use of trucks whose gross tonnage when loaded exceeds a certain maximum. In other cases the load which trucks may carry depends upon the width of the tire equipment. The prospective operator should communicate with the Public Service Commission or such other body as may have jurisdiction over the operation of trucks in his territory and inform himself in advance as to legal restrictions covering the operation of trucks on the highways.

BODY EQUIPMENT.

The selection of body equipment must be based primarily upon the general character of the loads to be hauled. In rare cases where the goods are highly perishable or must be carefully protected from weather conditions, it may be necessary to use specially constructed bodies. Under ordinary conditions, however, the operator usually has his choice of several types, and his selection, as a rule, is based upon his requirements and the initial cost of the equipment.

Body equipment is usually secured from one of three sources. Bodies may be built locally, according to the ideas of the operator, and superimposed on the chassis when delivered; or, bodies of regulation design may be furnished by the manufacturer of the chassis as regular or special equipment. Some concerns specialize in building truck bodies according to regular or special designs and will furnish a body of any design submitted by the purchaser.

Certain basic considerations are necessary in the selection of body equipment. The prospective operator should have a fairly clear idea of the general nature of the commodities which he will be obliged to haul. He should estimate the bulk of his load as compared to its weight. If any appreciable proportion of the ordinary load is perishable, necessitating special protection from heat, cold, or rain, consideration should be given to this fact in the selection of a truck body. If the average load is to be composed of package freight, the truck body will be much different from the one used if regular loads are composed of commodities shipped in bulk.

Of the large number of body types, many are entirely unsuited to the needs of the ordinary operator of a rural motor freight route. However, attention may be directed to a few of the more common types of bodies. While no uniform names have been applied to these general types, it is believed that the descriptions given herein will be sufficiently plain. The following are among the commonest types of truck bodies in use:

Stake body (open top).—This is a relatively cheap body, is easy to load, and is capable of carrying extra large loads of bulky goods. Because of its construction, it is adapted to a large variety of uses. It should be remembered, however, that because of the open top and the lack of protection on the sides, it offers little protection from the weather unless the load is well covered with canvas. It is not always easy to protect the load by means of a loose canvas cover, and for this reason, the open-top stake body is not as popular for rural hauling as is the next type mentioned.

Six or eight-post open-side body.—This body has a permanent waterproof top and, with the use of the customary side curtains, is a very popular and adaptable type. It is comparatively light in weight and offers much better protection to the load than does the open-top body. In winter, however, it is not easy to heat where it is necessary to protect a perishable load. This type of body is the most popular because of its light weight, general adaptability and cheapness.

Straight-side closed body (or van body).—This type offers the best possible protection to the load if it is so designed as to insure proper ventilation. It is possible to seal such bodies so as to protect the load from pilferage, this being a decided advantage where the load is a valuable one. The closed body is heavy, thus increasing the cost of truck operation and is initially expensive. It is not so easily loaded as the open-top, but may be used for hauling almost anything that is offered.

Open express body.—This body resembles the ordinary farm wagon, has no stakes at the sides, and is uncovered. It is well adapted for hauling milk or products shipped in bulk, such as grain. It is fairly cheap in price, but offers little or no protection from the weather. It is not adapted for hauling large loads of light bulky goods, and except for special purposes, should not be selected by the average operator.

Dump body.—This is an unusual type for rural hauling and is not adapted to a wide range of uses. It is heavy, unsatisfactory, and expensive for general rural hauling. It might be used advantageously for handling bulk grain or similar products, but should be selected only for special uses.

In general, the selection of body equipment is a problem which solves itself if proper forethought is given to the character of the business. There are many special variations from the general types of body mentioned above. If the prospective load promises to be heavy in proportion to its volume, the body need not be large. If, as is usual with miscellaneous farm loads, bulky loads may be carried, it is important that the body be of sufficient size to accommodate a capacity load for the truck.

TIRE EQUIPMENT.

It is important that due consideration be given to the selection of tires, in view of the fact that tire cost is one of the heavy items in motor hauling. There are two general types of truck tires in use—the solid and the pneumatic. There is a third type, the cushion tire, which has a limited use at the present time, but by far the greater proportion of motor trucks are equipped with either solid or pneumatic tires. The solid tire is more commonly used because it is more adaptable and cheaper than the pneumatic, does not suffer from blowouts or punctures, and stands up well on bad roads and under very heavy loads. The pneumatic tire for truck use is a recent development, and there is less known about the possibilities of pneumatic tires for heavy loads than is known concerning the solid tires. Advocates of the pneumatic tire claim lessened vibration for truck and load, greater speed, and increased gasoline mileage. Where speed is essential, the pneumatic tire should be considered carefully. Where economy is the prime factor, the question is debatable. The majority of practical operators, however, favor the solid tire. No attempt will be made in this publication to issue an authoritative statement regarding the merits of the two types.

The size of tires should depend upon two factors: (1) The weight of the ordinary load, and, (2) the character of the road. Under-size tires are not only uneconomical, but are injurious to the roads over which they travel. Over-size tires are initially expensive and, if the load is ordinarily light, are unnecessary. With slightly soft roads or extra heavy loads, over-size tires may be desirable. In general, the recommendations of the manufacturing company or its agents are more reliable than the judgment of an inexperienced operator. It is well for the prospective purchaser to consult local tire agencies in considering new equipment. It should be remembered that the agent can offer authoritative advice only when he is fully informed as to operating conditions, and when such advice is asked, the operator should state his case fully.

DETERMINATION OF RATES.

The Bureau of Markets has received many inquiries indicating that the question of a basis for the determination of motor freight or express rates is not clearly understood even by experienced operators. The operator of a regular commercial rural route (as distinguished from the farmer operating a truck for himself and a few of his neighbors) has little to guide him except the rates of other operators. As a rule, these are not sufficiently uniform to form an adequate or just basis of comparison. Many operators have established their rates on the basis of "what the traffic will bear." Naturally, rates so established have varied in different localities and for different commodities. Many operators have initiated service with rates so high as to drive profitable business away; others have gone to the other extreme and in their desire to attract business, have failed to give due consideration to operating costs and have lost heavily because their rates were too low. There are several factors which should be considered in the establishment of rates in any district. The value and the fragility of the load bear a direct relationship to the rate which should be charged. Very valuable or fragile loads involve a greater risk on the part of the carrier, and the tariff for the carriage of such goods should be sufficiently high to offset the risk involved. Where insurance is carried, this must be considered as an item of cost in calculating the rate to be charged. The length of the haul is naturally another prime consideration. It is comparatively easy to consider this item, as the cost, as a rule, varies directly with the distance. Road conditions also directly affect operating costs and, hence, must be considered in establishing rates. Where the roads are good, operating costs are low and charges for transportation can be lessened accordingly. Where poor roads are encountered, the additional cost must be featured in the rate schedule. The perishability and the bulk of the load also should be considered. The transportation of highly perishable goods involves a risk which must be paid for. Where goods are extremely light and bulky, it must be remembered that the truck when fully loaded may not carry its capacity in weight; hence, operating costs will be increased per pound, and this must be reflected in the rates. Some operators fail to consider competitive rates by railroad, electric line, boat line or other motor truck lines. It goes without saying that a profitable business will not be secured if rates are not in line with those of other carriers. It should be remembered, therefore, that careful consideration must be given to rates charged by other carriers. The class of service rendered will also directly affect the rate. Where complete delivery is made from the door of the shipper to the door of the consignee and service is rendered which is not duplicated by the railroad, the additional service must be considered in fixing the rate. In many cases rural motor routes make delivery of goods much more quickly than does the railroad, and where time in transit is a consideration, the additional value of such prompt service is to be considered. Return loads bear a direct relationship to the primary rate in that the operator who is assured of a profitable return load will be enabled to reduce his charges because of lessened cost per ton-mile.

There are many other minor considerations to be gone over by the beginner in the motor truck industry, but those mentioned above are basic in nature. Some operators catering to a business which ordinarily would go by freight have established rates which compare directly with freight rates. Most operators do an express business and base their rates accordingly. In some districts, in the effort to establish a fair rate, motor operators have added ordinary freight and express rates together and divided the sum by two. This is decidedly an unsound and unscientific method for the determination of such rates but represents an earnest effort to place the motor truck on a rate basis comparable with that of the chief competing carriers. Practically no rates have been established on the basis of cost plus a reason-

FIG. 4.—The farmers of Harford County, Maryland, operate a motor truck route for themselves with entire success. This is one of their roadside loading platforms, to which the farmer brings his milk by a short haul, and the truck takes it to Baltimore.

able profit. This is easy to understand because cost of operation is not well understood by most operators, and very few have any authoritative information in this connection.

The satisfactory rate must be one which is low enough to attract business and high enough to offer a reasonable profit to the operator. Where conditions do not permit the establishment of such a rate, care should be exercised in starting a route. As the rural motor business becomes more firmly established in various districts, the practical experience of operators will serve to indicate fair rate bases. In the meantime, it will be necessary for each operator to solve his own problems on the basis of local conditions in his district, paying particular attention to the features indicated in this bulletin.

COLLECTION AND DELIVERY ARRANGEMENTS.

It must be remembered that that two of the principal advantages of the motor truck, namely, lessened handling of goods in transit, and speedier transfer, are lost if satisfactory collection and delivery arrangements are not perfected. It may be well to mention and to discuss briefly collection methods in vogue among practical operators in various districts. It should be stated in advance that no system worthy of exact duplication has been found by investigators of the Bureau of Markets in studying the business arrangements of a large number of operators in various sections of the country. Collection and delivery arrangements, as a rule, have grown up gradually with the business and in many cases are cumbersome, unsystematic and expensive. The following common methods are suggested to prospective operators and may serve to stimulate thought in the direction of a more systematic handling of this phase of the motor-truck business.

FARM-TO-FARM COLLECTION.

Farm-to-farm collection usually is adopted on short rural routes where comparatively few stops are ordinarily made. Where heavy trucks are used, this method of collection is not entirely feasible because of the increased cost of operation. Where light trucks are used, however, it has proven reasonably satisfactory. One advantage of this method of collection is that the business of the operator is constantly brought to the attention of shippers along his route, and tonnage is thus secured which might otherwise move by different means. As has been indicated, farm-door collection is costly in time and gasoline, and the successful operator must charge rates which reflect his increased costs. In practically all instances it is not advisable to deviate far from the main highway in collecting the load. Most operators who gather produce at the farm door refuse to go far from the regular route over which they ordinarily travel.

CROSS ROADS COLLECTION.

Collection at cross roads involves fewer stops than are made when the truck collects goods at each farmhouse and commends itself to the businesslike operator. Such an arrangement is convenient both for the patrons and for the driver. Of course, this method of collecting goods makes it necessary for shippers to bring their goods to the cross roads, but in most cases this can readily be done with the facilities at hand on the farm. This method of collection is very popular in various sections of the country and probably will remain a permanent feature of the rural motor hauling business in many communities. In general, it affords a maximum of service and convenience for a minimum of cost and comes nearer to fulfilling the ideal condition than any other method now in vogue.

CENTRAL ASSEMBLING POINTS.

Very few rural routes have their business systematized to the extent of arranging for central assembling points where shippers may bring their goods for transportation to the city. Where proper arrangements are made, this method of collecting has much to commend it to the business-like operator. Where trucks of large capacity are used, the establishment of a few central assembling points will save operating the heavy truck in out-of-the-way districts and will materially lessen the cost of service to shippers. Two general methods may be used by the operator who desires to utilize central assembling points. The first method is to have the shippers bring their own products to the nearest central assembling point. In this respect, this system differs from the cross roads pick-up system only in that the number of stops for collecting loads are fewer. The second method is to arrange to have a lighter auxiliary truck to assemble all goods in a given district for loading on the heavy truck at the central assembling point or points. On one important demonstration route fostered by the Bureau of Markets, the first method of collection, *i. e.*, with shippers bringing their own products to the central assembling point, was adopted. Later it was found more satisfactory to arrange for an auxiliary pick-up service, utilizing a lighter truck to pick up goods for assembling at central points to be loaded on the heavy truck for transportation to market. It seems altogether likely that with the enlargement of rural motor service and the consequent systematizing of business, the central assembling point for gathering the load will grow in favor and importance.

Whatever method of collection is adopted by the operator, it is advantageous to have a small loading platform at each point where goods are to be picked up. This loading platform should be the same height from the ground as the floor of the truck, so as to facilitate the loading of the goods on the truck. Such platforms are inexpensive and save much time and trouble when business is flourishing.

DELIVERY METHODS.

Methods of making delivery vary as greatly as do methods of gathering the load. These, again, are determined by the class of business handled, the type of the load, and the size and nature of individual consignments. It is impossible to generalize on the subject in a publication of this kind, because satisfactory methods must be worked out on the ground so as to permit any changes which may be caused by local conditions. In many cases, and particularly by small operators, delivery is made directly to the door of the consignee. Where the business is on a large scale and is fairly well established, the operator often assesses an extra charge for direct delivery of packages which do not return a minimum gross revenue. This extra charge for complete delivery of small shipments varies from 25 cents to $2.00 per package. One large motor truck company operating in New York

City delivers free of charge to any point below 120th Street individual consignments returning a gross revenue of $1.00 or more. Packages returning a lesser revenue are delivered free to the downtown terminal of the company only ,an extra charge being assessed for complete delivery to the consignee.

Some rural operators have established city depots for the collection and delivery of goods. Commodities picked up at various points in the country are brought to these depots in the city. The consignee then calls for the goods, or a light truck for city use effects a complete delivery. In order, however, to utilize profitably the services of an auxiliary truck for city delivery, it is necessary for the operator to have a sufficient volume of business to justify the maintenance of such a vehicle. The establishment of a central terminal would solve the city delivery problems of the small operator. The central terminal plan is discussed in detail in a subsequent portion of this bulletin.

Most operators have found it more satisfactory to make complete delivery to the consignee, assessing a minimum charge on small shipments sufficient to cover complete service. Such an arrangement is almost always more satisfactory to the patrons. Offering complete delivery also emphasizes one of the desirable features of motor truck service, namely, complete transportation service to the door of the consignee with a minimum of handling in transit.

COLLECTION OF MONEY.

Nothing has yet been said concerning the collection of moneys. With the small operator, particularly the farmer-operator, the collection of money is usually a very informal matter. Cash is collected either from the shipper or from the consignee, according to previous understanding. Sometimes even the formality of a receipt is dispensed with. Where regular patrons furnish a dependable load, arrangements are often made for rendering weekly or monthly bills to these shippers. This necessitates more complete and careful bookkeeping on the part of the operator, but is more desirable from point of view of the regular patron, who may not always have the exact change to hand to the truck driver when he calls for or delivers the goods. In any event, financial transactions should be marked by the passing of documents, whether these be receipts, receipted bills of lading, or other evidence that money has changed hands.

KEEPING COST RECORDS.

Having established a motor route, it is imperative that adequate records be kept. In an investigation covering over 60 routes, the Bureau of Markets found numerous instances where operators who thought they were making a profit as a matter of fact were gradually using up the original investment for current expenses. It is obvious that a man who has no clear idea of his costs of operation cannot

Form M. T. 1. **U. S. DEPT. OF AGRICULTURE, BUREAU OF MARKETS.**

DRIVER'S DAILY REPORT CARD.

Date..*191*

Truck No..

OUTBOUND.

Leave..*at*....................*A. M.* / *P. M.*

Arrive..*at*....................*A. M.* / *P. M.*

INBOUND.

Leave..*at*....................*A. M.* / *P. M.*

Arrive..*at*....................*A. M.* / *P. M.*

Total mileage for day..

Total load outbound..*lbs.*

Total load inbound..*lbs.*

No. of delivery or pick-up stops..

Hours with helper....................*cost*....................

Gasoline used....................*gals. @*..........*c*

Oil used....................*pints @*..........*c*

Grease used....................*lbs. @*..........*c*

Cost of repairs (if any)..

Time laid up for repairs..*hrs.*

Ferries and tolls..

Hours not running....................*Reason*....................

....

Tires Changed { *Front* { *Right*.......................... / *Left*.......................... ; *Rear* { *Right*.......................... / *Left*.......................... }

Reasons for removal..

....

Condition of roads..

Remarks..

....

Driver

institute changes in business management which may be necessary or desirable from time to time. Investigators have found records of every sort, ranging from informal notes in a pocket note-book to elaborate auditing and accounting systems. The small operator is the chief offender in this connection, because he understands little of business records and is not disposed to add to his daily burden of work; elaborate truck cost systems seem too complicated to him. The Bureau of Markets has placed some cost accounting forms with several co-operating motor truck operators, for the purpose of gathering data on costs of maintenance and operation. The forms may not have been ideal for the purpose, but a number of operators found, to their surprise, that keeping complete and accurate records was not the impossible task which it appeared at first. It is not desirable to indicate a complete system of accounts in this bulletin, but the "Driver's Daily Report Card" on page 24 should prove a satisfactory basis for any permanent cost recording system. This form has been used successfully by the Bureau of Markets in cooperating with a large number of rural truck operators. It may not prove satisfactory under all conditions, but it is offered as a suggestion to those operators who desire to secure regular reports from their drivers each day.

The information conveyed by the driver's daily report card, coupled with that in the hands of the owner of the truck, can be transferred to permanent records of a type desirable to the owner. Whatever system is adopted, this one fact must be kept in mind, that periodically it should be possible to balance all receipts against all costs, to determine profit and loss. Any system which will enable the owner to do this without too much effort can be used.

UTILIZATION OF THE FARM TRUCK.

There are an increasing number of farm trucks, particularly on farms adjacent to large cities. Not all these trucks are loaded to full capacity on their periodical trips to the city. Few farmers have their business so arranged as to permit the use of the truck to its maximum capacity regularly. Many farmers need a motor truck, in spite of the fact that they are unable to use it to capacity on a regular basis. Such farmers have gradually begun to haul a part or all of their neighbors' products to market and in some cases, this practice has led to the establishment of a regular route. Where the business has warranted, farmer-owners have increased their facilities for hauling goods, and many substantial rural routes are the outgrowth of the individual farm haul. Some farmers have been enabled to purchase trucks because of the fact that their own business, coupled with that of their neighbors', has been sufficient to warrant the purchase of a truck. It cannot be doubted that the motor truck as a community institution will be increasingly important. The farmer who is hauling for his neighbors is performing a useful function. Such practice is susceptible of expansion and the farmer-operator can usually offer attractive rates to his neighbors. Farmers needing a motor truck for part time service would do well to investigate the possibilities of business in their neighborhoods. It has been found in several instances that co-operative action has proven feasible and the subsequent formation of a farmer's association has resulted. This feature of the motor hauling business is distinctly worth serious consideration by those who may be interested.

THE RETURN OR SUPPLEMENTARY LOAD.

The success or failure of many routes has depended largely on the ability of the truck owner to operate his truck at all times with loads of sufficient capacity to return at least a moderate profit. Too many routes have been started where a good one-way business was secured and the operator felt justified in returning with empty trucks. It is unsafe to generalize, but it may be definitely stated at this point that practically no route has ever been successful which has depended for its existence on a one-way load. Where truck operators have been farsighted enough to provide for even a partial load on the return trip, the business has offered a fair promise for success. Many of the more successful rural motor routes now in existence have achieved their success because of the fact that before operations commenced, the return load was arranged for. Those who contemplate embarking in the rural hauling business, would do well to look into the possibilities of securing contracts for supplementary or return loads, even though such contracts promise to pay little more than the cost of operating the truck. Most rural operators return from the city bringing back loads of general merchandise for country stores or supplies for farmers along the way. Where the operator makes it plain in advance that he proposes to cater to the merchant or farmer who makes his purchases in the city, he finds himself supported by a more or less permanent class of business which, while possibly not showing a very high net profit, makes it possible for him to handle his other business on a closer margin and with greater net profit to himself.

In many districts there are certain periods during which there is a heavy local demand for transportation facilities. Truck owners have taken advantage of this condition in many districts and have greatly improved the financial condition of their business. Special contracts for hauling outside of schedule hours are often exceedingly profitable and sometimes make it possible for the regular route to be operated regularly.

In general, it may be said that too few operators realize the importance of utilizing their trucks to full capacity at all times, and many failures can be traced to the fact that operators have tried to secure all of their profits from a one-way business.

THE CENTRAL TERMINAL.

A noticeable feature of the operation of rural motor routes into and out of various cities, which came under the observation of investigators of the Bureau of Markets, was the lack of central receiving or distributing stations. In each city the operators maintained their own individual stations and each carried on his business independent of the business of others.

Where a number of independent routes have their terminals in a given city, the over-head expenses incident to the maintenance of individual terminal stations are multiplied many times, while the advantages of a central terminal are lost altogether. These advantages are very real. In the first place, the establishment of a central terminal for a group of motor routes is in itself an advertisement of the service

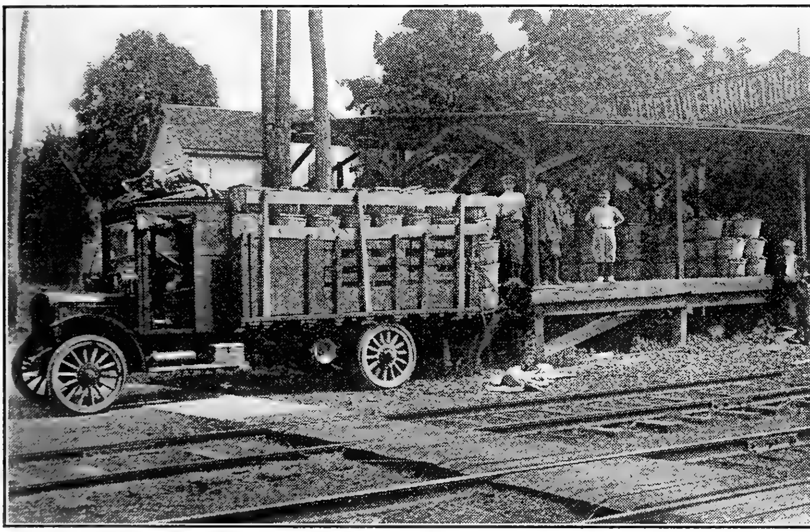

FIG. 5.—The peas in this load will go directly by motor truck to the dealer at the market 15 miles away and arrive in fresh condition. This is a concentration platform, to which perishable products are brought from all directions.

in that the attention of the shipping public is directed toward the possibilities of motor transportation. The use of the central terminal encourages and facilitates the transfer of goods originating on one route and destined to some point on another route. The problem of city delivery, which is a serious one in large cities, can be solved by the establishment of a common delivery service, supported by all operators who use the central terminal, and obviating the need for operating heavy trucks to scattered points in congested districts for the purpose of delivering relatively small consignments. Last, but not least, the use of the central terminal would effect some very material economies on such items as office rental, clerical assistance, telephone charges, heat, light, and related expenses ordinarily incurred with the maintenance of terminal facilities.

In view of these facts, the central city terminal is recommended to the consideration of groups of motor truck operators who maintain individual terminals. A central terminal company can possibly best be organized as a joint stock corporation. Expenses may be pro-rated on the basis of the volume of business transacted through the terminal by each contributor to the enterprise. It is realized that competitive influences might offer obstacles to the plan indicated, but the operation of such a terminal as the one herein described could be made independent of ordinary competitive factors.

If the motor truck as a freight or express carrier is to compete successfully with other carriers who have occupied the field for a longer time, the business must be organized on a basis which will compare favorably with the business of older and better established carriers. Central terminal facilities are just as necessary for motor routes as for other common carriers.

BUSINESS ARRANGEMENTS FOR STABILIZING THE BUSINESS OF THE RURAL MOTOR OPERATOR.

Mention has previously been made of desirable business features which should be incorporated in the practices of all rural truck operators. Among those mentioned were the determination of fair rate bases, the keeping of adequate cost and operating records, and the maintenance of dependable schedules. It is desired, in this connection, to direct attention to additional features which, if incorporated in the business of the rural motor operator, probably would do more to place the industry on a par with rail carriers than would any other changes which could be made. Reference is made to the use of a Standard Bill of Lading and the adoption of adequate insurance coverage.

THE STANDARD BILL OF LADING.

A satisfactory bill of lading should bind the operator to the obligations of a common carrier and should set forth the extent of his liability very clearly. It should be designed so as to permit the transfer of goods from one carrier to another. In addition to the features of the ordinary railroad bill of lading, it should include some of the features of the invoice and the expense bill so as to obviate the need for a large number of forms for a relatively small business. The accompanying form for a Standard Bill of Lading is offered as a suggestion to operators who desire to standardize their shipping documents. It will be noted that it is modeled, in a general way, on the ordinary "Uniform Bill of Lading," used by the railroads. Certain important changes have been made, however, to conform to the needs of the motor transportation business. The form contains certain items not ordinarily incorporated in the regular bill of lading, such as statements of value and shipping charges. While these are not a part of the ordinary bill of lading, it seems best to refer to the specimen document as a bill of lading, although it also includes the essentials of the invoice and the expense bill. It should be remembered that laws governing the business of common carriers vary in different States and in some cases it may be necessary to modify certain provisions of the suggested bill of lading to accord with existing laws.

STANDARD BILL OF LADING.

.... Company

Shippers' No. ....

Straight Bill of Lading—Original—Not Negotiable.

Agent's No. ....

RECEIVED, Subject to tariffs in effect on the date of issue of this original Bill of Lading, the property described below in apparent good order except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, which said company agrees to carry to its usual place of delivery at said destination. It is mutually agreed, as to each carrier of any or all of said property over all or any portion of said route to destination and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the conditions, whether printed or written, herein contained (including conditions on back hereof), and which are agreed to by the shipper and accepted for himself and his assigns.

Date, ... 191 .

From ....

Address of consignor at .... { Terminal of this company. / Store door of consignor } { Strike out one not used. }

Consigned to ....

Address .... City of .... State of ....

For delivery to { Terminal of this company at / Store door of consignee at / Address above given. } { Strike out delivery not desired. } ....

Route .... Truck No. ....

No. Packages.	Description of article.	Value of article.	Weight or bulk subject to correction.	Shipping charges.	War tax.	
						If charges are to be prepaid write or stamp here "To be Prepaid"
						Received $............ to apply in prepayment of the charges on the property described hereon
						.... Agent or Cashier
						If charges are to be collect, write or stamp here "Charges Collect"
						Where shipment is billed C. O. D. insert here amount to be collected on delivery (exclusive of shipping charges).
						Collect $............

The declared or released value of which is $..............

(If value declared is greater than 50 cents per pound, insurance at the tariff rate in effect to be added to charges.)

.... Shipper

.... Agent

Per ....

Per ....

(This Bill of Lading to be signed by the shipper and agent of carrier issuing same.)

(OVER)

CONDITIONS.

SECTION 1. The carrier or party in possession of any of the property herein described shall be liable for any loss thereof, or damage thereto, to the extent of the value declared in this bill of lading, except as herein after provided.

No carrier or party in possession of any of the property herein described shall be liable for any loss thereof or damage thereto or delay caused by the act of God, the public enemy, quarantine, or the authority of law, or the act or default of the shipper or the owner, or for difference in weights of grain, seeed or other commodities caused by natural shrinkage or discrepancies in public weights; and, except in cases of the negligence of this company or its agents, it shall not be liable for loss, damage or delay occurring while the property is stopped and held in transit at the request of the shipper, owner, or party entitled to make such requests, or resulting from default or vice in the property, or strikes, or the death, injury or escape of live freight.

SEC. 2. In issuing this bill of lading this company agrees to transport only over its own line, and except as otherwise provided by law, acts only as agent with respect to the portion of the route beyond its own line.

No carrier shall be liable for loss, damage or injury not occurring on its own route, or its portion of the through route, nor after said property has been delivered to the next carrier, except as such liability is or may be imposed by law, but nothing contained in this bill of lading shall be deemed to exempt the initial carrier from any such liability so imposed.

SEC. 3. No carrier is bound to transport said property by any particular truck, or in time for any particular market, or otherwise than with reasonable despatch, unless by specific agreement endorsed hereon. Every carrier shall have the right in case of physical necessity to forward property by any route or means between the point of shipment and the point of destination, but if such diversion shall be made the liability shall remain as if the entire carriage were made by the receiving carrier.

In consideration of the value herein declared being used as a basis for determining the rate to be charged, the amount of any loss or damage for which any carrier is liable shall be computed on the basis of such declared value of the property as herein stated under this bill of lading, including freight charges if paid. Except, in case the actual cash market value of the goods carried shall be less than the declared value, then settlement shall be made on the basis of actual cash market value on the date of shipment, but the shipper shall in no case be entitled, after a false declaration of value, to any refund of charges made.

Claims for loss, damage or delay must be made in writing to the originating or delivering carrier within thirty days after delivery of the property, or in case of failure to make delivery, then within thirty days after a reasonable time for the delivery has elapsed; and suits for loss, damage or delay shall be instituted only within two years and one day after delivery of the property, or in case of failure to make delivery, then within two years and one day after a reasonable time for delivery has elapsed.

SEC. 4. No carrier will carry or be liable in any way for any documents, specie or for any articles of extraordinary value unless a special agreement to do so and a stipulated value of the articles are endorsed hereon.

SEC. 5. Property not removed by the party entitled to receive it within forty-eight hours (exclusive of legal holidays) after notice of its arrival has been duly sent or given, as regards goods consigned to the terminal of the carrier, may be held at such terminal subject to a reasonable charge for storage, and the liability of this company shall be that of warehousemen only; or if such goods are herein consigned for delivery to a specified address other than the terminal of this company, the liability as common carrier shall terminate upon tender for delivery at the sidewalk or receiving platform of the consignee, and if the goods are not accepted on such tender, they shall be returned at the expense of the owner to the terminal of this company and held there subject to a reasonable charge for storage, or at the option of this company removed to and stored in a public or licensed warehouse at the cost of the owner and there held at the owner's risk and without liability of the carrier and subject to a lien for all freight and other lawful charges, including a reasonable charge for storage.

The carrier may make a reasonable charge for the detention for loading or unloading of any truck for a time in excess of thirty minutes exclusive of actual time consumed in such loading or unloading, and may add such charge to all other charges hereunder and shall hold such property subject to a lien therefor.

SEC. 6. Every party, whether principal or agent, shipping explosives or other dangerous goods without previous full written disclosure to the carrier of their nature and having the same expressly endrosed hereon, shall be liable for all loss or damage caused thereby and such goods may be warehoused at owner's risk and expense or destroyed without compensation.

SEC. 7. The owner, or consignee, shall pay the freight and all other lawful charges accruing on said property, and if required shall pay the same before delivery. If, upon inspection, it is ascertained that the articles shipped are not those described in this bill of lading, the transportation charges must be paid upon the articles actually shipped.

If any C. O. D. is not paid within thirty days after notice of non-delivery has been mailed to the shipper, the carrier may, at its option, return the property to the consignor.

SEC. 8. Any alteration, addition, or erasure in this bill of lading which shall be made without an endorsement thereof hereon, signed by the agent of the carrier issuing this bill of lading, shall be without effect, and this bill of lading shall be enforcible according to its original tenor.

INSURANCE ON LOADS CARRIED BY MOTOR TRUCKS.

The visible assets of the railroad, express company, or boat line offer assurance to shippers that the carrier is financially able to settle claims for damage to goods in transit. The operator of a motor route, particularly the small rural operator, can offer no such tangible evidence of his ability to meet obligations arising out of damages to goods intrusted to his care. Until he can offer protection to his patrons, the motor operator must labor under a handicap. The obvious solution of the problem is to obtain adequate insurance coverage. Such insurance should be for the full value of goods intrusted for shipment to the operator. The policy should cover all ordinary risks. Premiums should be paid by the operator from revenues derived from transportation charges, unless the value of the goods shipped exceeds a set maximum.

Bearing these facts in mind, the following are offered as suggestions for provisions to be incorporated in a satisfactory policy:

Provisions to be Incorporated in Policies Covering Shipments by Motor Truck.

1. For account of..as assured, or for account of whom it may concern, but warranted not to cover the interest of any alien enemies, including such persons, co-partnerships or corporations as now, or may hereafter appear in any Enemy Trading List issued by the War Trade Board of the United States of America.

2. Loss, if any, payable to the assured or order.

3. On all kinds of lawful goods and merchandise of every description held in their custody as warehousemen and forwarders, but only while contained in or on the following named and numbered automobile trucks. Whenever necessary and for such periods of time as shall be necessary, the assured shall be privileged to substitute any motor truck or motor trucks for those herein specified provided the details of the proposed substitution are reported to the assurers in advance and an additional premium paid if required.

* * * * * *

4. It is the purpose of this insurance to indemnify the assured to the amounts which they are obliged to pay on such goods or merchandise by reason of loss or damage only by (1) fire, including lightning and self ignition; (2) accidental collision of the motor truck with any other vehicle or object, moving or stationary; (3) overturning or skidding of the truck; (4) collapse of bridges; (5) perils of the seas, lakes, rivers or inland waters, only while on ferries or transfers; (6) theft of an entire shipping package or of over 5% of shipments made in bulk, but excluding all pilferage; and excluding the theft by any employee of the assured, or the shipper or his employee, or the consignee or his employees; also excluding all theft of merchandise accepted for delivery within the limits of the city, town or village in which the goods are received for shipment.

5. Valued at amounts declared by the shipper to the transportation company, but not exceeding actual invoice value or, in the absence of invoice, the cash market value at time and place of shipment. In the event of the amount declared being less than the invoice or cash market value, as above, any partial loss shall be adjusted in proportion as the value declared bears to the invoice or market value.

6. It is understood and agreed that the assured shall keep a record of all shipments covered hereunder, showing shipping points, destination and value of each shipment, which record shall be made prior to shipment. It is also expressly understood and agreed that no insurance shall be in effect for which record is not entered on such forms as shall be prescribed by the assurer. All shipments to be reported to the assurers, or their appointed agents, at the end of each..............................and premium payable monthly at the rate of.............................. per hundred dollars.

7. This policy shall not be vitiated by any unintentional error in description of route or interest, or by deviation, provided the same be communicated to the assurers as soon as known to the assured and an additional premium paid if required.

8. This policy to attach and cover on all shipments made on and after noon of..

9. If at the happening of any casualty, the assured or owner of the goods has any other insurance, identical with or similar to the terms of this policy, whether prior or subsequent thereto in date, or simultaneous with this insurance, then these assurers shall not be liable under this policy for a greater proportion of any amount of the property insured than the amount hereby insured shall bear to the whole insurance in effect, whether valid or not.

10. It is also agreed that the assured in claiming and accepting payment for any loss, damage or expense under this policy, thereby and by that act assigns and transfers to these assurers all right to claim for such loss, damage or expense against any person or persons, town or corporation or any government, and if so requested by these assurers shall prosecute therefor at the charge and for the account of these assurers, to the extent of the amount of the loss, damage or expense, and the attendant expenses of recovery paid and incurred by these assurers on account of said loss, damage or expense, or for the recovery of the same, shall be a lien upon such property hereby insured and recoverable against the assured.

11. It is mutually agreed that the acts of either party, or their agents, in securing, preserving, or recovering the property insured or any part thereof shall not be considered as prejudicial to the interest of either party as set forth in this policy. The use of general terms, or of anything less than a distinct, specified agreement clearly expressed and endorsed in this policy shall not be construed as a waiver of any printed or written conditions or restrictions herein contained.

12. This policy can be canceled at any time at the request of the assured or by the assurers by giving notice in writing at least fifteen days before such cancellation shall be effective.

It will be noted that in using the standard bill of lading, the operator does not assume greater liabilities than those imposed by law on common carriers. Adequate insurance coverage, in turn, will protect the operator who assumes such liabilities. The reporting form of policy outlined above is probably the best form for the average operator in that all goods, while in his possession, are insured for full market value and settlement is made on that basis. The reports referred to in Section 6 of the above policy provisions would be nothing more elaborate than carbon copies of all bills of lading issued by the carrier who takes out this form of insurance coverage. Should State legislation covering the business of insurance companies be in contravention of any of the suggested policy provisions, it will be necessary to modify the language of these provisions to accord with the statutes.

The use of the standard bill of lading and the adoption of the fullest form of insurance coverage are strongly recommended even to the small operator. Most operators will prefer to offer free insurance to the shipper on all goods valued below a certain maximum. It is suggested that a fair maximum for free insurance is about 50 cents per pound. When goods are valued at more than 50 cents per pound the shipper should, in addition to the regular shipping charge, be obliged to pay for the insurance coverage on the valuation in excess of 50 cents per pound. A scrutiny of the clause near the bottom of the standard bill of lading will make this point clear to the reader.

Only by the adoption of modern business methods can the future of the motor express business be assured. Many operators will hesitate to adopt the two important features, which have just been discussed, because they will fear complications in their business and the assumption of too great a burden of detailed clerical work. Business-like operators, who have given these features a thorough trial, have been surprised at the ease with which they have been able to accommodate their business to these changes. The small operator will find that the slight extra burden of work which he is assuming will be more than paid for in the increased business coming from patrons who are confident that any losses will be promptly and properly adjusted.

LIMITING FACTORS.

The chief factor limiting development in the field of rural motor hauling is the cost of operation as compared with that of railroads, electric lines, and boat lines. Cost of operation offers a problem which can only partially be solved by the operator. Careful attention to effecting economies may offset this limiting feature to some extent, but in the main the operator can not change his costs of operation to a very marked degree. This means that he must plan his business so that in competing with other carriers he is not working on an unequal basis. He must cater to a class of business which will pay a small additional premium for better service. To supplement this he must offer a speedier, more dependable or more complete service. For instance, many operators are successfully competing with other carriers whose basic expenses are lower because goods are picked up at the door of the shipper and unloaded at the door of the consignee with a minimum of handling in transit.

The second important limit to the extension of rural motor hauling is the condition of the average country highways. Road conditions bear a direct relation to operating costs. In extreme cases bad roads may prevent the use of motor trucks at all. In other and more common cases, poor roads may cause operating costs to be so high and truck operation so uncertain that the business is foredoomed to failure.

A third limitation to rural motor transportation, which has come to light under actual operating conditions, has to do with the financial responsibilities of the carriers. This feature has been thoroughly discussed in the paragraphs referring to the use of a standard bill of lading and the securing of adequate insurance coverage. The limitation is one which need cause no fear to the business-like operator who is willing to make the necessary changes in his business so that he may be on a par with other carriers.

The limitations herein mentioned must be carefully considered because they are real factors in actual practice. All can be met and solved by the business-like operator. It is to be expected that they will be solved as a better knowledge of the rural motor business is obtained and the possibilities of this form of transportation become more apparent both to the operator and to the prospective shipper.

CONCLUSIONS.

The foregoing discussion, although general in character, has been an attempt to bring forth one thought, viz; that under proper conditions, and where a fair knowledge of the limitations and difficulties obtains, motor truck transportation promises to play an important role in rural districts.

Mechanically, the experimental stage for the motor truck has passed. Its worth and its efficiency have been demonstrated very thoroughly under the most trying circumstances.

As operating equipment in a regularly established transportation business, where the financial difficulties faced by the ordinary common carrier are in evidence, the motor truck may still be considered as in the experimental stage. The problem of lifting it from this experimental stage is one that depends for its solution on careful planning and good business judgment rather than on greater mechanical perfection of the truck itself.

If the prospective operator can force himself to consider his motor equipment as merely a means toward an end, and will devote himself to a consideration of his business problems, his chances for success will be increased manifold. The motor truck as a common carrier has come to stay, but the measure of success for the individual will depend, as in other lines of business, on initiative and a proper sense of business proportions.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 771

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 21, 1919

A STUDY OF THE EFFECT OF STORAGE, HEAT, AND MOISTURE ON PYRETHRUM

By W. S. Abbott, *Scientific Assistant*

CONTENTS

INTRODUCTION

It has been generally accepted by entomologists that pyrethrum powder deteriorates rapidly under ordinary conditions of storage, but few or no data have been advanced to support this theory or to show under what conditions or how rapidly such deterioration takes place. The following experiments, made at the testing laboratory of the Insecticide and Fungicide Board of the United States Department of Agriculture, Vienna, Va., were conducted to ascertain the effect of exposure to heat, moisture, and the weather, and of storage in sealed glass containers, on whole and ground flower heads of *Pyrethrum cinerariaefolium* (Trev.).

METHODS OF TESTING

Two methods of testing the pyrethrum powder were used: (1) By dusting and (2) by dipping.

In the dusting tests small potted nasturtium plants, grossly infested with aphids (*Aphis rumicis* Linnaeus), were thoroughly dusted by means of a small hand dust gun.

In the dipping tests large specimens of the German roach or Croton bug (*Blattella germanica* Linnaeus) were dropped into a beaker containing a small amount of the pyrethrum powder to be tested, and the beaker was given a shake so that the insects were thoroughly covered with the powder. Each roach was then placed in a separate 8-ounce bottle and observed at frequent intervals, the time when the insect became inactive, i. e., unable to walk, and the time of death

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being recorded. With each set of experiments checks, consisting of 10 roaches dipped in fresh pyrethrum powder and 10 untreated, were used. The average mortality for the untreated roaches was found to be less than one roach in 108 hours, which is so small that the untreated series were omitted from the following tables.

EFFECT OF EXPOSURE TO WEATHER AND IN A ROOM

Table I shows the killing effect on roaches of whole and ground flower heads that had been exposed to the weather or in a room for various periods of time.

TABLE I.—*Effectiveness against roaches of whole and ground pyrethrum flower heads exposed to the weather or in a room. Ten roaches dipped for each test*

No.	Material.	Exposed—	Number of weeks.	Hours required to kill.		
				First roach.	Last roach.	Average.
1	Whole flower heads	To weather	2	19.3	43.3	31.2
2	....do	....do	12	19.6	92.1	34.6
3	....do	....do	21	23.2	3 active at end of 120 hours.	
4	Ground flower heads	....do	2	19.5	64.5	35
5	....do	....do	12	19.6	47.6	29.8
6	....do	....do	21	23.4	4 active at end of 120 hours.	
7	Whole flower heads	In room	2	24.	64.8	43.1
8	....do	....do	12	19.8	92.3	39
9	....do	....do	21	[1] 4.5	71.9	31
10	....do	....do	34	22.4	67	40.7
11	....do	....do	150	18	44.5	22
12	Ground flower heads	....do	2	19.5	64.5	39.5
13	....do	....do	12	19.7	43.9	26
14	....do	....do	21	[1] 6.1	27.5	22
15	....do	....do	34	22.1	46.5	36.4
16	....do	....do	136	26.1	1 active at end of 120 hours.	
17	....do	....do	150	42.1	8 active at end of 120 hours.	
18	Whole flower heads	In sealed jars	150	17.5	41.5	25.2
19	Ground flower heads	....do	2	19.3	43.3	36.2
20	....do	....do	12	19.9	44	27.4
21	....do	....do	21	23.5	47.5	30.7
22	....do	....do	34	18.3	46.9	35.2
23	....do	....do	136	22.3	46.3	28
24	....do	....do	150	17.9	44.1	21.9

[1] Probably injured in dipping.

The material used in these experiments was received as whole flower heads in April, 1915, when it was divided into six lots which were treated as follows:

No. 1. Whole flower heads, in a large open glass cylinder, were placed out of doors where they were fully exposed to the sun, wind, and rain.

No. 2. Powdered flower heads, sifted to 80 mesh, were exposed as in lot No. 1.

No. 3. Whole flower heads were placed in a shallow dish and allowed to stand on a shelf in the laboratory.

No. 4. Powdered flower heads (80 mesh) were exposed as in lot No. 3.

No. 5. Whole flower heads were kept in a tightly sealed fruit jar in the laboratory.

No. 6. Powdered flower heads (80 mesh) were kept as in lot No. 5.

At the times indicated in the table portions of these six lots were ground, sifted to 80 mesh, and tested against roaches by dipping the insects as described on page 1.

This table shows that an exposure to the weather for 12 weeks does not noticeably injure ground or whole flower heads, but that an exposure of 21 weeks materially reduces the efficiency of both, since at the end of this time they killed, in 120 hours, only 60 and 70 per cent, respectively.

When whole flower heads were exposed in an open dish in the laboratory for 150 weeks, they retained their full efficiency. Under the same conditions the powdered flower heads showed some deterioration in 136 weeks, and were of almost no value at the end of 150 weeks. Both flower heads and powder showed no loss of efficiency when kept in tightly closed jars for 150 weeks.

EFFECT OF STORAGE IN SEALED GLASS CONTAINERS

Tables II and III give a comparison of the effectiveness against aphids and roaches of whole and ground pyrethrum flower heads stored in glass containers for 5½ years.

The materials considered in these tables were received as whole flower heads in 1911. A portion of each sample was ground early in 1912 and stored in a tightly stoppered bottle. The remaining flower heads were stored in sealed fruit jars under the same conditions until March, 1918, when a portion of each lot was ground and tested in comparison with the powders prepared in 1912.

TABLE II.—*A comparison of the effectiveness against aphids of whole and ground pyrethrum flower heads stored in glass containers for 5½ years. One nasturtium plant, grossly infested with aphids, dusted in each test*

No.	Material.	Number of tests.	Ground in spring of 1912; tested March, 1918.	Number of tests.	Ground and tested, March, 1918.
1	California flowers	4	Ineffective	4	80–90 per cent killed or repelled.
2	Montenegrin flowers	4	....do	4	80–95 per cent killed or repelled.
3	Dalmatian flowers	4	....do	2	90 per cent killed or repelled.

TABLE III.—*A comparison of the effectiveness against roaches of ground and whole pyrethrum flower heads stored in glass containers for 5½ years. Ten roaches dipped for each test*

No.	Material.	Ground in spring of 1912, tested March, 1918—Hours required to kill roaches.	Ground and tested in March 1918—Hours required to kill—		
			First roach.	Last roach.	Average.
1	California flowers	7 killed in 120 hours	18.5	44	32
2	Montenegrin flowers	5 killed in 120 hours	18.9	72.8	36.7
3	Dalmatian flowers	6 killed in 120 hours	19.5	72	40.3

As will be noted in Table II, the powders ground in 1912 were ineffective in 1918, when tested against nasturtium aphids. Whole flower heads from the same stock, which had been kept in sealed fruit jars for 5½ years and were ground in 1918, killed from 80 to 90 per cent of the treated aphids. Fresh pyrethrum tested at the same time killed 90 per cent.

Table III gives the results of dipping tests against roaches with the same materials as used in Table II. In every case the powders ground in 1918 were found to be effective, all of the roaches being killed in from 32 to 40.3 hours, while in no case did the powders ground in 1912 kill all of the dipped roaches in 120 hours. Fresh pyrethrum, used at the same time, required on the average 31.3 hours to kill 10 roaches. These tests show that pyrethrum powder kept in tightly stoppered bottles for 5½ years loses practically all of its effectiveness, but that the unground flower heads stored under the same conditions for the same length of time are practically unhurt.

Table IV shows the effect, on powdered flower heads, of 5½ years' storage in tightly stoppered bottles or sealed glass fruit jars.

TABLE IV.—*A comparison of the effectiveness against nasturtium aphids of freshly ground Dalmatian closed flower heads and of the same powder after it had been stored in tight glass containers for 5½ years. One nasturtium plant, grossly infested with aphids, dusted for each test*

No.	Material.	Crop of—	Dalmatian closed flower heads ground in spring of 1912.					
			Tested November, 1912.			Tested March, 1918.		
			Number of tests.	Length of tests.	Results.	Number of tests.	Length of tests.	Results.
				Days.			*Days.*	
1	Wild flowers........	1908	1	1	98 per cent killed..	4	7	Ineffective.
2	.....do.............	1909	2	2	95-100 per cent killed.	2	7	Do.
3	.....do.............	1910	2	4	99 per cent killed..	2	7	Do.
4	Cultivated flowers...	1908	2	2	100 per cent killed.	4	7	Slightly effective.
5	.....do.............	1909	2	2	.....do...........	2	7	Ineffective.
6	.....do.............	1910	[1] 2	1	.....do...........	2	7	Do.

[1] The cabbage aphis (*Aphis brassicae* Linnaeus) was used in these tests.

The materials used in these tests were received in 1911 as whole flower heads, which were ground and sifted in the spring of 1912, and stored in sealed fruit jars or tightly stoppered bottles. These powders were tested against nasturtium aphids in November, 1912, and again in March, 1918.

As will be noted, all of these powders were found to be effective in November, 1912, and of almost no value in March, 1918. It is therefore evident that pyrethrum powder stored in sealed glass containers for 5½ years will lose practically all of its efficiency.

In connection with the deterioration of unground flower heads, it is of interest to note that, in the 1912 tests, practically no difference in effectiveness was found between the 1908, 1909, and 1910 crops, which indicates that the flower heads are not noticeably injured in four years under the commercial conditions of storage.

EFFECT OF SOAKING IN HOT OR COLD WATER

Table V shows the effectiveness against roaches of pyrethrum powder which had been soaked for 24 hours in hot or cold water.

TABLE V.—*Effectiveness against roaches of pyrethrum powder soaked for 24 hours in hot or cold water. Ten roaches dipped in each test*

No.	Treatment.	Hours required to kill.		
		First roach.	Last roach.	Average.
1	Check, untreated	21.7	35.9	25.9
2	Soaked in cold water	21.9	48.2	38.9
3	Soaked in hot water	[1] 2.5	1 living at end of 94 hours.	

[1] Probably injured in dipping.

The material used in test No. 1 was prepared by soaking 20 grams of pyrethrum powder (80 mesh) in 100 c. c. of cold water for 24 hours. The water was then filtered off and the powder dried at room temperature and resifted to 80 mesh.

The material used in test No. 2 was prepared in the same way, boiling water being used.

This table shows that pyrethrum soaked for 24 hours in cold water killed all of the dipped roaches in 48.2 hours, but required on the average 13 hours longer to kill than did the untreated powder. The pyrethrum treated with hot water killed only 9 roaches in 94 hours. It is therefore evident that cold water removes some of the active ingredients from pyrethrum powder, but not as much as is removed by hot water.

EFFECT OF EXPOSURE TO DRY HEAT

Table VI shows the effect on ground flower heads of exposure to dry heat for 18 hours.

TABLE VI.—*Effectiveness against roaches of pyrethrum powder exposed to dry heat for 18 hours. Ten roaches dipped in each test*

No.	Temperature.	Hours required to kill.		
		First roach.	Last roach.	Average.
1	Check, unheated	20.5	39.6	31.0
2	120° C.	19.6	43.6	30.9
3	120° C.	21.1	47.4	27.8
4	130° C.	1 dead in 48 hours.		
5	140° C.	None dead in 48 hours.		

The materials used in these tests were placed in open tubes and heated for 18 hours at the temperature given. The results show that an exposure to a temperature of 120° C. (248° F.) for 18 hours does not noticeably injure pyrethrum powder, but that a temperature of 130° C. (266° F.) or 140° C. (284° F.), for the same length of time, either destroys or drives off the active principle.

SUMMARY

1. Whole and ground flower heads kept in sealed fruit jars for 150 weeks were not injured.

2. Ground flower heads kept in tightly closed glass containers for 5½ years lost practically all of their effectiveness.

3. Whole flower heads kept in tightly closed glass containers for 5½ years were practically unhurt.

4. Whole flower heads exposed in an open dish in a room for 150 weeks were not injured.

5. Ground flower heads were not injured by an exposure for 34 weeks in an open dish in a room. Their value was materially reduced by an exposure of 136 weeks and they were practically worthless at the end of 150 weeks.

6. Whole and ground flower heads were uninjured by an exposure to the weather of 12 weeks, but an exposure of 21 weeks greatly reduced their efficiency.

7. Powdered flower heads heated at 120° C. for 18 hours were practically uninjured, but a temperature of 130° or 140° C. for the same length of time destroyed practically all of their effectiveness.

8. Ground flower heads were slightly injured by soaking for 24 hours in cold water, and materially injured by soaking for the same length of time in hot water.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTICIDES.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Arsenate of Lead as an Insecticide Against Hornworms in Dark Tobacco Districts. (Farmers' Bulletin 595.)

Hydrocyanic-Acid Gas Against Household Insects. (Farmers' Bulletin 699.)

Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)

Tobacco Hornworm Insecticide. (Farmers' Bulletin 867.)

Fumigation of Ornamental Greenhouse Plants with Hydrocyanic-Acid Gas. (Farmers' Bulletin 856.)

Information for Fruit Growers About Insecticides, Spraying, Apparatus, and Important Insect Pests. (Farmers' Bulletin 908.)

Spraying for the Control of Insects and Mites Attacking Citrus Trees in Florida. (Farmers' Bulletin 933.)

Commercial Bordeaux Mixtures: How to Calculate Their Value. (Farmers' Bulletin 994.)

Cactus Solution as an Adhesive in Arsenical Sprays for Insects. (Department Bulletin 160.)

Quassiin as a Contact Insecticide. (Department Bulletin 165.)

A Method of Fumigating Seed. (Department Bulletin 186.)

Chemical Composition of Lime-Sulphur Animal Dips. (Department Bulletin 451.)

Fumigation of Ornamental Greenhouse Plants with Hydrocyanic-Acid Gas. (Department Bulletin 513.)

A Study of the Effect of Storage Heat and Moisture on Pyrethrum. (Department Bulletin 771.)

Spraying for White Flies in Florida. (Bureau of Entomology Circular 173.)

PUBLICATIONS FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Important Insecticides, Directions for Preparation and Use. (Farmers' Bulletin 127.) Price 5 cents.

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Homemade Lime-Sulphur Concentrate. (Department Bulletin 197.) Price 5 cents.

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Use of Hydrocyanic-Acid Gas for Fumigating Greenhouses and Cold Frames. (Bureau of Entomology Circular 37.) Price 5 cents.

Flour Paste as Control for Red Spiders as Spreader for Contact Insecticides. (Bureau of Entomology Circular 166.) Price 5 cents.

Insecticide Studies, Pyrethrum Powders Containing Poisonous Metals: Compilation of Analyses of Insecticides and Fungicides: State Laws Governing Composition and Sale of Insecticides. (Bureau of Chemistry Bulletin 76.) Price 5 cents.

Lime-Sulphur-Salt Wash and Its Substitutes. (Bureau of Chemistry Bulletin 101.) Price 5 cents.

Lead Arsenate: 1, Composition of Lead Arsenate Found on Market; 2, Homemade Lead and Chemicals Entering Into Its Manufacture; 3, Action of Lead Arsenate on Foliage. (Bureau of Chemistry Bulletin 131.) Price 15 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 772

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. | PROFESSIONAL PAPER | March 20, 1920

THE GENERA OF GRASSES OF THE UNITED STATES, WITH SPECIAL REFERENCE TO THE ECONOMIC SPECIES.

By A. S. Hitchcock, *Systematic Agrostologist.*

CONTENTS.

SCOPE AND PLAN OF THE WORK.

The present bulletin describes all the genera of grasses that include species that are native, have been introduced, or are cultivated in the United States. Under each genus are given the species that are of economic importance, either as useful or harmful grasses. Of all grasses the grains are of the greatest importance. Chief among other useful grasses are those that are cultivated for meadow or pasture and those indigenous species which furnish forage upon the native pasture or ranges. Other important grasses are the sugar-producing species, those used in broom or paper making, and the ornamental species.

It is intended to give under each genus the botanical information concerning all our grasses that are conspicuous enough to have attracted the attention of agriculturists. The keys to the tribes and genera should enable the user to identify the genera of all our grasses, and the text under each genus should enable him to determine the species of our economic grasses. Under each genus are given the type[1] and the synonyms based upon American species, or the names that have been used in an American publication.

The following generic names, of which the types have not been found, are based on American material but are unidentifiable from the descriptions:

Anthipsimus Raf., Journ. de Phys. **89**: 105, 1819.[2] Based on *A. gonopodus* Raf., "Dry hills of the Ohio."

Dactylogramma Link, Hort. Berol. **2**: 248. 1833. Based on *D. cinnoides* Link, described from garden specimens grown from seed from western North America.

Flexularia Raf., Journ. de Phys. **89**: 105. 1819. Based on *F. compressa* Raf., "Kentucky and Ohio."

The tribes have been arranged in a new sequence based on the complexity of the flower structure, the most primitive being placed first and the most highly developed last. It is impossible to arrange them in a lineal sequence and at the same time represent their relationships, as the phylogenetic development has not been along a single line. The present arrangement is the closest approximation to natural relationships that can be shown in sequence. The highest development in any given tribe may be far more complex than the most primitive example of the tribe placed above it, but the relative development of each tribe is believed to be fairly represented by its position in the sequence. The bamboos are placed lowest, as certain genera, such as Arundinaria, show the least differentiation in the floral structure. The Andropogoneae and Tripsaceae are highly specialized, as is shown by the great diversity and complexity of the floral structures. The tribe Oryzeae of most authors includes two groups of diverse genera, each worthy of tribal rank. The allies of rice (Oryza) are here

[1] The type species of a genus is the species or one of the species the author had chiefly in mind when describing the genus. Most authors of to-day designate the type species, but earlier authors usually did not. To make the application of generic names more certain, old genera are now put on a type basis; that is, one of the original species is chosen as the type. If, then, a genus as originally established included species belonging in two or more genera the name of the genus goes with the type species and the species related to it. It will be seen that the type species of a genus as here given often bears a different generic name. (See Miegia, based on *Arundinaria macrosperma*, p. 22, and Panicularia, based on *Poa aquatica*, p. 34.) This means that the genus was based on a species previously described under a different genus. In this work the type species is given for all generic names, whether valid or synonyms. The reasons for selecting a certain species as the type are given in each case. Among several species, the one most familiar to the author of the genus may be selected as the type. Species described by Linnæus in his flora of Sweden (Flora Suecica) and in his flora of Lapland (Flora Lapponica) were familiar to him and are often the types of his genera. (For a further discussion of types, see Hitchcock, Generic Types with Special Reference to the Grasses of the United States, Amer. Journ. Bot. **5**: 248–253, May, 1918; and Report of the Committee on Generic Types of the Botanical Society of America, Science, n. ser. **49**: 333–336, Apr. 4, 1919.)

[2] The form for literature citations throughout this bulletin is in the main that used in publications of the United States National Herbarium.

retained in the tribe Oryzeae, while the allies of Indian rice (Zizania) have been segregated as the tribe Zizanieae. Several genera referred to Oryzeae in current works on the classification of the grasses but not represented in the United States are evidently not closely allied to either tribe. Their disposition is deferred, pending further study.

The tribe Nazieae (Zoysieae) also is composed of diverse genera. Hilaria and Aegopogon should be segregated from Nazia, Anthephora, and their allies. They are more closely related to certain of the Chlorideae, such as Bouteloua and Cathestecum. For the present they are appended to the Nazieae, as their final disposition must await a careful comparison with several genera outside our geographical limits.

One species of each genus is illustrated. A few of the larger genera are represented by more than one illustration, especially if the habit of the species shows considerable diversity. The chief figure of each illustration shows the habit of the plant, and the accessory figures show the structure of the spikelets and florets. The habit drawings are usually half natural size; the details of the spikelet are enlarged from 2 to 20 times. The parts of the spikelet shown are selected to indicate generic differences and are not uniformly of comparable parts, though there is always a figure of a spikelet and generally of a floret. The habit drawings are by Mary Wright Gill, and the details of the spikelet are by Agnes Chase.

There are in the United States about 1,500 species of grasses. Of these about 60 are cultivated. Approximately 140 native species are important forage grasses and are constituents of our stock ranges or of wild prairie hay. Many others are occasionally eaten by stock but are not sufficiently abundant to be included among our economic grasses. About 60 species are weeds introduced from foreign countries, chiefly from Europe.

In this bulletin the word grass is used in its botanical sense, that is, as applying only to plants of the natural family Poaceae (or Gramineae). Many plants other than grasses are used for forage, among such the clovers, alfalfa, vetches, peas, beans, and other leguminous species being the most important. Sedges and rushes resemble grasses but belong to distinct plant families. The rushes (Juncaceae) are distinguished by having small green flowers with a 6-parted perianth. The sedges (Cyperaceae) are distinguished from grasses by having 3-ranked leaves. The stems are often 3-sided. The leaves of grasses are 2-ranked and the stems are never 3-sided. The flowers of sedges are small and greenish, like those of grasses, but there is no bract (palea) between the flower and the rachilla. Sedges and rushes usually inhabit wet places or marshes, though some of them (such as the nut-grass, *Cyperus rotundus*) are weeds in cultivated soil. They are usually of little importance as forage plants. The sedges and rushes are not included in this bulletin.

The cultivated grasses may be classified according to their use as grains, forage grasses, sugar-producing grasses, textile grasses, soil binders, lawn grasses, and ornamental grasses.

Grains are those grasses whose fruit or grain is used for food or for stock feed. The common grains are wheat, corn, oats, rye, barley, rice, sorghum, and millet.

The forage grasses are those used for meadows, pastures, soiling, and silage.

Meadow grasses are those cut for hay. The chief meadow grasses of the United States are (1) in the cool humid region, timothy, redtop, orchard grass, and meadow fescue; (2) in the warm humid region, Bermuda grass, Johnson grass, and (in Florida) Natal grass; (3) in the dry area east of the Great Plains, millet and sorghum (including its varieties, such as kafir and Sudan grass); (4) in the northern part of the Great Plains, brome-grass; (5) on the Pacific coast, wheat, oats, and barley for the production of grain hay.

Wild hay is chiefly from three sources: (1) Prairie hay from the region lying just east of the Great Plains, including various native species such as big bluestem (*Andropogon furcatus*), little bluestem (*A. scoparius*), Indian grass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*); (2) fresh marsh hay from the region between the Dakotas and Michigan, including chiefly bluejoint (*Calamagrostis canadensis*), reed canary grass (*Phalaris arundinacea*), and slough-grass (*Beckmannia erucaeformis*); and (3) salt marsh hay used mostly for bedding and for packing, including usually salt-marsh grass (*Spartina patens*) and black-grass (a kind of rush, *Juncus gerardi*).

Pasture grasses are those that furnish forage to grazing animals. The two most important cultivated pasture grasses of the United States are bluegrass in the Northern States and Bermuda grass in the South. The meadow grasses are also used for pasture, and in the Gulf States carpet grass is of some importance.

The wild grasses used for grazing are commonly called range grasses. The most important are (1) on the Great Plains, buffalo grass, curly mesquite, and grama (*Bouteloua gracilis* and *B. hirsuta*); (2) in the Southwest, several species of grama (Bouteloua), Hilaria, and *Sporobolus airoides;* (3) in the mountain regions, pine-grass, blue bunch-grass, and mountain bunch-grass (in Oregon); Arizona fescue (in northern Arizona); and the wheat-grasses (in the Rocky Mountains).

Soiling grasses, those cut and fed green, include the common small grains, corn, and the sorghums, and (locally in the South) pearl millet and teosinte.

Any forage grass may be preserved in a silo, but corn is the one most commonly used for this purpose.

The most important lawn grasses are (1) in the North, bluegrass, Rhode Island bent, and creeping bent; (2) in the South, Bermuda grass, carpet grass, and St. Augustine grass.

The ornamental grasses include the reeds, such as pampas grass and eulalia; border grasses, such as fountain grass and blue fescue; and variegated grasses, such as ribbon grass.

Soil-binding grasses are species having vigorous rhizomes which hold sand or other loose soil and prevent erosion by water or wind. Banks are secured against water erosion by a covering of redtop or Bermuda grass. The most important sand binder in use in this country is beach-grass (*Ammophila arenaria*). This is planted upon sand dunes to prevent wind erosion.

The two sugar-producing grasses are sugar cane and the saccharine varieties of sorghum. No textile grasses are cultivated in the United States. The esparto grasses (*Spartina tenacissima* and *Lygeum spartum*) of Spain and Algeria furnish fiber for the manufacture of paper and cordage.

All these grasses are mentioned in the text under the proper genus. (See index.)

POACEAE, THE GRASS FAMILY.

Flowers perfect (rarely unisexual), small, with no distinct perianth, arranged in spikelets consisting of a shortened axis (*rachilla*) and 2 to many 2-ranked bracts, the lowest two being empty (the *glumes*, rarely one or both of these obsolete), the one or more succeeding ones (*lemmas*) bearing in their axils a single flower, and, between the flower and the rachilla, a second 2-nerved bract (the *palea*), the lemma, palea, and flower together constituting the floret; stamens 1 to 6, usually 3, with very delicate filaments and 2-celled anthers; pistil 1, with a 1-celled 1-ovuled ovary, 2 (rarely 1 or 3) styles, and usually plumose stigmas; fruit a caryopsis with starchy endosperm and a small embryo at the base on the side opposite the hilum.

Herbs, or rarely woody plants, with usually hollow stems (*culms*) closed at the nodes, and 2-ranked parallel-veined leaves, these consisting of 2 parts, the *sheath*, enveloping the culm, its margins overlapping or sometimes grown together, and the *blade*, usually flat; between the two on the inside, a membranaceous hyaline or hairy appendage (the *ligule*).

The spikelets are almost always aggregated in spikes or panicles at the ends of the main culms or branches. The perianth is usually represented by 2 (rarely 3) small hyaline scales (the *lodicules*) at the base of the flower inside the lemma and palea. The grain or caryopsis (the single seed and the adherent pericarp) may be free, as in wheat, or permanently inclosed in the lemma and palea, as in the oat. Rarely the seed is free from the pericarp, as in species of Sporobolus and Eleusine. The culms of bamboos are woody, as are also those of a few genera, such as Olyra and Lasiacis, belonging to other tribes. The culms are solid in our species of the tribes Tripsaceae and Andropogoneae. The margins of the sheaths are grown together in species of Bromus, Danthonia, Festuca, Melica, Panicularia, and other genera.

The parts of the spikelet may be modified in various ways. The first glume, and more rarely also the second, may be wanting. The lemmas may contain no flower, or even no palea, or may be reduced or rudimentary. Rarely, as in species of Agrostis and Andropogon, the palea is obsolete.

Most of the genera of grasses fall naturally into one of the two series or subfamilies. The remaining few are rather arbitrarily assigned to one or the other series. In the same manner, most of the genera may be assembled into distinct and well-marked tribes, but several are not closely allied to the other genera in the tribe to which they are assigned but are so placed for convenience in classification.

DESCRIPTIONS OF THE SUBFAMILIES AND KEYS TO THE TRIBES.

SUBFAMILY 1, POATAE.

Spikelets 1 to many flowered, the reduced florets, if any, above the perfect florets (except in Phalarideae; sterile lemmas below as well as above in Campulosus, Uniola, and Blepharidachne); articulation usually above the glumes; spikelets usually more or less laterally compressed.

Key to the tribes of Poatae.

Plants woody, the culms perennial; spikelets several-flowered. 1. **Bamboseae** (p. 22).

Plants herbaceous, the culms annual.

- Spikelets with 2 staminate, neuter, or rudimentary lemmas unlike and below the fertile lemma; no sterile or rudimentary florets above ---------- 8. **Phalarideae** (p. 199).
- Spikelets without sterile lemmas below the perfect floret (or these rarely present and like the fertile ones, a dissimilar pair below and a rudimentary floret above in Blepharidachne).
  - Spikelets unisexual, articulate below the glumes, 1-flowered, terete or nearly so ---------- 10. **Zizanieae** (p. 206).
  - Spikelets perfect (rarely unisexual but then not as above), usually articulate above the glumes.
    - Spikelets articulate below the glumes, 1-flowered, very flat, the lemma and palea about equal, both keeled; glumes small or wanting ---------- 9. **Oryzeae** (p. 204).

Spikelets articulate above the glumes (rarely below, but the glumes, at least one, well developed).
Spikelets 1-flowered in groups (short spikes) of 2 to 5 (single in Osterdamia), the groups racemose along a main axis, falling entire; lemma and palea thinner than the glumes _______________ 6. **Nazieae** (p. 165).
Spikelets not as above.
Spikelets sessile on a usually continuous rachis (short-pedicellate in Leptochloa; the rachis disarticulating in Monerma, Pholiurus, Hordeum, Sitanion, and a few species of allied genera).
Spikelets on opposite sides of the rachis; spike terminal, single _____________ 3. **Hordeae** (p. 87).
Spikelets on one side of the rachis; spikes usually more than 1, digitate or racemose.
7. **Chlorideae** (p. 171).
Spikelets pedicellate in open or contracted, sometimes spikelike, panicles (sessile and distant in *Eragrostis sessilispica*).
Spikelets 1-flowered ______ 5. **Agrostideae** (p. 121).
Spikelets 2 to many flowered.
Glumes as long as the lowest floret, usually as long as the spikelet; lemmas awned from the back (spikelets awnless in Koeleria and Sphenopholis).
4. **Aveneae** (p. 106).
Glumes shorter than the first floret (except in Dissanthelium with long rachilla joints); lemmas awnless or awned from the tip or from a bifid apex.
2. **Festuceae** (p. 24).

SUBFAMILY 2, PANICATAE.

Spikelets with one perfect terminal floret (disregarding those of the few monœcious genera and the staminate and neuter spikelets) and a sterile or staminate floret below, usually represented by a sterile lemma only, one glume sometimes (rarely both glumes) wanting; articulation below the spikelets, either in the pedicel, in the rachis, or at the base of a cluster of spikelets, the spikelets falling entire, singly, in groups, or together with joints of the rachis; spikelets, or at least the fruits, more or less dorsally compressed.

Key to the tribes of Panicatae.

Glumes membranaceous, the sterile lemma like the glumes in texture.
Fertile lemma and palea thinner than the glumes; sterile lemma awned from the notched summit _________ 11. **Melinideae** (p. 212).
Fertile lemma and palea indurate or at least firmer than the glumes.
12. **Paniceae** (p. 213).
Glumes indurate; fertile lemma and palea hyaline or membranaceous, the sterile lemma (when present) like the fertile one in texture.
Spikelets unisexual, the pistillate below, the staminate above, on the same inflorescence or in separate inflorescences.
14. **Tripsaceae** (p. 280).

Spikelets in pairs, one sessile and perfect, the other pedicellate and usually staminate or neuter (the pedicellate one sometimes obsolete, rarely both pedicellate); lemmas hyaline.
13. **Andropogoneae** (p. 252).

DESCRIPTIONS OF THE TRIBES AND KEYS TO THE GENERA.

Tribe 1, Bamboseae.

The tribe which includes the bamboos is for the most part confined to the Tropics and Subtropics. One genus extends into the southern United States. The bamboos have woody jointed, usually hollow culms either erect or vinelike. Some of the larger kinds are as much as a foot in diameter and 100 feet in height. The common economic species of the Tropics, such as *Bambos vulgaris* Schrad. (*Bambos bambos* (L.) Wight), because of the large hollow culms with hard partitions at the nodes found in most large species, can be used for a great variety of purposes. Many kinds of bamboos are cultivated for ornament in the warmer parts of the United States, especially in Florida and California. *Arundinaria japonica* Sieb. and Zucc. with several-flowered spikelets, and a few species of Phyllostachys, are hardy as far north as Washington. They form dense masses of shoots, usually 8 to 20 feet high. Phyllostachys does not usually flower in this country, but the plants can be distinguished by the internodes which are flattened on one side. Bambusa is a modified spelling of the original Bambos.

Tribe 2, Festuceae.

Spikelets more than 1-flowered, usually several-flowered, in open, narrow, or sometimes spikelike panicles; lemmas awnless or awned from the tip, rarely from between the teeth of a bifid apex; rachilla usually disarticulating above the glumes and between the florets.

A large and important tribe, mainly inhabitants of the cooler regions. The lemma is divided into several awns in Pappophorum and its allies, is deeply 2-lobed in Triplasis and in a few species of Triodia, 3-lobed in Blepharidachne, several-toothed in Orcuttia, and slightly 2-toothed in Bromus and a few other genera, the awn, when single, arising from between the teeth. The paleas are persistent upon the continuous rachilla in most species of Eragrostis. Scleropogon, Monanthochloë, Distichlis, and a few species of Poa and Eragrostis are diœcious. Gynerium, Cortaderia, Arundo, and Phragmites are tall reeds. In Blepharidachne there is a pair of sterile florets at the base of the single fertile floret, and a rudiment above. In some species of Melica there is, above the fertile florets, a club-shaped rudiment consisting of one or more sterile lemmas. In Uniola there are one to four sterile lemmas below the fertile ones. In *Melica imperfecta* and *M. torreyana* there may be but one perfect floret.

Key to the genera of Festuceae.

1a. Plants diœcious, the sexes very dissimilar, the pistillate lemmas with 3 long twisted divergent awns, the staminate lemma awnless or mucronate .... 30. SCLEROPOGON.

1b. Plants with perfect flowers, or, if diœcious, the sexes not dissimilar in appearance 2

2a. Lemmas divided at the summit into 5 to several awns or awnlike lobes 3

3a. Awnlike lobes 5; inflorescence a simple erect raceme .. 29. ORCUTTIA.

3b. Awns 9 or more 4

4a. Awns unmixed with awned teeth; all the florets falling attached, their awns forming a pappuslike crown, only the lowest floret fertile; panicles narrow .. 32. PAPPOPHORUM.

4b. Awns mixed with awned teeth; florets not falling attached, the rachilla disarticulating between them; panicles somewhat open .... 31. COTTEA.

2b. Lemmas awnless, with a single awn, or, if 3, the lateral awns minute 5

5a. Tall stout reeds with large plumelike panicles; lemmas or rachilla with long silky hairs as long as the lemmas 6

6a. Lemmas hairy; rachilla naked .... 19. ARUNDO.

6b. Lemmas naked; rachilla hairy .... 20. PHRAGMITES.

5b. Low or rather tall grasses, rarely over 5 feet tall 7

7a. Plants diœcious, perennial; lemmas glabrous; grasses of salt or alkaline soils 8

8a. Plants low and creeping; spikelets obscure, scarcely differentiated from the short crowded rigid leaves .... 16. MONANTHOCHLOË.

8b. Plants erect from creeping rhizomes; spikelets in a narrow simple exserted panicle .... 17. DISTICHLIS.

7b. Plants not diœcious (except in a few species of Poa with villous lemmas and in an annual species of Eragrostis) .. 9

9a. Spikelets of two forms, sterile and fertile intermixed; panicle dense, somewhat one-sided 10

10a. Fertile spikelets 2 or 3 flowered; sterile spikelets with numerous rigid awn-tipped glumes; panicle dense and spikelike .... 22. CYNOSURUS.

10b. Fertile spikelets with 1 perfect floret, long-awned; sterile spikelets with many obtuse glumes; panicle branchlets short, nodding. 23. ACHYRODES.

9b. Spikelets all alike in the same inflorescence 11

11a. Lemmas 3-nerved, the nerves prominent, often hairy 12

12a. Inflorescence a few-flowered head or capitate panicle overtopped by the leaves or partly concealed in them; lemmas toothed or cleft; low plants of the arid regions .. 13

13a. Inflorescence hidden among the sharp-pointed leaves, not woolly; plants annual (Chlorideae) .... 97. MUNROA.

13b. Inflorescence a capitate woolly panicle, not concealed; plants perennial 14

Key to the genera of Festuceae—Continued.

14a. Lemmas cleft either side of the midnerve to near the base, the lower two sterile, the third floret fertile, the fourth reduced to a 3-awned rudiment ___ 28. BLEPHARIDACHNE.

14b. Lemma 2-lobed but not deeply cleft, all fertile but the uppermost ___ 26. TRIODIA.

12b. Inflorescence an exserted open or spikelike panicle ___ 15

15a. Lemmas pubescent on the nerves or callus (except in *Triodia albescens*), the midnerve usually exserted as an awn or mucro ___ 16

16a. Nerves glabrous; callus densely hairy; lemmas firm; panicle large, diffuse ___ 15. REDFIELDIA.

16b. Nerves hairy at least below, the lateral ones often conspicuously so ___ 17

17a. Palea long-ciliate on the upper half ___ 27. TRIPLASIS.

17b. Palea sometimes villous but not long-ciliate on the upper half; perennials ___ 26. TRIODIA.

15b. Lemmas not pubescent on the nerves nor callus (the internerves sometimes pubescent), awnless ___ 18

18a. Glumes longer than the lemmas; lateral nerves of lemma marginal, the internerves pubescent ___ 14. DISSANTHELIUM.

18b. Glumes shorter than the lemmas; lateral nerves not marginal, the internerves glabrous ___ 19

19a. Lemmas chartaceous; grain large and beaked, at maturity forcing the lemma and palea open ___ 13. DIARINA.

19b. Lemmas membranaceous; if firm, the grain neither large nor beaked ___ 20

20a. Spikelets subterete; palea longer than the lemma, bowed out below ___ 12. MOLINIA.

20b. Spikelets compressed; palea not longer than the lemma, not bowed out below ___ 21

21a. Lemmas truncate; spikelets 2-flowered. 11. CATABROSA.

21b. Lemmas acute or acuminate; spikelets 3 to many flowered; rachilla continuous, the paleas usually persistent after the fall of the lemmas ___ 10. ERAGROSTIS.

11b. Lemmas 5 to many nerved, the nerves sometimes obscure ___ 22

22a. Spikelets with 1 to 4 empty lemmas below the fertile florets; nerves obscure; lemmas firm ___ 18. UNIOLA.

22b. Spikelets with no empty lemmas below the fertile florets; nerves usually prominent; lemmas membranaceous (firm in a few species of Bromus and Festuca) ___ 23

23a. Lemmas flabellate; glumes wanting; inflorescence dense, cylindric; low annual ___ 25. ANTHOCHLOA.

23b. Lemmas not flabellate; glumes present; inflorescence not cylindric ___ 24

24a. Palea winged on the lower half of the keels; spikelets linear, in a loose raceme ___ 5. PLEUROPOGON.

24b. Palea not winged on the lower half of the keels; inflorescence mostly paniculate ___ 25

25a. Lemmas as broad as long, the margins outspread; florets closely imbricate, horizontally spreading ___ 9. BRIZA.

25b. Lemmas longer than broad, the margins clasping the palea; florets not horizontally spreading ___ 26

Key to the genera of Festuceae—Continued.

26a. Callus of florets bearded; lemmas erose at the summit ______ 7. FLUMINEA.
26b. Callus not bearded (lemmas cobwebby at base in Poa); lemmas not erose (slightly in Puccinellia) ______ 27
27a. Lemmas keeled on the back (somewhat rounded in *Poa scabrella* and its allies) ______ 28
28a. Spikelets strongly compressed, crowded in one-sided clusters at the ends of the stiff, naked panicle branches ______ 21. DACTYLIS.
28b. Spikelets not strongly compressed, not crowded in one-sided clusters ______ 29
29a. Lemmas awned from a minutely bifid apex (awnless or nearly so in *Bromus unioloides* and *B. brizaeformis*); spikelets large ______ 2. BROMUS.
29b. Lemmas awnless; spikelets small ______ 8. POA.
27b. Lemmas rounded on the back (slightly keeled toward the summit in Festuca and Bromus) ______ 30
30a. Glumes papery; lemmas firm, strongly nerved, scarious-margined; upper florets sterile, often reduced to a club-shaped rudiment infolded by the broad upper lemmas; spikelets tawny or purplish, usually not green ______ 24. MELICA.
30b. Glumes not papery; upper florets not unlike the others ______ 31
31a. Nerves of the lemma parallel, not converging at the summit or but slightly so; lemmas awnless mostly obtuse ______ 32
32a. Nerves prominent; plants usually rather tall, growing in woods or fresh-water marshes ______ 4. PANICULARIA.
32b. Nerves faint; plants low, growing in saline soil. 6. PUCCINELLIA.
31b. Nerves of the lemma converging at the summit; lemmas awned or pointed (upper florets only minutely awn-tipped in *Bromus brizaeformis*) ______ 33
33a. Lemmas entire, awned from the tip or pointed (minutely toothed in *Festuca elmeri* and *F. gigantea*) ______ 3. FESTUCA.
33b. Lemmas awned or awn-tipped from a minutely bifid apex ______ 2. BROMUS.

TRIBE 3, HORDEAE.

Spikelets 1 to several flowered, sessile on opposite sides of a jointed or continuous axis forming symmetrical (not one-sided) spikes.

This small but important tribe, found in the temperate regions of both hemispheres, includes our most important cereals, wheat, barley, and rye. The rachis is flattened or concave next to the spikelets, or in some genera is thickened and hollowed out, the spikelets being more or less inclosed in the hollows. In Triticum and its allies there is one spikelet at each node of the rachis; in Hordeum and its allies there are two or three at each node. In Lolium and its allies the spikelets are placed edgewise to the rachis, and the first or inner glume is suppressed except in the terminal spikelet. The rachilla of the spikelet disarticulates at maturity in several genera. In some species of Elymus and especially in Sitanion the glumes are very slender, extending into long awns, in the latter genus sometimes divided into several slender bristles. In this tribe the blades of the leaves bear on each side at the base a small appendage or auricle.

Key to the genera of Hordeae.

1a. Spikelets solitary at each node of the rachis (rarely 2 in species of Agropyron, but never throughout) ---- 2
- 2a. Spikelets 1-flowered, sunken in hollows in the rachis; spikes slender, cylindric; low annuals ---- 3
  - 3a. Lemmas awned; florets lateral to the rachis ---- 36. SCRIBNERIA.
  - 3b. Lemmas awnless; florets dorsiventral to the rachis ---- 4
    - 4a. First glume wanting ---- 42. LEPTURUS.
    - 4b. First glume present, the pair standing in front of the spikelet ---- 43. PHOLIURUS.
- 2b. Spikelets 2 to several flowered, not sunken in the rachis ---- 5
  - 5a. Spikelets placed edgewise to the rachis; first glume wanting except in the terminal spikelet ---- 41. LOLIUM.
  - 5b. Spikelets placed flatwise to the rachis ---- 6
    - 6a. Plants perennial ---- 33. AGROPYRON.
    - 6b. Plants annual ---- 7
      - 7a. Glumes ovate, 3-nerved ---- 34. TRITICUM.
      - 7b. Glumes subulate, 1-nerved ---- 35. SECALE.

1b. Spikelets more than 1 at each node of the rachis ---- 8
- 8a. Spikelets 3 at each node of the rachis, 1-flowered, the lateral pair pediceled, usually reduced to awns ---- 40. HORDEUM.
- 8b. Spikelets 2 at each node of the rachis, alike, 2 to 6 flowered ---- 9
  - 9a. Glumes wanting or reduced to 2 short bristles; spikelets horizontally spreading at maturity; spikes very loose ---- 39. HYSTRIX.
  - 9b. Glumes usually equaling the florets; spikelets appressed or ascending ---- 10
    - 10a. Rachis continuous (rarely tardily disarticulating); glumes broad or narrow, entire ---- 37. ELYMUS.
    - 10b. Rachis disarticulating at maturity; glumes subulate, extending into long awns, these and the awns of the lemmas making the spike very bristly ---- 38. SITANION.

TRIBE 4, AVENEAE.

Spikelets 2 to several flowered in open or contracted panicles, or rarely in racemes (solitary in *Danthonia unispicata*); glumes usually as long as or longer than the first lemma, commonly longer than all the florets; lemmas usually awned from the back or from between the teeth of a bifid apex, the awn bent, often twisted, the callus and rachilla joints usually villous.

A rather small tribe widely distributed in both warm and cool regions. In our genera the rachilla is prolonged beyond the upper floret as a slender stipe (except in Aspris). The lemma is awnless or nearly so in Sphenopholis and in our species of Koeleria. These genera are placed in this tribe because they appear to be closely allied to Trisetum with which they agree in having oblanceolate glumes about as long as the first floret.

Key to the genera of Aveneae.

1a. Spikelets awnless or the upper lemma mucronate (rarely short-awned in Sphenopholis) ---------- 2
  2a. Articulation below the glumes; glumes distinctly different in shape, the second widened above ---------- 46. SPHENOPHOLIS.
  2b. Articulation above the glumes; glumes similar in shape. 44. KOELERIA.
1b. Spikelets awned (awnless in *Trisetum wolfii*) ---------- 3
  3a. Florets 2, one perfect, the other staminate ---------- 4
    4a. Lower floret staminate, the awn twisted, geniculate, exserted ---------- 48. ARRHENATHERUM.
    4b. Lower floret perfect, awnless; awn of upper floret hooked. 51. NOTHOLCUS.
  3b. Florets 2 or more, all alike except the reduced upper ones ---------- 5
    5a. Awn arising from between the teeth of a bifid apex, flattened, twisted; inflorescence a simple panicle or reduced to a raceme or even to a single spikelet ---------- 52. DANTHONIA.
    5b. Awn dorsal, not flattened; lemma often bifid at apex ---------- 6
      6a. Spikelets large, the glumes over 1 cm. long ---------- 47. AVENA.
      6b. Spikelets less than 1 cm. long ---------- 7
        7a. Lemmas keeled, bidentate; awn arising from above the middle ---------- 45. TRISETUM.
        7b. Lemmas convex; awn from below the middle ---------- 8
          8a. Rachilla prolonged behind the upper floret; lemmas truncate and erose-dentate at summit ---------- 49. AIRA.
          8b. Rachilla not prolonged; lemmas tapering into 2 slender teeth ---------- 50. ASPRIS.

TRIBE 5, AGROSTIDEAE.

Spikelets 1-flowered, usually perfect, arranged in open, contracted, or spikelike panicles, but not in true spikes nor in one-sided racemes.

A large and important tribe, inhabiting more especially the temperate and cool regions. The articulation of the rachilla is usually above the glumes, the mature floret falling from the persistent glumes, but in a few genera the articulation is below the glumes, the mature spikelet falling entire (Alopecurus, Cinna, Polypogon, Lycurus, and Limnodea). The palea is small or wanting in some species of Agrostis. In a few genera the rachilla is prolonged behind the palea as a minute bristle, or sometimes as a more pronounced villous stipe (Brachyelytrum, Limnodea, Cinna, three species of Agrostis, Gastridium, Calamagrostis, Ammophila, and Lagurus). In some genera the rachilla joint between the glumes and the lemma is slightly elongated, forming a hard stipe which remains attached to the mature fruit as a pointed callus. The callus is well marked in Stipa (especially in *S. spartea* and its allies) and in Aristida, the mature lemma being terete, indurate, and convolute, the palea wholly inclosed. In many genera the lemma is awned either from the tip or from the back, the awn being trifid in Aristida.

Key to the genera of Agrostideae.

1a. Glumes wanting; a low annual .... 58. COLEANTHUS.
1b. Glumes present (the first obsolete in *Muhlenbergia schreberi* and sometimes in Brachyelytrum and Phippsia) 2
2a. Rachilla articulate below the glumes, these falling with the spikelet 3
3a. Spikelets in pairs in a spikelike panicle, one perfect, the other staminate or neuter, the pair falling together .... 63. LYCURUS.
3b. Spikelets all alike 4
4a. Glumes long-awned .... 62. POLYPOGON.
4b. Glumes awnless 5
5a. Rachilla not prolonged behind the palea; panicle dense and spikelike; glumes united toward the base, ciliate on the keel .... 61. ALOPECURUS.
5b. Rachilla prolonged behind the palea; panicle narrow or open, not dense; glumes not united, not ciliate on the keel 6
6a. Panicle narrow; lemma with a slender bent twisted awn from the bifid apex .... 60. LIMNODEA.
6b. Panicle open and drooping; lemma with a minute straight awn just below the entire apex .... 59. CINNA.
2b. Rachilla articulate above the glumes 7
7a. Fruit dorsally compressed, indurate, smooth and shining, awnless .... 74. MILIUM.
7b. Fruit laterally compressed or terete, awned or awnless 8
8a. Fruit indurate, terete, awned, the nerves obscure; callus well developed, oblique, bearded 9
9a. Awn trifid, the lateral divisions sometimes short, rarely obsolete (when obsolete no line of demarcation between awn and lemma as in the next) .... 77. ARISTIDA.
9b. Awn simple, a line of demarcation between the awn and the lemma 10
10a. Awn persistent, twisted and bent, several to many times longer than the slender fruit; callus sharp-pointed .... 76. STIPA.
10b. Awn deciduous, not twisted, sometimes bent, rarely more than 3 or 4 times as long as the plump fruit; callus short, usually obtuse .... 75. ORYZOPSIS.
8b. Fruit thin or firm, but scarcely indurate, if firm, the nerves prominent or evident; callus not well developed 11
11a. Glumes longer than the lemma (lemma equaling the glumes in *Agrostis spica-venti, A. aequivalvis,* and *A. thurberiana*) 12
12a. Panicle feathery, capitate, nearly as broad as long; spikelets woolly .... 66. LAGURUS.
12b. Panicle not feathery; spikelets not woolly 13
13a. Glumes compressed-carinate, abruptly mucronate, stiffly ciliate on the keels; panicle dense, cylindric or ellipsoid .... 64. PHLEUM.
13b. Glumes not compressed-carinate, not ciliate 14

Key to the genera of Agrostideae—Continued.

14a. Glumes saccate at base; lemma long-awned; inflorescence contracted, shining .... 65. GASTRIDIUM.
14b. Glumes not saccate at base; lemma awned or awnless; panicles open or contracted 15
15a. Florets bearing a tuft of hairs at the base from the short callus, the hairs at least half as long as the lemma; palea present .... 53. CALAMAGROSTIS.
15b. Florets without hairs at the base or with short hairs rarely as much as half the length of the lemma (*Agrostis hallii*); palea usually small or wanting .... 56. AGROSTIS.
11b. Glumes not longer than the lemma, usually shorter (the awn tips longer in *Muhlenbergia racemosa*) 16
16a. Lemma awned from the tip or mucronate, 3 to 5 nerved (lateral nerves obsolete in *Muhlenbergia repens*) 17
17a. Rachilla prolonged behind the palea; floret stipitate. 73. BRACHYELYTRUM.
17b. Rachilla not prolonged; floret not stipitate .... 68. MUHLENBERGIA.
16b. Lemma awnless or awned from the back 18
18a. Florets bearing a tuft of hairs at the base from the short callus; lemma and palea chartaceous, awnless 19
19a. Panicles spikelike; rachilla prolonged .... 54. AMMOPHILA.
19b. Panicles open; rachilla not prolonged .... 55. CALAMOVILFA.
18b. Florets without hairs at base 20
20a. Nerves of lemma densely silky .... 70. BLEPHARONEURON.
20b. Nerves of lemma not silky 21
21a. Caryopsis at maturity falling from the lemma and palea; seed loose in the pericarp, this usually opening when ripe; lemma 1-nerved 22
22a. Inflorescence capitate in the axils of broad bracts .... 71. CRYPSIS.
22b. Inflorescence an open or contracted panicle. 69. SPOROBOLUS.
21b. Caryopsis not falling from the lemma and palea, remaining permanently inclosed in them; seed adnate to the pericarp 23
23a. Panicles few-flowered, slender, rather loose; glumes minute, unequal, the first often wanting; a low arctic alpine perennial .... 57. PHIPPSIA.
23b. Panicle many-flowered, spikelike; glumes well developed, about equal 24
24a. Panicle short, partly inclosed in the sheath; low annual .... 72. HELEOCHLOA.
24b. Panicle elongate; perennial .... 67. EPICAMPES.

TRIBE 6, NAZIEAE.

Spikelets subsessile in short spikes of 2 to 5 (single in Osterdamia), each spike falling entire from the continuous axis, usually 1-flowered, all perfect, or perfect and staminate together in the same spike; glumes usually firmer than the lemma and palea, sometimes awned, the lemma awnless.

This small and unimportant tribe is known also as Zoysieae. In Osterdamia the spikelets are single and have only one glume, this coriaceous, much firmer than the lemma and palea, the palea sometimes obsolete.

Key to the genera of Nazieae.

1a. Spikelets single; first glume wanting ---------- 79. OSTERDAMIA.
1b. Spikelets in clusters of 2 to 5; first glume present ---------- 2
  2a. Spikelets bearing hooked spines on the second glume, the group forming a little bur ---------- 78. NAZIA.
  2b. Spikelets not bearing hooked spines, mostly cleft and awned ---------- 3
    3a. Groups of spikelets erect, the spike not one-sided ---------- 80. HILARIA.
    3b. Groups of spikelets nodding along one side of the delicate axis ---------- 81. AEGOPOGON.

TRIBE 7, CHLORIDEAE.

Spikelets 1 to several flowered, in 2 rows on one side of a continous rachis forming one-sided spikes or spikelike racemes, these solitary, digitate, or racemose along the main axis.

A large and rather important tribe, confined mostly to warm regions. The group is heterogeneous, the only common character of the genera (aside from the characters that place them in Poatae) being the arrangement of the spikelets in one-sided spikes. Chloris and the allied genera form a coherent group, in which the spikelet consists of one perfect floret and, above this, one or more modified or rudimentary florets. Leptochloa, Eleusine, and their allies, with several-flowered spikelets, are more nearly related to certain genera of Festuceae. The spike is reduced to two or three spikelets or even to one spikelet and is sometimes deciduous from the main axis in Cathestecum and in some species of Bouteloua. In Campulosus there are two sterile florets below the perfect one.

Key to the genera of Chlorideae.

1a. Plants monœcious or diœcious; a low stoloniferous perennial ---------- 98. BULBILIS.
1b. Plants with perfect flowers ---------- 2
  2a. Spikelets with more than one perfect floret ---------- 3
    3a. Inflorescence a few-flowered head or capitate panicle hidden among the sharp-pointed leaves; a low spreading annual ---------- 97. MUNROA.
    3b. Inflorescence exserted ---------- 4
      4a. Spikes solitary, the spikelets distant, appressed, several-flowered ---------- 83. TRIPOGON.
      4b. Spikes more than 1 ---------- 5
        5a. Spikes numerous, slender, racemose on an elongate axis ---------- 82. LEPTOCHLOA.
        5b. Spikes few, digitate or nearly so ---------- 6
          6a. Rachis of spike extending beyond the spikelets ---------- 85. DACTYLOCTENIUM.
          6b. Rachis not prolonged ---------- 84. ELEUSINE.
  2b. Spikelets with only 1 perfect floret, often with additional imperfect florets above ---------- 7

Key to the genera of Chlorideae—Continued.

7a. Spikelets without additional modified florets, the rachilla sometimes prolonged ---------- 8
  8a. Rachilla articulate below the glumes, the spikelets falling entire- 9
    9a. Glumes unequal, narrow ---------- 90. SPARTINA.
    9b. Glumes equal, broad and boat shaped ---------- 89. BECKMANNIA.
  8b. Rachilla articulate above the glumes ---------- 10
    10a. Spikes digitate; rachilla prolonged ---------- 86. CAPRIOLA.
    10b. Spikes racemose along the main axis; rachilla not prolonged- 11
      11a. Spikes slender, divaricate, the main axis elongating and becoming loosely spiral in fruit ---------- 88. SCHEDONNARDUS.
      11b. Spikes short and rather stout, appressed, the axis unchanged in fruit ---------- 87. WILLKOMMIA.

7b. Spikelets with 1 or more modified florets above the perfect one ---------- 12
  12a. Spikelets with 2 sterile florets below the perfect one; second glume bearing a squarrose spine on the back; spike single, recurved ---------- 91. CAMPULOSUS.
  12b. Spikelets with no sterile florets below the perfect one; second glume without a squarrose spine; spikes usually several ---------- 13
    13a. Spikes digitate or nearly so ---------- 14
      14a. Fertile lemma 1-awned or awnless ---------- 93. CHLORIS.
      14b. Fertile lemma 3-awned ---------- 94. TRICHLORIS.
    13b. Spikes racemose along the main axis ---------- 15
      15a. Spikelets distant, appressed; spikes slender, elongate. 92. GYMNOPOGON.
      15b. Spikelets contiguous or crowded, not appressed; spikes usually short and rather stout ---------- 16
        16a. Spikelets 3 in each spike, the 2 lateral staminate or rudimentary; spikes falling entire ---------- 96. CATHESTECUM.
        16b. Spikelets 2 to many (rarely 1) in each spike, all alike; spikes usually persistent, the florets falling. 95. BOUTELOUA.

TRIBE 8, PHALARIDEAE.

Spikelets with one perfect terminal floret and, below this, a pair of staminate or neuter florets.

A small tribe of about six genera, only three of which are found in the United States. In Phalaris the lateral florets are reduced to minute scalelike lemmas closely appressed to the edges of the fertile floret. In Torresia the lateral florets are staminate and as large as the fertile floret.

Key to the genera of Phalarideae.

1a. Lateral florets staminate; spikelets brown and shining ---------- 99. TORRESIA.
1b. Lateral florets neuter; spikelets green or yellowish ---------- 2
  2a. Lateral florets reduced to small awnless scalelike lemmas; spikelets much compressed laterally ---------- 101. PHALARIS.
  2b. Lateral florets consisting of awned hairy sterile lemmas exceeding the fertile floret; spikelet terete ---------- 100. ANTHOXANTHUM.

Tribe 9, Oryzeae.

Spikelets 1-flowered, perfect, strongly laterally compressed, paniculate; glumes reduced or wanting; palea apparently 1-nerved; stamens 6.

A small tribe whose affinities are not evident. It includes rice, the important food plant.

Key to the genera of Oryzeae.

Glumes minute; lemma often awned ---------- 102. Oryza.
Glumes wanting; lemma awnless ---------- 103. Homalocenchrus.

Tribe 10, Zizanieae.

Spikelets unisexual, the pistillate terete or nearly so; glumes shorter than the lemma, usually one or both obsolete, the pedicel disarticulating below the spikelet.

A small tribe of uncertain affinities; the species aquatic or subaquatic, of no economic importance except the Indian rice (Zizania).

Key to the genera of Zizanieae.

1a. Culms slender; plants low; staminate and pistillate spikelets borne in separate inflorescences ---------- 2
  2a. Inflorescence a few-flowered spike; plants not stoloniferous. 107. Hydrochloa.
  2b. Inflorescence a panicle; plants stoloniferous ---------- 106. Luziola.
1b. Culms robust; plants tall; staminate and pistillate spikelets borne in the same panicle ---------- 3
  3a. Plants annual; pistillate spikelets on the ascending upper branches, the staminate on the spreading lower branches of the panicle ---------- 105. Zizania.
  3b. Plants perennial; pistillate spikelets at the ends, the staminate below on the same branches of the panicle ---------- 104. Zizaniopsis.

Tribe 11, Melinideae.

Spikelets disarticulating below the glumes, these very unequal, the first minute, the second and the sterile lemma equal, membranaceous, strongly nerved, the latter bearing a slender awn from the notched summit; fertile lemma and palea thinner in texture, awnless.

A tribe of about a dozen genera, none of which is represented in the United States. The only economic species is *Melinis minutiflora* (see p. 212).

Tribe 12, Paniceae.

Spikelets with one perfect terminal floret and below this a sterile floret and two glumes; fertile lemma and palea indurate or at least firmer than the glumes and sterile lemma; articulation below the spikelet.

A large tribe, confined mostly to warm regions, and containing few economic species. The first glume is wanting in some genera, such as Paspalum, and rarely the second glume also (Reimarochloa).

The spikelets are usually awnless, but the glumes and sterile lemma are awned in Echinochloa and Oplismenus, and the second glume and sterile lemma in Tricholaena. In Eriochloa and in some species of Brachiaria the fertile lemma is awn-tipped. In Chaetochloa there are, beneath the spikelet, one or more bristles, these representing sterile branchlets. In Pennisetum similar bristles form an involucral cluster, falling with the spikelet. In Cenchrus the bristles are united, forming a bur. The spikelets are of two kinds in Amphicarpon, aerial and subterranean. The culms are woody and perennial in Lasiacis and Olyra.

Key to the genera of Paniceae.

1a. Spikelets of two kinds ---------- 2
2a. Spikelets all perfect, but those of the aerial panicle not perfecting grains; the fruitful spikelets borne on subterranean branches ---------- 127. AMPHICARPON.
2b. Spikelets unisexual, the pistillate above, the staminate below on the branches of the same panicle; blades broad, elliptic. OLYRA. (See p. 252.)
1b. Spikelets all of one kind ---------- 3
3a. Spikelets sunken in the cavities of the flattened corky rachis. 112. STENOTAPHRUM.
3b. Spikelets not sunken in the rachis ---------- 4
4a. Spikelets subtended or surrounded by 1 to many distinct or more or less connate bristles, forming an involucre ---------- 5
5a. Bristles persistent, the spikelets deciduous ---------- 124. CHAETOCHLOA.
5b. Bristles falling with the spikelets at maturity ---------- 6
6a. Bristles not united at base, slender, often plumose. 125. PENNISETUM.
6b. Bristles united into a burlike involucre, the bristles retrorsely barbed ---------- 126. CENCHRUS.
4b. Spikelets not subtended by bristles ---------- 7
7a. Glumes or sterile lemma awned (awn short and concealed in the silky hairs of the spikelet in Tricholaena, awn reduced to a point in *Echinochloa colonum*) ---------- 8
8a. Inflorescence paniculate; spikelets silky ---------- 123. TRICHOLAENA.
8b. Inflorescence of unilateral simple or somewhat compound racemes along a common axis; spikelets smooth or hispid, not silky ---------- 9
9a. Blades lanceolate, broad and thin; glumes 2-lobed, awned from between the lobes. 121. OPLISMENUS.
9b. Blades long and narrow; glumes awned from the tip ---------- 122. ECHINOCHLOA.
7b. Glumes and sterile lemma awnless ---------- 10
10a. Fruit cartilaginous-indurate, flexible, usually dark colored, the lemma with more or less prominent white hyaline margins, these not inrolled ---------- 11
11a. Spikelets covered with long silky hairs, arranged in racemes, these panicled ---------- 109. VALOTA.
11b. Spikelets glabrous or variously pubescent but not long-silky ---------- 12

Key to the genera of Paniceae—Continued.

12a. Spikelets in slender racemes more or less digitate at the summit of the culms ---------- 110. SYNTHERISMA.
12b. Spikelets in panicles ---------- 13
13a. Fruiting lemma boat shaped; panicles narrow. 108. ANTHAENANTIA.
13b. Fruiting lemmas convex; panicles diffuse -- 111. LEPTOLOMA.
10b. Fruit chartaceous-indurate, rigid ---------- 14
14a. Spikelets placed with the back of the fruit turned away from the rachis of the racemes, usually single (not in pairs) ---------- 15
15a. First glume and the rachilla joint forming a swollen ringlike callus below the spikelet ---------- 113. ERIOCHLOA.
15b. First glume present or wanting, not forming a ringlike callus below the spikelet ---------- 16
16a. First glume present; racemes racemose along the main axis ---------- 114. BRACHIARIA.
16b. First glume wanting; racemes digitate or subdigitate. 115. AXONOPUS.
14b. Spikelets placed with the back of the fruit turned toward the rachis of the spikelike racemes, or pedicellate in panicles ---------- 17
17a. Fruit long-acuminate; both glumes wanting - 116. REIMAROCHLOA.
17b. Fruit not long-acuminate, at least one glume present ---------- 18
18a. First glume typically wanting; spikelets plano-convex, subsessile in spikelike racemes ---------- 117. PASPALUM.
18b. First glume present; spikelets usually in panicles ---------- 19
19a. Second glume inflated-saccate, this and the sterile lemma much exceeding the stipitate fruit. 120. SACCIOLEPIS.
19b. Second glume not inflated-saccate ---------- 20
20a. Culms woody and bamboolike; fruit with a tuft of down at the apex ---------- 119. LASIACIS.
20b. Culms herbaceous; no tuft of down at the apex of the fruit ---------- 118. PANICUM.

TRIBE 13, ANDROPOGONEAE.

Spikelets in pairs along a rachis, the usual arrangement being one of the pair sessile and fertile, the other pedicellate and staminate or neuter, or rarely wanting, only the pedicel present; fertile spikelet consisting of one perfect terminal floret and, below this, a staminate or neuter floret, the lemmas thin or hyaline, and two awnless glumes, one or usually both firm or indurate.

A large tribe, confined mostly to warm regions. The rachis is usually jointed, disarticulating at maturity, with the spikelets attached. In a few genera it is thickened. Sometimes the racemes are shortened to 1 or 2 joints and borne on branches, the whole forming a panicle (as in Holcus and Sorghastrum) instead of a series of racemes. In a few genera the spikelets of the pair are alike. In Trachypogon the fertile spikelet is pedicellate and the sterile one nearly sessile.

Key to the genera of Andropogoneae.

1a. Spikelets all perfect, surrounded by a copious tuft of soft hairs______ 2
2a. Rachis continuous, the spikelets falling; spikelets of the pair unequally pedicellate____ 3
3a. Racemes in a narrow spikelike panicle, spikelets awnless____ 128. IMPERATA.
3b. Racemes in a broad fan-shaped panicle; spikelets awned. 129. MISCANTHUS.
2b. Rachis breaking up into joints at maturity with the spikelets attached; one spikelet sessile, the other pedicellate_____________ 4
4a. Spikelets awnless_______________________________ 130. SACCHARUM.
4b. Spikelets awned________________________________ 131. ERIANTHUS.
1b. Spikelets unlike, the sessile perfect, the pedicellate sterile (sessile spikelet staminate, pedicellate spikelet perfect in Trachypogon)____ 5
5a. Pedicel thickened, appressed to the thickened rachis joint (at least parallel to it) or adnate to it; spikelets awnless, appressed to the joint____ 6
6a. Rachis joint and pedicel adnate, forming a short flat joint, this sunken in the open side of the globose first glume of the sessile spikelet; sterile spikelet conspicuous__ 140. RYTILIX.
6b. Rachis joint and pedicel distinct, the sessile spikelet appressed to them, its first glume lanceolate_______________ 7
7a. Racemes subcylindric; rachis joints and pedicels glabrous, much thicker at the summit, the spikelets sunken in the hollow below; sterile spikelet rudimentary_____ 139. MANISURIS.
7b. Racemes flat; rachis joints and pedicels woolly, not much thicker at the summit; sterile spikelet staminate or neuter ____ 138. ELYONURUS.
5b. Pedicel not thickened (if slightly so the spikelets awned), neither appressed nor adnate to the rachis joint, this usually slender; spikelets usually awned____________________________________ 8
8a. Fertile spikelet with a hairy-pointed callus, formed of the attached supporting rachis joint or pedicel; awns strong__ 9
9a. Racemes reduced to a single joint, long-peduncled in a simple open panicle_________________________ 135. RHAPHIS.
9b. Racemes of several to many joints, single_____________ 10
10a. Primary spikelet subsessile, sterile, persistent on the continuous axis after the fall of the fertile pedicellate spikelet, the pedicel forming the callus. 137. TRACHYPOGON.
10b. Primary spikelet sessile, fertile; pedicellate spikelet sterile; lower few to several pairs of spikelets all staminate or neuter____________________ 136. HETEROPOGON.
8b. Fertile spikelet without a callus, the rachis disarticulating immediately below the spikelet; awns slender__________ 11
11a. Racemes of several to many joints, solitary, digitate, or aggregate____________________________ 132. ANDROPOGON.
11b. Racemes reduced to one or few joints, these mostly peduncled in a subsimple or compound panicle______ 12
12a. Pedicellate spikelets staminate____________ 133. HOLCUS.
12b. Pedicellate spikelets wanting, the pedicel only present____________________________ 134. SORGHASTRUM.

TRIBE 14, TRIPSACEAE.

Spikelets unisexual, the staminate in pairs, or sometimes in threes, 2-flowered, the pistillate usually single, 2-flowered, the lower floret sterile, imbedded in hollows of the thickened articulate axis and falling attached to the joints, or inclosed in a thickened involucre or sheath or, in Zea, crowded in rows on a thickened axis (cob); glumes membranaceous or thick and rigid, awnless; lemmas and palea hyaline, awnless. Plants monœcious.

This small tribe of seven genera is scarcely more than a subtribe of Andropogoneae. It is also known as Maydeae.

Key to the genera of Tripsaceae.

1a. Staminate and pistillate spikelets in separate inflorescences, the first in a terminal tassel, the second in the axils of the leaves — 2
  2a. Pistillate spikes distinct, the spikelets embedded in the hardened rachis, this disarticulating at maturity — 142. EUCHLAENA.
  2b. Pistillate spikes grown together forming an ear, the grains at maturity much exceeding the glumes — 143. ZEA.
1b. Staminate and pistillate spikelets in separate portions of the same spike, the pistillate below — 3
  3a. Spikes short, the 1 or 2 flowered pistillate portion inclosed in a beadlike sheathing bract — 144. COIX.
  3b. Spikes many-flowered, the pistillate portion breaking up into several 1-seeded joints; no beadlike sheathing bract — 141. TRIPSACUM.

DESCRIPTIONS OF THE GENERA.

1. BAMBOSEAE, THE BAMBOO TRIBE.

1. ARUNDINARIA Michx.

Spikelets few to many flowered, large, compressed, the rachilla disarticulating above the glumes and between the florets; glumes unequal, shorter than the lemmas, the first sometimes wanting; lemmas acute or acuminate or mucronate, faintly many-nerved; palea about as long as the lemma, prominently 2-keeled.

Shrubs or tall reeds, with woody perennial branching culms, flat blades with petioles articulate with the sheaths, and loose racemes or panicles. Species about 25, in the Tropics of both hemispheres; 2 species in the southeastern United States.

Type species: *Arundinaria macrosperma* Michx.

Arundinaria Michx., Fl. Bor. Amer. **1**: 73. 1803. One species described.

Miegia Pers., Syn. Pl. **1**: 101. 1805. A single species, based on *Arundinaria macrosperma* Michx., is included.

Macronax Raf., Med. Repos. ser. 2. **5**: 353. 1808. Based on "The Arundinaria of Michaux."

Our two species, *Arundinaria tecta* (Walt.) Muhl. (fig. 1) and *A. macrosperma* (Pl. I), are the only native representatives of the tropical tribe Bamboseae, or Bambuseae, the bamboos. Our species are known, respectively, as small and large cane. Both flower infre-

LARGE CANE (ARUNDINARIA MACROSPERMA). INFLORESCENCE, LEAVES, FLORETS, AND RIPE GRAINS.

MEADOW FESCUE (FESTUCA ELATIOR) IN FLOWER.

FIG. 1.—Small cane, *Arundinaria tecta*. Flowering shoot and leafy branch, × ½; spikelet and floret, × 2.

quently. The first is rarely over 6 feet tall, with drooping blades, the inflorescence on leafless or nearly leafless shoots from the base of the plant. This is found from Maryland southward. The other species grows to a height of as much as 25 or 30 feet and forms, in the alluvial river bottoms of the Southern States, dense thickets called canebrakes. The racemes are borne on leafy branches, the species flowering less frequently than the small cane.

Stock are fond of the young plants and of the leaves and seeds, and both species furnish much forage in localities where they are abundant. The young shoots are sometimes used as a potherb. The stems or culms of the large cane are used for fishing rods, pipestems, baskets, mats, light scaffolding, and for a variety of other purposes.

2. FESTUCEAE, THE FESCUE TRIBE.

2. Bromus L., the brome-grasses.

Spikelets several to many flowered, the rachilla disarticulating above the glumes and between the florets; glumes unequal, acute, the first 1 to 3 nerved, the second usually 3 to 5 nerved; lemmas convex on the back or keeled, 5 to 9 nerved, 2-toothed at the apex, awnless or usually awned from between the teeth; palea usually shorter than the lemma.

Annual or perennial, low or rather tall grasses, with closed sheaths, flat blades, and open or contracted panicles of large spikelets. Species about 100, in temperate regions; about 43 species in the United States, of which 17 are introductions, mostly from Europe.

Type species: *Bromus secalinus* L.

Bromus L., Sp. Pl. 76, 1753; Gen. Pl., ed. 5, 33. 1754. Linnæus describes 11 species, all but the last 2 of which are still retained in the genus. The citation given after Bromus in the Genera Plantarum is "Mont. 32." This refers to figure 32 in the plate accompanying Monti's Catalogi Stirpium Agri Bononiensis Prodromus, published in 1719. This figure represents a spikelet of *Bromus secalinus*, or of a closely allied species. As *Bromus secalinus* is the first species described in the Species Plantarum and was described in the flora of Sweden, this species is chosen as the type.

Ceratochloa Beauv., Ess. Agrost. 75, pl. 15, f. 7. 1812. A single species included. *Festuca unioloides* Willd., which is the basis of *Bromus unioloides* (Willd.) H. B. K.

Zerna Panz., Denkschr. Baier. Akad. Wiss. Müench. **4**: 296. 1813. (Ideen Gatt. Gräser 46, pl. 11, f. 3.) Eleven species are included. *Bromus sterilis* L., the one figured, is taken as the type.

Serrafalcus Parl., Rar. Pl. Sic. **2**: 14. 1840. Six species are included. *Bromus racemosus* L., on which the first species is based, is taken as the type.

Forasaccus Bubani, Fl. Pyren. **4**: 380. 1901. Proposed for Bromus L., not Bromus of the ancients, which is said to be wild oats.

The section Ceratochloa has large compressed spikelets with compressed-keeled glumes and lemmas. One species, *Bromus unioloides* (Willd.) H. B. K., is cultivated as a forage grass under the name of rescue grass or Schrader's brome-grass. This is an annual or biennial grass 1 to 2 feet tall, with pubescent sheaths and narrow panicles of smooth spikelets as much as an inch long, the lemmas acuminate or awn-tipped. Rescue grass is a native of South America and is cultivated occasionally in our Southern States for winter forage. The other species of this section are natives of the western half of the United States. They are all perennials and have large awned spikelets. *Bromus carinatus* Hook. and Arn. and *B. marginatus* Nees are common on the Pacific coast. They have pubescent or scabrous spikelets, the first with an awn longer than the lemma, the second with an awn shorter than the lemma. *Bromus carinatus* often appears like an annual, flowering the first year.

The species of Bromus in which the spikelets are not compressed-keeled fall into two rather well-marked groups, perennials and annuals. The most important species of the first group is *Bromus inermis* Leyss., a European species known also as awnless brome-grass, Hungarian brome-grass, smooth brome-grass, and brome-grass. It is erect, 2 to 3 feet tall, with creeping rhizomes and narrow, many-flowered panicles with erect or ascending branches and smooth narrow spikelets about an inch long, the lemmas acute, awnless, or nearly so. Awnless brome-grass is cultivated for hay and pasture in the northern portion of the Great Plains from northern Kansas to Minnesota and Montana. It is more drought resistant than timothy and in the region mentioned can be grown farther west than that species, but does not thrive south of central Kansas. All the other perennial species are natives except *B. erectus*, occasionally introduced from Europe, and all have distinctly awned lemmas. *Bromus purgans* L. is a common woodland species in the Eastern States. This has an open drooping panicle with nearly terete spikelets, the lemmas pubescent over the back. The closely allied and equally common *B. ciliatus* L. (fig. 2) differs in having lemmas glabrous on the back and pubescent on the margins only. Several species are found in the Western States, *B. porteri* (Coult.) Nash, with close drooping panicle and softly pubescent spikelets, being common in the Rocky Mountains.

The group of annuals includes weedy species introduced mostly from Europe. The best known of these in the Eastern States is *Bromus secalinus* (fig. 3), chess or cheat, a weed of waste places and sometimes infesting grain fields. Formerly it was believed by the credulous that under certain conditions wheat changed into chess. Chess in a wheat field is due to chess seed in the soil or to chess seed in the wheat sown. Chess is a smooth grass 1 to 3 feet tall, with flat blades and open drooping panicles of smooth turgid spikelets, the lemmas broad and inrolled above, the awn about as long as the lemma. *Bromus commutatus* Schrad. differs in having pubescent sheaths.

On the Pacific coast the annual species of Bromus have become conspicuous. They thrive on all open ground at lower altitudes in

FIG. 2.—Wild brome-grass, *Bromus ciliatus*. Plant, × ½; spikelet and floret, × 5.

FIG. 3.—Chess (cheat), *Bromus secalinus.* Plant, × ½; spikelet and floret, × 5.

spring and early summer, and on the approach of the summer dry season they ripen their seed and turn brown. They often cover vast areas and have become a great pest. The commonest species are *B. rubens* L., with contracted panicles of narrow usually purplish spikelets; *B. hordeaceus* L., with compact panicles of short turgid usually pubescent spikelets like those of *B. secalinus; B. villosus* Forsk., with open rather few-flowered panicles and narrow spikelets with awns as much as 2 inches long; and *B. tectorum* L. (fig. 4), a rather small softly pubescent species, with drooping panicles of narrow spikelets. *Bromus trinii* Desv., found chiefly in the desert regions of California, introduced from Chile, is peculiar in having a bent awn twisted below. *Bromus arenarius* Labill., a recent introduction from Australia, is becoming common. This has an open panicle with capillary curved pedicels and short, pubescent spikelets.

The perennial species of Bromus are important forage grasses on the mountain ranges of the Western States. The annual species are good forage grasses when they are young, but they are rather evanescent. The fruits of *B. villosus* and *B. rubens* and their allies are injurious to stock, the sharp-pointed florets working their way into the eyes and nostrils. *Bromus secalinus* is grown for hay in Washington, in Oregon, and in Georgia.

For a revision of the species of Bromus found in the United States, see Shear, U. S. Dept. Agr., Div. Agrost. Bull. 23. 1900.

3. FESTUCA L., the fescue grasses.

Spikelets few to several flowered, the rachilla disarticulating above the glumes and between the florets; glumes narrow, acute, unequal, the first sometimes very small; lemmas rounded on the back, membranaceous or somewhat indurate, 5-nerved, the nerves often obscure, acute or rarely obtuse, awned from the tip or rarely from a minutely bifid apex.

Annual or perennial low or rather tall grasses of varied habit, the spikelets in narrow or open panicles. Species about 100, in the temperate and cool regions; about 40 species in the United States, 7 of which are introductions from Europe.

Type species: *Festuca ovina* L.

Festuca L., Sp. Pl. 73, 1753; Gen. Pl., ed. 5, 33. 1754. Linnæus describes 11 species. *Festuca ovina* is chosen as the type, as it is the first of the original species that is economic and is described in the flora of Sweden. Most of the original species are still retained in Festuca but *F. decumbens* is now placed in Sieglingia, *F. fluitans* in Panicularia, and *F. cristata* in Koeleria (*K. phleoides*).

Vulpia Gmel., Fl. Badens. 1: 8. 1805. One species, *V. myuros*, based on *Festuca myuros* L., is described, and two species of Festuca having a single stamen are mentioned in a note. *Festuca myuros* is taken as the type.

Schedonorus Beauv., Ess. Agrost. 99, pl. 19, f. 2. 1812. The first of the 25 species included and the one figured is "*Bromus elatior*" (L.) Koel., based on *Festuca elatior*. The figure shows a floret with a short awn below the minutely bidentate apex, as found in occasional specimens of *F. elatior*, which species is taken as the type.

FIG. 4.—Downy brome-grass, *Bromus tectorum*. Plant, × ½; spikelet and floret, × 5.

Dasiola Raf., Neogenyt. 4. 1825. "Type Festuca monandra" Ell., renamed *D. elliottea* Raf. This is *F. sciurea* Nutt.

Chloamnia Raf., Neogenyt. 4. 1825. Two species are included, *Festuca tenella* and *F. bromoides*. The first, which is *F. octoflora* Walt., is taken as the type.

Hesperochloa (Piper) Rydb., Bull. Torrey Club **39**: 106. 1912. Based on Festuca subgenus Hesperochloa Piper, the type and only species of which is *F. confinis* Vasey.

Wasatchia Jones, Contr. West. Bot. **14**: 16. 1912. A single species is included, *W. kingii* (Watson) Jones, based on *Poa kingii* Watson, which is the same as *F. confinis* Vasey.

Gnomonia Lunell, Amer. Midl. Nat. **4**: 224. 1915. A new name proposed for Festuca L., not Dodonaeus, 1551.

FIG. 5.—*Festuca octoflora*. Plant, × ½; spikelet and floret, × 5.

The subgenus Vulpia, including annuals with mostly narrow panicles and flowers with but one stamen, is represented in the United States by 13 species, 2 of which, *Festuca myuros* L. and *F. bromoides* L., are introductions from Europe. *Festuca octoflora* Walt. (fig. 5), with spikelets usually more than 5-flowered and hard terete glabrous or scabrous lemmas with no scarious margin, is common throughout the United States. Several native species of this subgenus are found on the Pacific coast.

The subgenus Hesperochloa includes a single species *Festuca confinis* Vasey, a stout tufted perennial with creeping rhizomes, firm flat blades, and narrow panicles of awnless spikelets.

The remaining species, all perennials, are placed in the subgenus Eufestuca. Mountain bunch-grass (*F. viridula* Vasey) with narrow flat or loosely involute blades and awnless spikelets is common in the subalpine meadows of the northwestern mountains where it constitutes an important part of the forage. *Festuca subulata* Trin., a common woodland species of the Northwestern States, has flat thin blades and very open panicles of long-awned spikelets. Much resembling this is *F. subuliflora* Scribn., which is peculiar in having a stipelike elongation at the base of the florets. An allied Californian species, *F. elmeri* Scribn. and Merr., has spikelets like *F. subulata*, but the awn arises between the two minute teeth of the lemma. *Festuca obtusa* Spreng. is an eastern woodland species with very loose sparingly branched panicle and few awnless spikelets. The largest species of the genus in the United States is *F. californica* Vasey, found in dry woods of western California and Oregon. This grows in large tufts, with culms as much as 5 feet tall, hard flat or loosely involute blades, pilose on the collar, and large panicles.

The type species, *Festuca ovina*, is the representative of a large group of varieties or closely allied species in Europe. *Festuca ovina* itself is cultivated as a lawn or pasture grass under the name of sheep's fescue. It is a tufted grass 6 to 18 inches tall with firm, short, involute blades, crowded at the base of the slender culms, and narrow panicles of short-awned spikelets. This grass is used in mixtures for sterile or stony soil. Three allied European species are used in the same way but especially in mixtures for lawns. These are *F. duriuscula* L., hard fescue (a species rare in America), with blades about 1 mm. broad; *F. heterophylla* Lam., with flat stem blades; and *F. capillata* Lam., with very fine blades and awnless spikelets. Red fescue, *F. rubra* L. (fig. 6), differs in the loosely tufted culms with decumbent usually red bases. This is native in both Europe and America. Two species allied to *F. ovina* are native in the Western States and are both important range grasses. These are *F. idahoensis* Elmer (*F. ingrata* (Hack.) Rydb.), blue bunch-grass, with pale narrow stiff harshly scabrous blades 6 to 15 inches long, and awned spikelets, common from British Columbia to Colorado and California; and *F. arizonica* Vasey, Arizona fescue, with nearly awnless spikelets, found in northern Arizona and southern Utah.

The most important cultivated species of the genus is *Festuca elatior* L., meadow fescue (Pl. II; fig. 7). This is a smooth perennial, 1 to 4 feet high, with flat blades and a narrow but rather loose panicle 4 to 8 inches long, the awnless spikelets about half an inch long. Meadow fescue is cultivated for hay and pasture in the humid region, especially in Tennessee, Missouri, and eastern Kansas. There are two agricultural varieties of this species. The taller form with larger more open panicle is distinguished as tall fescue. The form more

FIG. 6.—Red fescue, *Festuca rubra*. Plant, × ½; spikelet and floret, × 5.

FIG. 7.—Meadow fescue, *Festuca elatior*. Plant, × ½; spikelet and floret, × 5.

commonly cultivated, usually called meadow fescue, is 2 or 3 feet tall and has a nearly simple panicle, sometimes racemose above and slightly branched at the base. In eastern Kansas the incorrect name English bluegrass is sometimes applied to this species.

For a revision of the species of Festuca found in North America, see Piper, Contr. U. S. Nat. Herb. **10**:1–48, pl. 1–15. 1906.

Scleropoa Griseb., Spicil. Fl. Rumel. **2**:431. 1844.

The one species, *Scleropoa rigida* (L.) Griseb., a native of southern Europe, is sparingly introduced in the United States, mostly as a ballast plant. It is a low annual with racemes of spikelets resembling those of Puccinellia. The glumes are 1-nerved, the lemmas convex on the back and obscurely nerved. The type is *Poa rigida* L.

Brachypodium Beauv., Ess. Agrost. 100, 155. 1812.

One species, *Brachypodium distachyon* (L.) Beauv., of Europe, has been found on ballast at Portland, Oreg., and Camden, N. J. It is a low tufted annual, with stiff culms ending in a raceme of 1 to few short-pediceled, many-flowered cylindric spikelets, the awned lemmas rounded on the back, the paleas stiffly ciliate on the keels.

4. Panicularia Heister.
(*Glyceria* R. Br.)

Spikelets few to many flowered, subterete or slightly compressed, the rachilla disarticulating above the glumes and between the florets; glumes unequal, short, obtuse or acute, usually scarious, mostly 1-nerved; lemmas broad, convex on the back, firm, usually obtuse, awnless, scarious at the apex, 5 to 9 nerved, the nerves parallel, usually prominent.

Usually tall aquatic or marsh grasses, with flat blades, closed or partly closed sheaths, and open or contracted panicles. Species about 35, in the temperate regions of both hemispheres; 16 species in the United States.

Type species: *Poa aquatica* L.

Panicularia Heister; Fabr., Enum. Pl. Hort. Helmst., ed. 2, 373. 1763. The genus is based on the species that Linnæus named *Poa aquatica*.

Festucaria Heister; Fabr., Enum. Pl. Hort. Helmst., ed. 2, 374. The genus is based on the species that Linnæus named *Festuca fluitans*.

Glyceria R. Br., Prodr. Fl. Nov. Holl. 179. 1810. Based on *Festuca fluitans* L.

Nevroloma Raf., Journ. de Phys. **89**: 106. 1819. "Type, le Briza canadensis de Michaux." This is *Panicularia canadensis*.

Our species are divided into two rather well marked groups. One group, consisting of five species, has linear spikelets usually as much as 1 cm. long. These species are represented by *Panicularia fluitans*, the type of Festucaria and Glyceria. The group to which *P. aquatica* belongs has ovate or oblong spikelets usually not over 5 mm. long.

The commonest species is *Panicularia nervata* (Willd.) Kuntze (fig. 8), with small prominently 7-nerved spikelets in open panicles. *Panicularia canadensis* (Michx.) Kuntze has larger less prominently

FIG. 8.—Manna grass, *Panicularia nervata*. Plant, × ½; spikelet and floret, × 5.

nerved spikelets. *Panicularia grandis* (S. Wats.) Nash has very large panicles of oblong spikelets, the lemmas prominently 7-nerved. *Panicularia pauciflora* (Presl) Kuntze, found in the western mountains, has 5-nerved lemmas and rather small panicles.

The species are sometimes called manna grass and fowl meadow grass. They are all excellent forage grasses, but usually form no very important part of the grazing because they are limited to swampy regions. Hydrocyanic acid has been found in *Panicularia nervata*, and some cases of cattle poisoning have been ascribed to it.[1]

5. Pleuropogon R. Br.

Spikelets several to many flowered, linear, the rachilla disarticulating above the glumes and between the florets; glumes unequal, membranaceous or subhyaline, scarious at the somewhat lacerate tip, the first 1-nerved, the second obscurely 3-nerved; lemmas membranaceous, 7-nerved, with a round indurate callus at base, the apex entire or 2-toothed, the midnerve extending into a short mucro or into an awn; palea 2-keeled, the keels winged on the lower half.

Soft annuals or perennials, with flat blades and loose racemes of rather large spikelets. Species three, one in the arctic region and two on the Pacific coast of the United States.

Type species: *Pleuropogon sabinii* R. Br.

Pleuropogon R. Br., Suppl. App. Parry's Voy. 189, pl. D. 1823. A single species described and figured.

Lophochlaena Nees, in Taylor, Ann. Nat. Hist. 1: 283. 1838. Type *L. californica*, the only species described.

Our species are found in bogs and wet meadows. One, *Pleuropogon californicus* (Nees) Benth. (fig. 9), an annual with ascending spikelets, is confined to California. The other, *P. refractus* (Gray) Benth., a perennial with drooping spikelets, is found from northern California to Washington. They are palatable grasses, but occur too infrequently to be of economic value.

6. Puccinellia Parl.

Spikelets several-flowered, usually terete or only slightly flattened, the rachilla disarticulating above the glumes and between the florets; glumes unequal, shorter than the first lemma, obtuse or acute, rather firm, often scarious at the tip, the first 1-nerved or sometimes 3-nerved, the second 3-nerved; lemmas usually firm, rounded on the back, obtuse or acute, rarely acuminate, usually scarious and often erose at the tip, glabrous or puberulent toward the base, 5-nerved, the nerves parallel, obscure or indistinct, rarely rather prominent; palea about as long as the lemma or somewhat shorter.

Annual, or usually perennial, low pale smooth cespitose grasses, with narrow or open panicles. Species about 25, mostly along coasts

[1] Alsberg and Black. Journ. Biol. Chem. 21: 601. 1915.

FIG. 9.—*Pleuropogon californicus.* Plant, × ½; spikelet, × 3; floret, × 5.

and on interior alkali soil of the cool and arctic regions of the Northern Hemisphere; about 12 species in the United States, on the Atlantic coast south to Delaware, on the Pacific coast south to Point Reyes, and in the western interior south to New Mexico.

Type species: *Poa distans* L.

Puccinellia Parl., Fl. Ital. 1: 366. 1848. Parlatore describes 4 species, *P. distans* (L.) Parl., *P. festucaeformis* (Host) Parl., *P. gussonii* Parl., and *P. maritima* (Huds.) Parl. The first is selected as the type.

Atropis Rupr., in Griseb. in Ledeb. Fl. Ross. 4: 388. 1853. Based upon Poa, section Atropis Rupr.,[1] of which the type and only species is *Poa distans* L.

Puccinellia differs from Poa in the rounded lemmas with indistinct and parallel nerves. The species are mostly confined to the brackish marshes of the coast. One species, *Puccinellia nuttalliana* (Schult.) Hitchc. (*P. airoides* (Nutt.) Wats. and Coult.) (fig. 10), is common in alkaline soils of the interior from Minnesota to Washington and south to New Mexico. This species furnishes considerable forage where it is common.

7. Fluminea Fries.
(*Scolochloa* Link.)

Spikelets 3 to 4 flowered, the rachilla disarticulating above the glumes and between the florets; glumes nearly equal, somewhat scarious and lacerate at summit, the first 3-nerved, the second 5-nerved, about as long as the first lemma; lemmas firm, rounded on the back, villous on the callus, 7-nerved, the nerves rather faint and unequal, extending into a scarious lacerate apex; palea narrow, flat, about as long as the lemma.

Tall perennials, with succulent rhizomes, flat blades, and spreading panicles. Species two, one in eastern Siberia, the other in northern Eurasia and northern North America, extending south to Iowa.

Type species: *Festuca borealis* Mert. and Koch.

Scolochloa Link, Hort. Berol. 1: 136, 1827, not Scolochloa Mert. and Koch. 1823. Based on *Arundo festucacea* Willd. (*Scolochloa festucacea* Link), the only species described. Scolochloa Mert. and Koch is based on *Arundo donax* L.

Fluminea Fries, Summa Veg. Scand. 247. 1846. Based on *Festuca borealis*. A single species is included, its name being given as "*Festuca borealis* or *Fluminea arundinacea*." This is the same as *Scolochloa festucacea*.

Our single species, *Fluminea festucacea* (Willd.) Hitchc. (*Arundo festucacea* Willd., *Graphephorum festucaceum* Gray, *Scolochloa festucacea* (Willd.) Link) (fig. 11), is a marsh grass found from Iowa and Minnesota northward. It has some value for forage and is often a constituent of marsh hay.

8. Poa L., the bluegrasses.

Spikelets 2 to several flowered, the rachilla disarticulating above the glumes and between the florets, the uppermost floret reduced or rudimentary; glumes acute, keeled, somewhat unequal, the first

[1] Beitr. Pflanzenk. Russ. Reich. 2: 61. 1845 (Fl. Samoj. Cis.).

FIG. 10.—*Puccinellia nuttalliana*. Plant, × ½; spikelet and floret, × 5.

FIG. 11.—*Fluminea festucacea.* Plant, × ½; spikelet and floret, × 5.

1-nerved, the second usually 3-nerved; lemmas somewhat keeled, acute or acutish, awnless, membranaceous, often somewhat scarious at the tip, 5-nerved, the nerves sometimes pubescent.

Annual, or usually perennial, species of low or rather tall grasses, with spikelets in open or contracted panicles, the narrow blades flat or folded, ending in a navicular point. Species probably over 200, in the temperate and cool regions; about 90 in the United States, being especially numerous in the western mountains.

Type species: *Poa pratensis* L.

Poa L., Sp. Pl. 67, 1753; Gen. Pl., ed. 5, 31. 1754. Linnæus describes 17 species, 8 of which are still retained in the genus. *Poa pratensis* is chosen as the type because it is an important economic species and because it is among the species described under Poa in the Flora Lapponica. The first of the original species, *P. aquatica*, is now referred to Panicularia; *P. flava* to Triodia; *P. pilosa, P. amabilis, P. eragrostis, P. capillaris*, and *P. tenella* to Eragrostis; *P. malabarica* to Centotheca; *P. chinensis* to Leptochloa.

Paneion Lunell, Amer. Midl. Nat. 4: 221. 1915. Proposed for Poa L., the word poa being a Greek common noun, meaning herb, the author regarding it "unfit as [a] generic name."

The base of the lemma sometimes bears a tuft of loose cottony hairs. A group of western species, including *Poa scabrella* (Thurb.) Benth. of California (fig. 12), *P. nevadensis* Vasey of the Great Basin, and *P. sandbergii* Vasey of the northern Rocky Mountain region, have narrow, nearly terete spikelets, in narrow panicles, the lemmas rounded on the back, glabrous, scabrous or minutely pubescent below. Several species, such as mutton grass (*P. fendleriana* (Steud.) Vasey) and its allies, *P. douglasii* Nees, and *P. arachnifera* Torr., are diœcious. A few species, such as *P. annua* L., *P. bigelovii* Vasey and Scribn. of Arizona, *P. howellii* Vasey and Scribn., and *P. bolanderi* Vasey of California, are annual. Some of the perennial species, such as *P. scabrella*, are bunch grasses, and some like *P. pratensis* and *P. compressa* produce creeping rhizomes. *Poa macrantha* Vasey, a diœcious sand-dune grass of Oregon, has spikelets as much as half an inch long.

The bluegrasses are of great importance because of their forage value, some species being cultivated for pasture and others forming a large part of the forage on the mountain meadows of the West.

The most important species of the genus is *Poa pratensis* L. (Pl. III; fig. 13) commonly known as Kentucky bluegrass, or simply bluegrass. This is a smooth perennial, with creeping rhizomes, erect culms 1 to 3 feet high, soft flat or folded blades and open pyramidal panicles 2 to 4 inches long, the lower branches in a whorl of usually 5, the spikelets mostly 4 to 6 flowered, the florets cobwebby at base, the keel and marginal nerves villous. Bluegrass is a native of Europe, but is widely naturalized in the cooler parts of this country and is cultivated for pasture and for lawns. It is the standard pasture grass in the humid regions of the United States where the soil contains plenty of lime.

FIG. 12.—*Poa scabrella.* Plant, × ½; spikelet and floret, × 5.

KENTUCKY BLUEGRASS (POA PRATENSIS).

CANADA BLUEGRASS (POA COMPRESSA) IN FLOWER.

ANNUAL BLUEGRASS (POA ANNUA).

UNIOLA LATIFOLIA.

A tuft removed from the near-by woods and photographed in the open. A native species worthy of cultivation for ornament.

Fig. 13.—Bluegrass, *Poa pratensis*. Plant, × ½; spikelet and floret, × 5.

The name Kentucky bluegrass has been used because in Kentucky the bluegrass pastures have been a prominent feature of the agriculture of the State. In the northern portion of its range it is usually called June-grass. Bluegrass flourishes as far west as eastern Nebraska and as far south as Virginia and in the mountains to northern Alabama. In the valleys of the western mountains and in the humid region of the Pacific coast, from northern California to British Columbia, bluegrass is the common pasture grass. In the regions where bluegrass is used for pasture it is the standard lawn grass. By liming the soil and by artificial watering bluegrass may be grown for lawns beyond the limits outlined above, but it can not be made to thrive in the warmer parts of the Southern States or in the arid regions of the Southwest.

Poa compressa L. (Pl. IV), cultivated under the name of Canada bluegrass, is of some commercial importance, being grown in the region that is adapted to the growth of Kentucky bluegrass, but it is used chiefly on sterile sandy or clay soils where the latter species does not thrive. Canada bluegrass differs from Kentucky bluegrass in its blue-green color, distinctly compressed stems, and narrow less-branched panicles. It produces abundant rhizomes that throw up numerous scattered stems, mostly 6 to 15 inches tall, these being usually solitary rather than tufted. On account of its wiry, compressed stems it is called in some localities wire-grass and flat-stem.

Two other species of Poa occasionally grown but of little agricultural importance are *Poa trivialis* L., rough-stalked meadow grass, a species lacking rhizomes, but resembling *P. pratensis* in its panicle, distinguished easily by its backwardly roughened sheaths; and *Poa palustris* L. (*P. triflora* Gilib., *P. serotina* Ehrh.) known to seedsmen as fowl meadow grass, a smooth, rather tall, tufted grass, differing from bluegrass in the absence of rhizomes, in the larger more open panicle, and in the smaller, 2 to 4 flowered spikelets.

Poa arachnifera Torr., Texas bluegrass, has been used in some of the Southern States as a winter pasture grass and as a lawn grass. It is an erect diœcious grass, 1 to 2 feet high, with strong rhizomes and narrow panicles, 2 to 4 inches long, the staminate spikelets glabrous, the pistillate spikelets with a copious tuft of woolly hairs at the base of the florets. Texas bluegrass is a native of Oklahoma and Texas.

Poa annua L., annual bluegrass (Pl. V), is a low, soft, light-green, annual grass that is frequently found as a weed in lawns and gardens. It thrives in the spring or even in the winter in southerly regions, forming fine light-green patches, which die out later in the season, leaving unsightly spots. *Poa annua* is a native of Europe, but is widely introduced in America.

Several species are important range grasses. Malpais bluegrass (*Poa scabrella*), a bunch grass, with slightly roughened sheaths and narrow panicles of cylindric spikelets, the lemmas pubescent below, is common at lower altitudes in California. Mutton grass (*P. fendleriana*) is important in the Southwest. Little bluegrass (*P. sandbergii*), differing from malpais bluegrass in having smooth sheaths, is common at medium altitudes (2,000 to 8,000 feet) throughout the Northwest.

9. BRIZA L., the quaking grasses.

Spikelets several-flowered, broad, often cordate, the florets crowded and spreading horizontally, the rachilla glabrous, disarticulating above the glumes and between the florets, the uppermost floret reduced; glumes about equal, broad, papery-chartaceous, with scarious margins; lemmas papery, broad, with scarious, spreading margins, cordate at base, several-nerved, the nerves often obscure, the apex in our species obtuse or acutish; palea much shorter than the lemma.

Annual or perennial, low grasses, with erect culms, flat blades, and usually open, showy panicles, the pedicels in our species capillary, allowing the spikelets to vibrate in the wind. Species about 20, the greater number South American. The three species found in the United States are introductions from Europe and occur here as occasional weeds in waste places.

Type species: *Briza media* L.

Briza L., Sp. Pl. 70, 1753; Gen. Pl., ed. 5, 32. 1754. Linnæus describes 4 species, *B. minor*, *B. media*, *B. maxima*, and *B. eragrostis*. The first three were familiar to Linnæus as cultivated plants in the Hortus Cliffortianus, and the second, which is selected as the type species, was described in his flora of Sweden. The first three species are now retained in Briza, the last is referred to Eragrostis.

Of the three species found in this country, one, *Briza media* (fig. 14), is perennial, and two, *B. minor* and *B. maxima*, are annual. The spikelets of *B. maxima*, a species sometimes cultivated for ornament under the name quaking grass, are large and showy, half an inch long, drooping on slender pedicels. *Briza minor*, with smaller upright spikelets, is rather common on the Pacific coast.

10. ERAGROSTIS Host.

Spikelets few to many flowered, the florets usually closely imbricate, the rachilla disarticulating above the glumes and between the florets, or continuous, the lemmas deciduous, the paleas persistent; glumes somewhat unequal, shorter than the first lemma, acute or acuminate, 1-nerved, or the second rarely 3-nerved; lemmas acute or acuminate, keeled or rounded on the back, 3-nerved, the nerves usually prominent; palea 2-nerved, the keels sometimes ciliate.

Annual or perennial grasses of various habit, the inflorescence an open or contracted panicle. Species more than 100, tropical and temperate regions; 33 species in the United States, in all except the cool or mountain regions.

Type species: *Briza eragrostis* L.

Eragrostis Host, Gram. Austr. **4**: 14, pl. 24. 1809. One species is described, but no generic description is given. The genus Eragrostis was first diagnosed by Beauvois,[1] the type being *Eragrostis eragrostis*, based on *Poa eragrostis* L.

Erochloë Raf., Neogenyt. 4, 1825; Bull. Bot. Seringe **1**: 221. 1830. Rafinesque first proposed the name in 1825 but mentioned no species. In 1830 he gives the name to "Poa spectabilis seu amabilis," (*Eragrostis pectinacea* and *E. amabilis*, respectively, not the same species, as Rafinesque implies).

Acamptoclados Nash, in Small, Fl. Southeast. U. S. 139. 1903. The type, indicated on page 1327, is *Eragrostis sessilispica* Buckl., the only species described. The genus is placed in Chlorideæ on account of the sessile spikelets distant along the panicle branches.

Neeragrostis Bush, Trans. Acad. St. Louis **13**: 178. 1903. The type species is indicated, *Poa weigeltiana* Reichenb. The genus includes also *N. hypnoides* (*Eragrostis hypnoides*).

Erosion Lunell, Amer. Midl. Nat. **4**: 221. 1915. Proposed for "Eragrostis Beauv. . . . The name to be avoided, as built on another grass name."

FIG. 14.—Quaking grass, *Briza media*. Plant, × ½; spikelet and floret, × 5.

In many species the rachilla is continuous and does not disarticulate as in most species of the tribe Festuceae. The grain is free and falls with the lemma, leaving the palea upon the rachilla. To this group

[1] Ess. Agrost. 70, pl. 14, f. 11. 1812.

belong two common annual weeds, *Eragrostis cilianensis* (All.) Link (*E. megastachya* (Koel.) Link, *E. major* Host), a disagreeable smelling grass (fig. 15) with rather compact panicles of large spikelets (3 mm. wide), the keels of the lemmas glandular dotted, and *E. caroliniana* (Spreng.) Scribn., with open panicles of small spikelets (about 1.5 mm. wide).

Eragrostis pectinacea (Michx.) Nees (fig. 16) is a perennial with handsome purple open panicles, which at maturity separate from the plant and tumble before the wind.

Eragrostis hypnoides (Lam.) B. S. P. is a spreading diœcious annual found on sandy river banks. *Eragrostis ciliaris* (L.) Link (fig. 17) and *E. amabilis* (L.) Wight and Arn. (*E. plumosa* Link) are tropical annuals that extend into the Gulf States. They have conspicuously ciliate paleas and disarticulating rachilla. A common perennial species in sandy soil from Kansas to Texas is *E. secundiflora* Presl (*E. oxylepis* Torr.) with contracted purple panicles, the rachilla disarticulating and the florets falling separately.

In general, the species of Eragrostis have little forage value.

11. Catabrosa Beauv.

Spikelets mostly 2-flowered, the florets somewhat distant, the rachilla disarticulating above the glumes and between the florets; glumes unequal, shorter than the lower floret, flat, nerveless, irregularly toothed at the broad truncate apex; lemmas broad, prominently 3-nerved, the nerves parallel, the broad apex scarious; palea about as long as the lemma, broad, scarious at the apex.

Aquatic perennials, with creeping bases, flat soft blades, and open panicles. Species seven, in northern Eurasia and North America, extending south to New Brunswick and Colorado; one in Chile.

Type species: *Aira aquatica* L.

Catabrosa Beauv., Ess. Agrost. 97, pl. 19, f. 8. 1812. The species illustrated is *C. aquatica*. Another name mentioned is a nomen nudum.

Catabrosa aquatica (L.) Beauv. (fig. 18) is found in mountain meadows around springs and watercourses. It is an unimportant forage grass.

12. Molinia Schrank.

Spikelets 2 to 4 flowered, the florets distant, the rachilla disarticulating above the glumes, slender, prolonged beyond the upper floret, and bearing a rudimentary floret; glumes somewhat unequal, acute, shorter than the first lemma, 1-nerved; lemmas membranaceous, narrowed to an obtuse point, 3-nerved; palea bowed out below, equaling or slightly exceeding the lemma.

FIG. 15.—Stink-grass, *Eragrostis cilianensis.* Plant, × ½; spikelet and floret, × 5.

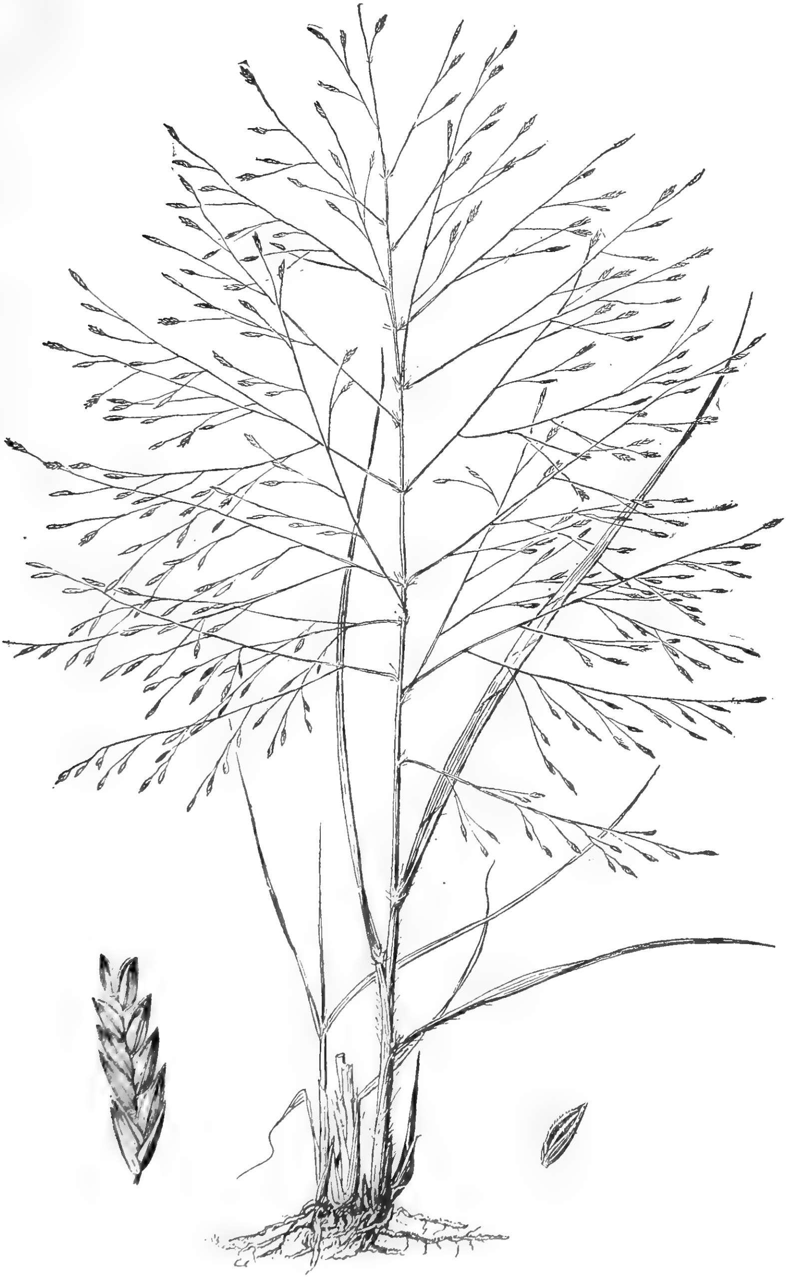

FIG. 16.—Love-grass, *Eragrostis pectinacea*. Plant, × ½; spikelet and floret, × 5.

Slender tufted perennials, with flat blades and narrow, rather open panicles. Species five, Europe and Asia; one sparingly introduced in the United States.

FIG. 17.—*Eragrostis ciliaris.* Plant, × ½; spikelet and floret, × 5.

Type species: *Aira caerulea* L.
Molinia Schrank, Baier. Fl. 1: 336. 1789. A single species described, *M. varia*, of which *Aira caerulea* L. is given as a synonym.

Molinia caerulea (L.) Moench (fig. 19) is introduced in a few localities in the Eastern States from New England to Pennsylvania. In Europe this is considered to be a good forage grass. A form with striped leaves is cultivated for ornament, being used for borders.

13. DIARINA Raf.

Spikelets few-flowered, the rachilla disarticulating above the glumes and between the florets; glumes unequal, acute, shorter than the lemmas, the first 1-nerved, the second 3 to 5 nerved; lemmas chartaceous, pointed, 3-nerved, the nerves converging in the point, the upper floret reduced; palea chartaceous, 2-nerved, obtuse, at maturity the lemma and palea widely spread by the large turgid beaked caryopsis with hard shining pericarp.

Perennials, with slender rhizomes, broadly linear, flat blades, long-tapering below, and narrow, few-flowered panicles. Species two, one in eastern Asia and one in the eastern United States.

Type species: *Festuca diandra* Michx.

Diarina Raf., Med. Repos. **5**: 352. 1808. Rafinesque bases a new genus on *Festuca diandra* Michx. (not Moench, 1794). He renames the species *D. festucoides*. Beauvois[1] spells the name Diarrhena, crediting it to "Shmal" [Rafinesque-Schmalz] and renames the single species *D. americana*.

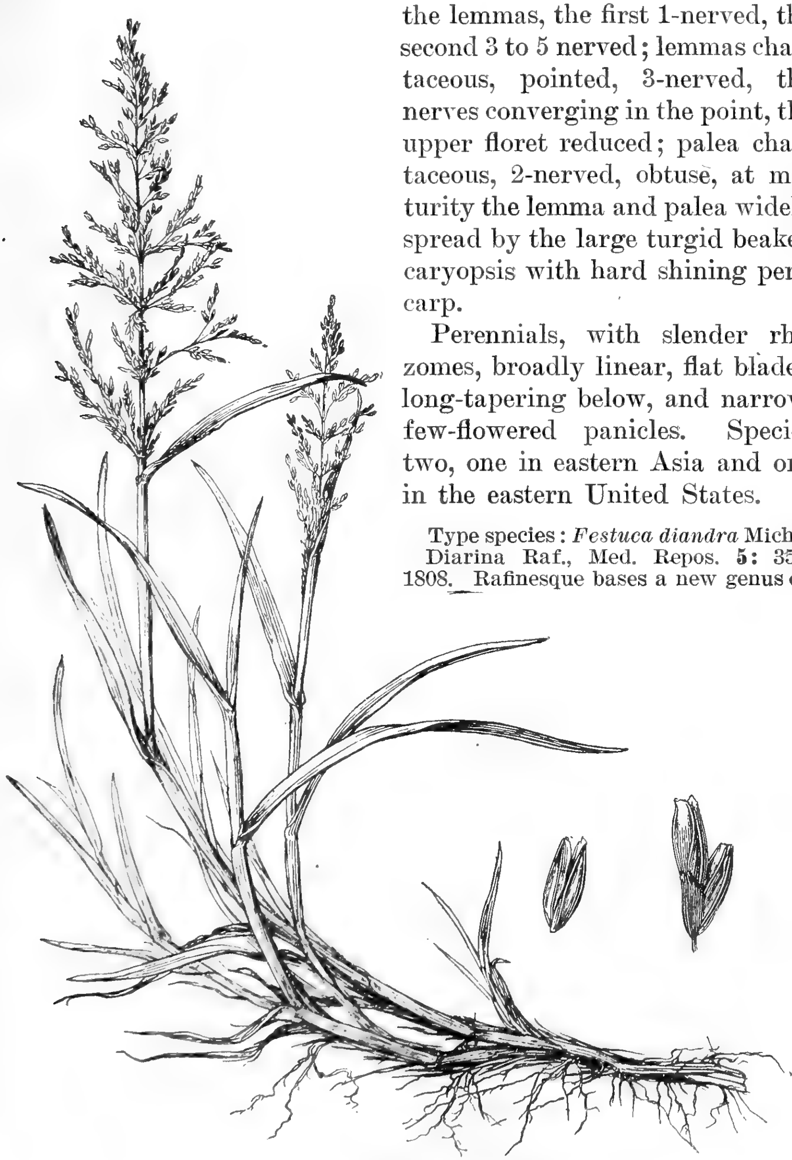

FIG. 18.—*Catabrosa aquatica*. Plant, × ½; spikelet and floret, × 5.

[1] Ess. Agrost. 142, pl. 25, f. 1. 1812.

Korycarpus Zea; Lag., Gen. and Sp. Nov. 4. 1816. The only species described is *K. arundinaceus* Zea, which is the same as *Diarina festucoides*. Lagasca cites the reference "Ac. Matr. 1806," but there seems to be no evidence that the name Korycarpus was published earlier than 1816.

Our single species, *Diarina festucoides* Raf. (fig. 20), is found in rich woods through the eastern United States. It is of little importance as a forage grass.

14. DISSANTHELIUM Trin.

Spikelets mostly 2-flowered, the rachilla slender, disarticulating above the glumes and between the florets; glumes firm, nearly equal, acuminate, much longer than the lower floret, mostly exceeding all

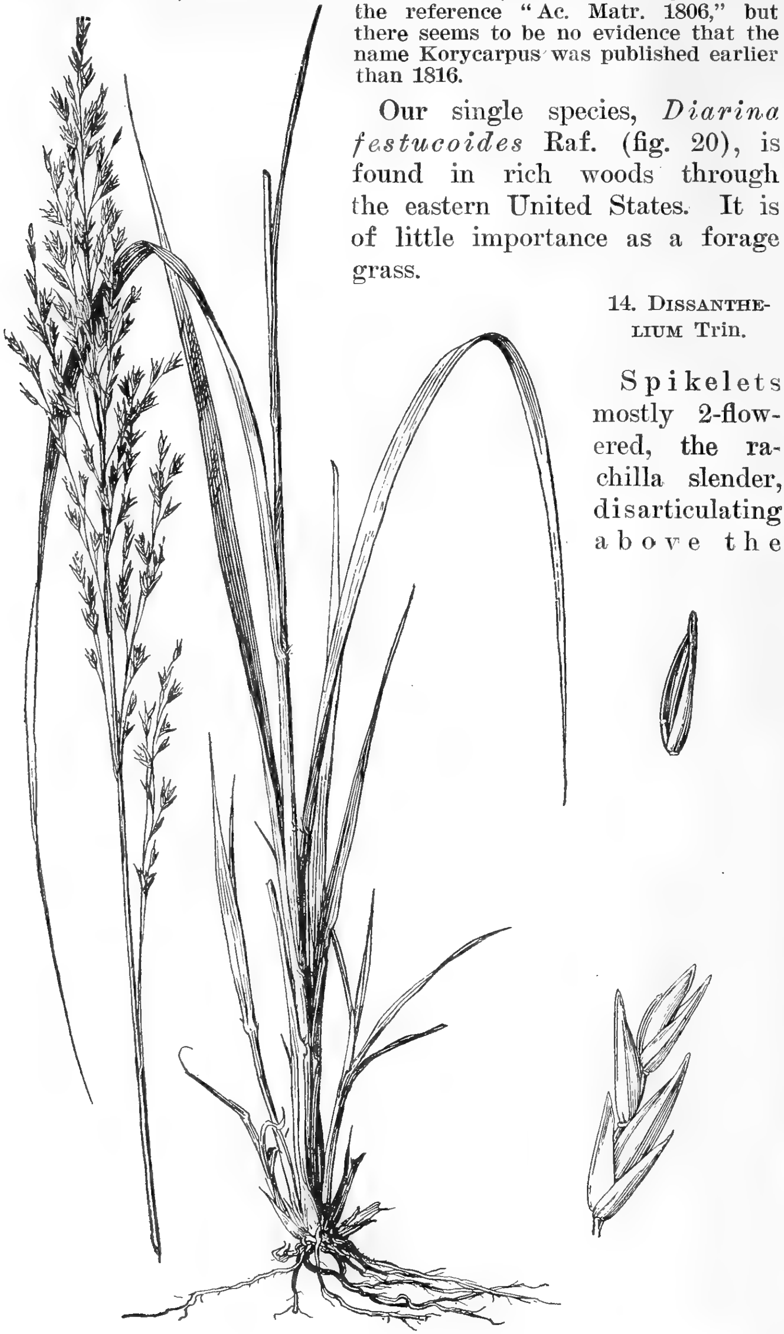

FIG. 19.—*Molinia caerulea*. Plant, × ½; spikelet and floret, × 5.

the florets, the first 1-nerved, the second 3-nerved; lemmas strongly compressed, oval or elliptic, acute, awnless, 3-nerved, the lateral nerves near the margin; palea somewhat shorter than the lemma.

Annual or perennial grasses, with narrow panicles. Species two, one in Mexico and South America, the other in California.

FIG. 20.—*Diarina festucoides*. Plant, × ½; spikelet and floret, × 5.

Type species: *Dissanthelium supinum* Trin.
Dissanthelium Trin., Linnæa **10**: 305. 1836. One species described.
Stenochloa Nutt., Journ. Acad. Phila. II. **1**: 189. 1848. One species described, *S. californica*.

Our Californian species, *Dissanthelium californicum* (Nutt.) Benth. (fig. 21), is an annual with flat blades and a narrow somewhat open panicle. It is a rather rare species found in southern California and the islands off the coast and has no economic value.

FIG. 21.—*Dissanthelium californicum*. Plant, × ½; spikelet and floret, × 5.

The second species of the genus is *Dissanthelium supinum* Trin., a low tufted perennial, with narrow, folded or convolute blades and short, densely flowered panicles. This is found on alpine summits in Mexico, Bolivia, and Peru. It has been called *Deschampsia matthewsii* Ball and *Dissanthelium sclerochloides* Fourn.

15. REDFIELDIA Vasey.

Spikelets compressed, few-flowered, mostly 3 or 4 flowered, the rachilla disarticulating above the glumes and between the florets; glumes somewhat unequal, 1-nerved, acuminate; lemma chartaceous, 3-nerved, the nerves parallel, densely villous at base; palea as long as the lemma; grain free.

A rather tall perennial, with rhizomes and a large panicle with diffuse capillary branches. Species one; sand hills of the Great Plains.

Type species: *Graphephorum flexuosum* Thurb.
Redfieldia Vasey, Bull. Torrey Club **14**: 133. 1887. One species described, *R. flexuosa* (Thurb.) Vasey.

FIG. 22.—*Redfieldia flexuosa.* Plant, × ½; spikelet and floret, × 5.

Redfieldia flexuosa (fig. 22) is a gregarious sand-hill grass, one of the few species found growing in the drifting sand, which it tends to hold in place with its numerous creeping rhizomes. The species is found from South Dakota to Kansas. It has little value for forage but much value as a sand binder.

16. Monanthochloë Engelm.

Plants diœcious; spikelets 3 to 5 flowered, the uppermost florets rudimentary, the rachilla disarticulating tardily in pistillate spikelets; glumes wanting; lemmas rounded on the back, convolute, narrowed above, several-nerved, those of the pistillate spikelets like the blades in texture; palea narrow, 2-nerved, in the pistillate spikelets convolute around the pistil, the rudimentary uppermost floret inclosed between the keels of the floret next below.

A creeping wiry perennial, with clustered short subulate leaves, the spikelets at the ends of the short branches only a little exceeding the leaves. Species two, one on muddy shores of the ocean in tropical America, one in Argentina.

Type species: *Monanthochloë littoralis* Engelm.

Monanthochloë Engelm., Trans. Acad. St. Louis 1: 1436. 1859. Only one species described.

Monanthochloë littoralis (fig. 23) is found within our limits only in southern Florida, southern Texas, and southern California, on tidal flats, sometimes covering extensive areas. Owing to the inconspicuousness of the spikelets, the flowering stage can be determined only on close examination. The species has no economic importance except as it tends to convert mud flats into permanent soil.

The leaves next the spikelet are reduced, but always present a short though well-marked blade or foliaceous tip with a distinct ligule. The branches bearing the spikelets are short and clustered. The uppermost leaf, the one nearest the spikelet, usually has no bud or branch in its axil. The leaf next below bears a bud or short branch and a well-developed prophyllum. The prophylla of branches somewhat lower may be as large as the sheath of the leaf, and the two nerves may extend into prominent foliaceous tips. As the branch develops, the prophyllum usually splits down the middle and the two halves stand one on each side. The uppermost leaf sometimes has in its axil a thin membranaceous nerveless obtuse bract which clasps the spikelets like a second (upper) glume, but probably this is to be interpreted as a prophyllum, subtending a branch which failed to develop.

17. Distichlis Raf.

Plants diœcious; spikelets several to many flowered, the rachilla of the pistillate spikelets disarticulating above the glumes and between the florets; glumes unequal, broad, acute, keeled, mostly

3-nerved, the lateral nerves sometimes faint or obscured by striations and intermediate nerves; lemmas closely imbricate, firm, the pistillate coriaceous, the margins bowed out near the base, acute or

Fig. 23.—*Monanthochloë littoralis.* Plant, × ½; pistillate spikelet and floret, × 5.

acutish, 3-nerved, with several intermediate nerves or striations; palea as long as the lemma or shorter, the pistillate coriaceous, inclosing the grain.

Low perennials, with extensively creeping scaly rhizomes, erect, rather rigid stems, and short, dense, rather few-flowered panicles. Species about six, in salt marshes of the coast and interior in America, one extending to Australia; three species in the United States, one widely distributed and two confined to Texas and northern Mexico.

Type species: *Uniola spicata* L.

Distichlis Raf., Journ. de Phys. **89**: 104. 1819. *Distichlis maritima* is indicated as the type by Rafinesque, who gives *Uniola spicata* L. as a synonym.

Brizopyrum Presl, Rel. Haenk. **1**: 280. 1830. Presl describes five species, of which the first two belong to Distichlis. None is figured. The first species, *B. boreale* (*Distichlis spicata*), is selected as the type.

The common species, *Distichlis spicata* (L.) Greene (fig. 24), is found along both coasts and in salt or alkali spots in the interior, and extends southward to South America and to Australia. It is an erect, gregarious grass usually not more than a foot high, with pale spikelets, the staminate having a softer texture than the pistillate. The common name is salt or alkali grass, though these names are sometimes applied to other species. In general it has little value for forage but in the interior basins, such as the vicinity of Salt Lake, it is utilized for grazing when better grasses are not available. The large amount of salt or alkali may cause digestive disturbances. This species is variable, and two forms have been distinguished as species, *D. stricta* (Torr.) Rydb. and *D. dentata* Rydb., both from the Western States.

The two species of the Southwest are not well known. *Distichlis texana* (Vasey) Scribn., a larger grass than *D. spicata*, with less compressed spikelets and a long, narrow, loose panicle, is found from Texas to Durango. *Distichlis multinervosa* (Vasey) Piper is an anomalous species from western Texas known only from the type collection. It differs in having a villous rachilla and 7-nerved membranaceous lemmas, rounded on the back and villous on the lower part, and in the 2-lobed palea.

18. Uniola L.

Spikelets 3 to many flowered, the lower one to four lemmas empty, the rachilla disarticulating above the glumes and between the florets; glumes compressed-keeled, rigid, usually narrow, nerved, acute or acuminate, or rarely mucronate; lemmas compressed, sometimes conspicuously flattened, chartaceous, many-nerved, the nerves sometimes obscure, acute or acuminate, the empty ones at the base usually successively smaller, the uppermost usually reduced; palea rigid, sometimes bowed out in the winged keels.

Perennial, rather tall, erect grasses, with flat or sometimes convolute blades and narrow or open panicles of compressed, sometimes very broad and flat spikelets. Species nine, all North American.

six being represented in the United States, these inhabiting the Southeastern States, some species extending as far north as Long Island and as far west as Kansas and Texas.

FIG. 24.—Salt-grass, *Distichlis spicata*. Staminate plant and a pistillate panicle, × ½; pistillate spikelet and floret, × 5.

Type species: *Uniola paniculata* L.

Uniola L., Sp. Pl. 71, 1753; Gen. Pl., ed. 5, 32. 1754. Linnæus describes two species, *U. paniculata* and *U. spicata*. The first species is selected as the type. The second is now referred to Distichlis.

Trisiola Raf., Fl. Ludov. 144. 1817. A single species, *T. paniculata*, based on *Uniola paniculata* L., is included.

Nevroctola Raf., Neogenyt. 4. 1825. "Type Uniola maritima or paniculata." *Uniola maritima* Michx. is *U. paniculata* L.

Chasmanthium Link, Hort. Berol. **1**: 159. 1829. A single species, *C. gracile*, based on *Uniola gracilis* Michx., is included. This is the same as *U. laxa* (L.) B. S. P.

Uniola paniculata, seaside oats, common on the coastal sand dunes from Virginia to Texas, is a stout, pale grass, with extensively creeping rhizomes, long-attenuate, firm blades, and large, drooping, heavy, rather compact panicles of large, flat, stramineous spikelets. It is an excellent sand binder. *Uniola latifolia* Michx. (Pl. VI; fig. 25) is a woodland grass with broad flat blades and handsome, open, drooping, rather few-flowered panicles of large, very flat green spikelets. The species is worthy of use in landscape gardening. This and the remaining species of Uniola are of minor importance as forage grasses, as they are not sufficiently abundant. The seeds of *U. palmeri* Vasey are used for food by the Cocopa Indians.

19. ARUNDO L.

Spikelets several-flowered, the florets successively smaller, the summits of all about equal, the rachilla glabrous, disarticulating above the glumes and between the florets; glumes somewhat unequal, membranaceous, 3-nerved, narrow, tapering into a slender point, about as long as the spikelet; lemmas thin, 3-nerved, densely long-pilose, gradually narrowed at the summit, the nerves ending in slender teeth, the middle one longer, extending into a straight awn.

Tall perennial reeds, with broad linear blades and large plumelike terminal panicles. Species about six, in the warmer parts of the Old World; one introduced in America.

Type species: *Arundo donax* L.

Arundo L., Sp. Pl. 81, 1753; Gen. Pl., ed. 5, 35. 1754. Linnæus describes six *C*) represents the spikelets of *Arundo donax*, which is fully described on page Genera Plantarum is "Scheuch. **3**: 14, 3." Scheuchzer's figure 14 (*A*, *B*, and *C*) represents the spikelets of *Arundo donax*, which is fully described on page 159 of Scheuchzer's work, Agrostographia. Hence, *Arundo donax*, the second species described by Linnæus, is the type species of the genus. The other original species are now referred as follows: *A. bambos* to Bambos, *A. phragmites* to Phragmites, *A. epigejos* and *A. calamagrostis* to Calamagrostis, *A. arenaria* to Ammophila.

Arundo donax, the giant reed (Pl. VII; fig. 26), is cultivated as an ornamental grass for lawn groups or borders. In tropical America it is frequently used for hedges, and the stems are utilized for a variety of purposes, such as the making of lattices in the construction of huts. The giant reed has become naturalized in the Southwestern States and sometimes forms a dense growth along irrigation ditches. There is a cultivated ornamental variety with white-striped blades (*A. donax versicolor* (Mill.) Kunth). This was mentioned in Miller's Gardener's Dictionary in 1768 as *Arundo versicolor*.

GIANT REED (ARUNDO DONAX). CULTIVATED FOR ORNAMENT.

ORCHARD GRASS (DACTYLIS GLOMERATA) IN FLOWER.

FIG. 25.—*Uniola latifolia.* Plant, × ½; spikelet and floret, × 3.

FIG. 26.—Giant reed, *Arundo donax*. Rhizome, leaves, and panicle, × ⅓; spikelet and floret, × 3.

The giant reed is one of the largest of the herbaceous grasses, its stem being as much as 20 feet tall. Ordinarily it grows in cultivation to a height of 6 to 10 feet. The rhizome is thick and knotty. The blades are flat, 2 to 3 inches broad (smaller on the branches), and distributed rather equally along the culm, the distichous arrangement being conspicuous. The handsome feathery panicle is 1 to 2 feet long, the spikelets being about one-half inch long. In the Southwest this is sometimes called by the Mexican name carrizo. The stems of the giant reed are used for making clarionet and organ-pipe reeds.

Two large cultivated grasses or reeds allied to Arundo are Gynerium and Cortaderia.

Gynerium Humb. and Bonpl., Pl. Aequin. **2:** 105, pl. 115. 1809. The single species described and figured is *G. saccharoides* Humb. and Bonpl. This species, now called *G. sagittatum* (Aubl.) Beauv., is a giant diœcious grass as much as 30 or 40 feet tall, with culms clothed below with old sheaths from which the blades have fallen, sharply serrulate blades, commonly 6 feet long and about 2 inches wide (forming a great fan-shaped summit to the sterile culms), and pale, plumy, densely flowered panicles 3 or more feet long, the main axis erect, the branches drooping; spikelets several-flowered, the pistillate with long-attenuate glumes and smaller long-silky lemmas, the staminate with shorter glumes and glabrous lemmas. This grass, found along streams in tropical America, is cultivated occasionally in greenhouses under the name of uva grass.

Cortaderia Stapf, Gard. Chron. III. **22:** 396. 1897. Stapf includes five species in the genus, the first of which is *C. argentea.* The genus is technically designated on the page indicated in the citation, but on a preceding page (p. 378) he says, "Taking *Gynerium argenteum* as representative of the Cortaderas, . . .". Hence *Gynerium argenteum* is selected as the type. This species, called *C. argentea* (Nees) Stapf, is an erect diœcious perennial reed, growing in large bunches, with numerous long, narrow, basal blades, very rough on the margins, and stout flowering culms 6 to 10 feet high, with beautiful feathery, silvery white or pink panicles or plumes 1 to 3 feet long; spikelets 2 to 3 flowered, the pistillate silky with long hairs, the staminate naked; glumes white and papery, long and slender; lemmas bearing a long slender awn. This grass, called pampas grass, is a native of Argentina. It is cultivated as a lawn ornamental, being hardy in the warmer parts of the United States. Pampas grass is cultivated commercially in southern California for the plumes, which are used for decorative purposes. The plants grow here to enormous size, as much as 20 feet in height.

20. PHRAGMITES Adans., the reeds.

Spikelets several-flowered, the rachilla clothed with long silky hairs, disarticulating above the glumes and at the base of each joint between the florets, the lowest floret staminate or neuter; glumes 3-nerved, or the upper 5-nerved, lanceolate, acute, unequal, the first about half as long as the upper, the second shorter than the florets; lemmas narrow, long-acuminate, glabrous, 3-nerved, the florets successively smaller, the summits of all about equal; palea much shorter than the lemma.

Perennial reeds, with broad, flat linear blades and large terminal panicles. Species three, one in Asia, one in Argentina, and one cosmopolitan.

Type species: *Arundo phragmites* L.

Phragmites Adans., Fam. Pl. **2**: 34, 559. 1763. Adanson cites "Arundo Scheuz. 161," which Linnæus also cites under *Arundo phragmites*. Adanson cites besides four other pre-Linnæan references, two of them queried. The other two, which may refer to sugar cane or to sorghum, are to be excluded because the few generic characters given, especially that the spikelets have several perfect flowers, do not at all apply to them, but do apply to *Arundo phragmites*. Trinius[1] publishes Phragmites as a new genus based on *Arundo phragmites* L., changing the specific name to *P. communis*.

Trichoon Roth, Archiv Bot. Roemer **1**^{3}: 37. 1798. Based on *Arundo karka* Retz., an East Indian species of Phragmites.

Miphragtes Nieuwl., Amer. Midl. Nat. **3**: 332. 1914. The name suggested for Phragmites Trin. not Phragmites Adans. in case Trichoon Roth and Oxyanthe Steud., to each of which Nieuwland transfers the specific name "Phragmites," should not "be applicable."

Our single species *Phragmites communis* Trin. (*P. phragmites* (L.) Karst.) (fig. 27) is a tall reed with creeping rhizomes, leaves about an inch broad, and panicles commonly a foot long. It grows in marshes, around springs, and along lakes and streams throughout the United States. Besides the rhizomes it produces extensively creeping leafy stolons. In the Southwest this species, in common with *Arundo donax*, is called by the Mexican name carrizo and is used for lattices in the construction of adobe huts. The stems were used by the Indians for the shafts of arrows, and in Mexico and Arizona for mats and screens.

21. DACTYLIS L.

Spikelets few-flowered, compressed, finally disarticulating between the florets, nearly sessile in dense one-sided fascicles, these borne at the ends of the few branches of a panicle; glumes unequal, carinate, acute, hispid-ciliate on the keel; lemmas compressed-keeled, mucronate, 5-nerved, ciliate on the keel.

Perennials, with flat blades and fascicled spikelets. Species two or three, in Eurasia; one, *Dactylis glomerata*, a native of Europe, cultivated and naturalized in the United States.

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[1] Fund. Agrost. 134. 1820.

FIG. 27.—Reed, *Phragmites communis.* Rhizomes, leaves, and panicles, × ⅓; spikelet and floret, × 3.

FIG. 28.—Orchard grass, *Dactylis glomerata*. Plant, × ½; spikelet and floret, × 5.

Type species: *Dactylis glomerata* L.

Dactylis L., Sp. Pl. 71, 1753; Gen. Pl., ed. 5, 32. 1754. Linnæus describes two species, *D. cynosuroides* from Virginia, and *D. glomerata* from Europe. The latter species being described in his flora of Sweden is chosen as the type.

Dactylis glomerata, orchard grass (Pl. VIII; fig. 28), is a well-known meadow and pasture grass, cultivated in the humid region of the United States. It is a rather coarse, erect, perennial bunch-grass, soon forming large tussocks, with culms 2 to 4 feet tall, flat blades as much as one-third of an inch wide, panicles 3 to 8 inches long, with a few stiff branches, spreading in flower, appressed in fruit. In England this is called cocksfoot grass. Orchard grass is recommended for shaded situations, as it withstands shade better than our other meadow grasses.

22. Cynosurus L.

Spikelets of two kinds, sterile and fertile together, the fertile sessile, nearly covered by the short-pediceled sterile one, these pairs imbricate in a dense one-sided spikelike panicle; sterile spikelets consisting of two glumes and several narrow, acuminate, 1-nerved lemmas on a continuous rachilla; fertile spikelets 2 or 3 flowered, the glumes narrow, the lemmas broader, rounded on the back, awn-tipped, the rachilla disarticulating above the glumes.

Species four, in the Mediterranean region; one occasionally cultivated in the United States and sparingly escaped into waste places.

Type species: *Cynosurus cristatus* L.

Cynosurus L., Sp. Pl. 72, 1753; Gen. Pl., ed. 5, 33. 1754. Linnæus describes nine species. The first species, *C. cristatus*, is chosen as the type because it is an economic species and is one of three species described in his flora of Sweden. Of the remaining Linnæan species, one, *C. echinatus*, is now retained in Cynosurus; *C. lima* is referred to Wangenheimia; *C. durus*, to Scleropoa; *C. coeruleus*, to Sesleria; *C. aegyptius*, to Dactyloctenium; *C. indicus*, to Eleusine; *C. paniceus*, to Polypogon; *C. aureus*, to Achyrodes.

FIG. 29.—Crested dog's-tail grass, *Cynosurus cristatus*. Plant, × ½; fertile spikelet and floret, × 5.

The only species in the United States is *Cynosurus cristatus* L. (fig. 29), known as crested dog's-tail grass. This is occasionally sown in mixtures for meadows, but has nothing especially to recommend it. It is a tufted perennial 1 to 2 feet tall, the panicles 2 to 4 inches long.

23. Achyrodes Boehmer.
(*Lamarckia* Moench.)

Spikelets of two kinds, in fascicles, the terminal one of each fascicle fertile, the others sterile; fertile spikelet, with 1 perfect floret, the rachilla produced beyond the floret, bearing a small awned empty lemma or reduced to an awn; glumes narrow, acuminate or short-awned, 1-nerved; lemma broader, raised on a slender stipe, scarcely nerved, bearing just below the apex a delicate straight awn; sterile spikelets linear, 1 to 3 in each fascicle, consisting of 2 glumes similar to those of the fertile spikelet, and numerous distichously imbricate, obtuse, awnless, empty lemmas.

A low, erect annual, with flat blades and oblong, one-sided, compact panicles, the crowded fascicles drooping, the fertile being hidden, except the awns, by the numerous sterile ones. Species one, a native of southern Europe, naturalized in southern California.

Type species: *Cynosurus aureus* L.

Achyrodes Boehmer, in Ludw. Def. Gen. Pl. 420. 1760. The genus is based on a phrase name of Tournefort, which Linnæus cites under *Cynosurus aureus* L.

Lamarckia Moench, Meth. Pl. 201. 1794. A single species is described, *L. aurea* (*Cynosurus aureus* L.).

Chrysurus Pers., Syn. Pl. 1: 80. 1805. A single species, *C. cynosuroides*, based on *Cynosurus aureus* L., is included.

The single species, *Achyrodes aureum* (L.) Kuntze (fig. 30), is abundantly naturalized in southern California. It is called goldentop because of its beautiful golden yellow panicles.

24. Melica L.

Spikelets 2 to several flowered, the rachilla disarticulating above the glumes and between the florets, prolonged beyond the perfect florets and bearing at the apex two or three gradually smaller empty lemmas, convolute together or the upper inclosed in the lower; glumes somewhat unequal, thin, often papery, scarious-margined, obtuse or acute, sometimes nearly as long as the lower floret, 3 to 5 nerved, the nerves usually prominent; lemmas convex, several-nerved, membranaceous or rather firm, scarious-margined, sometimes conspicuously so, awnless or sometimes awned from between the teeth of the bifid apex.

Rather tall perennials, with the base of the culm often swollen into a corm, with closed sheaths, usually flat blades, narrow or sometimes open, usually simple panicles of relatively large spikelets. Species about 60, in the cooler parts of both hemispheres; 18 in the United States, mostly woodland grasses.

Type species: *Melica nutans* L.

Melica L., Sp. Pl. 66, 1753; Gen. Pl., ed. 5, 31. 1754. Linnæus describes three species, *M. ciliata*, *M. nutans*, and *M. altissima*, all species of Eurasia and all now retained in the genus Melica. In the Flora Lapponica, where the generic name was first used, the only species described is referred by Linnæus in the Species Plantarum to *M. nutans;* hence this species is selected as the type.

Bromelica Farwell, Rhodora **21**: 77. 1919. Based on Melica, section Bromelica Thurb., of which the type is *M. bromoides* Gray (*M. geyeri* Munro).

FIG. 30.—Golden-top, *Achyrodes aureum*. Plant, × ½; fertile spikelet and floret, × 5.

In our eastern species, *Melica mutica* Walt. (fig. 31) and *M. nitens* Nutt., the sterile lemmas form a rather prominent truncate or hood-

FIG. 31.—*Melica mutica.* Plant, × ½; spikelet and floret, × 5.

shaped body back of the upper floret, and the glumes and fertile lemmas are conspicuously scarious. In many of the western species the sterile lemmas are small and narrow, forming an inconspicuous body at the top of the rachilla, and the glumes and fertile lemmas are either broad or rather narrow with less conspicuous scarious margins. In *M. imperfecta* Trin., of California, there is but one fertile floret. One group of species with narrow, scarcely flattened spikelets and little-differentiated upper florets has been segregated as a section under the name Bromelica. The awned species of the genus, *M. aristata* Thurb. (fig. 32), *M. smithii* (Porter) Vasey, and *M. purpurascens* (Torr.) Hitchc., belong to this group. The inflorescence of Melica is usually narrow, a simple panicle or even a raceme, but in *M. smithii*, *M. geyeri* Munro, and *M. nitens* it may be an open but rather few-flowered panicle. The corms produced by many species are characteristic and have suggested the name onion grass often applied to them. The genus is distinguished from allied genera by the scarious margins of the glumes and lemmas. The awned species of the section Bromelica approach closely to Bromus.

The species of Melica, commonly called melic grasses, are in general excellent forage grasses. They are, however, not gregarious, and do not ordinarily furnish any large proportion of the forage of the ranges. The two most important species on the ranges are *M. bella* Piper and *M. spectabilis* Scribn. They have broad spikelets, bulbous bases, and narrow panicles, the first with erect pedicels, the second with slender recurved pedicels.

25. Anthochloa Nees.

Spikelets few-flowered, subsessile, on a simple axis and imbricate, the rachilla disarticulating above the glumes and between the florets; glumes (in our species) wanting; lemmas thin-membranaceous, flabelliform, whitish, petallike, many nerved; palea narrower than the lemma, hyaline.

Low annuals or perennials, with close spikes. Species three; two in the Andes, one in California.

Type species: *Anthochloa lepidula* Nees.

Anthochloa Nees; Meyen, Reise um Erde **2**: 14. 1835. One species mentioned. The description is meager and scarcely constitutes technical publication. It is as follows: "Wir sammelten hier ein sehr kleines aber äusserst schönes Gras, das die neue Gattung Anthochloa bildet und von Herrn Nees v. Esenbeck *Anthochloa lepidula* genannt worden ist (Anthochloa genus proximum Melicae, differt glumis brevioribus, valvula superiori quadrifida!)." The genus is first described by Endlicher[1] but no species is mentioned. Remy[2] describes the genus and one species (*A. rupestris*).

Stapfia Davy, Erythea **6**: 110, pl. 3, 1898, not Stapfia Chodat, 1897. One species described, *S. colusana*.

Neostapfia Davy, Erythea **7**: 43. 1899. A new name for Stapfia Davy.

Davyella Hack., Oesterr. Bot. Zeitschr. **49**: 133. 1899. A new name proposed for Stapfia Davy, not Chodat.

[1] Gen. Pl. 99. 1836. [2] Ann. Sci. Nat. Bot. III. **6**: 347. 1846.

FIG. 32.—*Melica aristata.* Plant, × ½; spikelet and floret, × 5.

Our species, *Anthochloa colusana* (Davy) Scribn. (fig. 33), is known only from the type collection, from Colusa County, Calif. It is an annual, with broad flat leaves with no distinction between sheath and blade, and dense cylindric spikes, the upper part of the axis bearing, instead of spikelets, lanceolate-linear empty bracts.

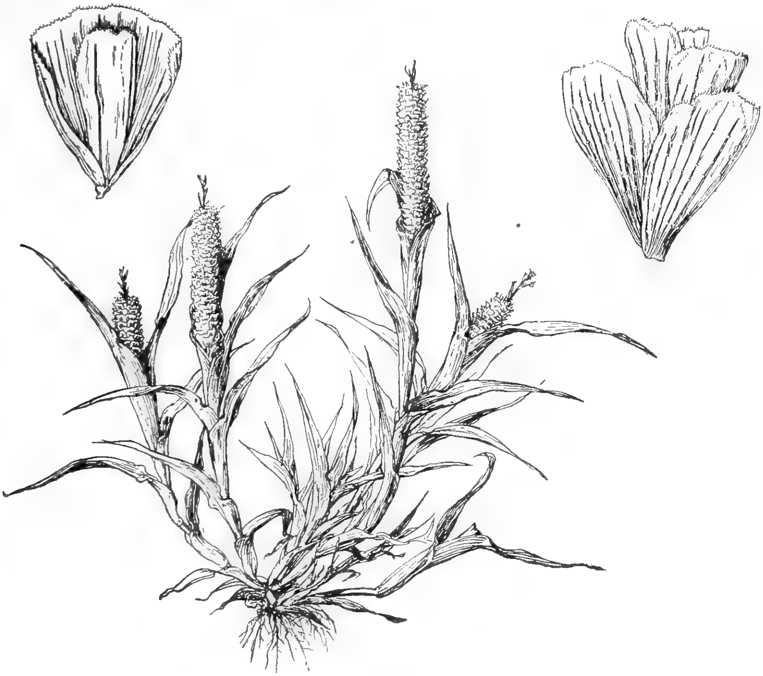

FIG. 33.—*Anthochloa colusana*. Plant × ½; spikelet and floret, × 5.

26. TRIODIA R. Br.

Spikelets several-flowered, the rachilla disarticulating above the glumes and between the florets; glumes membranaceous, often thin, nearly equal in length, the first sometimes narrower, 1-nerved or the second rarely 3 to 5 nerved, acute or acuminate; lemmas broad, rounded on the back, the apex from minutely emarginate or toothed to deeply and obtusely lobed, 3-nerved, the lateral nerves near the margins, the midnerve excurrent between the lobes as a minute point or as a short awn, the lateral nerves often excurrent as minute points, all the nerves pubescent below (subglabrous in one species), the lateral ones sometimes conspicuously so throughout; palea broad, the two nerves near the margin, sometimes villous.

Erect, tufted perennials, rarely rhizomatous or stoloniferous, the blades usually flat, the inflorescence an open or contracted panicle, or a cluster of few-flowered spikes interspersed with leaves. Species about 25, mostly in America; 15 species in the United States.

Type species: *Triodia pungens* R. Br.

Triodia R. Br., Prodr. Fl. Nov. Holl. **1**: 182. 1810. Six species are described, the first of which is selected as the type. In this the lemma is firm, rather obscurely 3-nerved, villous along the lower half of the back and margins, 2-toothed at the summit, the midnerve excurrent between the acute teeth as a short awn as long as the teeth, the lateral nerves extending into the teeth.

Tricuspis Beauv., Ess. Agrost. 77, pl. 15, f. 10, 1812, not Tricuspis Pers., 1807. The figured species is *T. caroliniana*, discussed in the following paragraph.

Tridens Roem. and Schult., Syst. Veg. **2**: 34. 1817. Under the description of the genus is a reference to a figure of Beauvois.[1] Beauvois describes the figure (which represents *Triodia flava*) under the name *Tricuspis caroliniana*. Under the description of the genus (p. 77) Beauvois mentions two species, *Poa caerulescens* Michx. and *Tricuspis novaeboracensis* Beauv. Both are nomina nuda, the first never having been published by Michaux, and Beauvois giving no description of the second. Roemer and Schultes on a later page (p. 599) describe the single species referred to Tridens, under the name *T. quinquefida*, based upon *Poa quinquefida* Pursh, which is *Triodia flava*.

Windsoria Nutt., Gen. Pl. **1**: 70. 1818. Two species are described, *W. poaeformis* Nutt., which is *Triodia flava*, and *W. ambigua* (Ell.) Nutt. The first is selected as the type.

Rhombolytrum Link, Hort. Berol. **2**: 296. 1833. The single species described is *R. rhomboidea* from Chile. Bentham and Hooker[2] state that two North American species, *Triodia albescens* and *T. trinerviglumis*, are allied to this. Nash[3] recognizes the genus Rhombolytrum and transfers to it *Sieglingia albescens* (Vasey) Kuntze.

Erioneuron Nash, in Small, Fl. Southeast. U. S. 143. 1903. The type, *Uralepis pilosa*, is indicated on page 1327 of the same work. Only one species included.

Dasyochloa Willd.; Rydb., Colo. Agr. Exp. Sta. Bull. **100**: 37. 1906. (Flora of Colorado.) The name first appeared in Steudel's Nomenclator[4] as a synonym of Uralepis (Uralepsis), where two species are listed, *D. avenacea* Willd. and *D. pulchella* Willd., both being herbarium names. The type and only species mentioned is *D. pulchella* (H. B. K.) Willd.

Some authors have referred our species to Sieglingia Bernh.[5] The type of Sieglingia is *Festuca decumbens* L. This species seems to represent a distinct genus, differing in having 5 to several nerved lemmas. The single species, *S. decumbens* (L.) Bernh., a native of Europe, is found in Newfoundland, but does not occur in the United States.

The species of Triodia are diverse in habit and in floral characters, but it does not seem practicable to segregate any of them as distinct genera. *Triodia flava* (the type of Tridens) and *T. pulchella* (the type of Dasyochloa) represent the two extremes, but they are connected by a series of intergrading species. The type species of Triodia, *T. pungens*, of Australia, in the form of its spikelets, stands about midway between our two extremes. Its spikelets, though less pubescent, are much like those of *T. avenacea*, with the midnerve of the lemma excurrent between the teeth, the lateral nerves not excurrent but extending into the teeth. *Triodia pulchella* H. B. K. (fig. 34) differs in habit from all the other species. It sends up from the basal cluster of leaves slender branches with elongate internodes, which produce at the extremity a cluster of short leaves and short, few-flowered spikes. Later from these clusters are produced slender branches, which in their turn form clusters of leaves and spikelets. The clusters bend to the ground and take root, so that ultimately there is formed a colony of these clusters

[1] Beauv. Ess. Agrost. pl. 15, f. 10. 1812.
[2] Gen. Pl. **3**: 1176. 1883.
[3] In Britton, Man. 129. 1901.
[4] Nom. Bot., ed. 2, **1**: 484. 1840.
[5] Syst. Verz. Pflanz. Erfurt. 40. 1800.

of leaves and spikelets connected by the slender internodes. This species and two others, *T. avenacea* H. B. K. and *T. nealleyi* Vasey,

FIG. 34.—*Triodia pulchella.* Plant, × ½; spikelet and floret, × 5.

agree in having deeply 2-lobed lemmas, the midnerve excurrent between the lobes as an awn. The last two species and *T. pilosa* (Buckl.) Merr. have short, spikelike panicles, but the last species differs in having acuminate lemmas. These four species and *T. mutica* (Torr.) Scribn. agree in having woolly lemmas, the lower part of the three nerves being long-villous, and in having paleas villous on the wings. *Triodia mutica* has a somewhat elongate panicle and differs in having very obtuse, broad, sometimes minutely notched, awnless lemmas, the lateral nerves disappearing before reaching the margin. The aforementioned species might be set off under Erioneuron, but they would not form a coherent group.

Triodia flava (L.) Hitchc. (*Poa flava* L.) (fig. 35) has an open, elegantly drooping panicle of purple spikelets, the nerves of the lemmas pubescent below, extending into 3 mucros. This is common in autumn through the Eastern States in meadows and open woodland and is sometimes called purple-top. It exudes a sticky substance on the culm below the panicle and on the main branches of the inflorescence, to which dirt adheres. One species, *T. drummondii* Scribn. and Kearney, produces rhizomes.

Three species (besides *T. mutica* mentioned above) have a spikelike panicle. These are *T. albescens* Vasey, with glabrous lemmas; *T. elongata* (Buckl.) Scribn., with glumes nearly as long as the spikelet; and *T. stricta* (Nutt.) Vasey, with shorter glumes but mucronate lemmas. The other species have more or less open panicles.

In general the species of Triodia are of little importance agriculturally. *Triodia pulchella* is often abundant on the ranges, but is not relished by stock, the little dry plants being seldom eaten.

27. Triplasis Beauv.

Spikelets few-flowered, the florets remote, the rachilla slender, terete, disarticulating above the glumes and between the florets; glumes nearly equal, smooth, 1-nerved, acute; lemmas narrow, 3-nerved, 2-lobed, the nerves parallel, pubescent or villous, the lateral pair near the margin, the midnerve excurrent as an awn, as long as or longer than the lobes; palea shorter than the lemma, 2-keeled, the keels densely long-ciliate on the upper half.

Slender tufted annuals or perennials, with short blades, short, open, few-flowered purple panicles terminating the culms, and cleistogamous narrow panicles in the axils of the leaves. Species three; southeastern United States.

Type species: *Triplasis americana* Beauv.

Triplasis Beauv., Ess. Agrost. 81, pl. 16, f. 10. 1812. The single species, *T. americana*, is figured.

Uralepis Nutt., Gen. Pl. 62. 1818. Nuttall describes two species, *U. purpurea*, based on *Aira purpurea* Walt. (*Triplasis purpurea* (Walt.) Chapm.) and *U. aristulata*, which is the same species. The first is selected as the type. The name is spelled Uralepsis, but this is a typographical error. Nuttall states that it is based on the Greek words oura and lepis.

Diplocea Raf., Amer. Journ. Sci. 1: 252. 1819. One species described, *D. barbata*, which is the same as *Triplasis purpurea*.

Merisachne Steud., Syn. Pl. Glum. 1: 117. 1854. Contains one species, *M. drummondii* Steud., *Drummond* 330, from Texas (*Triplasis purpurea*).

FIG. 35.—Purple-top, *Triodia flava*. Plant, × ½; spikelet and floret, × 5.

The three species are found in sandy soil in the Eastern States, *Triplasis purpurea* (fig. 36) from Maine to Florida and from the Great Lakes to Texas. *Triplasis intermedia* is confined to Florida; *T. americana* is found from North Carolina to Florida. All the species, besides the small panicles of cleistogamous spikelets in the upper sheaths, have additional cleistogamous spikelets, reduced to a single large floret, at the bases of the lower sheaths. The culms break at the nodes bearing these cleistogenes, the ripe seed remaining attached to the internode. The species are of no importance except as they tend to hold sandy soil.

For a revision of the species of Triplasis, see Nash, Bull. Torrey Club **25**: 561–565. 1898.

28. Blepharidachne Hack.

Spikelets 4-flowered, the rachilla disarticulating above the glumes but not between the florets; glumes nearly equal, about as long as the spikelet, compressed, 1-nerved, thin, acuminate, smooth; lemmas deeply 3-lobed, 3-nerved, the first and second sterile, containing a palea but no flower, the third fertile, the fourth reduced to a 3-awned rudiment.

Low annuals or perennials, with short, congested, few-flowered panicles scarcely exserted from the subtending leaves. Species two; one in Argentina, one in Nevada.

Type species: *Eremochloë kingii* S. Wats.

Eremochloë S. Wats., in King, Geol. Expl. 40th Par. 382, pl. 40, 1871, not Eremochloa Büse, 1854. Two species are described, one *E. kingii* from Nevada and the other, in a footnote, *E. bigelovii*, from southern New Mexico. The two specimens are to be referred to the same species.

Blepharidachne Hack., in Engl. and Prantl, Pflanzenfam. 2^2: 126. 1887. In a footnote the name Blepharidachne is substituted for Eremochloë S. Wats., because of the earlier Eremochloa Büse. The author of Blepharidachne is given as "Hook.," a typographical error for Hack.

Blepharidachne kingii (S. Wats.) Hack. (fig. 37), found on the plains and foothills of Nevada (and New Mexico according to Watson), has been collected only a few times.

A second species, *Blepharidachne benthamiana* (Hack.) Hitchc. (*Munroa benthamiana* Hack.[1]) grows in dry regions of Argentina. In habit it resembles our *Munroa squarrosa*, but in floral structure it agrees with Blepharidachne, having two sterile florets, one fertile floret, and a 3-awned rudiment.

29. Orcuttia Vasey.

Spikelets several-flowered, the upper florets reduced; rachilla persistent, continuous, the florets falling away or tardily disarticulating; glumes nearly equal, shorter than the lemmas, broad, irregularly 2 to 5

[1] In Kuntze, Rev. Gen. Pl. 3^2: 357. 1898.

FIG. 36.—*Triplasis purpurea.* Plant, × ½; spikelet, floret (above) showing beard on the nerves of the palea and cleistogene (at left), a cleistogamous fertile 1-flowered spikelet from the axil of a lower leaf, all × 5.

toothed, many-nerved, the nerves extending into the teeth; lemmas firm, prominently 13 to 15 nerved, the broad summit with 5 long teeth or with numerous short teeth; palea broad, 2-nerved, as long as the lemma.

FIG. 37.—*Blepharidachne kingii.* Plant, × 1; spikelet and perfect floret, the latter showing the rudiment behind the palea, × 5.

Low cespitose annuals, with short blades and terminal spikelike racemes, the spikelets relatively large, appressed, the upper aggregate, the lower more or less remote. Species two; California and Lower California.

Type species: *Orcuttia californica* Vasey.

Orcuttia Vasey, Bull. Torrey Club **13**: 219, pl. 16. 1886. The one species described was collected by C. R. Orcutt at San Quentin Bay, Lower California.

Our species, both in California, are *Orcuttia greenei* Vasey, from Chico, of which only the type collection is known, and *O. californica* (fig. 38), which has been collected at Goose Valley. The latter species is distinguished by having 5-toothed lemmas; *O. greenei* has truncate lemmas, the nerves extending into short points.

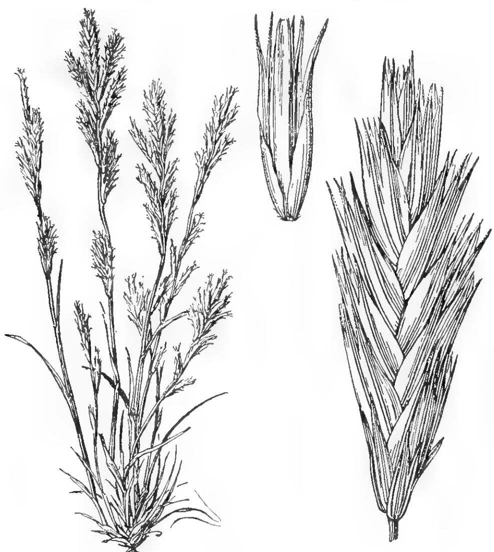

FIG. 38.—*Orcuttia californica.* Plant, × ½; spikelet and floret, the latter without a joint of the rachilla, this not disarticulating, × 5.

30. Scleropogon Philippi.

Plants diœcious. Staminate spikelets several-flowered, pale, the rachilla not disarticulating; glumes about equal, a perceptible internode between, membranaceous, long-acuminate, 1-nerved or obscurely 3-nerved, nearly as long as the first lemma; lemmas similar to the glumes, somewhat distant on the rachilla, 3-nerved or obscurely 5-nerved, the apex mucronate; palea obtuse, shorter than the lemma. Pistillate spikelets several-flowered, the upper florets reduced to awns, the rachilla disarticulating above the glumes but not separating between the florets or only tardily so; glumes acuminate, 3-nerved, with a few fine additional nerves, the first about half as long as the second; lemmas narrow, 3-nerved, the nerves extending into 3 slender, scabrous, spreading awns, the florets falling together forming a cylindric many-awned fruit, the lowest floret with a sharp-bearded callus as in Aristida; palea narrow, the two nerves near the margin, produced into short awns.

A perennial stoloniferous grass, with short flexuous blades and narrow few-flowered racemes or simple panicles, the staminate and pistillate strikingly different in appearance. Species one; Chile to southwestern United States.

Type species: *Scleropogon brevifolius* Philippi.

Scleropogon Philippi, Anal. Univ. Chile **36**: 205. 1870. Only one species described.

Lesourdia Fourn., Bull. Soc. Bot. France **27**: 102, pl. 3, 4. 1880. Two species are proposed, *L. multiflora* and *L. karwinskyana*, both referable to the same species, *Scleropogon brevifolius*.

This species (fig. 39) is found on semiarid plains and open valley lands from southern Colorado to Texas and Arizona and southward. The mature pistillate spikelets break away and with their numerous long spreading awns form "tumbleweeds" that are blown before the wind. The pointed barbed callus readily penetrates clothing or wool, the combined florets acting like the single floret of the long-awned aristidas. As a forage grass, this is inferior to grama; but on overstocked ranges, where it tends to become established, it is useful in preventing erosion. It is called burro grass.

31. Cottea Kunth.

Spikelets several-flowered, the uppermost reduced, the rachilla disarticulating above the glumes and between the florets; glumes two, about equal, nearly equaling the lower lemma, with several parallel nerves; lemmas rounded on the back, villous below, prominently 9 to 11 nerved, the nerves extending partly into awns of irregular size and partly into awned teeth; palea awnless, a little longer than the body of the lemma.

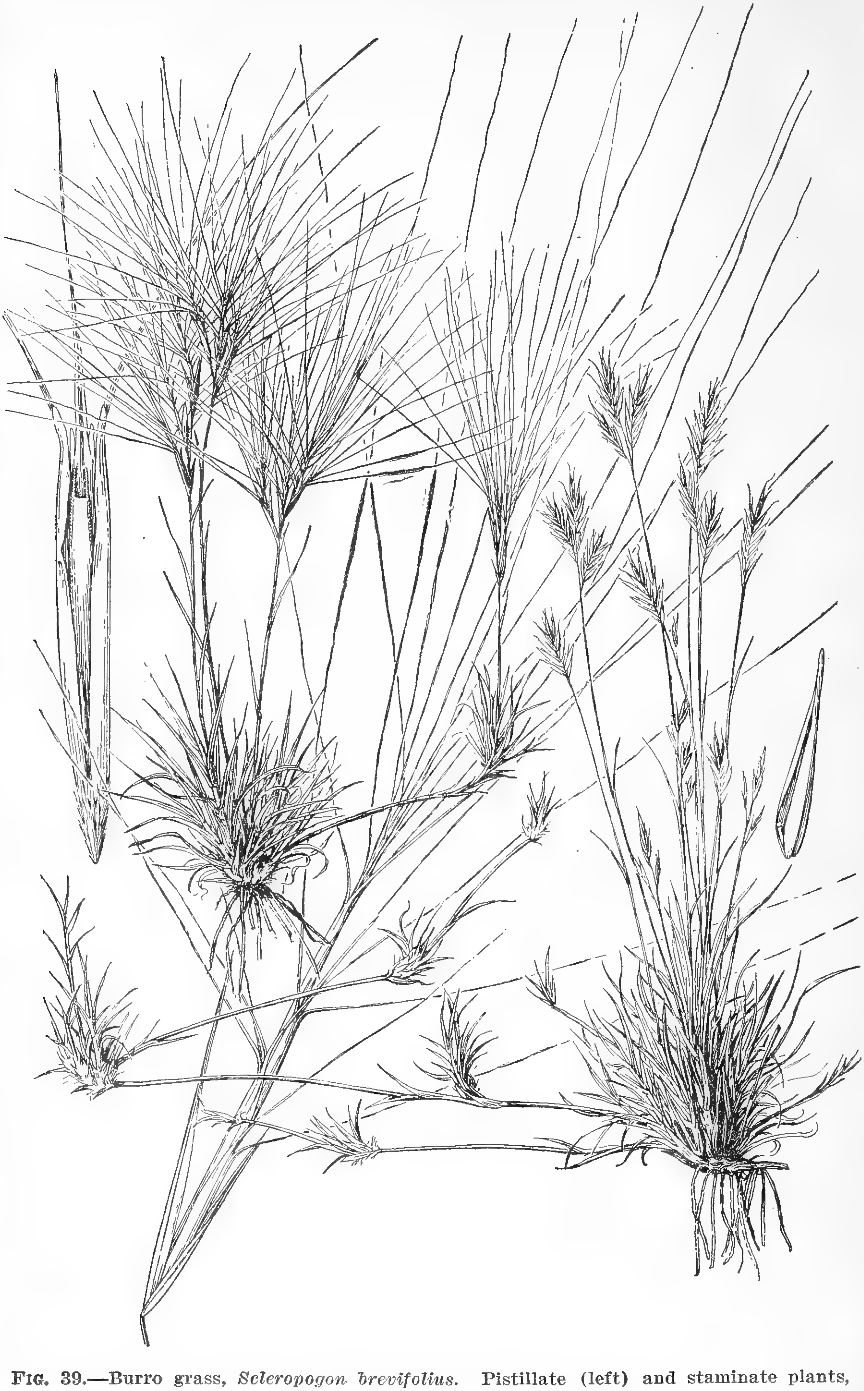

FIG. 39.—Burro grass, *Scleropogon brevifolius.* Pistillate (left) and staminate plants, × ½; pistillate spikelet, × 2; pistillate and staminate floret, × 5.

An erect tufted branching perennial, with oblong open panicles. Species one; western Texas to southern Arizona and southward to Argentina.

Type species: *Cottea pappophoroides* Kunth.
Cottea Kunth, Rev. Gram. **1**: 84. 1829. A single species mentioned, from Peru.

This genus is allied to Pappophorum and very closely related to Anthoschmidtia of Africa. It differs from the first in the several-flowered spikelets that separate between the florets and in the awns interspersed with awned teeth. Anthoschmidtia differs in having glumes longer than the florets and in having lemmas with five awns alternating with four lobes.

Cottea pappophoroides Kunth (fig. 40) is not abundant enough to have agricultural importance in the United States. Cleistogenes are produced in the lower sheaths.[1]

32. PAPPOPHORUM Schreb.

Spikelets 2 to 5 flowered, the upper reduced, the rachilla disarticulating above the glumes but not between the florets, the internodes very short; glumes nearly equal, keeled, thin-membranaceous, as long as or longer than the body of the florets, 1 to several nerved, acute; lemmas rounded on the back, firm, obscurely many nerved, dissected above into numerous spreading scabrous or plumose awns, the florets falling together, the awns of all forming a pappuslike crown; palea as long as the body of the lemma, 2-nerved, the nerves near the margin.

Erect, cespitose perennials, with narrow or spikelike tawny or purplish panicles. Species 20, in the dry parts of the Old World, in Australia, and from Texas to Argentina; 3 species in the United States, from Texas to Arizona.

Type species: *Pappophorum alopecuroideum* Vahl.
Pappophorum Schreb.; Vahl, Symb. Bot. **3**: 10. 1794. Only one species described.
Enneapogon Desv.; Beauv., Ess. Agrost. 81, pl. 16, f. 11. 1812. Beauvois mentions *Enneapogon desvauxii*, *Pappophorum gracile*, *P. nigricans*, *P. pallidum*, and *P. purpurascens*. The first one, being figured, is selected as the type.
Polyrhaphis (Trin.) Lindl., Veg. Kingd. 115. 1847. Based on Pappophorum, section Polyrhaphis Trin., under which a single species, *P. alopecuroides* Vahl, is included.

Pappophorum bicolor Fourn., with purplish, rather loose panicles, is found in southern and western Texas; *P. vaginatum* Buckl. (fig. 41), with pale, slender, spikelike panicles, and *P. wrightii* S. Wats. (fig. 42), with plumbeous short spikelike panicles and 9-nerved lemma, the nerves extending into 9 equal plumose awns, are found from western Texas to southern Arizona. *Pappophorum wrightii* produces cleistogamous spikelets in the lower sheaths. The cleistogenes are larger than the normal florets, but the awns are almost wanting. As is the

[1] Chase, Amer. Journ. Bot. 5: 256. 1918.

FIG. 40.—*Cottea pappophoroides.* Plant, × ½; spikelet, floret, and cleistogene (left) from axil of lower leaf, all × 5.

FIG. 41.—*Pappophorum vaginatum.* Plant, × ½; spikelet and perfect floret, × 5.

case with other grasses producing cleistogenes in the lower sheaths, the culms disarticulate at the lower nodes. Our species are of minor

FIG. 42.—*Pappophorum wrightii.* Plant, × ½; spikelet, perfect floret, and cleistogene (below) from axil of lower leaf, all × 5.

agricultural importance, the second and third sometimes constituting a fair proportion of the forage on sterile hills.

3. HORDEAE, BARLEY TRIBE.

33. AGROPYRON Gaertn.

Spikelets several-flowered, solitary (or rarely in pairs), sessile, placed flatwise at each joint of a continuous (rarely disarticulating) rachis, the rachilla disarticulating above the glumes and between the florets; glumes two, equal, firm, several nerved, usually shorter than the first lemma, acute or awned, rarely obtuse or notched; lemmas convex on the back, rather firm, 5 to 7 nerved, usually acute or awned from the apex; palea shorter than the lemma.

Perennials or sometimes annuals, often with creeping rhizomes, with usually erect culms and green or purplish, usually erect spikes. Species about 60, in the temperate regions of both hemispheres; about 25 species in the United States.

Type species: *Agropyron triticeum* Gaertn.
Agropyron Gaertn., Nov. Comm. Acad. Sci. Petrop. **14**: 539, pl. 19, f. 4. 1770. Gaertner describes two species, *A. cristatum*, based on *Bromus cristatus* L., and a new species, *A. triticeum*. The second species is figured. The species are referred by some authors to Triticum. Some adopt the spelling Agropyrum.

The two original species of Agropyron are annuals, but all the North American species are perennials. Nine of our species produce creeping rhizomes. One of these is the well-known quack-grass or couch-grass (*A. repens* (L.) Beauv.) (Pl. IX; fig. 43), introduced from Europe. On account of its rhizomes, it is a troublesome weed in fields and meadows. Quack-grass can be distinguished by the glabrous, awnless or short-awned lemmas, awn-pointed glumes, thin, flat, usually sparsely pilose blades, and the yellowish rhizomes. An allied native species, *A. smithii* Rydb., differs in its pale rhizomes and its firm glaucous blades, soon involute in drying, the nerves prominent on the upper side. This species, called western wheat-grass and bluestem, is common west of the Mississippi River, where it is one of the most important native forage grasses. Another common species of this group is *A. dasystachyum* (Hook.) Scribn. (including *A. subvillosum* (Hook.) E. Nels.), found along the Great Lakes and westward.

Of the species without rhizomes seven have awnless or short-awned lemmas. The commonest species of this group is *A. tenerum* Vasey, called slender wheat-grass. This is an erect grass 2 to 4 feet high, with flat blades and slender spikes, the broad glumes nearly as long as the spikelet. It ranges from New England to Washington, and southward in the Western States to Mexico. Slender wheat-grass is an excellent forage grass and produces a good quality of hay. The seed is offered by a few western seedsmen. This species is the only native grass that has been successfully cultivated and whose seed is on the market.

One of the long-awned species, *Agropyron spicatum* (Pursh) Scribn. and Smith (*A. divergens* Nees), called bunch-grass, or more distinctively blue bunch wheat-grass, is of especial value as a forage grass. It is common in the Columbia Basin, where it is one of the chief range grasses. The species is distinguished by its erect bunchy habit and by the spreading awns of the lemmas, giving the spike a bristly appearance.

FIG. 43.—Quack-grass, *Agropyron repens.* Plant, × ½; spikelet, × 3; floret, × 5.

Two of our species have disarticulating spikes, thus approaching Sitanion. These are *Agropyron saxicola* (Scribn. and Smith) Piper, of Washington, and *A. scribneri* Vasey, a spreading mountain species

QUACK-GRASS (AGROPYRON REPENS).

BOTTLE-BRUSH GRASS (HYSTRIX PATULA).

A native species worthy of cultivation for ornament.

found at altitudes of 12,000 to 14,000 feet. In some species there are two spikelets at the nodes of the rachis. This is especially frequent in *A. smithii* and allies it with Elymus.

In general, all the species of Agropyron are forage grasses. They form an important part of the forage on the western range and in the valleys often grow in sufficient abundance to produce hay.

For a revision of the species of Agropyron found in the United States, see Scribner and Smith, U. S. Dept. Agr., Div. Agrost. Bull. **4**: 25–36. 1897.

34. Triticum L.

Spikelets 2 to 5 flowered, solitary, sessile, placed flatwise at each joint of a continuous or articulate rachis, the rachilla disarticulating above the glumes and between the florets or continuous; glumes rigid, 3 to several nerved, the apex abruptly mucronate or toothed or with one to many awns; lemmas keeled or rounded on the back, many-nerved, ending in one to several teeth or awns.

Annual, low or rather tall grasses, with flat blades and terminal spikes. Species about 10, southern Europe and western Asia; none in the United States except *Triticum aestivum*, the cultivated wheat.

Type species: *Triticum aestivum* L.

Triticum[1] L., Sp. Pl. 85, 1753; Gen. Pl., ed. 5, 37. 1754. Linnæus describes seven species, *T. aestivum*, *T. hybernum*, *T. turgidum*, *T. spelta*, *T. monococcum*, *T. repens*, *T. caninum*. The citation in the Genera Plantarum is to Tournefort's figures 292 and 293 which represent, the first, beardless wheat, and the second, bearded wheat. These two forms, beardless and bearded, are named by Linnæus *T. aestivum*, the bearded wheat, and *T. hybernum*, the beardless wheat. *Triticum aestivum* is chosen as the type because it has priority of position in the Species Plantarum. Linnæus divides the genus into two groups, "annua" and "perennia." The latter group, including *Triticum repens* and *T. caninum*, is now referred to Agropyron.

Zeia Lunell, Amer. Midl. Nat. **4**: 225. 1915. Based on "*Triticum spelta* Linn." Agropyron Gaertn. is included in the genus proposed.

The most important species of Triticum is the cultivated wheat, *T. aestivum* L. (*T. vulgare* Vill., *T. sativum* Lam.). A large number of varieties are in cultivation, some with smooth lemmas, some with velvety lemmas, some with long awns (fig. 44), some awnless (fig. 44, *A*). Durum wheat and club wheat are races, each with several varieties. *Triticum monococcum* L., einkorn or 1-grained wheat, is grown sparingly in Europe. *Triticum dicoccum* Schrank, emmer, is cultivated in this country as a forage plant. In emmer the axis breaks up into joints, each joint bearing a spikelet which remains entire, each floret permanently inclosing its grain.[2]

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[1] In the Species Plantarum the word appears in the plural, Tritica, probably inadvertently.

[2] For a classification of wheats, see Jessen, Deutschlands Gräser 191, 1863; Körnicke, Handb. Getreidebaues **1**: 40, 1885; Hackel in Engl. and Prantl, Pflanzenfam. II, **2**: 80, 1887; True Grasses, translated by Scribner and Southworth, 180, 1890; Schulz, Mitt. Natf. Ges. Halle **1**: 14. 1911. For an account of *T. dicoccoides* Körn., recently found by Aaronsohn on Mount Hermon, Palestine, see Aaronsohn, Verh. Zool. Bot. Ges. Wien **59**: 485, 1909; U. S. Dept. Agr., Bur. Pl. Ind. Bull. **180**: 38, 1910; Cook, U. S. Dept. Agr., Bur. Pl. Ind. Bull. **274**. 1913.

FIG. 44.—Wheat, *Triticum aestivum*. Plant with awned spikes (bearded wheat) and (*A*) a nearly awnless spike (beardless wheat), both × ½; spikelet and floret, × 3.

35. Secale L.

Spikelets usually 2-flowered, solitary and sessile, placed flatwise against the rachis; the rachilla disarticulating above the glumes and produced beyond the upper floret as a minute stipe; glumes narrow, rigid, acuminate or subulate-pointed; lemmas broader, sharply keeled, 5-nerved, ciliate on the keel and exposed margins, tapering into a long awn.

Erect, mostly annual grasses, with flat blades and dense terminal spikes. Species five, in the temperate regions of Eurasia; one species cultivated in the United States and frequently escaped along waysides.

Type species: *Secale cereale* L.

Secale L., Sp. Pl. 84, 1753; Gen. Pl. 36. 1754. Linnæus describes four species: *S. cereale*, *S. villosum*, *S. orientale*, and *S. creticum*. The second species is now referred to Haynaldia, the third to Agropyron. The first species is chosen as the type, as it is a well-known economic species.

Secale cereale (fig. 45), common rye, is cultivated extensively in Europe and to some extent in the United States for the grain, but here it is frequently grown as a forage crop. Rye is used for winter forage in the South and for fall and spring pasture in the intermediate region, and for green feed farther north. It is also used for green manure and as a nurse crop for lawn mixtures, especially on public grounds when it is desired to cover the ground quickly with a green growth. Cultivated rye probably has been developed from the wild perennial European species *S. montanum* Guss. In the wild species of Secale the rachis disarticulates, but in *S. cereale* it is continuous.

36. Scribneria Hack.

Spikelets 1-flowered, solitary, appressed and lateral to the somewhat thickened continuous rachis, the rachilla disarticulating above the glumes, prolonged as a very minute hairy stipe; glumes equal, narrow, firm, acute, keeled on the outer nerves, the first 2-nerved, the second 4-nerved; floret with short hairs at the base; lemma shorter than the glumes, membranaceous, rounded on the back, obscurely nerved, the apex shortly bifid, the lobes obtuse, the faint midnerve extending as a slender straight awn; palea 2-nerved, about as long as the lemma.

Low annual, with slender cylindric spikes. Species one.

Type species: *Lepturus bolanderi* Thurb.

Scribneria Hack., Bot. Gaz. 11: 105, pl. 5. 1886. One species described, based on *Lepturus bolanderi* Thurb.

The single species, *Scribneria bolanderi* (Thurb.) Hack. (fig. 46), is found in sandy sterile ground in the mountains from central California to Washington. It is too small and rare to be of economic importance.

FIG. 45.—Rye, *Secale cereale*. Plant, × ½; spikelet, × 3; floret showing rudiment back of palea, × 5.

37. ELYMUS L.

Spikelets 2 to 6 flowered, sessile in pairs (rarely 3 or more or solitary) at each node of a continuous rachis, the florets dorsiventral to the rachis; rachilla disarticulating above the glumes and between the florets; glumes equal, usually rigid, sometimes indurate below, narrow, sometimes subulate, 1 to several nerved, acute to aristate, somewhat asymmetric and often placed in front of the spikelets; lemmas rounded on the back or nearly terete, obscurely 5-nerved, acute or usually awned from the tip.

Erect, usually rather tall grasses, with flat or rarely convolute blades and terminal spikes, the spikelets usually crowded, sometimes somewhat distant. Species about 45, in the temperate regions of the Northern Hemisphere; 25 species in the United States, most of them in the Western States.

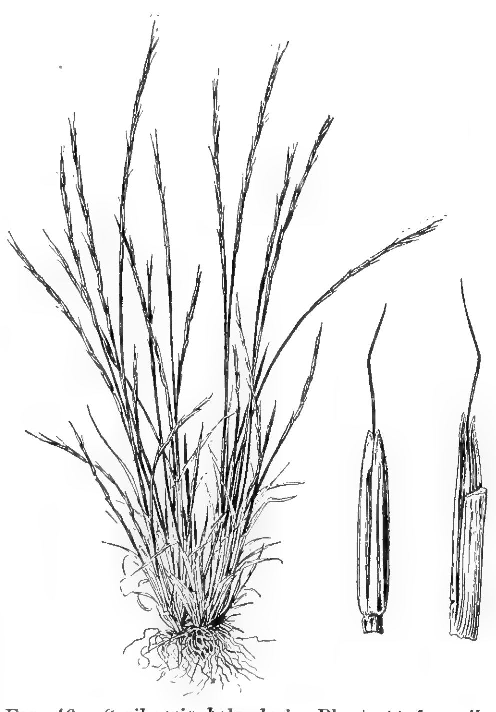

FIG. 46.—*Scribneria bolanderi.* Plant, × ½; spikelet with joint of rachis, × 5; the same, front view, × 5.

Type species: *Elymus sibiricus* L.

Elymus L., Sp. Pl. 83, 1753; Gen. Pl., ed. 5, 36. 1754. Linnæus describes five species, *E. arenarius, E. sibiricus, E. canadensis, E. virginicus,* and *E. caput-medusae,* all of which are still retained in the genus. The first use of the name Elymus by Linnæus was in his Hortus Upsaliensis (1748), where two species are described, the first being cited in the Species Plantarum under *E. virginicus* the second under *E. sibiricus. Elymus sibiricus* is chosen as the type because it is the first of the five species in the Species Plantarum that is described in the Hortus Upsaliensis.

Terrellia Lunell, Amer. Midl. Nat. **4**: 227. 1915. Proposed for Elymus L., not Elymus of various ancient authors.

The asymmetric glumes, in many species standing in front of the spikelet instead of strictly distichous and in some species united at the very base, have been the object of investigations as to their morphological identity. Schenck[1] considers them to be developed from lateral branches at the base of the spikelet. Schuster[2] states that the first or outer glume originates as a single organ but soon

[1] Bot. Jahrb. Engler **40**: 97–113. 1907.
[2] Flora **100**: 213–266, pl. 2–5. 1910.

divides into two parts, which stand side by side below the spikelet, the second glume being suppressed.

In the group of *Elymus virginicus* L. and its allies the glumes are indurate at the base and bowed out. They stand in front of the spikelet rather than at each side, so that the contiguous glumes of the pair of spikelets are not back to back but side by side. In *E. arenarius* L., *E. glaucus* Buckl., and allied species, the glumes are less distinctly in front of the spikelets. The rachis of the spike is usually continuous but in *E. saundersii* Vasey, and, to a less extent, in *E. macounii* Vasey, the rachis disarticulates, showing a transition to Sitanion. In many species, such as *E. simplex* Scribn. and Merr., and *E. salina* Jones (named from Salina Pass), the middle spikelets are in pairs, but those toward the base and apex of the spike are single at the nodes. Such species are a transition to Agropyron. On the other hand *Agropyron smithii* often has one or more pairs of spikelets and may be considered a transition to Elymus. But in the former species the glumes are narrow or almost subulate, which shape is to be found in Elymus rather than in Agropyron. The spikelets are usually not more than two at each node of the rachis, but in *E. triticoides* Buckl. there are often, and in *E. condensatus* Presl. usually, more than two spikelets at each node. Sometimes in the latter species (rarely in the former) the spike is branched so that the inflorescence is a condensed panicle instead of a spike. *Elymus caput-medusae* L. is an annual introduced from Europe; the other species are native perennials. Some species form extensively creeping rhizomes, such as *Elymus mollis* Trin., of the sandy seacoasts of northern North America, *E. flavescens* Scribn. and Smith, of the interior dunes of the Columbia River basin, and *E. triticoides* Buckl., of alkaline soil of the Western States. *Elymus canadensis* L. (fig. 47) and *E. virginicus*, usually called wild rye, are common in the eastern half of the United States. The first has a bushy nodding head; the latter an erect, stiff head.

The species of Elymus are for the most part good forage grasses, and in some localities form a part of the native hay. In the wooded areas of the Northwest, *E. glaucus* Buckl. is one of the valuable secondary species on the ranges. It has flat, thin leaves, erect awned spikes, broad glumes, and no rhizomes.

38. Sitanion Raf.

Spikelets 2 to few flowered, the uppermost floret reduced, sessile, usually 2 at each node of a disarticulating rachis, the rachis breaking at the base of each joint, remaining attached as a pointed stipe to the spikelets above; glumes narrow or setaceous, 1 to 3 nerved, the nerves prominent, extending into one to several awns, these (when more than one) irregular in size, sometimes mere lateral

FIG. 47.—Wild rye, *Elymus canadensis*. Plant, × ½; spikelet and floret, × 3.

appendages of the long central awn, sometimes equal, the glume being bifid; lemmas firm, convex on the back, nearly terete, the apex slightly 2-toothed, 5-nerved, the nerves obscure, the central nerve extending into a long, slender, finally spreading awn, sometimes one or more of the lateral nerves also extending into short awns; palea firm, nearly as long as the body of the lemma, the two keels serrulate.

Low or rather tall cespitose perennials, with bristly spikes. Species about six, in the dry regions of the western United States.

Type species: *Sitanion elymoides* Raf.

Sitanion Raf., Journ. de Phys. **89**: 103. 1819. One species is described, which is the same as *Aegilops hystrix* Nutt.

Polyanthrix Nees, Ann. Nat. Hist. ser. 1. **1**: 284. 1838. A single species based on *Aegilops hystrix* Nutt., which is *Sitanion hystrix* (Nutt.) J. G. Smith.

This genus is closely related to Elymus, and until recent years has been almost universally included in it. The characters which separate Sitanion are the disarticulating rachis, together with the slender glumes and long-awned lemmas.

There are three groups of species. *Sitanion planifolium* J. G. Smith and its allies have lanceolate rather than setaceous glumes, which are usually 1-awned or occasionally 2-awned. The awns are less spreading and the rachis disarticulates rather tardily. These species are found from California to Washington.

A second series, including *Sitanion jubatum* J. G. Smith and its allies, has glumes cleft nearly to the base into three to several setaceous lobes. These species also are confined to the Pacific Coast States.

The third series includes Nuttall's original species, *Sitanion hystrix* (Nutt.) J. G. Smith (fig. 48) and several allied species, found from the Great Plains to the Pacific coast. In some, the glumes are setaceous and entire; in others, some of the glumes are cleft into two equal, or usually unequal, awned lobes.

The species of the three groups differ among themselves by only slight characters, and each group may represent several closely allied species or a single species with several forms or varieties.

When young all the species furnish forage, but at maturity the disarticulated joints of the spike, with their pointed rachis joints and long-awned spikelets, are blown about by the wind and often cause injury to stock, penetrating the nose and ears, working in by means of the forwardly roughened awns, and causing inflammation. The species are generally known as squirreltail or foxtail grasses.

For a revision of the genus, see Smith, U. S. Dept. Agr., Div. Agrost. Bull. 18. 1899.

39. Hystrix Moench.

Spikelets 2 to 4 flowered, sessile, 1 to 3 at each node of a continuous flattened rachis, horizontally spreading at maturity;

glumes reduced to short or minute awns, the first usually obsolete, both often wanting in the upper spikelets; lemmas convex, rigid,

FIG. 48.—*Sitanion hystrix.* Plant, × ½; spikelet with rachis joint attached and floret, × 3.

tapering into long awns, 5-nerved, the nerves obscure except toward the tip; palea about as long as the body of the lemma.

Erect perennials, with flat blades and bristly, loosely flowered spikes. Species four, in temperate regions; one in the Himalayas, one in New Zealand, and two in the United States.

Type species: *Elymus hystrix* L.

Asperella Humb., Magaz. Bot. Roem. and Usteri **7**: 5, 1790, not Asprella Schreb., 1789, a typonym of Homalocenchrus Mieg. A single species, *A. hystrix*, based on *Elymus hystrix* L.

Hystrix Moench, Meth. Pl. 294. 1794. One species described, *H. patula*, based on *Elymus hystrix* L.

Gymnostichum Schreb., Beschr. Gräs. **3**: 127, pl. 47. 1810. One species described, *G. hystrix*, based on *Elymus hystrix* L.

Our species are both woodland grasses, one, *Hystrix patula* Moench (*H. hystrix* (L.) Millsp.) (Pl. X; fig. 49), in the Mississippi Valley and eastward; the other, *H. californica* (Boland.) Kuntze, in western central California. They have little forage value, as they are nowhere abundant. The first species mentioned, sometimes called bottle-brush grass, is worthy of cultivation for ornament.

40. Hordeum L.

Spikelets 1-flowered, 3 (sometimes 2) together at each node of the articulate rachis (continuous in *Hordeum vulgare*), the back of the lemma turned from the rachis, the middle one sessile or subsessile, the lateral ones pediceled; rachilla disarticulating above the glumes and, in the central spikelet, prolonged behind the palea as a bristle and sometimes bearing a rudimentary floret; lateral spikelets usually imperfect, sometimes reduced to bristles; glumes narrow, often subulate and awned, rigid, standing in front of the spikelet; lemmas rounded on the back, 5-nerved, usually obscurely so, tapering into a usually long awn.

Annual or perennial low or rather tall grasses, with flat blades and dense terminal cylindric-spikes. Species about 20, in the temperate regions of both hemispheres; 10 species in the United States, 3 being introduced from Europe.

Type species: *Hordeum vulgare* L.

Hordeum L., Sp. Pl. 84, 1753; Gen. Pl., ed. 5, 37. 1754. Linnæus describes six species, *H. vulgare, H. hexastichon, H. distichon, H. zeocriton, H. murinum,* and *H. jubatum.* The citation given in the Genera Plantarum is to Tournefort's plate 295, which represents *Hordeum vulgare.* This species is therefore the type. All the Linnæan species are retained in the genus at present, but the first four are usually considered to be forms of one species.

Zeocriton Beauv., Ess. Agrost. 114, pl. 21, f. 2. 1812. Ten species of Hordeum having staminate or sterile lateral spikelets are included; *H. distichum,* the species figured, is taken as the type.

Critesion Raf., Journ. de Phys. **89**: 103. 1819. A single species is described, *C. geniculatus* Raf. This is *Hordeum jubatum* L.

The most important species of the genus is *Hordeum vulgare* (fig. 50), the cultivated barley. This is an annual, resembling bearded wheat, the awns as much as 6 inches long. In common or 4-rowed barley the 3 spikelets of each cluster are fertile, the lateral spikelets of the opposite sides of the spike being imbricate in a row, so that the spike appears to be 4-rowed. In 6-rowed barley (*H. hexastichon* L.)

FIG. 49.—Bottle-brush grass, *Hystrix patula*. Plant, × ½; spikelet and floret, × 3.

the lateral spikelets form rather distinct rows. In 2-rowed barley (*H. distichon* L.) the lateral spikelets are all infertile and reduced,

FIG. 50.—Barley, *Hordeum vulgare*. Plant, × ½; *A*, a spike of beardless barley, × ½; group of three spikelets and a floret, the latter showing the rudiment back of the palea, × 3.

so that only the row of central spikelets on each side of the spike is prominent. Naked barley is a kind of 2-rowed barley in which the grain is free from the lemma and palea. Rice barley (*H. zeocriton* L.), with spreading spikelets and divergent awns, is not grown in this country and but sparingly in Europe. Beardless barley (*H. vulgare trifurcatum* Wenderoth) (fig. 50, *A*) is a variety of 6-rowed barley in which the awns are suppressed or converted into irregular short lobes or teeth. Schulz[1] divides the cultivated barleys into two groups. The first group, derived from *H. spontaneum* Koch, includes the 2-rowed varieties. The second group, derived from *H. ischnatherum* (Coss.) Schulz, includes the 4 and 6 rowed varieties. The glumes of Hordeum are thought by Schenck to be sterile spikelets or branchlets. (See footnote under Elymus, p. 93.)

Three common species of Hordeum are annuals. One of these, *H. pusillum* Nutt., with glumes broadened above the base, is a native species. The other two, introduced from Europe, are common weeds on the Pacific coast. In *H. murinum* L. a part of the glumes are ciliate; in *H. gussoneanum* Parl. the glumes are setaceous, smooth below. *Hordeum nodosum* L. (fig. 51) is similar to *H. pusillum* but differs in being perennial and in having uniformly subulate glumes. This species is abundant throughout the western half of the United States. Another perennial species, *H. jubatum* L., called squirreltail grass because of its soft brushlike spikes, is common in the Western States, where it is not infrequently a troublesome weed in alfalfa fields. This species is called foxtail in Wyoming, barley grass in Utah, and tickle grass in Nevada. *Hordeum murinum*, mentioned above, is called barley grass, foxtail, and wild barley in different localities.

The species of Hordeum furnish forage during the early stages of growth before the awns are produced. The mature spikes break up into sharp-pointed joints that become a serious pest to stock. These joints with the forwardly roughened awns work into the eyes and nostrils of animals, causing inflammation.

For a revision of the species of Hordeum found in the United States, see Scribner and Smith, U. S. Dept. Agr., Div. Agrost. Bull. **4**:23–25. 1897.

41. LOLIUM L.

Spikelets several-flowered, solitary and sessile, placed edgewise to the continuous rachis, one edge fitting to the alternate concavities, the rachilla disarticulating above the glumes and between the florets; first glume wanting (except on the terminal spikelet), the second outward, strongly 3 to 5 nerved, equaling or exceeding the second floret; lemmas rounded on the back, 5 to 7 nerved, obtuse, acute, or awned.

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[1] Mitt. Natf. Ges. Halle **1**: 18. 1911.

FIG. 51.—*Hordeum nodosum*. Plant, × ½; group of three spikelets with rachis joint attached and a floret, the latter showing the rudiment back of the palea, × 3.

Annuals or perennials, with flat blades and simple terminal flat spikes. Species about eight, in Eurasia, four of these being introduced in the United States.

Type species: *Lolium perenne* L.

Lolium L., Sp. Pl. 83, 1753; Gen. Pl., ed. 5, 36. 1754. Linnæus describes two species, *L. perenne* and *L. temulentum*. The first is chosen as the type, as it is an economic species. Both were described in the flora of Sweden.

Two species are of agricultural importance. *Lolium perenne*, English or perennial rye-grass, was the first meadow grass to be cultivated in Europe as a distinct segregated species, the meadows and pastures formerly being mixed native species. This and the next are probably the most important of the European forage grasses. English rye-grass is a biennial or short-lived perennial, 2 to 3 feet tall, with glossy dark-green leaves and a slender spike as much as a foot long, the spikelets 8 to 10 flowered, somewhat longer than the glume, the lemmas awnless. Italian rye-grass, *L. multiflorum* Lam. (*L. italicum* A. Br.) (Pl. XI; fig. 52), differs from the preceding in having awned lemmas and usually a greater number of florets to the spikelet. Both species are used to a limited extent for meadow, pasture, and lawn. They are of some importance in the South for winter forage. *Lolium multiflorum* is common in the humid region of the Pacific coast, where it is often called Australian rye-grass.

In the Eastern States the rye-grasses are often sown in mixtures for parks or public grounds, where a vigorous early growth is required. The young plants can be distinguished from bluegrass by the glossy dark-green foliage.

Lolium temulentum L., darnel, is occasionally found as a weed in grain fields and waste places. It is in bad repute, because of the presence in the fruit of a narcotic poison, said to be due to a fungus. Darnel is supposed to be the plant referred to as the tares sown by the enemy in the parable of Scripture. It is an annual, with glumes as much as an inch long and exceeding the 5 to 7 florets.

42. Lepturus R. Br.
(*Monerma* Beauv.)

Spikelets 1-flowered, embedded in the hard, cylindric, articulate rachis, placed edgewise thereto, the first glume wanting except on the terminal spikelet, the second glume closing the cavity of the rachis and flush with the surface, indurate, nerved, acuminate, longer than the joint of the rachis; lemma lying next the rachis, hyaline, shorter than the glume, 3-nerved; palea hyaline, 2-nerved, a little shorter than the lemma; rachilla not disjointing, the spikelet falling entire, attached to its rachis joint.

Low annuals or perennials, with hard cylindric spikes. Species three, all from the Eastern Hemisphere, one introduced in California.

FIG. 52.—Italian rye-grass, *Lolium multiflorum.* Plant, × ½; spikelet, × 3; floret, × 5.

ITALIAN RYE-GRASS (LOLIUM MULTIFLORUM)

TALL OAT-GRASS (ARRHENATHERUM ELATIUS).

Type species: *Rottboellia repens* Forst.

Lepturus R. Br., Prodr. Fl. Nov. Holl. 207. 1810. One species described, *L. repens*, based on *Rottboellia repens* Forst.

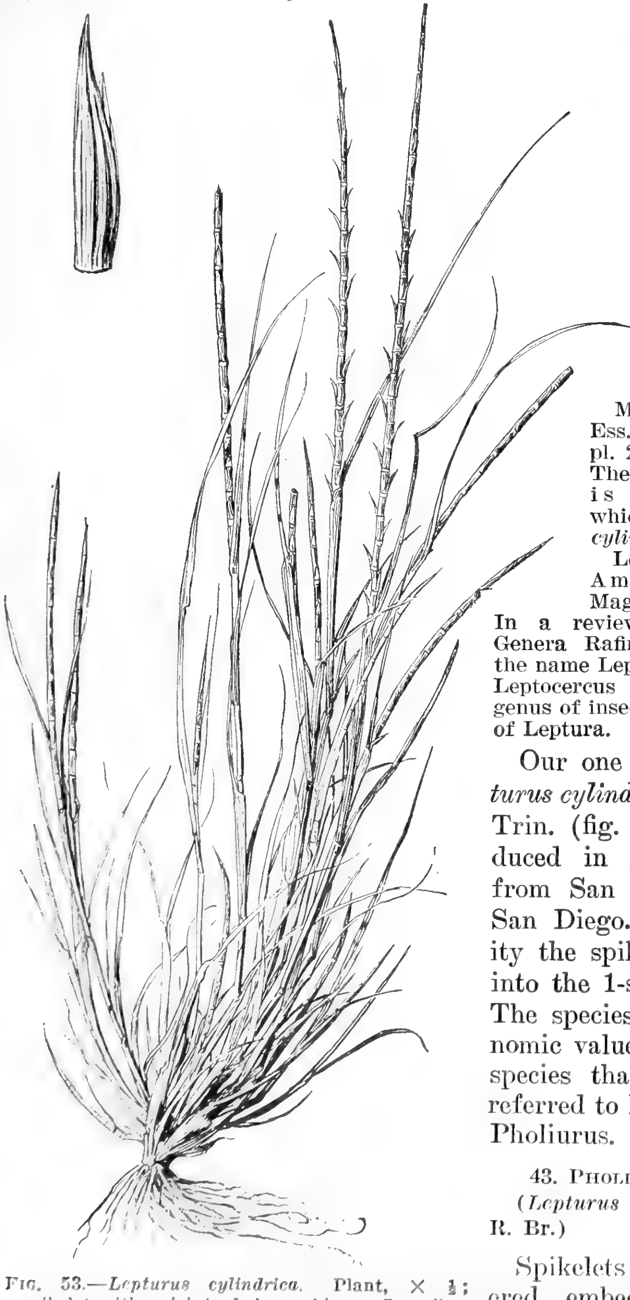

FIG. 53.—*Lepturus cylindrica.* Plant, × ½; spikelet with a joint of the rachis, × 5; spikelet, front view, × 5.

Monerma Beauv., Ess. Agrost. 116, pl. 20, f. 10. 1812. The species figured is *M. monandra*, which is *Lepturus cylindrica*.

Leptocercus Raf., Amer. Monthly Mag. 4: 190. 1819. In a review of Nuttall's Genera Rafinesque changes the name Lepturus R. Br. to Leptocercus because of a genus of insects by the name of Leptura.

Our one species, *Lepturus cylindrica* (Willd.) Trin. (fig. 53), is introduced in salt marshes from San Francisco to San Diego. At maturity the spike breaks up into the 1-seeded joints. The species has no economic value. For other species that have been referred to Lepturus, see Pholiurus.

43. PHOLIURUS Trin.

(*Lepturus* of authors, not R. Br.)

Spikelets 1 or 2 flowered, embedded in the articulate rachis and falling attached to the joints; glumes two, placed in front of the spikelet and inclosing it, coriaceous, 5-nerved, acute, asymmetric, appearing like halves of a single split glume; lemma lying next to the axis, smaller than the glumes, hyaline, keeled, scarcely more than 1-nerved; palea a little shorter than the lemma, hyaline, 2-nerved.

Low annuals, with cylindric spikes. Species four, in the Eastern Hemisphere, one introduced into the United States.

Type species: *Rottboellia pannonica* Host.

Pholiurus Trin., Fund. Agrost. 131. 1820. Based on a single species, *Rottboellia pannonica* Host. This species has 2-flowered spikelets.

Lepiurus Dumort., Obs. Gram. Belge 140, pl. 15, f. 57. 1823. A single species based on "Rottbolia incurvata L." fils.

The species of Pholiurus have been referred by most recent authors to Lepturus, the type of which was, by the same authors, referred to Monerma.

Our species, *Pholiurus incurvatus* (L.) Hitchc. (*Aegilops incurvata* L.,[1] *Lepturus filiformis* (Roth.) Trin.) (fig. 54), has 1-flowered spikelets. It is introduced along the borders of salt marshes

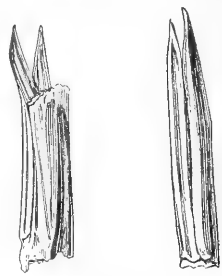

FIG. 54.—*Pholiurus incurvatus*. Plant, × ½; spikelet with a joint of the rachis, × 5; spikelet, front view, × 5.

from Maryland to Virginia and from Marin County to San Diego, Calif. It has no economic value.

4. AVENEAE, THE OAT TRIBE.

44. KOELERIA Pers.

Spikelets 2 to 4 flowered, compressed, the rachilla disarticulating above the glumes and between the florets, prolonged beyond the perfect florets as a slender bristle or bearing a reduced or sterile floret at the tip; glumes usually about equal in length but unequal in shape, the lower narrow and sometimes shorter, 1-nerved, the upper somewhat broader above the middle, wider than the lower, 3 to 5 nerved;

[1] Sp. Pl. ed. 2, 2: 1490. 1763.

lemmas somewhat scarious and shining, the lowermost a little longer than the glume, obscurely 5-nerved, acute or short-awned, the awn, if present, borne just below the apex.

Annual or perennial, slender, low or rather tall grasses, with narrow blades and spikelike panicles. Species about 20, in the temperate regions of both hemispheres; two species in the United States, one native and one introduced.

Type species: *Aira cristata* L.

Koeleria Pers., Syn. Pl. 1:97. 1805. Persoon describes five species, *K. gracilis*, *K. cristata*, *K. tuberosa*, *K. phleoides*, and *K. villosa*. Of these, *K. cristata* and *K. phleoides* were described by Linnæus, the first under Aira, the second under Festuca. The first of these is selected as the type, as it has priority of position in the Species Plantarum.

Airochloa Link, Hort. Berol, 1:126. 1827. Six species are included. *Koeleria cristata*, upon which the first species is based, is taken as the type.

Brachystylus Dulac, Fl. Hautes Pyr. 85. 1867. Based on "Koeleria Pers."

Recently a monograph of Koeleria was published by Domin[1] in which many species were described. Several of these were based upon material from the United States but appear to be only forms of the widely distributed *K. cristata*.

Koeleria cristata (L.) Pers. (fig. 55) is the only species native in North America. This is a common constituent of grassland on prairies, plains, and in open woods from Ontario to British Columbia and south to northern Mexico. It is a cespitose perennial, with slender, erect culms a foot or two high, with a pale, shining, densely flowered panicle 2 to 5 inches long. The species varies much, but the forms, except *K. cristata longifolia* Vasey, of California, with longer blades and larger, more open panicles, can not be distinguished as varieties. The slender form, of the semiarid plains and foothills of the West, is held by some as distinct and called *K. gracilis* Pers. The spikelets of *K. cristata* are mostly 2 or 3 flowered, with a slender prolongation of the rachilla, and the lemmas are acute or mucronate, but not awned. The habit suggests a species of Poa, from which genus it is distinguished by its mostly 2 or 3 flowered spikelets, acute lemmas, and the culm puberulent below the panicle. A second species, *K. phleoides* (Vill.) Pers., a low annual with short-awned lemmas, is introduced from Europe in a few localities. Hackel (Nat. Pflanzenfam.) places Koeleria in the Festuceæ, but South American and Old World species of Koeleria, with lemmas awned below the apex, as well as the shining culm and spikelets of *K. cristata*, show clearly an affinity to Trisetum. For this reason the genus is here placed in Aveneae, although the glumes do not exceed the florets as they do in nearly all the Aveneae.

Koeleria cristata is a good forage grass and is a constituent of much of the native pasture throughout the Western States.

45. Trisetum Pers.

Spikelets usually 2-flowered, sometimes 3 to 5 flowered, the rachilla prolonged behind the upper floret, usually villous; glumes somewhat

[1] Monographie der Gattung Koeleria. 1907.

unequal, acute, awnless, the second usually longer than the first floret; lemmas usually short-bearded at the base, 2-toothed at the apex, the teeth often awned, bearing from the back below the cleft apex a straight and included, or usually bent and exserted, awn.

FIG. 55.—*Koeleria cristata.* Plant, × ½; spikelet and floret, × 5.

Tufted perennials with flat blades and open or usually contracted or spikelike panicles. Species about 65, in the arctic and temperate regions of both hemispheres; eight species in the United States, mostly in the mountains.

Type species: *Avena flavescens* L.

Trisetum Pers., Syn. Pl. 1:97. 1805. Persoon describes 11 species. The seventh species, *T. pratense* Pers., based on *Avena flavescens* L., is chosen as the type, because it is historically the oldest species.

Graphephorum Desv., Nouv. Bull. Soc. Philom. Paris 2: 189. 1810. Based on *Aira melicoides* Michx.

The name Trisetum refers to the three awns on the lemma of many of the species, one from the back and one from each of the teeth. In two of our species, *T. melicoideum* (Michx.) Scribn. and *T. wolfii* Vasey, the awn from the back is included within the glume or is wanting. *Trisetum spicatum* (L.) Richter (fig. 56) is found at high altitudes in all the western mountains and is widespread at high altitudes and in the arctic regions of the Northern Hemisphere. It is an erect grass with a spikelike, often dark-colored panicle, the awn exserted and bent. *Trisetum canescens* Buckl., of the Western States, is a woodland grass with narrow but rather loose panicles. *Trisetum cernuum* Trin., of the Northwest, has broad flat blades and a loose open penicle, with lax drooping branches, the florets distant in the usually 3-flowered spikelets. *Trisetum pennsylvanicum* (L.) Roem. and Schult. (*Sphenopholis palustris* (Michx.) Scribn.), *T. hallii* Scribn., and *T. interruptum* Buckl. have been referred to Sphenopholis. In the first, the upper lemma is slightly bearded at base, the lower glabrous; in the other two, the lemmas are glabrous. In these three species the articulation is below the spikelet, as in Sphenopholis, for which reason Scribner placed them in that genus, but their awned, relatively thin lemmas and their glumes alike in shape place them more naturally in Trisetum.

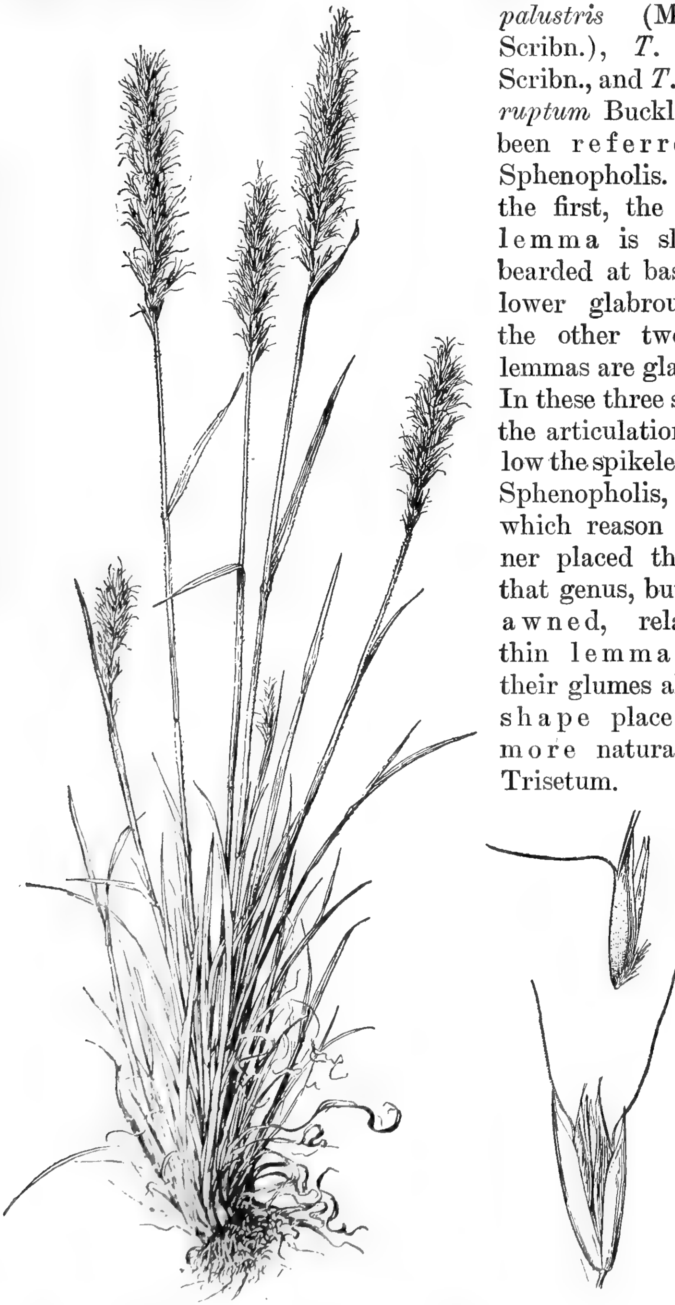

FIG. 56.—*Trisetum spicatum.* Plant, × ½; spikelet and floret, × 5.

The species of Trisetum are all valuable for grazing. *Trisetum spicatum* constitutes an important part of the forage on alpine slopes.

46. Sphenopholis Scribn.
(*Eatonia* of authors, not Raf.)

Spikelets 2 or 3 flowered, the pedicel disarticulating below the glumes, the rachilla produced beyond the upper floret as a slender bristle; glumes unlike in shape, the first narrow, acute, 1-nerved, the second broadly obovate, 3 to 5 nerved, somewhat coriaceous; lemmas firm, scarcely nerved, awnless, the first a little shorter or a little longer than the second glume.

Perennial grasses, with usually flat blades and narrow panicles. Species four, in the United States, extending into Mexico and the West Indies.

Type species: *Aira obtusata* Michx.

Reboulea Kunth, Rev. Gram. 1: 341, pl. 84, 1830, not Rebouillia Raddi, 1818. *R. gracilis*, the only species described, is the same as *Aira obtusata* Michx.

Colobanthus (Trin.) Spach. Suites Buff. 13: 163, 1846, not Bartl., 1830. Trinius applied the name to a section of Trisetum. The type is *Koeleria pennsylvanica* DC. (*Sphenopholis pallens*), the first of two species mentioned by Trinius, the other being *Aira obtusata* Michx.

Sphenopholis Scribn., Rhodora 8: 142. 1906. A new name is proposed for the group of grasses then known as Eatonia, and the type species is designated. Scribner showed that the original description of Eatonia Raf. could not apply to the genus as later described by Endlicher.[1] The type species of Eatonia Raf. proves to be *Panicum virgatum*.[2] The genus Sphenopholis was revised by Scribner in the above-mentioned paper.

One species, *Sphenopholis obtusata* (Michx.) Scribn. (fig. 57), is widespread, but not very abundant, throughout the eastern half of the United States. In the western portion of its range the panicle is condensed and spikelike (var. *lobata* (Trin.) Scribn.). All the species are forage grasses, but they are usually not abundant enough to be of much importance.

47. Avena L., oats.

Spikelets 2 to several flowered, the rachilla bearded, disarticulating above the glumes and between the florets; glumes about equal, membranaceous or papery, several-nerved, longer than the lower floret, usually exceeding the upper floret; lemmas indurate, except toward the summit, 5 to 9 nerved, bidentate at the apex, bearing a dorsal bent and twisted awn (this straight and reduced in *Avena sativa*).

Annual or perennial, low or moderately tall grasses, with narrow or open, usually rather few-flowered panicles of usually large spikelets. Species about 55, in the temperate regions; only a few in the Western Hemisphere; 7 species in the United States, only 2 being native.

Type species: *Avena sativa* L.

Avena L., Sp. Pl. 79, 1753; Gen. Pl., ed. 5, 34. 1754. Linnæus describes 10 species, 3 of which are now retained in Avena. These are *A. sativa*, *A. fatua*, and *A. pratensis*. The other species are now referred as follows: *A. sibirica* to

[1] Gen. Pl. 99. 1837. [2] Hitchcock, Contr. U. S. Nat. Herb. 15: 87. 1910.

Stipa, *A. elatior* to Arrhenatherum, *A. pennsylvanica* to Trisetum, *A. flavescens* to Trisetum, *A. fragilis* to Gaudinia, *A. spicata* to Danthonia. In the Genera Plantarum, Linnæus cites Tournefort's figure 267 (error for 297), which is *Avena sativa*. Hence this is the type species.

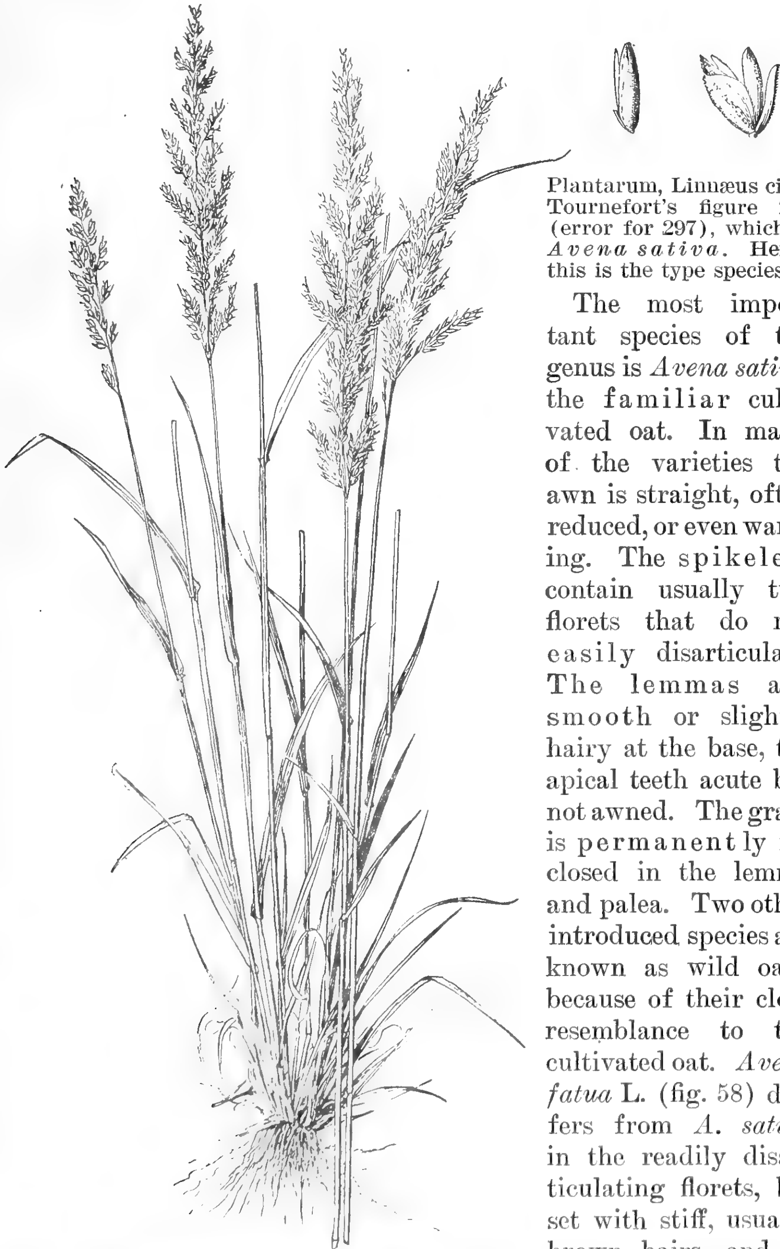

FIG. 57. *Sphenopholis obtusata*. Plant, × ½; spikelet and floret, × 5.

The most important species of the genus is *Avena sativa*, the familiar cultivated oat. In many of the varieties the awn is straight, often reduced, or even wanting. The spikelets contain usually two florets that do not easily disarticulate. The lemmas are smooth or slightly hairy at the base, the apical teeth acute but not awned. The grain is permanently inclosed in the lemma and palea. Two other introduced species are known as wild oats, because of their close resemblance to the cultivated oat. *Avena fatua* L. (fig. 58) differs from *A. sativa* in the readily disarticulating florets, beset with stiff, usually brown hairs, and in the well-developed geniculate and twisted awn. A variety of this (*A. fatua glabrata* Peterm.) has glabrous florets. In our other species of wild oats, *A. barbata* Brot., the pedicels are more slender, the spikelets pendulous, and the teeth of

FIG. 58.—Wild oats, *Avena fatua*. Plant, × ½; spikelet and floret, × 2.

the lemma are prolonged into delicate awns. These species of wild oats are common on the Pacific coast, where they are weeds, but are utilized for hay. Much of the grain hay of that region is made from either cultivated or wild oats.

The varieties of cultivated oat are derived from three species of Avena. The common varieties of this country and of temperate and mountain regions in general are derived from *A. fatua*. The Algerian oat grown in North Africa and Italy and the red oat of our Southern States are derived from *A. sterilis*. A few varieties adapted to dry countries are derived from *A. barbata*[1].

Avena sterilis L., animated oats, is sometimes cultivated as a curiosity. When laid on the hand or other moist surface the fruits twist and untwist as they lose or absorb moisture.

Our two native species, found in the Rocky Mountain region, are perennials, with narrow few-flowered panicles of erect spikelets smaller than those of *Avena sativa*. They are excellent forage grasses, but occur only scatteredly.

48. ARRHENATHERUM Beauv.

Spikelets 2-flowered, the lower floret staminate, the upper perfect, the rachilla disarticulating above the glumes, produced beyond the florets as a slender bristle; glumes rather broad and papery, the first 1-nerved, the second a little longer than the first and about as long as the spikelet, 3-nerved; lemmas 5-nerved, hairy on the callus, the lower bearing near the base a twisted, geniculate, exserted awn, the upper bearing a short, straight, slender awn just below the tip.

Perennial, rather tall grasses, with flat blades and rather dense panicles. Species about six, in the temperate regions of Eurasia; one species introduced into the United States.

Type species: *Arrhenatherum avenaceum* Beauv.

Arrhenatherum Beauv., Ess. Agrost. 55, pl. 11, f. 5. 1812. Beauvois figures one species, which he calls *Arrhenatherum avenaceum*. This is *Avena elatior* L., and is now called *Arrhenatherum elatius* (L.) Mert. and Koch.

Arrhenatherum elatius (Pl. XII; fig. 59) is occasionally cultivated in the humid regions of the United States as a meadow grass under the name of tall oat-grass. It is a fairly satisfactory forage grass, but the seed is expensive and often of poor quality. This species is often found growing spontaneously in grassland and along roadsides in the Northern States.

A variety, *Arrhenatherum elatius bulbosum* (Presl) Koch, has appeared recently in some of the Atlantic States. It differs from the ordinary form in having at the base of the stem a moniliform string of 2 to 5 small corms 5 to 10 mm. in diameter.

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[1] See Journ. Hered. 5: 56, 1914, a translation of an article by Trabut. Also see Norton, Amer. Breed. Assoc. 3: 281. 1907.

49. AIRA L.

(*Deschampsia* Beauv.)

Spikelets 2-flowered, disarticulating above the glumes, the hairy rachilla prolonged behind the upper floret as a stipe, this sometimes bearing a reduced floret; glumes about equal, acute or acutish, membranaceous; lemmas thin, truncate and 2 to 4 toothed at the summit, bearing a slender awn from or below the middle, the awn straight, bent, or twisted.

Low or moderately tall annual or usually perennial grasses, with shining pale or purplish spikelets in narrow or open panicles. Species about 35, in the temperate and cool regions of both hemispheres, 6 of these being in the United States.

Type species: *Aira caespitosa* L.

Aira L., Sp. Pl. 63, 1753; Gen. Pl., ed. 5, 31. 1754. Fourteen species are described. The name was first used for a genus by Linnæus in his Flora Lapponica in 1737, where he describes four species. These four species are named in the Species Plantarum: 7. *A. spicata*, 8. *A. caespitosa*, 9. *A. flexuosa*, 10. *A. montana*. The first of these, *A. spicata*, is referred to Trisetum; the other three belong to Deschampsia, as recognized in most American botanies. The genus Aira, as accepted by Bentham and Hooker in the Genera Plantarum and by Hackel in the Natürlichen Pflanzenfamilien, is based upon the last two of the original Linnæan

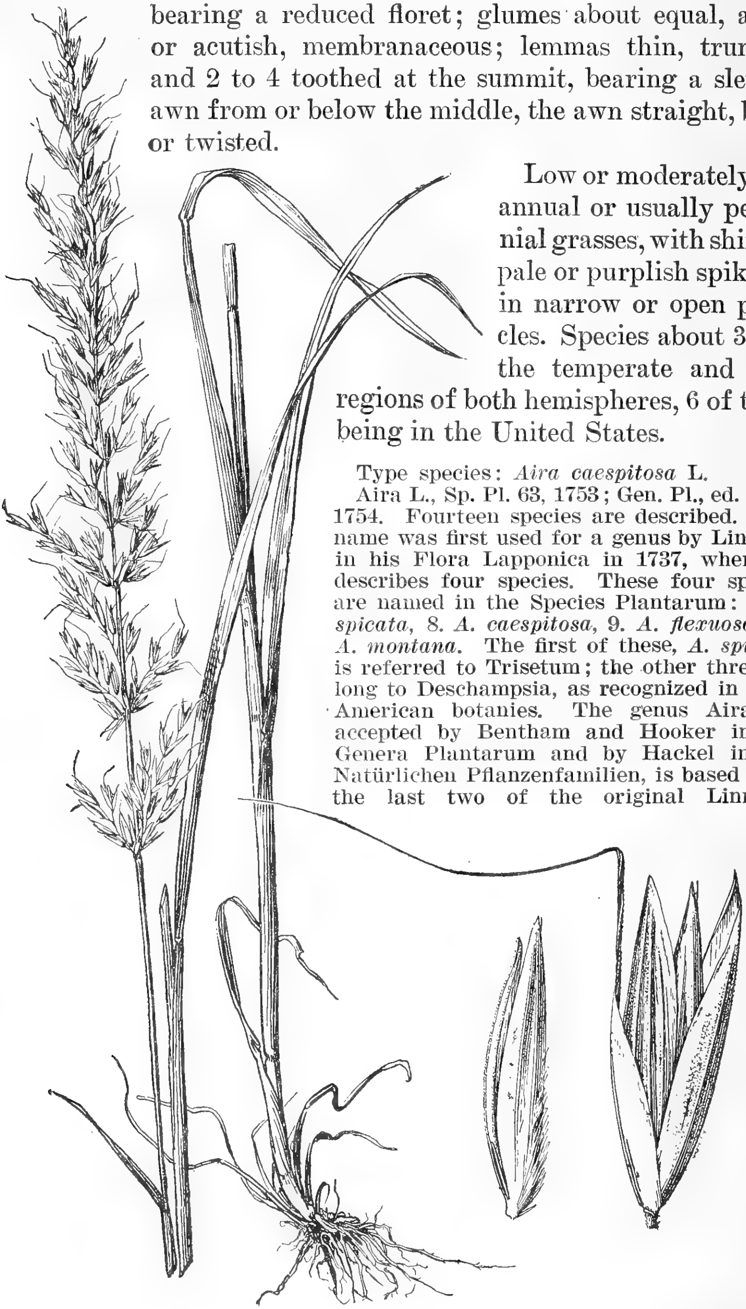

FIG. 59.—Tall oat-grass, *Arrhenatherum elatius*. Plant, × ½; spikelet and fertile floret, × 5.

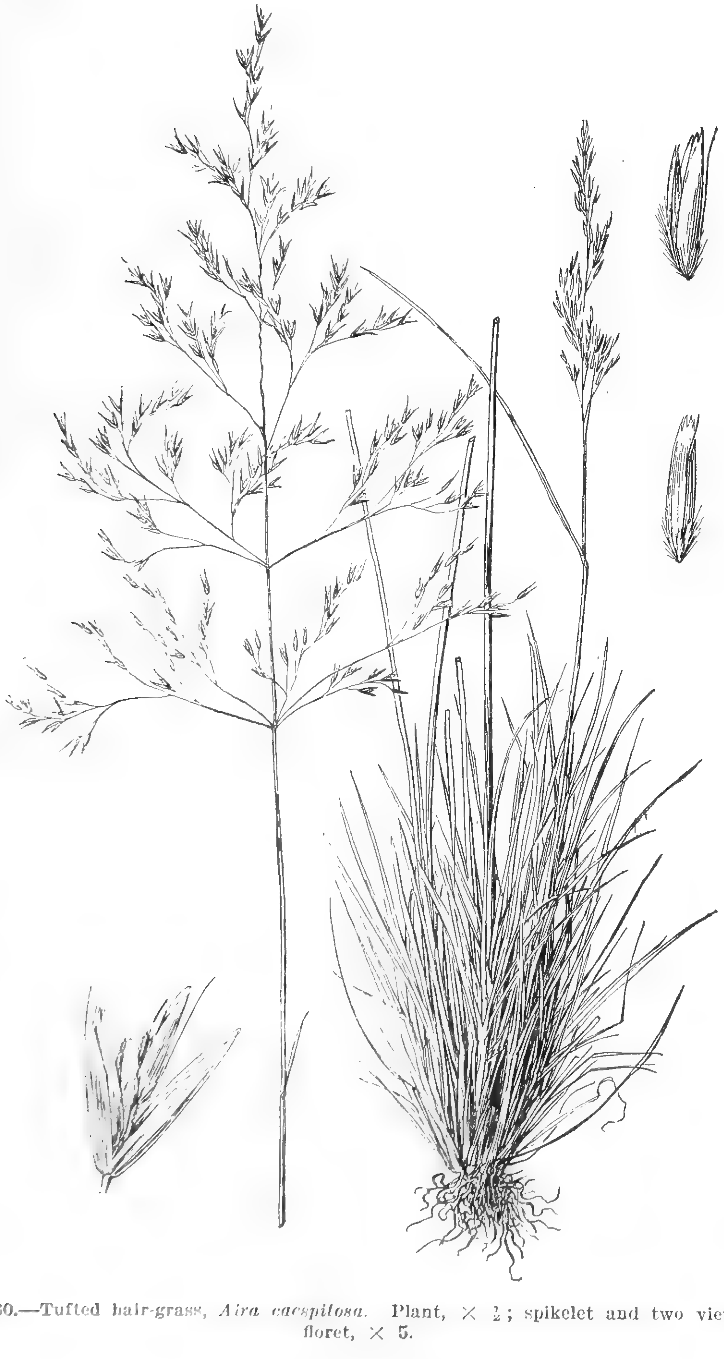

FIG. 60.—Tufted hair-grass, *Aira caespitosa*. Plant, × ½; spikelet and two views of floret, × 5.

species, *A. praecox* and *A. caryophyllea*, which are found in southern Europe and are not described by Linnæus in his Flora Lapponica nor in his Flora Suecica. Linnæus's generic idea of Aira is evidently represented by the four species first included in the genus. From these *Aira caespitosa* is arbitrarily selected as the type.

Deschampsia Beauv., Ess. Agrost. 91, pl. 18, f. 3. 1812. The figured species, the type, is *D. caespitosa*.

Lerchenfeldia Schur., Enum. Pl. Transs. 753. 1866. Three species are included. *Aira flexuosa* L., on which *L. flexuosa* is based, is taken as the type.

Aira danthonioides Trin. of the Pacific coast is an annual. *Aira caespitosa* L. (*Deschampsia caespitosa* Beauv.) (fig. 60) is common in moist or wet soil from Newfoundland to Alaska and south to New Jersey, Illinois, and, in the western mountains, to New Mexico and southern California. It is a tufted perennial 1 to 4 feet high, with smooth, narrow, folded blades and open drooping panicles, 4 to 12 inches long, of shining pale-bronze or purplish spikelets. This species, sometimes called tufted hair-grass, is often the dominant grass in mountain meadows, where it furnishes excellent forage.

50. Aspris Adans.

(*Aira* of authors.)

Spikelets 2-flowered, the rachilla disarticulating above the glumes, not prolonged; glumes about equal, acute, membranaceous or subscarious; lemmas firm, rounded on the back, tapering into two slender teeth, the callus with a very short tuft of hairs, bearing on the back below the middle a slender, geniculate, twisted, usually exserted awn, this reduced or wanting in the lower floret in one species.

Low, delicate annuals with small open or contracted panicles. Species about nine, in southern Europe, three being introduced in the United States.

Type species: *Aira praecox* L.

Aspris Adans., Fam. Pl. 2: 496, 522. 1763. The references cited are also cited by Linnæus under *Aira praecox*.

Caryophyllea Opiz, Seznam 27. 1852. Based on *Aira caryophyllea*.

Fussia Schur., Enum. Pl. Transs. 754. 1866. Three species, *F. praecox*, *F. caryophyllea*, and *F. capillaris*, are included. *Aira praecox*, upon which the first species is based, is taken as the type.

Our three species are *Aspris caryophyllea* (L.) Nash (fig. 61), *A. praecox* (L.) Nash, and *A. capillaris* (Host) Hitchc. (*Aira capillaris* Host). They are found frequently on the Pacific coast and occasionally in the Eastern States. The species are of no economic importance.

Weingaertneria canescens Bernh. has been found upon ballast at Philadelphia and on Marthas Vineyard. This is a low, tufted annual with pale, contracted panicles, differing from the species of Aspris in having club-shaped awns.

51. Notholcus Nash.

(*Holcus* of authors.)

Spikelets 2-flowered, the pedicel disarticulating below the glumes, the rachilla curved and somewhat elongate below the first floret, not prolonged above the second floret; glumes about equal, longer than the two florets; first floret perfect, its lemma awnless; second floret staminate, its lemma awned on the back.

FIG. 61.—*Aspris caryophyllea.* Plant, × ½; spikelet and two views of floret, × 5.

Perennial grasses, with flat blades and contracted panicles. Species about eight, Europe and Africa; two introduced into the United States.

Type species: *Holcus lanatus* L.

Ginannia Bubani, Fl. Pyren. **4**: 321, 1901, not Scop., 1777, nor Dietr., 1804. Based on "Holcus L. et Auctor.," the two species included, *G. pubescens* and *G. mollis*, showing that it is to the species congeneric with *Holcus lanatus* L. that the name is applied.

Notholcus Nash; Hitch., in Jepson, Fl. Calif. **3**: 126. 1912. Only one species described. Notholcus is derived from the Greek nothos, false, and Holcus, the generic name formerly applied to this group. Nash [1] spells the name Nothoholcus. For a discussion of the reasons for the change of name, see page 266. The generic name Holcus is there applied to the sorghums, necessitating a new name for the velvet grass.

The common species in the United States is *Notholcus lanatus* (L.) Nash (*Holcus lanatus* L.), known as velvet grass (fig. 62). This species is introduced in various places in the Eastern States and also on the Pacific coast, where it is abundant. It is an erect, grayish, velvety-pubescent grass 2 to 3 feet tall, with a contracted pale or purplish panicle 2 to 4 inches long. Velvet grass is sometimes recommended as a meadow grass, but for this purpose it has little value except on moist sandy or sterile soil where other grasses will not thrive. It has been used with some success in sandy fields around the mouth of the Columbia River in Washington and Oregon.

A second species, *Notholcus mollis* (L.) Hitchc., with creeping rhizomes, has been introduced in California, where it is rare.

52. Danthonia Lam. and DC.

Spikelets several-flowered, the rachilla readily disarticulating above the glumes and between the florets; glumes about equal, broad and papery, acute, mostly exceeding the uppermost floret; lemmas rounded on the back, obscurely several-nerved, the base with a strong callus, the apex bifid, the lobes acute, usually extending into slender awns, a stout awn arising from between the lobes; awn flat, tightly twisted below, geniculate, exserted, including three nerves of the lemma.

Tufted, low or moderately tall perennials, with few-flowered, open, or spikelike panicles of rather large spikelets. Species about 100, in the temperate regions of both hemispheres; especially abundant in South Africa; 12 species in the United States, about equally divided between the Eastern and the Western States.

Type species: *Avena spicata* L.

Danthonia Lam. and DC., Fl. Franc. **3**: 32. 1805. The work cited is a local flora in which the two French species are described, *D. decumbens* (which is the same as *Sieglingia decumbens*) and *D. provincialis*. The authors, however, mention in the paragraph preceding the one devoted to the generic description that "besides the species described below one ought to refer to this genus, 1st, *Avena spicata* L. or *Avena glumosa* Michx.; 2d, *Avena calicina* Lam. not Vill." Of the four species mentioned, three are congeneric with *Avena spicata* and correspond with the generic description better than does *Danthonia decumbens*, which is the first species described under Danthonia. *Avena spicata* is selected as the type of Danthonia.[2] Piper [3] has selected *Festuca decumbens* L. (*Danthonia decumbens*) as the type of Danthonia because it is the first species described under Danthonia, and takes up Merathrepta Raf. for the species generally referred to Danthonia. Nelson and Macbride [4] take up Pentameris Beauv. in place of Merathrepta.

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[1] Britt. and Brown, Illustr. Fl., ed. 2, **1**: 214. 1913.

[2] See Hitchc., Bot. Gaz. **57**: 328. 1914.

[3] Contr. U. S. Nat. Herb. **11**: 122. 1906.

[4] Bot. Gaz. **56**: 469. 1913.

FIG. 62.—Velvet grass, *Notholcus lanatus*. Plant, × ½; spikelet, florets with glumes removed, and mature fertile floret, all × 5.

Pentameris Beauv., Ess. Agrost. 92, pl. 18, f. 8. 1812. *P. thuarii* is the type, as this is the single species mentioned and figured. This is a South African species and represents a group in which the lateral teeth of the lemmas are 2-awned. The group is considered to be generically distinct from Danthonia by Stapf.[1] The name is taken up by Nelson and Macbride in place of Merathrepta Raf.[2]

Merathrepta Raf., Bull. Bot. Seringe **1**: 221. 1830. The genus is described briefly and *Avena spicata* mentioned. This species is, therefore, the type.

One species of Danthonia, *D. spicata* (L.) Beauv. (fig. 63), is common on sterile hills and in dry, open woods in the Eastern States, where it is sometimes called poverty grass. It can be recognized, even when not in flower, by its small tufts of curly leaves. In the Western States the species are found in grassland and contribute somewhat toward the forage value of the range, but usually they are not abundant. All our species produce cleistogenes (enlarged fertile cleistogamous spikelets) in the lower sheaths,[3] and the culms finally disarticulate at the nodes below these.

FIG. 63.—Wild oat-grass, *Danthonia spicata*. Plant, × ½; spikelet, floret, and a cleistogene from the axil of a lower leaf, all × 5.

[1] Thiselt. Dyer, Fl. Cap. 7: 512. 1898.
[2] See following paragraph on Merathrepta.
[3] Chase, Amer. Journn. Bot. 5: 254. 1918.

5. AGROSTIDEAE, THE TIMOTHY TRIBE.

53. Calamagrostis Adans.

Spikelets 1-flowered, the rachilla disarticulating above the glumes, usually prolonged behind the palea as a short, commonly hairy bristle; glumes about equal, acute or acuminate; lemma shorter and usually more delicate than the glumes, the callus bearing a tuft of hairs, which are often copious and as long as the lemma, awned from the back, usually below the middle, the awn being delicate and straight, or stouter and exserted, bent and sometimes twisted; palea shorter than the lemma.

Perennial, usually moderately tall or robust grasses, with small spikelets in open or usually narrow, sometimes spikelike panicles. Species over 100, in the cool and temperate regions of both hemispheres; 26 species in the United States, mostly in the western mountains.

Type species: *Arundo calamagrostis* L.

Calamagrostis Adans., Fam. Pl. 2: 31, 530. 1763. Adanson describes no species but in the index there is given under Kalamagrostis Diosk., three names or citiations, Negil. Arab., Gramen. Sheuz. t. 3. f. 5., and Arundo Lin. The reference to Scheuchzer is found in Linnæus's Species Plantarum under *Arundo calamagrostis* (1: 82), which consequently is the type of Calamagrostis.

Deyeuxia Clarion; Beauv., Ess. Agrost. 43, pl. 9, f. 9, 10. 1812. Type, *D. montana*, the first of the two species figured.

Amagris Raf., Princip. Fondament. Somiologie 27. 1814. A new name proposed for Calamagrostis, because that is formed of two other names.

Athernotus Dulac, Fl. Hautes Pyr. 74. 1867. Based on "Calamagrostis Ad." Lunell[1] uses this name for Calamovilfa, but Dulac bases the genus on Calamagrostis Adans., and the three species he includes belong in Calamagrostis, not in Calamovilfa.

By some authors the species with prolonged rachilla are segregated as a distinct genus, Deyeuxia, the name Calamagrostis being retained for those species in which the rachilla is not prolonged. The American species all belong to the section Deyeuxia.

Four Pacific coast species have loose, open panicles. In all the other species the panicle is rather compact, in some cases spikelike. The commonest species in the United States is *Calamagrostis canadensis* (Michx.) Beauv. (fig. 64), growing in swamps and low ground from New England to Oregon, and southward in the mountains and northward to the arctic circle. It is an important source of wild hay from Wisconsin to North Dakota, but is of only medium value for grazing. Much of the marsh hay of Wisconsin and Minnesota belongs to this species, which in that region is called bluejoint. This is the dominant grass in the interior of Alaska. The species is distinguished by having flat blades, a somewhat lax, usually nodding panicle, the hairs at the base of the floret copious and as long as the lemma, the awn straight, delicate, not exserted beyond the glumes, the latter 3 to 5 mm. long.

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[1] Amer. Midl. Nat. 4: 218. 1915.

FIG. 64.—Bluejoint, *Calamagrostis canadensis*. Plant, × ½; spikelet and floret, × 5.

Calamagrostis scabra Presl, closely allied to the above, but with somewhat larger spikelets, is abundant along the coast from Oregon to Alaska. This has been incorrectly referred to *C. langsdorfii* (Trin.) Link, of Siberia. In general, the species of Calamagrostis are important forage grasses. Pine-grass (*C. rubescens* Buckl.) is common in the mountains of Oregon and Washington, where it forms an important part of the forage.

For a revision of the species of Calamagrostis found in the United States, see Kearney, U. S. Dept. Agr., Div. Agrost. Bull. 11. 1898.

54. Ammophila Host.

Spikelets 1-flowered, compressed, the rachilla disarticulating above the glumes, produced beyond the palea as a short bristle, hairy above; glumes about equal, chartaceous; lemma similar to and a little shorter than the glumes, the callus bearing a tuft of short hairs; palea nearly as long as the lemma.

A tough, rather coarse, erect perennial, with hard, scaly, creeping rhizomes, long, tough, involute blades, and a pale, dense, spikelike panicle. One species is found on the sandy seacoast of Europe and northern North America as far south as North Carolina and on the shores of the Great Lakes, a second species around the Baltic.

Type species: *Arundo arenaria* L.

Ammophila Host, Gram. Austr. **4:** 24, pl. 41. 1809. Only one species described, *A. arundinacea* Host, based on *Arundo arenaria* L.

Psamma Beauv., Ess. Agrost. 143, pl. 6, f. 1. 1812. The one species, *P. littoralis*, is *Ammophila arenaria*.

Ammophila arenaria (L.) Link (fig. 65) is an important sand-binding grass in Europe, being used there to hold the barrier dunes along the coast. In this country it has been tried with success on Cape Cod and at Golden Gate Park, San Francisco.[1] It is called beach-grass and less frequently marram grass and sea marram.

55. Calamovilfa Hack.

Spikelets 1-flowered, the rachilla disarticulating above the glumes, not prolonged behind the palea; glumes unequal, acute, chartaceous; lemma a little longer than the second glume, chartaceous, awnless, glabrous or pubescent, the callus bearded; palea about as long as the lemma.

Perennial, rigid, usually tall grasses, with narrow or open panicles, some species with creeping rhizomes. Species four, confined to the United States and southern Canada.

Type species: *Calamagrostis brevipilis* Gray.

Calamovilfa Hack., True Grasses 113. 1890. The True Grasses is a translation by Scribner and Southworth of the article on grasses in Engler and Prantl's Natürlichen Pflanzenfamilien. Scribner has added bracketed notes. In a para-

[1] For a full discussion, see Hitchcock, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 57; Westgate, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 65. 1904.

FIG. 65.—Beach-grass, *Ammophila arenaria*. Plant, × ½; spikelet and floret, × 5.

graph quoted from Hackel ("Hackel in MS.") is a statement that two species, *Calamagrostis brevipilis* Gray and *C. longifolia* Hook., may best be considered a separate genus, Calamovilfa. Scribner adds a note formally describing the genus Calamovilfa and mentions the two species, *Calamovilfa brevipilis* and *C. longifolia.* The first is selected as the type.

The genus differs from Calamagrostis in the chartaceous lemma, from our species of Calamagrostis in the absence of a prolonged rachilla, and from Ammophila in the more open panicles and in the absence of the prolongation of the rachilla.

The four species are *Calamovilfa brevipilis* (Torr.) Scribn., in the pine barrens from New Jersey to North Carolina; *C. curtissii* (Vasey) Scribn., confined to Florida; *C. longifolia* (Hook.) Scribn. (fig. 66), of the Great Plains and the dune region of Lake Michigan; *C. gigantea* (Nutt.) Scribn. and Merr., also of the Great Plains. The first two species are without creeping rhizomes; the other two have numerous stout rhizomes and are excellent sand binders. *Calamovilfa longifolia* and *C. gigantea* are closely related. They are differentiated by the less expanded panicle and glabrous florets of the first and the spreading panicle, larger spikelets, and villous florets of the second.

Calamovilfa longifolia, the commonest species, is of some value for forage, but is rather coarse and woody.

56. Agrostis L., the bent-grasses.

Spikelets 1-flowered, disarticulating above the glumes, the rachilla usually not prolonged; glumes equal or nearly so, acute, acuminate, or sometimes awn-pointed, carinate, usually scabrous on the keel and sometimes on the back; lemma obtuse, usually shorter and thinner in texture than the glumes, awnless or dorsally awned, often hairy on the callus; palea usually shorter than the lemma, 2-nerved in only a few species, usually small and nerveless or obsolete.

Annual or usually perennial, delicate or moderately tall grasses, with glabrous culms, flat or sometimes involute, scabrous blades, and open or contracted panicles of small spikelets. Species about 100, in the temperate and cold regions of the world, especially in the Northern Hemisphere. About 25 species are found in the United States, some of these being found also in Europe.

Type species: *Agrostis stolonifera* L.

Agrostis L., Sp. Pl. 61. 1753; Gen. Pl., ed. 5, 30. 1754. Linnæus describes 12 species, dividing them into two groups, Aristatae and Muticae. The description of the genus refers to the lemma as being awned and to the presence of a palea ("Cor. bivalvis . . . altera majore aristata"). If the type species must agree with the description in the fifth edition of the Genera Plantarum.[1] it must be chosen from the first group, Aristatae, and from those

[1] See American Code of Botanical Nomenclature, Bull. Torrey Club 34: 174. 1907. The statement is made that "the genera of Linnæus's Species Plantarum (1753) are to be typified through the citations given in his Genera Plantarum (1754)." There is no citation given for Agrostis and the code does not definitely require that the genera must be interpreted by the descriptions here given; hence the type species may be chosen independent of this description.

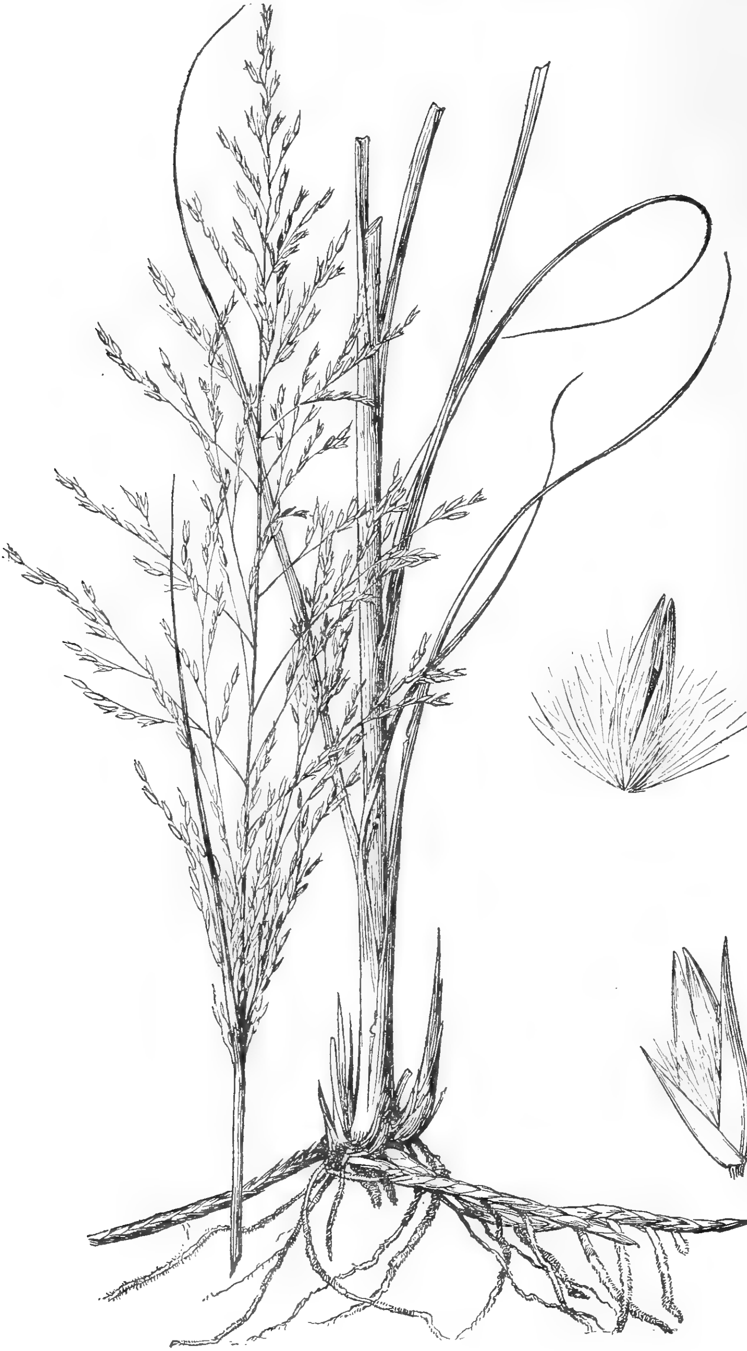

FIG. 66.—*Calamovilfa longifolia.* Plant, × ½; spikelet and floret, × 5.

species possessing a palea. From this standpoint the type species would be *Agrostis spica-venti*, which is referred by many botanists to Apera but which is here included in Agrostis. However, the description of Agrostis in the fifth edition was not written by Linnæus for that edition. It was copied from the first edition, published in 1737, at which time Linnæus's concept of Agrostis was chiefly based on *Stipa calamagrostis*. By the time the Species Plantarum was prepared his concept of the genus Agrostis had changed, but he did not make the corresponding change in the description in the fifth edition of the Genera Plantarum which he prepared at the same time. It seems best, then, to ignore this description and select the type species from the economic species. Therefore *A. stolonifera*[1] has been selected as the type species of Agrostis. Several of the original species are now referred to other genera: *A. miliacea* and *A. paradoxa* to Oryzopsis; *A. arundinacea* to Calamagrostis; *A. minima* to Mibora; *A. virginica* and *A. indica* to Sporobolus.

Vilfa Adans., Fam. Pl. **2**: 495. 1763. Adanson cites " Gramen canin. supin. C. B. Theat. 12 " and in the index, " Gramen canin. supin. minus C. B." Linnæus[2] gives under *Agrostis stolonifera* the citation, " Gramen caninum supinum minus Scheuch. gram. 128." Scheuchzer[3] credits the citation to C. Bauhin. Therefore *Agrostis stolonifera* L. is the type of Vilfa Adans.

Apera Adans., Fam. Pl. **2**: 495. 1763. Adanson refers directly to "Agrostis 1. Lin. Sp. 61." The first species of Agrostis described by Linnæus in his Species Plantarum (p. 61) is *A. spica-venti*, which becomes the type of Apera.

Trichodium Michx., Fl. Bor. Amer. **1**: 41, pl. 8. 1803. Two species are described, *T. laxiflorum* and *T. decumbens*. The first species, illustrated in plate 8, is the type. This is the same as *Afrostis hiemalis*. *Trichodium decumbens* is the same as *A. perennans*. Michaux distinguished the genus from Agrostis by the absence of the palea.

Agraulus Beauv., Ess. Agrost. 5, pl. 4, f. 7. 1812. Two species, based on *Agrostis canina* L. and *A. alpina* Willd., are included, the first being figured and therefore the type.

Anemagrostis Trin., Fund. Agrost. 128. 1820. Two species, based on *Agrostis spica-venti* L. and *A. interrupta* L., are included, the first of which is taken as the type.

Notonema Raf., Neogenyt. 4. 1825. A single species is included, *Agrostis arachnoides* Ell. (*A. elliottiana* Schult.)

Podagrostis Scribn. and Merr., Contr. U. S. Nat. Herb. **13**: 58. 1910. Based upon Agrostis, section Podagrostis Griseb. in Ledeb. Fl. Ross. **4**: 436. 1853. A single species, *Agrostis aequivalvis* Trin., referred here in each case. *A. thurberiana* Hitchc. also belongs to this group, which forms a section of Agrostis.

In *Agrostis spica-venti*, *A. aequivalvis*, and *A. thurberiana* the rachilla is prolonged behind the palea as a minute bristle or stipe, and the lemma and palea are nearly equal and about as long as the glumes. The palea is obsolete in many species (which have been separated by some authors under the generic name of Trichodium), and is much shorter than the lemma in several other species. The awn, when present, may arise from the back of the lemma just above

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[1] See Hitchcock, Bot. Gaz. **38**: 141. 1904. On the basis of the specimen in the Linnæan Herbarium and of the synonymy, the name *A. stolonifera* was there applied to the species called *A. verticillata* Vill. But on reconsideration it seems best to accept the name as applied by Swedish botanists. Linnæus was most familiar with the Swedish grass, and cites as the first synonym under *A. stolonifera* the phrase name he had applied to it in his Flora Suecica. He confused with this the South European species, *A. verticillata*, a specimen of which in his herbarium he marked *" A. stolonifera,"* but we may assume that he intended to apply the name *A. stolonifera* to the grass from Sweden. In the latter work Linnæus states that the plant is known popularly as Kryp-hwen. Dr. Carl Lindman, who has kindly sent a series of specimens of the species in question, states in a letter that the grass in Sweden called Krypven (the modern spelling) is the species described by Swedish botanists as *A. stolonifera*. This has a long ligule, an open panicle, and an erect culm decumbent at base or producing stolons.

[2] Sp. Pl. 62. 1753. [3] Agrost. 128. 1719.

the base (*A. howellii* Scribn.) or from about the middle (*A. exarata microphylla* (Steud.) Hitchc.) or from just below the apex (*A. spica-venti*, *A. elliottiana*). The hairs on the callus are usually minute, but are half as long as the lemma in *A. hallii* Vasey. Three of our species are annuals, *A. spica-venti* L., introduced from Europe; *A. exigua* Thurb., of California; and *A. elliottiana* Schult., of the Southern States.

The genus furnishes several species that are important forage plants either under cultivation or in the mountain meadows of the Western States. The most important is *Agrostis palustris* Huds. (*A. alba* of authors[1]) (Pl. XIII; fig. 67), known usually as redtop because of the reddish

[1] The name *Agrostis alba* L. (Sp. Pl. 63. 1753) is of doubtful application. In the original publication the name is founded solely on the citation "Roy. lugdb. 59" (Royen, Flora Leydensis). Royen's citation of synonym refers to Poa (apparently *P. nemoralis*). There are several sheets in Linnæus's herbarium, one of which bears the name, *Agrostis alba,* in Linnæus's script. These specimens are the *Agrostis alba* as generally understood, but,

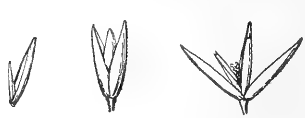

FIG. 67.—Redtop, *Agrostis palustris.* Plant, × ½; spikelet, open and closed, and floret, × 5.

REDTOP (AGROSTIS PALUSTRIS).

TIMOTHY (PHLEUM PRATENSE).

color of the panicle. This species is an erect plant 2 to 4 feet high, producing rhizomes, and often decumbent at base, with flat blades, prominent, somewhat pointed ligule, and an open, usually reddish panicle, 2 to 12 inches long, contracted in fruit, the branches in whorls. Redtop is cultivated as a meadow and pasture grass in the Northern States, especially upon soils lacking in lime and upon soils too wet for timothy. In Pennsylvania and some other localities this species is called herd's-grass.

Agrostis capillaris L. (*A. tenuis* Sibth., *A. vulgaris* With., *A. alba vulgaris* Thurb.), Rhode Island bent,[1] differs from redtop in its smaller size, more delicate culms and foliage, short truncate ligule, smaller, more open, and fewer flowered panicle, not contracting after flowering. Stolons are usually absent but may be as much as 4 to 8 inches long. Rhode Island bent is often used as a lawn grass, especially in the Northeastern States, where the soil is lacking in lime and bluegrass does not thrive. In some botanical works the name *Agrostis canina* has been incorrectly applied to Rhode Island bent. *Agrostis canina* L., a European species occasionally introduced into the Eastern States, is a frequent constituent of the commercial seed of creeping bent. It is called velvet bent and gives promise of being a fine lawn grass.

Carpet bent, also called creeping bent, is a form of *A. stolonifera*. This produces stolons from 1 to 4 feet long and is also used as a lawn grass in the same region as that described for Rhode Island bent. The seed has been imported from southern Germany.

Fiorin is a name that was applied in England to a coast form with stoloniferous habit, long ligule, and narrow dense panicles. This form is found along the northern Atlantic coast of Europe and America and along the Pacific coast from British Columbia to northern California. It has been called *A. maritima* Lam. and *A. alba maritima* (Lam.) Meyer. It is apparently indigenous in America, while *A. capillaris* and *A. palustris* appear to be introductions.

Several native species of Agrostis are found in the western part of the United States, especially in mountain meadows. One of the commonest of the western species is *A. exarata* Trin., with contracted, sometimes spikelike, panicles and awned or awnless spikelets, found at all altitudes throughout the western portion of the United States.

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according to Jackson (Index to the Linnæan Herbarium, Proc. Linn. Soc. London, 124th Sess. Suppl. 1912), these specimens were added to the herbarium after 1753 and can not, therefore, have weight in determining the original application of the name. Linnæus did not refer, under *Agrostis alba*, to his flora of Sweden. It would appear that he did not intend to apply the name originally to a Swedish plant. The species usually known as *Agrostis alba* is common in Sweden, but apparently was included by Linnæus under *A. stolonifera*, to which it is closely allied. It was not until later that he applied the name to the species as now represented in his herbarium. Under these circumstances it seems best to drop the name *Agrostis alba*, as has been done by Piper (U. S. Dept. Agr. Bull. 692, 1918) and by Stapf, as indicated in a letter to Piper.

[1] See Piper, The Agricultural Species of Bent Grasses. U. S. Dept. Agr. Bull. 692. 1918.

This is an important range grass. Common on the Pacific slope is *A. diegoensis* Vasey, with creeping rhizomes, spreading panicles, and often awned spikelets.

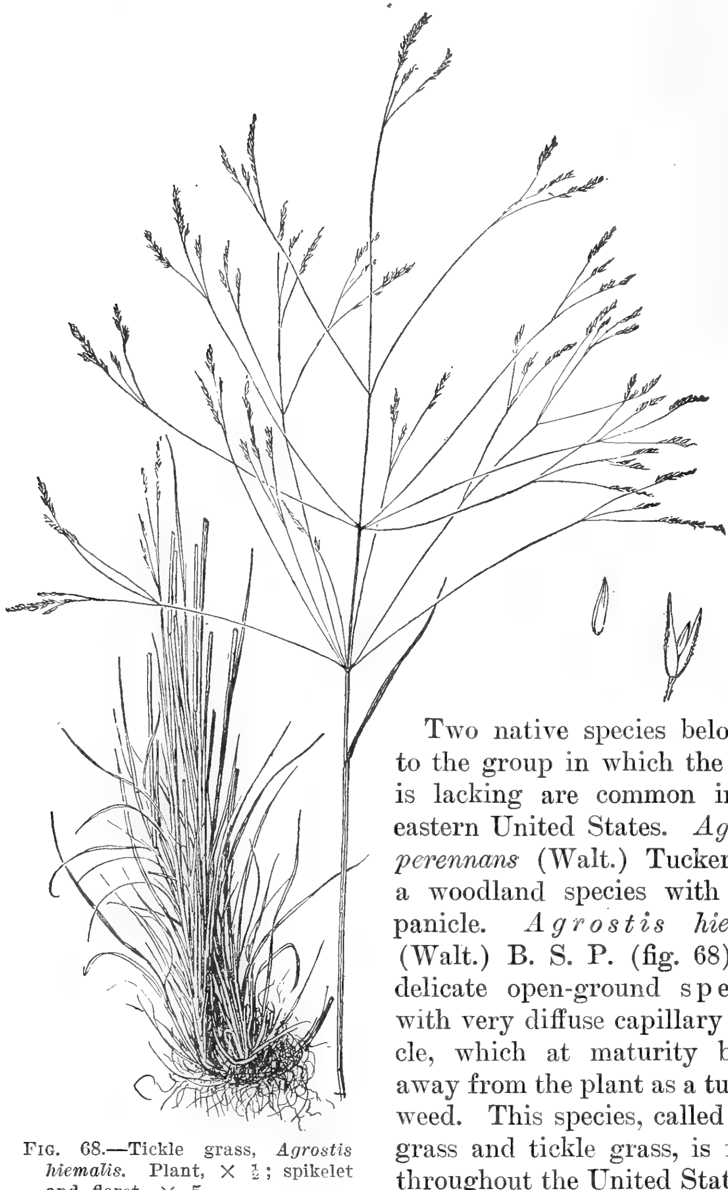

FIG. 68.—Tickle grass, *Agrostis hiemalis.* Plant, × ½; spikelet and floret, × 5.

Two native species belonging to the group in which the palea is lacking are common in the eastern United States. *Agrostis perennans* (Walt.) Tuckerm. is a woodland species with open panicle. *Agrostis hiemalis* (Walt.) B. S. P. (fig. 68) is a delicate open-ground species with very diffuse capillary panicle, which at maturity breaks away from the plant as a tumbleweed. This species, called hairgrass and tickle grass, is found throughout the United States.

Agrostis spica-venti L. (fig. 69), a European species, sparingly introduced in the Eastern States, has been made the type of a distinct genus, Apera, being distinguished by the prolongation of the rachilla and the long delicate awn from

FIG. 69.—*Agrostis spica-venti.* Plant, × ½; glumes and floret, × 5.

just below the apex of the lemma. These characters are not deemed sufficient to separate it from our species. The rachilla is prolonged in *A. aequivalvis* and a similar awn is found in the annual *A. elliottiana* Schult.

For a revision of the species of Agrostis found in the United States, see Hitchcock, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 68. 1905.

57. Phippsia (Trin.) R. Br.

Spikelets 1-flowered, disarticulating above the glumes, the rachilla not prolonged; glumes unequal, minute, the first sometimes wanting; lemma thin, somewhat keeled, 3-nerved, acute; palea a little shorter than the lemma, dentate.

A dwarf, tufted perennial, with narrow, few-flowered panicles of small spikelets. Species one, in the arctic regions of both hemispheres; also on the alpine summits of Colorado.

Type species: *Agrostis algida* Soland.

Colpodium subgenus Phippsia Trin., in Spreng. Neu. Entd. **2**: 37. 1821.

Fig. 70.—*Phippsia algida*. Plant, × ½; spikelet and branchlet of inflorescence with the glumes of lower spikelets remaining, and floret, all × 5.

Phippsia R. Br., Suppl. App. Parry's Voy. 184. 1824. A single species described, *P. algida*, based on *Agrostis algida* Soland.

Phippsia algida (Soland.) R. Br. (fig. 70) is known in the United States only from a few localities in the alpine regions of Colorado. It was first described as *Agrostis algida* by Solander.[1]

58. Coleanthus Seidel.

Spikelets 1-flowered; glumes wanting; lemma ovate, hyaline, terminating in a short awn; palea broad, 2-keeled.

A dwarf annual, about an inch high, with short flat blades and small few-flowered panicles. Species one, northern Eurasia, introduced in America.

Type species: *Schmidtia subtilis* Tratt.

Schmidtia Tratt., Fl. Oesterr. Kaiserth. **1**: 12, pl. 10, 1816, not Schmidtia Moench, 1802. Only one species described.

Coleanthus Seidel; Roem. and Schult., Syst. Veg. **2**: 276. 1817. Only one species described, *C. subtilis*, based on *Schmidtia subtilis*.

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[1] In Phipps Voy. 200. 1810.

Coleanthus subtilis (Tratt.) Seidel (fig. 71), introduced from Europe, grows on mud flats along the Columbia River, where it was collected by Howell (on Sauvies Island, Oreg.) and by Suksdorf (western Klickitat County, Wash.).

Mibora minima (L.) Desv. has been found at Plymouth, Mass. This, the only species of the genus, is a low annual, differing from Coleanthus and Phippsia in having glumes longer than the lemma, the very small spikelets in simple spikes. Introduced from Europe.

59. Cinna L.

Spikelets 1-flowered, disarticulting below the glumes, the rachilla forming a stipe below the floret and produced behind the palea as a minute bristle; glumes equal, 1-nerved; lemma similar to the glumes,

Fig. 71.—*Coleanthus subtilis.* Plant, × 1; lemma and palea and two views of spikelet with ripe caryopsis, × 20.

nearly as long, 3-nerved, bearing a minute, short, straight awn just below the apex; palea apparently 1-nerved, 1-keeled.

Tall perennial grasses, with flat blades and paniculate inflorescence. Species three, North America and northern Eurasia, two in the United States and one in Mexico and southward.

Type species: *Cinna arundinacea* L.

Cinna L., Sp. Pl. 5, 1753; Gen. Pl., ed. 5, 6. 1754. A single species is described.

Abola Adans., Fam. Pl. **2**: 31, 511. 1763. Based on "Cinna Lin."

Cinnastrum Fourn., Mex. Pl. **2**: 90. 1886. Two species are given, *C. miliaceum* and *C. poaeforme*, both referable to *Cinna poaeformis* (H. B. K.) Scribn. and Merr.

The prolongation of the rachilla is less than 0.5 mm. in our species, but in *Cinna poaeformis* of Mexico it is half as long as the palea. The palea is 1-nerved in *C. arundinacea.* In *C. poaeformis* the 2 nerves are close together but distinct. In *C. latifolia* the palea is apparently 1-nerved, but the 2 nerves separated when the palea is split along the keel.

Cinna arundinacea (fig. 72), with somewhat contracted panicle and spikelets 5 mm. long, grows in moist, usually shaded places in the eastern United States; *C. latifolia* (Trev.) Griseb., with open panicle and spikelets 4 mm. long, grows in damp woods across the continent in the northern part of the United States, mostly at medium and high elevations.

Fig. 72.—Wood reed-grass, *Cinna arundinacea*. Plant, × ½; spikelet and floret, × 5.

Both species furnish excellent forage, but are usually not abundant enough to be of much importance.

60. Limnodea L. H. Dewey.

Spikelets 1-flowered, disarticulating below the glumes, the rachilla prolonged behind the palea as a short, slender bristle; glumes equal, firm; lemma membranaceous, smooth, nerveless, 2-toothed at the apex, bearing from between the teeth a slender bent awn, twisted at base; palea a little shorter than the lemma.

A slender annual with flat blades and narrow panicles. Species one, Florida to Texas.

Type species: *Greenia arkansana* Nutt.

Greenia Nutt., Trans. Amer. Phil. Soc. **5:** 142, 1837, not Greenea Wight and Arn., 1834. Type *G. arkansana*, the only species described.

Sclerachne Torr.; Trin., Mém. Acad. St. Pétersb. VI. Sci. Nat. **4**[1]**:** 273, 1841, not Sclerachne R. Br. and Benn., 1838. Two species are described, *S. arkansana* Torr. and *S. pilosa* Trin. The first, based on *Greenia arkansana* Nutt., is the type.

Thurberia Benth., Journ. Linn. Soc. Bot. **19:** 58, 1881, not Thurberia A. Gray, 1854. Type *Greenia arkansana* Nutt., the name Thurberia being substituted for Greenia.

Limnodea L. H. Dewey, Contr. U. S. Nat. Herb. **2:** 518. 1894. Only one species described.

Limnodea arkansana (Nutt.) L. H. Dewey (fig. 73), has probably no agricultural value. A form with pilose

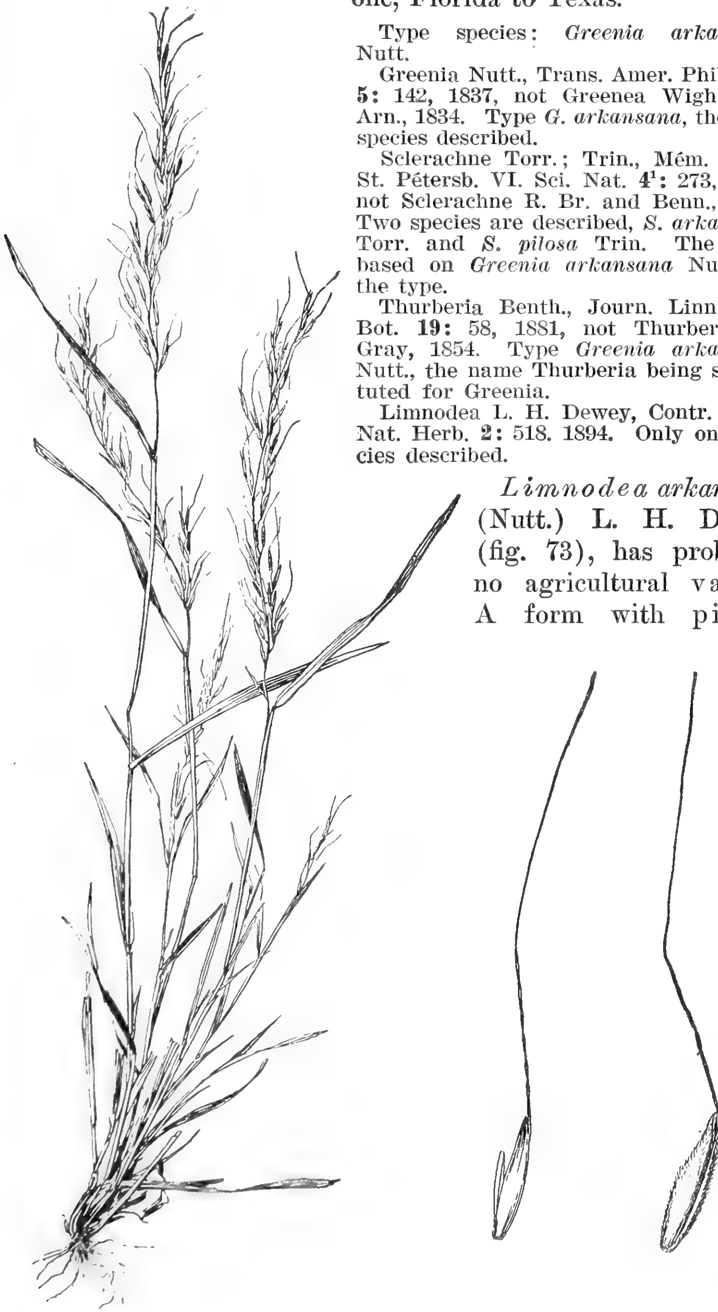
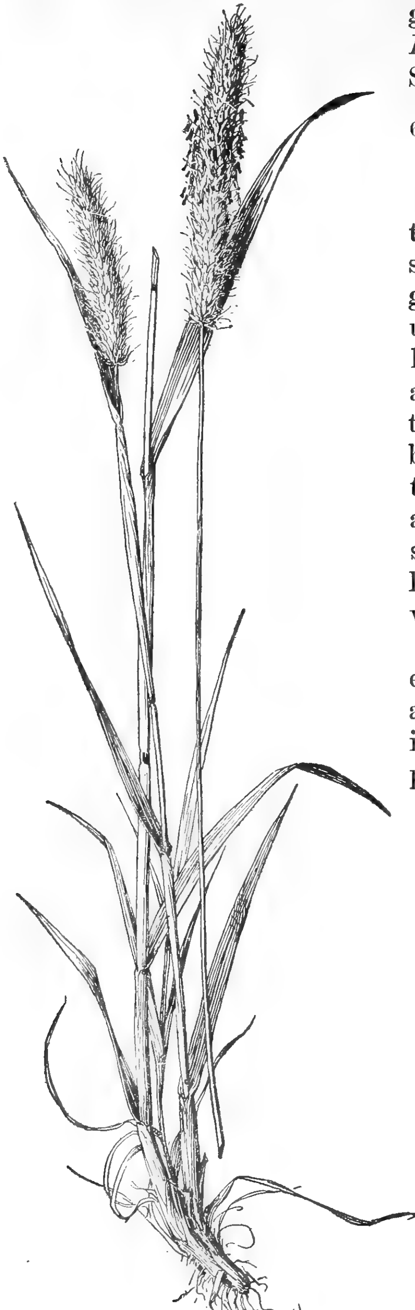


FIG. 73.—*Limnodea arkansana.* Plant, × ½; spikelet and floret, × 5.



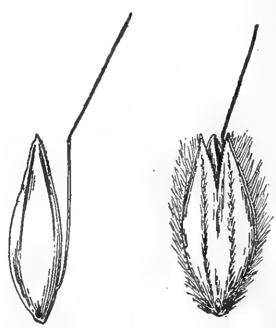


FIG. 74.—Meadow foxtail, *Alopecurus pratensis*. Plant, × ½; spikelet and floret, × 5.

glumes has been named *L. arkansana pilosa* (Trin.) Scribn.

61. ALOPECURUS L., the meadow foxtails.

Spikelets 1-flowered, disarticulating below the glumes, strongly compressed laterally; glumes equal, awnless, usually united at base, ciliate on the keel; lemma about as long as the glumes, 5-nerved, obtuse, the margins united at base, bearing from below the middle a slender dorsal awn, this included or exserted two or three times the length of the spikelet; palea wanting.

Low or moderately tall perennial grasses with flat blades and soft, dense, spikelike panicles. Species about 25, in temperate regions of the Northern Hemisphere. Of the eight North American species, two are introductions from Europe and two are widely distributed in

Eurasia. Some of the European species with a distinct palea have been segregated as the genus Colobachne.

Type species: *Alopecurus pratensis* L.

Alopecurus L., Sp. Pl. 60, 1753; Gen. Pl., ed. 5, 30. 1754. Four species are described, *A. pratensis*, *A. geniculatus*, *A. hordeiformis*, and *A. monspeliensis*. The third and fourth species do not agree with Linnæus's generic description and are now referred, the third to Pennisetum and the fourth to Polypogon. The other two were well known to Linnæus and were described in his flora of Sweden. The first, being an economic species, is chosen as the type species of the genus.

Alopecurus pratensis L. (fig. 74), meadow foxtail, is sometimes used as a meadow grass in the eastern United States. It is recommended for mixtures on moist soil, being nutritious and producing early forage. Meadow foxtail is an erect grass, 2 to 3 feet tall, with short rhizomes, loose, often inflated, sheaths, and spikes or heads 2 to 4 inches long and about one-fourth of an inch thick. Introduced from Europe, where it is favorably known as a meadow grass.

Alopecurus geniculatus L. is a low, pale, soft grass, usually 6 to 18 inches high, with decumbent rooting bases and slender panicles 1 to 3 inches long and about one-eighth of an inch thick, the delicate awn bent and protruding about twice the length of the spikelet. Found in moist places across the continent. An allied and more common species, *A. aristulatus* Michx. (*A. geniculatus aristulatus* (Michx.) Torr.), is distinguished by the scarcely exserted awns. *Alopecurus alpinus* J. E. Smith (*A. occidentalis* Scribn.), a northern species extending into the Rocky Mountains of the United States, has a short, thick spike with spikelets woolly all over. *Alopecurus californicus* Vasey, of the northwestern Pacific coast region, has slender spikes, 1 to 3 inches long and one-fourth of an inch thick, the spikelets 3 mm. long. The species of Alopecurus are all palatable and nutritious, but usually are not found in sufficient abundance to be of great importance.

62. Polypogon Desf.

Spikelets 1-flowered, the pedicel disarticulating a short distance below the glumes, leaving a short-pointed callus attached; glumes equal, entire or 2-lobed, awned from the tip or from between the lobes, the awn slender, straight; lemma much shorter than the glumes, hyaline, usually bearing a slender straight awn shorter than the awns of the glumes.

Annual or perennial usually decumbent grasses, with flat blades and dense, bristly, spikelike panicles. Species about 10, in the temperate regions of the world, chiefly in the Eastern Hemisphere, three species being introductions into the United States.

Type species: *Alopecurus monspeliensis* L.

Polypogon Desf., Fl. Atlant. 1: 66. 1798. Only one species described, this based on *Alopecurus monspeliensis* L.

Polypogon lutosus (Poir.) Hitchc. (*Agrostis lutosa* Poir., *P. littoralis* J. E. Smith, based on *Agrostis littoralis* With., 1796, not Lam., 1791), a perennial with awns scarcely longer than the glumes, is frequent on the Pacific coast. *Polypogon monspeliensis* (L.) Desf. (fig. 75) is an annual with soft, bristly, green or yellowish spikes 1 to 6 inches long, the awns much longer than the glumes. This is a common weed on the Pacific coast and is occasional in the Atlantic

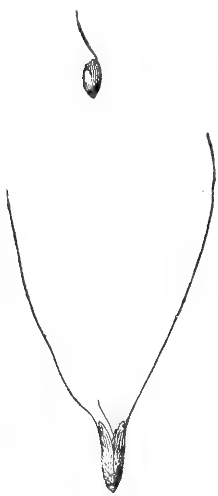


FIG. 75.—*Polypogon monspeliensis*. Plant, × ½; spikelet and floret, × 5.

States. *Polypogon maritimus* Willd. is a rare species found in Georgia and California, and differs from the preceding in having deeply lobed lemmas, the lobes ciliate. Our species are relished by stock, and *P. monspeliensis* is sometimes sufficiently abundant on low meadows to be of importance.

63. LYCURUS H. B. K.

Spikelets 1-flowered, the rachilla articulate above the glumes; glumes awned, the first usually 2-awned; lemma narrow, firm, longer than the glumes, terminating in a slender awn.

Low perennial grasses, with dense spikelike panicles, the spikelets borne in pairs, the lower of the pair sterile, the short branchlets deciduous. Species two, in arid regions from the southwestern United States to northern South America.

Type species: *Lycurus phleoides* H. B. K.

Lycurus H. B. K., Nov. Gen. and Sp. **1:** 141, pl. 45. 1816. Two species are described, *L. phleoides* and *L. phalaroides.* The first species, being figured, is chosen as the type.

Pleopogon Nutt., Journ. Acad. Nat. Sci. Phila. II. **1:** 189. 1848. A single species, *P. setosum*, is included. This is *Lycurus phleoides.*

Lycurus phleoides (fig. 76), the only species in the United States, is a low bunch-grass with slender erect culms about a foot high, with a dense, narrow, lead-color panicle 1 or 2 inches long. The species, sometimes called Texas timothy and wolftail, is common on the Mexican Plateau and

FIG. 76.—Wolftail, *Lycurus phleoides.* Plant, × ½; group of two spikelets, glumes of fertile spikelet, and two views of fertile floret, × 5.

extends north to Texas, Colorado, and Arizona. It is often an important constituent of grazing areas.

64. Phleum L.

Spikelets 1-flowered, laterally compressed, disarticulating above the glumes; glumes equal, membranaceous, keeled, abruptly mucronate or awned; lemma shorter than the glumes, hyaline, broadly truncate, 3 to 5 nerved; palea narrow, nearly as long as the lemma.

Fig. 77.—Timothy, *Phleum pratense*. Plant, × ½; spikelet and floret, × 5.

Annuals or perennials, with erect culms, flat blades, and dense, cylindric panicles. About 10 species, in the temperate regions of both hemispheres.

Type species: *Phleum pratense* L.

Phleum L., Sp. Pl. 59, 1753; Gen. Pl., ed. 5, 29. 1754. Four species are described, *P. pratense*, *P. alpinum*, *P. arenarium*, and *P. schoenoides*. The first species is chosen as the type because it is the only cultivated species in the genus. The first three species are still retained in Phleum; the fourth is referred to Heleochloa.

Stelephuras Adans., Fam. Pl. 2: 31, 607. 1763. Based on Phleum L.

Four species of Phleum are found in the United States. Our only native species is *P. alpinum* L., mountain timothy, a perennial with short spikes, two or three times as long as wide, found in the northern regions of Eurasia and America and extending south in the mountains of New England, in the Rocky Mountains to Mexico, and in the Sierra Nevada and Coast Ranges to the San Jacinto Mountains.

Mountain timothy produces a fair amount of nutritious forage, which remains green till late in the season and is considered a valuable late sheep feed. It is an important constituent of mountain meadows. This species is distinguished from common timothy by the shorter, broader heads and by the absence of the swollen base of the stem or so-called bulb. Two species, *P. graecum* Boiss. and Heldr. and *P. bellardi* Willd., are annuals introduced from Europe and found here only at a few coast points on dumping grounds for ballast.

The fourth species is timothy, *Phleum pratense* L. (Pl. XIV; fig. 77), an erect, short-lived perennial, 2 to 4 feet tall, with elongate cylindric inflorescences or "heads" several times longer than broad. The stems are swollen at the base, and the glumes, like those of mountain timothy, are ciliate on the keel. Timothy, a native of Europe and northern Asia, is now commonly cultivated in this country and in Europe as a meadow grass, and is found growing without cultivation in waste places, roadsides, and old fields throughout most of the United States. It is the most important meadow grass grown in America, and timothy hay is the standard for all grass hay sold on the market. The region of the United States favorable for the growing of timothy is the crop area known as the cool humid region, which includes the northeastern portion west to the Great Plains and south to Virginia and Missouri, or farther in the mountains. Another timothy area is found on the Pacific coast from northern California to Puget Sound. Much timothy is grown in favorable localities in the western mountains. In some localities timothy is known as herd's-grass.

See Evans, U. S. Dept. Agr., Farmers' Bull. 502, 1912; McClure, U. S. Dept. Agr., Farmers' Bull. 508, 1912; Williams, U. S. Dept. Agr. Yearbook, **1896:** 147, 1897; Scribner, U. S. Dept. Agr., Div. Agrost. Bull. **20:** fig. 47. 1900.

65. Gastridium Beauv.

Spikelets 1-flowered, the rachilla disarticulating above the glumes, prolonged behind the palea as a minute bristle; glumes unequal, somewhat enlarged or swollen at the base; lemma much shorter than the glumes, hyaline, broad, truncate, awned or awnless; palea about as long as the lemma.

Annual grasses, with flat blades and pale, shining, spikelike panicles. Species two, in the Mediterranean region; one introduced into the United States.

Type species: *Milium lendigerum* L.

Gastridium Beauv., Ess. Agrost. 21, pl. 6, f. 6. 1812. Beauvois mentions only one species, *Milium lendigerum*, but the description of the plate bears the name *Gastridium australe*.

Gastridium ventricosum (Gouan) Schinz and Thell.[1] (*G. lendigerum* (L.) Gaud.) (fig. 78), with an awned lemma, a common weed on the Pacific coast, appears to have no economic value.

FIG. 78.—*Gastridium ventricosum.* Plant, × ½; spikelet and floret, × 5.

66. LAGURUS L.

Spikelets 1-flowered, the rachilla disarticulating above the glumes, pilose under the floret, produced beyond the palea as a bristle; glumes equal, thin, 1-nerved, villous, gradually tapering into a plumose aristiform point; lemma shorter than the glumes, thin, glabrous, bearing on the back above the middle a slender, exserted, somewhat geniculate, dorsal awn, the summit bifid, the divisions delicately awn-tipped; palea narrow, thin, the two keels ending in minute awns.

An annual grass, with pale, dense, ovoid or oblong woolly heads. Species one, in the Mediterranean region and introduced sparingly in California.

Type species: *Lagurus ovatus* L. Lagurus L., Sp. Pl. 81, 1753; Gen. Pl., ed. 5, 34. 1754. Only one species described.

Lagurus ovatus (fig. 79) is sometimes cultivated as an ornamental, the woolly heads being used for dry bouquets.

67. EPICAMPES Presl.

Spikelets 1-flowered, the rachilla disarticulating above

[1] This name is based on *Agrostis ventricosa* Gouan, Hort. Monsp. 39, pl. 1, f. 2, 1762, which was published earlier in the year than *Milium lendigerum* L., Sp. Pl., ed. 2, 91, 1762, as shown by Linnæus's reference to Gouan's work in the preface to the second edition of his Species Plantarum.

the glumes; glumes about equal; lemma equaling or longer than the glumes, 3-nerved, often bearing a slender awn just below the tip.

FIG. 79.—Hare's-tail grass, *Lagurus ovatus*. Plant, × ½; spikelet and floret, × 5.

Tall cespitose perennials, with open, narrow, or spikelike panicles. Species 15, northern South America to Mexico, 5 extending into the southwestern United States.

Type species: *Epicampes strictus* Presl.

Epicampes Presl, Rel. Haenk. **1**: 235, pl. 39. 1830. Only one species described.

Crypsinna Fourn., Mex. Pl. **2**: 90. 1886. Three species are mentioned, *C. stricta*, *C. macroura*, and *C. setifolia*. In the generic description the panicle is said to be densely spiciform. This applies best to the second species, *C. macroura*, which is chosen as the type.

One species, *Epicampes rigens* Benth. (fig. 80), with long, slender, cylindric, pale, spikelike panicles, the glumes shorter than the lemma, is found from western Texas to southern California. This species, called deer-grass, and the four other species, *E. ligulata* Scribn., *E. berlandieri* Fourn., *E. subpatens* Hitchc.,[1] and *E. emersleyi*

[1] **Epicampes subpatens, n. sp.** Culms erect, glabrous, 50 to 100 cm. tall; sheaths glabrous, slightly scabrous, compressed-keeled, especially those of the innovations; ligule softly membranaceous, 1 to 2 cm. long; blades flat or folded, scabrous, 1 to 3 mm. wide, the lower as much as 50 cm. long; panicles narrow but rather loose, mostly 20 to 40 cm. long, the branches ascending, more or less fascicled or whorled, naked below; spikelets about 3 mm. long,

FIG. 80.—Deer-grass, *Epicampes rigens*. Plant, × ½; spikelet and floret, × 5.

(Vasey) Hitchc. (*Muhlenbergia emersleyi* Vasey, *M. vaseyana* Scribn.), are forage grasses. A Mexican species, *E. macroura* Benth., is of considerable economic importance, the roots being used in the manufacture of scrubbing brushes.

68. MUHLENBERGIA Schreb.

Spikelets 1-flowered, the rachilla disarticulating above the glumes; glumes usually shorter than the lemma, obtuse to acuminate or awned, the first sometimes small or rarely obsolete; lemma firm-membranaceous, 3 to 5 nerved, with a very short, usually minutely pilose callus, the apex acute, sometimes bidentate, extending into a straight or flexuous awn, or sometimes only mucronate.

Perennial or rarely annual low or moderately tall grasses, tufted or rhizomatous, the culms simple or much branched, the inflorescence a narrow or open panicle. Species about 80, mostly in Mexico and the southwestern United States, a few in the eastern part of the Old World; 40 species in the United States.

Type species: *Muhlenbergia schreberi* Gmel.

Muhlenbergia Gmel., Syst. Nat. **2**: 171. 1791. Only one species mentioned.

Dilepyrum Michx., Fl. Bor. Amer. **1**: 40. 1803. Two species are described, *D. aristosum*, which is *Brachyelytrum erectum*, and *D. minutiflorum*, which is *Muhlenbergia schreberi* Gmel. They are equally eligible as the type. The second is chosen, in order to conserve the generic name Brachyelytrum.

Podosemum Desv., Nouv. Bull. Soc. Philom. Paris **2**: 188. 1810. The type is *Stipa capillaris* Lam. (*P. capillaris* Desv.), the only species mentioned.

Clomena Beauv., Ess. Agrost. 28, pl. 7, f. 10. 1812. The type is *C. peruviana*, the only species mentioned. This is *Muhlenbergia peruviana* (Beauv.) Steud.

Trichochloa Beauv., Ess. Agrost. 29, pl. 8, f. 2. 1812. The type and only species is *T. purpurea*. This has not been identified. Roemer and Schultes say it is *Trichochloa expansa* DC. (*Muhlenbergia expansa* (DC.) Trin.).

Tosagris Beauv., Ess. Agrost. 29, pl. 8, f. 3. 1812. The type is *T. agrostidea*, the only species mentioned. This has not been identified, but it appears to be a species of Muhlenbergia.

Sericrostis Raf., Neogenyt. 4. 1825. "Type *Stipa sericea* Mx. or *diffusa* Walter." This is *Muhlenbergia capillaris* (Lam.) Trin.

Calycodon Nutt., Journ. Acad. Phila. II. **1**: 186. 1848. The type is *C. montanum* (*Muhlenbergia montana* Hitchc.), the only species described.

Vaseya Thurb., in Gray, Proc. Acad. Phila. **1863**: 79. 1863. The type is *V. comata* Thurb., the only species described. This is *Muhlenbergia andina* (Nutt.) Hitchc. (*Calamagrostis andina* Nutt.).

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often tinged with purple; glumes about as long as the lemma, papery, acutish, scabrous; lemma narrowed and scabrous above, villous below, awnless, or occasionally those of a few of the spikelets with a flexuous awn about 1 cm. long.

Type, U. S. National Herbarium no. 905799, collected in a rocky ravine, Guadeloupe Mountains, near Queen, N. Mex., altitude 7,000 feet, Sept. 5, 1915, by A. S. Hitchcock, no. 13541.

This species is closely allied to *Epicampes emersleyi*, from which it differs in the awnless spikelets and larger, looser, and more spreading panicles. The writer examined the two forms in the Guadeloupe Mountains, southern New Mexico, and concluded from these field observations that the awned and awnless forms represented two distinct but closely allied species. The delicate awns are not noticeable at a distance but the more open panicle was always found to be associated with the awnless spikelets.

Other specimens in the U. S. National Herbarium.—TEXAS: Limpia Canyon, *Nealley* 133. Chisas Mountains, *Bailey* 392. Guadeloupe Mountains, *Bailey* 739. Western Texas, *Wright* 729. NEW MEXICO: Socorro, *Plank* 53. Silver City, *Greene* 439. ARIZONA: Patagonia, *Hitchcock* 3719. Chiracahua Mountains, *Toumey* 15a. Santa Catalina Mountains, *Griffiths* 7149.

[1] Syst. Veg. **2**: 384. 1817.

Chaboissaea Fourn., Mex. Pl. **2**: 112. 1886. A single species, *C. ligulata*, is included. This is *Muhlenbergia ligulata* (Fourn.) Scribn. and Merr.

Muhlenbergia is a somewhat artificial genus, including species of very diverse habit. It differs from Sporobolus in the 3-nerved awned or mucronate lemma, and from Agrostis in the firmer lemma, usually longer than the glumes. One group, including *M. squarrosa* (Trin.) Rydb. (fig. 81), *M. repens* (Presl) Hitchc., and their allies, has been usually referred to Sporobolus. The species of this group are included in Muhlenbergia because of the 3-nerved mucronate or awned lemmas, but they form a distinct section or possibly a distinct genus.

FIG. 81.—*Muhlenbergia squarrosa.* Plant, × ½; spikelet and floret, × 5.

In *M. repens* the lateral nerves of the lemma are commonly obsolete, and the apex is sometimes scarcely mucronate.

Of the species found in the United States two are annuals, *M. depauperata* Scribn., with acuminate or awned glumes, and *M. microsperma* (DC.) Kunth, with obtuse glumes, both growing in the extreme Southwest. The latter species produces cleistogenes in the axils of the lower sheaths. *Muhlenbergia mexicana* (L.) Trin. and its allies have branching stems and numerous panicles. The glumes are reduced in *M. schreberi* (fig. 82), the type species, the first being obsolete and the second not over 0.5 mm. long. In *M. montana* (Nutt.) Hitchc. (*Calycodon montanum* Nutt.; *Muhlenbergia trifida* Hack.; *M. gracilis* of authors, not H. B. K.) the second glume is 3-toothed. *Muhlenbergia capillaris* (Lam.) Trin. (fig. 83), of the Southern States, is a handsome perennial with diffuse purple panicles.

There are nine species in the Eastern States; the others are western or mainly southwestern. Many of the western species are important range grasses and often form a considerable proportion of the grass flora of the arid and semiarid regions. The commonest of these are *M. montana* and *M. wrightii* Vasey. The second has a spikelike leaden-hued panicle.

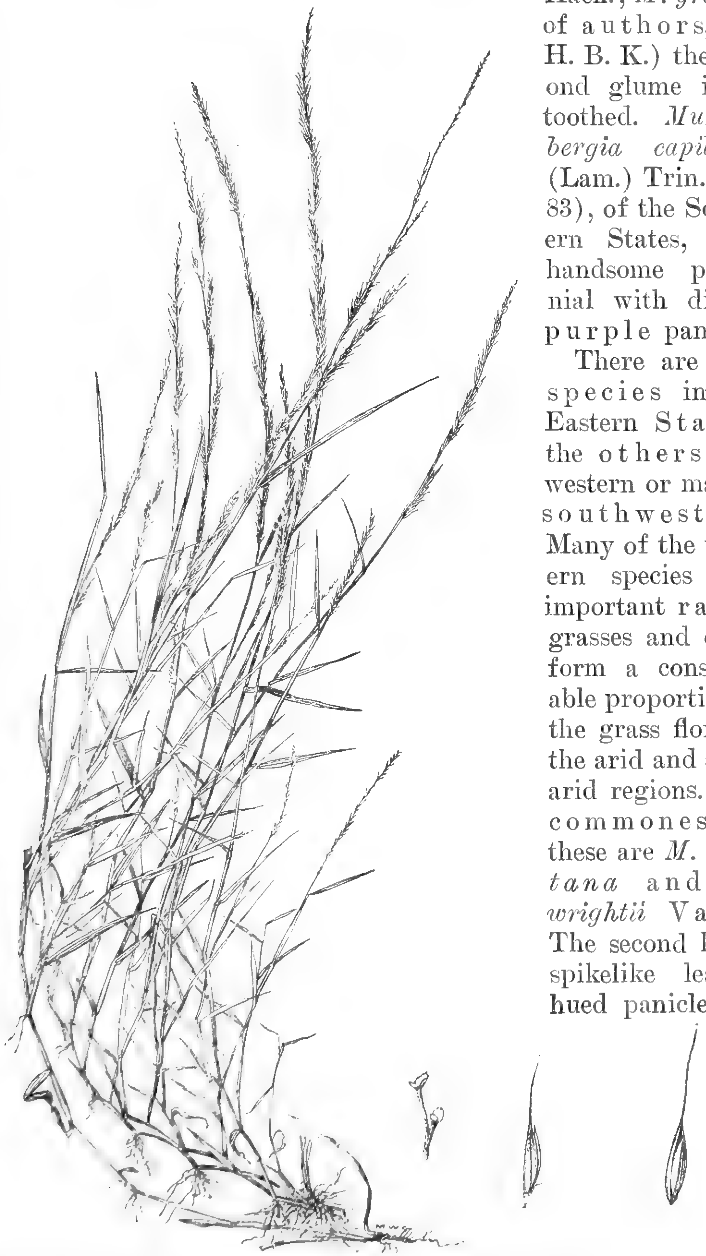

FIG. 82.—Nimble Will, *Muhlenbergia schreberi*. Plant, × ½; branchlet showing both first and second glumes of two spikelets, spikelet with obsolete first glume, and floret, all × 5.

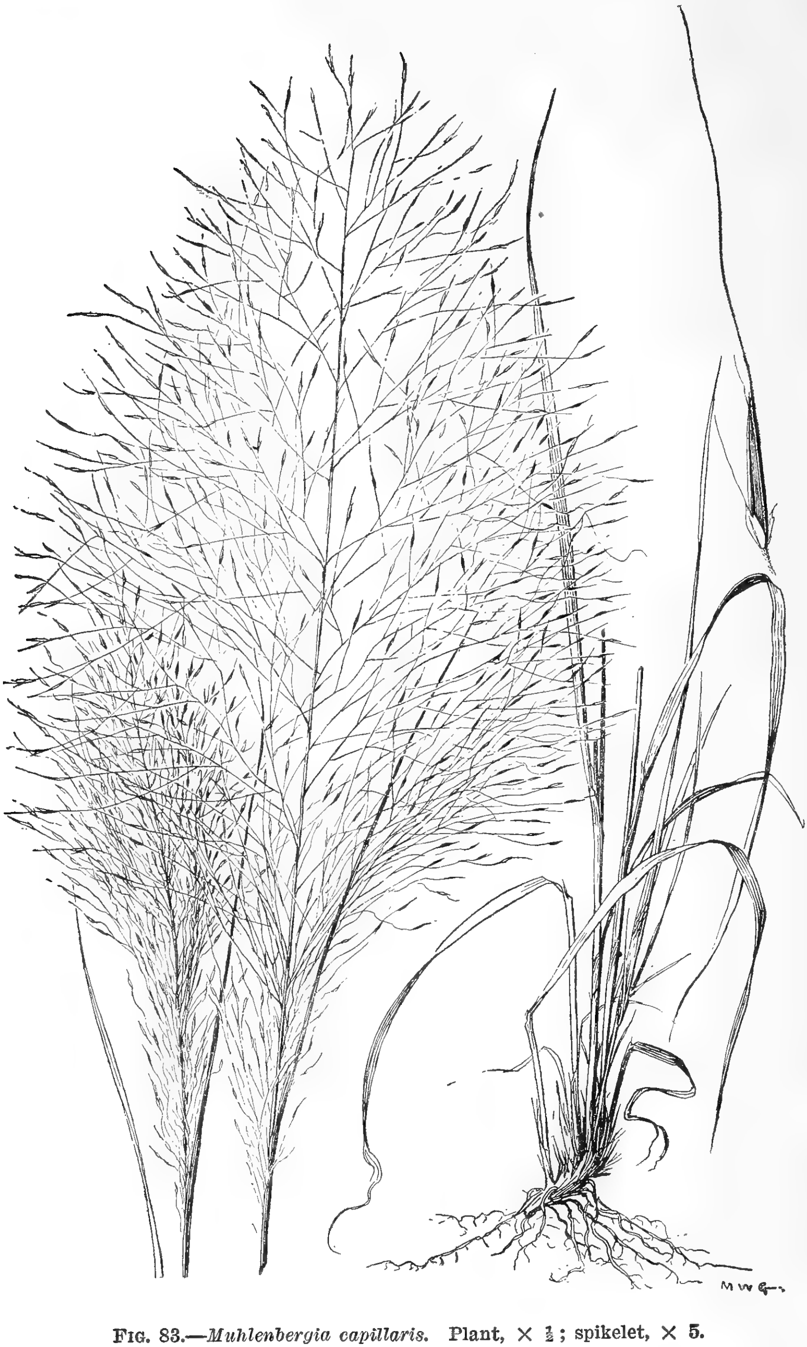

FIG. 83.—*Muhlenbergia capillaris.* Plant, × ½; spikelet, × 5.

69. SPOROBOLUS R. BR.

Spikelets 1-flowered, the rachilla disarticulating above the glumes; glumes awnless, usually unequal, the second often as long as the spikelet; lemma membranaceous, 1-nerved, awnless; palea usually prominent and as long as the lemma or longer; seed free from the pericarp.

Annual or perennial grasses, with small spikelets in open or contracted

FIG. 84.—Smut-grass, *Sporobolus berteroanus*. Plant, × ½; spikelet and floret, × 5.

panicles. Species about 95, in the warm regions of both hemispheres, most abundant in America; 36 species in the United States.

Type species: *Agrostis indica* L.

Sporobolus R. Br., Prodr. Fl. Nov. Holl. 169. 1810. Three species are described, *S. indicus, S. elongatus,* and *S. pulchellus.* Brown states that Sporobolus includes Agrostis species of Linnæus. Of the three species described by Brown only the first was known to Linnæus and included by him under Agrostis. Hence the first species is chosen as the type.

Agrosticula Raddi, Agrost. Bras. 33, pl. 1, f. 2. 1823. Type *A. muralis,* the only species described.

Bennetia Raf., Bull. Bot. Seringe 1: 220. 1830. *Agrostis juncea* Michx. is the only species included. This is *Sporobolus gracilis* (Trin.) Merr.

Crystostachys Steud., Syn. Pl. Glum. 1: 181. 1854. The type is *C. vaginata,* the only species described. From the description this appears to be *Sporobolus vaginaeflorus.*

Bauchea Fourn., Mex. Pl. 2: 87. 1886. Type *B. karwinskyi,* the only species described. This is *Sporobolus wrightii.*

The fruit is free from the lemma and palea, and falls readily from the spikelet at maturity. Because of this character the species have been called drop-seed grasses. The genus differs from Muhlenbergia in having 1-nerved awnless lemmas and from Agrostis in having lemmas as long as the glumes or longer and as firm.

Four species of the United States are annual. One of them, *Sporobolus vaginaeflorus* (Torr.) Wood, is called poverty grass, because it grows in sterile soil. This has narrow panicles, partly or wholly inclosed in the sheaths. Several of the perennial species have creeping rhizomes. One of these, *S. virginicus* (L.) Kunth, is a common seashore grass in the Southern States. It has erect stems 6 to 10 inches tall, with spikelike panicles of pale spikelets. The other species of the genus are erect bunch-grasses. *Sporobolus berteroanus* (Trin.) Hitchc. and Chase (fig. 84), with long, slender, spikelike panicles, is common in the Southern States (*S. indicus* of the manuals, not *S. indicus* (L.) R. Br.). This species is called smut-grass, because the inflorescence is frequently affected with a black fungus. The glumes are about equal and much shorter than the lemma. *Sporobolus cryptandrus* (Torr.) Gray (fig. 85) is common on sandy soil, especially in the interior of the country. This has very small spikelets in panicles sometimes partly inclosed in the upper sheath, only the upper portion spreading, or even entirely inclosed in the swollen sheaths. There is a conspicuous tuft of hairs at the summit of the sheaths. In winter the leaves and stems become fibrous and much frayed out by the wind.

Two species of the Southwest are important forage grasses in the arid and semiarid regions. *Sporobolus airoides* Torr. (fig. 86), growing in dense, tough clumps, the stems 1 or 2 feet high, and with large spreading panicles, is found on somewhat alkaline soil and is called bunch-grass or alkali saccaton. It ranges from Nebraska to

Montana and Texas. *Sporobolus wrightii* Munro, saccaton, is much taller, with a large but narrow panicle. This is found from Arizona to western Texas.

Most of the perennial species of Sporobolus are palatable forage grasses, but few of them are abundant enough to be of importance. On the Arizona Plateau, *S. interruptus* Vasey is an important range grass. It is called black sporobolus, because of the dark, narrow, loosely flowered panicle.

70. BLEPHARONEURON Nash.

Spikelets 1-flowered, the rachilla disarticulating above the glumes; glumes subequal, rather broad; lemma 3-nerved, the nerves densely pilose; palea densely pilose between the two nerves.

A perennial grass with an open, narrow panicle. Species one; southwestern United States and northern Mexico.

Type species: *Vilfa tricholepis* Torr.

Blepharoneuron Nash, Bull. Torrey Club **25:** 88. 1898. Only one species mentioned, *B tricholepis* (Torr.) Nash.

FIG. 85.—Sand dropseed, *Sporobolus cryptandrus*. Plant × ½; spikelet and floret, the palea splitting, × 5.

FIG. 86.—Alkali saccaton, *Sporobolus airoides*. Plant, × ½; spikelet and floret, × 5.

The single species (fig. 87) is a tufted grass about a foot high, found on open or rocky soil at middle altitudes from Colorado to central Mexico. It is a palatable grass, sufficiently abundant in places to be of importance. Until recent years the species was included in Sporobolus.

71. Crypsis Ait.

Spikelets 1-flowered, the rachilla disarticulating below the glumes; glumes about equal, narrow, acute; lemma broad, thin, awnless; palea similar to the lemma, about as long, 2-nerved, readily splitting between the nerves; fruit a utricle, the seed free from the thin pericarp.

A spreading annual, with capitate inflorescences in the axils of broad bracts, these being enlarged sheaths with short rigid blades. Species one, in the Mediterranean region; sparingly introduced into the United States.

Type species: *Schoenus aculeatus* L.

Crypsis Ait., Hort. Kew. **1**: 48. 1789. A single species is mentioned, with two varieties or forms, α (the equivalent of the species), based on *Schoenus aculeatus* L., and β, based on *Phleum schoenoides* L. The first is the type.

Bentham and Hooker[1] state that the spikelet has four glumes and no palea. Hackel[2] states that the palea is 1-nerved. Our specimens show an evidently 2-nerved palea.

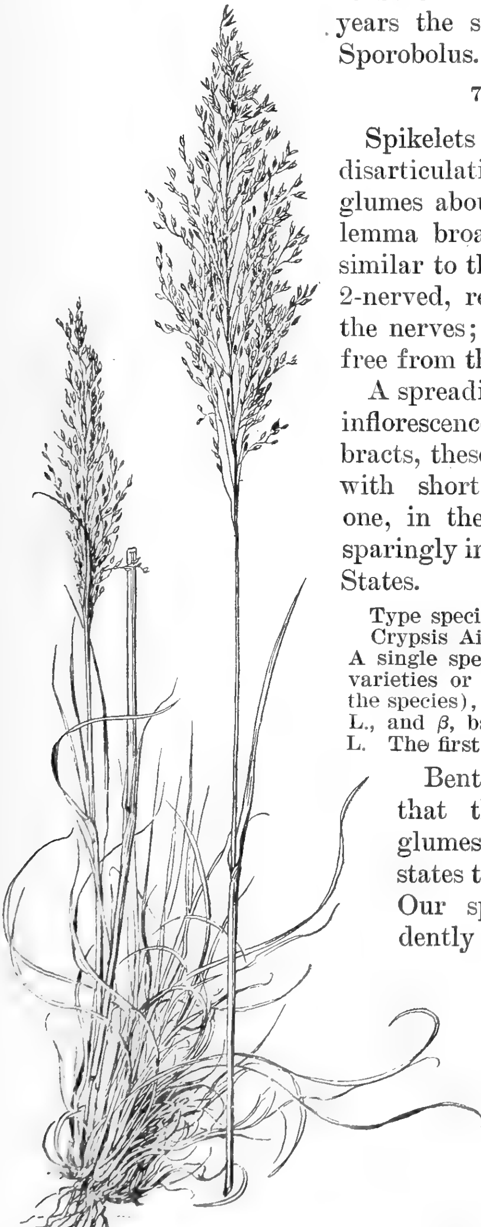

Fig. 87.—*Blepharoneuron tricholepis.* Plant, × ½; spikelet and floret, × 5.

[1] Gen. Pl. **3**: 1139. 1883.

[2] Engl. and Prantl, Pflanzenfam. **2**[2]: 48. 1887.

Crypsis aculeata (L.) Ait. (fig. 88) has been introduced in a few places in California.

72. HELEOCHLOA Host.

Spikelets 1-flowered, the rachilla disarticulating above the glumes; glumes about equal, narrow, acute; lemma broader, thin, a little longer than the glumes; palea nearly as long as the lemma, 2-nerved, readily splitting between the nerves; caryopsis free from the lemma and palea.

Low perennial spreading grasses, with oblong, dense, spikelike panicles, terminal and on short lateral branches, the subtending leaves

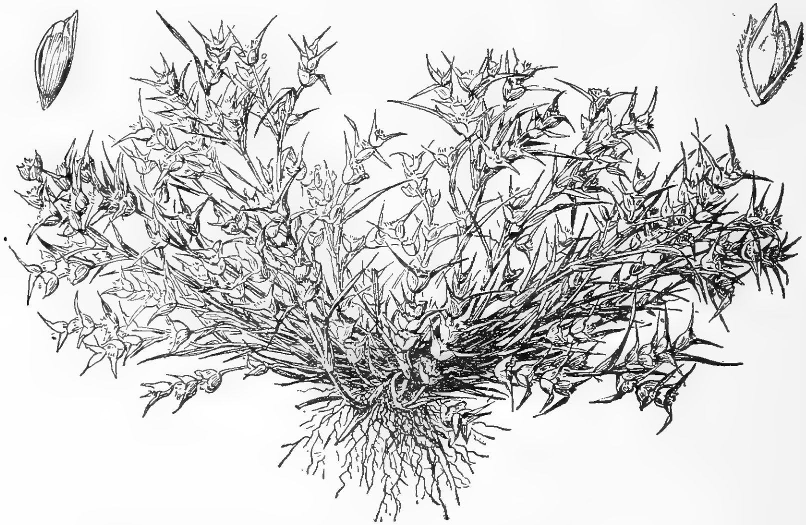

FIG. 88.—*Crypsis aculeata.* Plant, × ½; spikelet and floret, the palea splitting, × 5.

with inflated sheaths and reduced blades. Species about seven, in the Mediterranean region, one introduced into the United States.

Type species: *Heleochloa alopecuroides* Host.
Heleochloa Host, Gram. Austr. 1: 23. 1801. Two species are described, *H. alopecuroides* and *H. schoenoides,* both of which are figured. The first is chosen as the type.

Heleochloa schoenoides (L.) Host (fig. 89) has been introduced into the eastern United States at several points from Massachusetts and Delaware to Illinois.

73. BRACHYELYTRUM Beauv.

Spikelets 1-flowered, the rachilla disarticulating above the glumes, prolonged behind the palea as a slender naked bristle; glumes very short, unequal, the first sometimes obsolete, the second sometimes awned; lemma firm, narrow, 5-nerved, the base extending into a pronounced oblique callus, the apex terminating in a long straight scabrous awn.

Perennial erect, slender grasses, with short knotty rhizomes, flat blades and narrow, rather few-flowered panicles. Species one, North American.

FIG. 89.—*Heleochloa schoenoides.* Plant, × ½; spikelet and floret, the palea splitting, × 5.

Type species: *Muhlenbergia erecta* Schreb.

Brachyelytrum Beauv., Ess. Agrost. 39, pl. 9, f. 2. 1812. The type is the figured species, *B. erectum*, based on *Muhlenbergia erecta*.

Brachyelytrum erectum (Schreb.) Beauv. (fig. 90), found in rich rocky woods in the northeastern quarter of the United States, is of no economic importance. It has been known also as *B. aristatum* Beauv.

74. MILIUM L.

Spikelets 1-flowered, disarticulating above the glumes; glumes equal, obtuse, membranaceous, rounded on the back; lemma a little shorter than the glumes, obtuse, awnless, obscurely nerved, rounded on the back, dorsally compressed, in fruit becoming indurate, smooth, and shining, the margins inclosing the lemma, as in Panicum.

Moderately tall grasses with flat blades and open panicles. Species about six, in the cooler parts of Eurasia, one of which is found also in northeastern North America.

Type species: *Milium effusum* L.

Milium L., Sp. Pl. 61, 1753; Gen. Pl., ed. 5, 30. 1754. Two species are described, *M. effusum* and *M. confertum.* The first species is chosen as the type as it was the one best known to Linnæus, being described in his flora of Sweden. The second species is now reduced to a variety of *M. effusum.* Milium is an ancient Latin name for the common millet of Europe (*Panicum miliaceum* L.). Linnæus applied this name to the genus above described.[1]

Milium effusum L. (fig. 91), millet grass, the only representative of the genus in America, is a slender erect perennial 3 to 4 feet tall, found in cool woods from Nova Scotia to Illinois. It is of no economic importance.

75. ORYZOPSIS Michx.

Spikelets 1-flowered, disarticulating above the glumes; glumes about equal, obtuse or acuminate; lemma indurate, usually about as long as the glumes, broad, oval or oblong, nearly terete, usually pubescent, with a short, blunt, oblique callus, and a short, deciduous, sometimes bent and twisted awn; palea inclosed by the edges of the lemma.

Perennial, mostly low grasses, with flat or often involute blades and terminal narrow or open panicles. Species about 20, in the north temperate regions of both hemispheres; 13 species in the United States.

Type species: *Oryzopsis asperifolia* Michx. (fig. 92).

Oryzopsis Michx., Fl. Bor. Amer. **1**: 51. 1803. A single species described.

Dilepyrum Raf., Med. Repos. **5**: 351. 1808. Rafinesque here announces a new work and gives the names of several proposed new genera and species. One of these is "Dilepyrum, the Orizopsis of do [Michaux]." The type, then, is *Oryzopsis asperifolia* Michx.

Piptatherum Beauv., Ess. Agrost. 17. pl. 5, f. 10. 1812. Beauvois mentions five species and figures two, *P. coerulescens* and *P. punctatum*. *Milium coerulescens*, the basis of the first species, is chosen as the type.

Eriocoma Nutt., Gen. Pl. **1**: 40. 1818. The type is *E. cuspidata* Nutt., the only species described. This is the same as *Oryzopsis hymenoides*.

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[1] For a discussion of Milium and Panicum, see Hitchcock and Chase, Contr. U. S. Nat. Herb. **15**: 11. 1910.

FIG. 90.—*Brachyelytrum erectum.* Plant, × ½; branchlet, with glumes of two spikelets, and floret, × 5.

Urachne Trin., Fund. Agrost. 109. 1820. Trinius cites Beauvois's two figures mentioned above, which represent *Piptatherum coerulescens* and *P. punctatum*, and at the end of his generic description lists three species, *U. coerulescens* (*Milium coerulescens* Desf.), *U. virescens* (*Milium paradoxum* Scop.), and *U. parviflora* (*Agrostis miliacea* L.). The first of these is chosen as the type.

Fendlera Steud., Syn. Pl. Glum. **1**:419. 1854. Type, *F. rhynchelytroides* Steud., the only species described. This is the same as *Oryzopsis hymenoides*.

The commonest species is *Oryzopsis hymenoides* (Roem. and Schult.) Ricker, found throughout the region west of the Rocky Mountains on dry soil. This has an open divaricate panicle and densely long-silky lemmas. The species of Oryzopsis are grazed by stock, but usually are not in sufficient abundance to be of importance, except Indian mountain rice (*O. hymenoides*).

The allied Mexican and South American genera, Nasella Desv. and Piptochaetium Presl, differ in having an obliquely obovate fertile lemma, the apex gibbous, and the awn eccentrically attached.

76. Stipa L., the spear-grasses.

Spikelets 1-flowered, disarticulating above the glumes, the articulation oblique, leaving a bearded, sharp-pointed callus attached to the base of the floret; glumes membranaceous, often papery, acute,

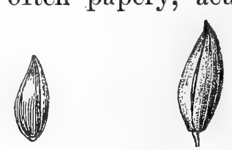

Fig. 91.—Millet grass, *Milium effusum*. Plant, × ½; spikelet and floret, × 5.

acuminate or even aristate, usually long and narrow; lemma narrow, terete, firm or indurate, strongly convolute, terminating in a usually bent and twisted, prominent, persistent awn; palea inclosed in the convolute lemma.

Perennial grasses, with usually convolute blades and narrow panicles. Species about 100, in the temperate regions of the world, especially on plains and steppes; 30 species in the United States, mostly in the western part.

FIG. 92.—Mountain rice, *Oryzopsis asperifolia*. Plant, × ½; spikelet and floret, × 5.

Type species: *Stipa pennata* L.

Stipa L., Sp. Pl. 78, 1753; Gen. Pl., ed. 5, 34. 1754. Linnaeus describes three species, *S. pennata*, *S. juncea*, and *S. avenacea*. The first two are from central and southern Europe, the third from Virginia. The first species is selected as the type.

Podopogon Raf., Neogenyt. 4. 1825. Two names are given, "*Stipa avenacea*" L. and "*barbata*" Michx., both belonging to the same species.

FIG. 93.—Porcupine grass, *Stipa spartea*. Plant, × ½; glumes and floret, × 2.

Some of the western species have plumose or feathery awns, those of *Stipa neo-mexicana* (Thurb.) Scribn. being 4 to 8 inches long, plumose to the second bend, those of the handsome *S. speciosa* Trin. and Rupr. plumose below the single bend. A striking species of the upper Mississippi Valley is *Stipa spartea* Trin. (fig. 93), called porcupine grass and devil's darning needles. The rigid indurate fruiting lemma is about three-fourths of an inch long, tapering below into a very sharp hairy point, which acts like a barb, and terminating above in a stout awn as much as 6 inches long. At maturity the awn bends twice near the middle and becomes tightly twisted below the first bend. Variations in moisture cause the awn to twist and untwist, by which movement and by the aid of the sharp callus it can penetrate the soil. Several other species have elongate awns, such as *S. avenacea* L. of the eastern half of the United States and *S. comata* Trin. and Rupr. of the western half, the latter species being called needle-and-thread grass, because of the long flexuous upper portion of the awns. *Stipa viridula* Trin. and its allies have a narrow compact panicle and comparatively inconspicuous awns 1 or 2 inches long. One of these species, *S. vaseyi* Scribn., is called sleepy grass, because of the narcotic effects sometimes produced upon horses when they have fed upon it. Sleepy grass, found in New Mexico and Colorado, is a stout grass 3 to 5 feet high, with a narrow panicle as much as a foot long, the sheaths hairy at the throat. In *S. tenuissima* Trin. (fig. 94) of New Mexico the fruit is very small, less than 3 mm. long.

The species of Stipa are for the most part valuable forage plants. The most important species on the ranges are *S. viridula*, *S. minor* (Vasey) Scribn., and *S. lettermani* Vasey. They are known as porcupine grasses. All have narrow panicles. One of the Old World species, *S. tenacissima* L., furnishes a part of the esparto or alfa grass of Spain and Algeria that is used in the manufacture of paper and cordage.

77. Aristida L., the needle grasses.

Spikelets 1-flowered, the rachilla disarticulating obliquely above the glumes; glumes equal or unequal, narrow, acute, acuminate, or awn-tipped; lemma indurate, narrow, terete, convolute, with a hard, sharp-pointed, usually minutely bearded callus at base, terminating above in a usually trifid awn.

Annual or perennial, mostly low grasses, with narrow, frequently convolute blades and narrow or sometimes open panicles. Species about 150, in the warmer regions of the world; 36 species in the United States; especially abundant in the Southwestern States.

FIG. 94.—*Stipa tenuissima.* Plant, × ½; spikelet, × 2; glumes and floret, × 5.

Type species: *Aristida adscensionis* L.

Aristida L., Sp. Pl. 82, 1753; Gen. Pl., ed. 5, 35. 1754. A single species is described.

Streptachne R. Br., Prodr. Fl. Nov. Holl. 174. 1810. A single species, *S. stipoides*, is included. In this the lateral awns are obsolete.

Chaetaria Beauv., Ess. Agrost. 30, pl. 8, f. 5, 6. 1812. Twenty-five species are listed, two, *C. stricta* (based on *Aristida stricta* Michx.) and *C. capillaris*, are illustrated. *Aristida stricta* (fig. 5) is taken as the type.

Curtopogon Beauv., Ess. Agrost. 32, 159, pl. 8, f. 7. 1812. The only species included is based on *Aristida dichotoma* L.

Trixostis Raf., Bull. Bot. Seringe 1: 221. 1830. A single species, "*Aristida gracilis*" [Ell.], is included.

Moulinsia Raf., Bull. Bot. Seringe 1: 221. 1830. A single species, "*Aristida lanosa*" Muhl., is included.

Ortachne Nees, in Seeman, Bot. Voy. Herald 225. 1857. A single species, based on *Streptachne pilosa* H. B. K., is included.

In one group of the genus the lateral awns are reduced to mere points or are entirely absent. Two species of this group (section Streptachne) are found in Arizona, *Aristida scabra* (H. B. K.) Kunth, with a curved but not twisted awn, and *A. schiedeana* Trin. and Rupr., with a twisted awn. The former is found also in southern Florida. In three species the awn is articulate at base, *A. desmantha* Trin. and Rupr., with short neck, *A. tuberculosa* Nutt., an annual with a slender, twisted neck, and *A. californica* Thurb., a perennial with a slender, twisted neck. *Aristida dichotoma* Michx., a small annual with a coiled central awn, is common in the Eastern States. Two other annuals are common in the eastern part of our country, *A. gracilis* Ell., with the central spreading or reflexed awn less than half an inch long, and *A. oligantha* Michx. (fig. 95), with awns 2 or 3 inches long. The type species, *A. adscensionis* L. (*A. bromoides* H. B. K.), has a wide distribution in warm countries and extends into the southwestern United States. This is a low annual, usually much branched at base, with contracted panicle, the first glume about half as long as the second, and awns about one-third of an inch long. A common perennial species in the semiarid regions of the West is *A. longiseta* Steud., called dog-town grass, because it is especially abundant on the new soil of prairie-dog communities. *Aristida fendleriana* Steud. is an allied species of the same region. The first has a long second glume, about four-fifths of an inch long, and awns as much as 3 or 4 inches long. The second has a shorter second glume, about three-fifths of an inch long, and awns less than 2 inches long, and grows in dense tufts with curly leaves crowded at the base of the plant. *Aristida purpurea* Nutt. differs in having slender curved pedicels. These species are troublesome when the fruit is ripe, because this with its spreading awns becomes detached at maturity and is blown about by the wind. These fruits are sometimes scattered in vast quantities, the wind hurling them across the plains with the sharp-pointed callus in advance. They work their way into the wool of sheep and into the nostrils and eyes of all classes of stock.

FIG. 95.—Needle grass, *Aristida oligantha*. Plant, × ½; glumes and floret, × 2.

The species of Aristida are of distinctly minor importance for forage except in the Southwest, where several species, such as *A. longiseta*, are eaten by stock before the flowers are produced. The annual species of the Eastern States are often found on open sterile soil. and hence are called poverty grass, a name applied also to annuals of other genera.

6. NAZIEAE, THE CURLY-MESQUITE TRIBE.

78. NAZIA Adans.
(*Tragus* Hall.)

Spikelets 1-flowered, in small spikes of 2 to 5, the spikes subsessile, falling entire, the spikelets sessile on a very short zigzag rachis, the first glumes small, thin, or wanting, appressed to the rachis, the second glumes of the two lower spikelets strongly convex with 3 thick nerves bearing a row of squarrose, stout hooked prickles along each side, the two second glumes forming the halves of a little bur, the upper 1 to 3 spikelets reduced and sterile; lemmas and palea thin, the lemma flat, the palea strongly convex.

Low annual grasses, with flat blades and terminal inflorescence, the burs or spikes rather closely arranged along an elongate, slender axis. Species three, in the tropical regions of both hemispheres; two species being introduced in the southern United States.

Type species: *Cenchrus racemosus* L.

Nazia Adans., Fam. Pl. **2**: 581. 1763. The genus is based on *Cenchrus racemosus* L.

Tragus Hall., Stirp. Helv. **2**: 203. 1768. Haller cites pre-Linnæan authors who connect Tragus with *Cenchrus racemosus* L.

Lappago Schreb., Gen. Pl. 55. 1789. A new name is proposed for Tragus Hall.

Echisachys Neck., Elem. **3**: 228. 1790. No species are given. The author cites "Cenchrus Lin.," but his description shows that it is Linnæus's first species, *Cenchrus racemosus*, that he is renaming.

Nazia racemosa (L.) Kuntze, with 3 to 5 spikelets in each cluster, the lower about 4 mm. long, is found in open ground from Texas to Arizona, and *N. aliena* (Spreng.) Scribn. (fig. 96), with two spikelets in each cluster, the lower 2 to 3 mm. long, here and there through the Southern States to Arizona. They are somewhat weedy grasses of no economic importance.

79. OSTERDAMIA Neck.
(*Zoysia* Willd.)

Spikelets 1-flowered, laterally compressed, appressed flatwise against the slender rachis, glabrous, disarticulating below the glumes; first glume wanting; second glume coriaceous, mucronate, or short-awned, completely infolding the thin lemma and palea, the palea sometimes obsolete.

Perennial low grasses with creeping rhizomes, short, pungently pointed blades, and terminal spikelike racemes, the spikelets on short appressed pedicels. Species about five, southeastern Asia to New Zealand.

Type species: *Agrostis matrella* L.

Osterdamia Neck., Elem. Bot. **3**: 218. 1790. In a note appended to the paragraph on Agrostis, Necker states, "Agrostis matrella Lin. species distincta, agrostidis proxima, quam osterdamiam appellamus, charactere sequenti." Although Osterdamia, Agrostis, Milium, and many other groups are called by Necker species of his genus Achyrophyton, these so-called species are the equivalent of the genera of his contemporaries and are usually so recognized by botanical writers.

Zoysia Willd., Ges. Naturf. Freund. Berlin, Neue Schrift. **3**: 440. 1801. Type and only species, *Z. pungens* Willd.

Matrella Pers., Syn. Pl. **1**: 73. 1805. Type species, *Agrostis juncea* Lam., the only species described.

Several years ago a species of this genus was introduced into the United States as a lawn grass under the names Korean lawn grass and Japanese lawn grass. It was recommended for the Southern States and was said to be hardy as far north as Connecticut.[1] The species then intro-

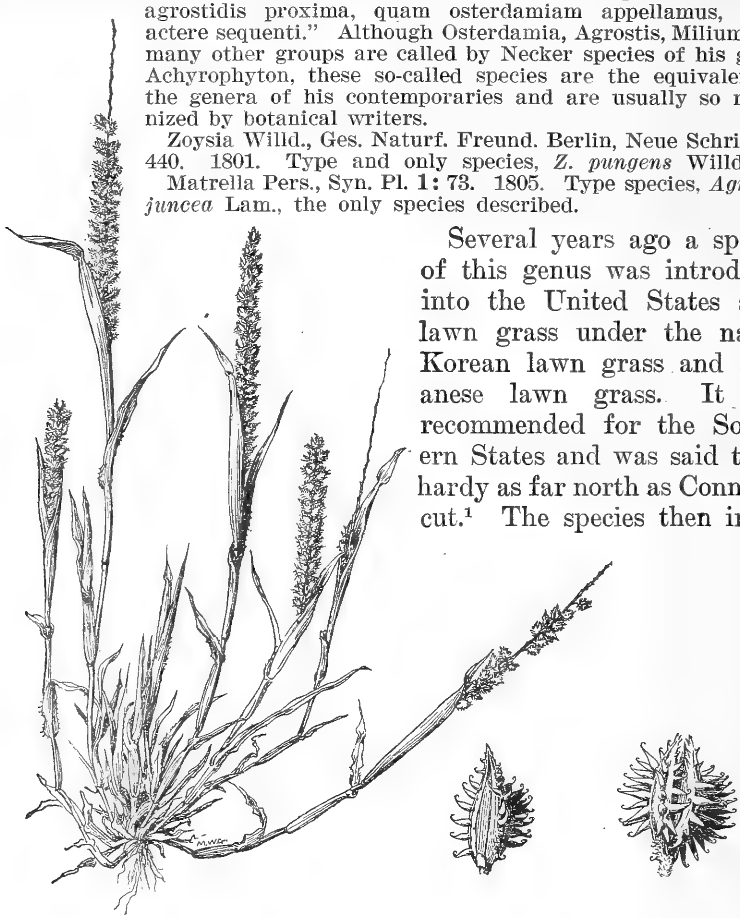

Fig. 96.—*Nazia aliena*. Plant, × ½; group of spikelets (spike) and single spikelet, × 5.

duced appears to be *Osterdamia japonica* (Steud.) Hitchc. (*Zoysia japonica* Steud.). Recently a fine-leaved species, *Osterdamia tenuifolia* (Willd.) Kuntze, has been introduced into Florida and has given favorable results. The original species, *O. matrella* (L.) Kuntze (fig. 97), manila grass, is common in the Philippine Islands.

[1] Scribner, U. S. Dept. Agr., Div. Agrost. Bull. **3**: 95. 1896.

80. Hilaria H. B. K.

Spikelets sessile, in groups of 3, the groups falling from the axis entire, the central spikelet (next the axis) fertile, 1-flowered, the 2 lateral spikelets staminate, 2-flowered; glumes coriaceous, those of the 3 spikelets forming a false involucre, in some species connate at the base, more or less asymmetric, usually bearing an awn on

Fig. 97.—Manila grass, *Osterdamia matrella*. Plant, × ½; spikelet, × 10; floret with caryopsis, the palea obsolete, × 10.

one side from about the middle; lemma and palea hyaline, about equal in length.

Perennial low grasses, the groups of spikelets appressed to the axis, in terminal spikes. Species five, in arid regions, southwestern United States to Central America, all but one found within the limits of the United States.

Type species: *Hilaria cenchroides* H. B. K.
Hilaria H. B. K., Nov. Gen. and Sp. 1: 116. 1816. Only one species described.

Pleuraphis Torr., Ann. Lyc. N. Y. 1: 148, pl. 10. 1824. Type species *P. jamesii* Torr., the only one described.

Hexarrhena Presl, Rel. Haenk. 1: 326, pl. 45. 1830. Type species *H. cenchroides* Presl, the only one described. This is the same as *Hilaria cenchroides*.

FIG. 98.—Curly mesquite, *Hilaria belangeri*. Plant, × ½; single spike, × 1; group of spikelets seen from front or outside, showing staminate spikelets in front and top of fertile spikelet behind, × 5; same group from behind or next the axis, showing the fertile spikelet in front and the two staminate spikelets behind, × 5; fertile spikelet as seen from the inside, × 5; fertile floret, × 5; staminate spikelet, × 5.

Schleropelta Buckl., Prel. Rep. Geol. and Agr. Surv. Tex. App. 1. 1866. A single species is included, *S. stolonifera* Buckl., which is the same as *Hilaria belangeri* Steud.

Hilaria belangeri Steud. (fig. 98) is a common grass on the Great Plains of Texas and northern Mexico. In Texas it is called curly mesquite. It is a low grass, forming wiry stolons that in favorable soil produce a close, firm sod. The flowering culms are a few inches high and terminate in a short spike. Curly mesquite is an important grazing grass of the uplands of Texas. Our species has commonly been referred to the related, *H. cenchroides*, of Mexico.

Hilaria jamesii (Torr.) Benth. (fig. 99), an erect grass about a foot high, with glumes narrowed above, is found from Wyoming to Texas and southern California. This is called galleta grass in New Mexico. *Hilaria mutica* (Buckl.) Benth., found from Texas to Arizona, differs from the preceding in having some of the glumes broadened above. This species is sometimes called tobosa grass. *Hilaria rigida* (Thurb.) Benth., with felty pubescent branched culms, is found from Utah to southern California. This also is called galleta grass. All the species of Hilaria are important range grasses. The last three species, with scaly rhizomes instead of stolons and with glumes bearing an awn on one side, compose Pleuraphis, held by some as a genus distinct from Hilaria.

81. Aegopogon Humb. and Bonpl.

Spikelets short-pedicellate, in groups of 3, the group short-pedunculate, spreading, the peduncle disarticulating from the axis and forming a pointed stipe below the group, this falling entire; central spikelet shorter pedicellate, fertile, the 2 lateral ones longer pedicellate and staminate or neuter; glumes membranaceous, notched at the apex, the midnerve extending into a point or awn; lemma and palea thinner than the glumes, extending beyond them, the lemma 3-nerved, the central nerve and sometimes also the lateral ones extending into awns, the palea 2-awned.

Annual low, lax grasses, with short, narrow, flat blades and loose racemes of delicate flower clusters. Species three, Arizona to Bolivia, one within the United States.

Type species: *Aegopogon cenchroides* Humb. and Bonpl.

Aegopogon Humb. and Bonpl.; Willd. Sp. Pl. **4:** 899. 1806. Only one species is described.

Hymenothecium Lag., Elench. Pl. 7. 1816. In the Elenchus, a list of seeds, occurs *Hymenothecium tenellum* Lag. based on *Cynosurus tenellus* Cav. The genus was published as new by Lagasca in Genera et Species Plantarum, a work appearing in the same year as the preceding but supposed to be somewhat later. In this work (p. 4) four species are given, *H. unisetum*, *H. tenellum*, *H. trisetum* (*Cynosurus gracilis* Cav.), and *H. quinquesetum*. *Cynosurus tenellus* Cav. is accepted as the type.

Schellingia Steud., Flora **33:** 231, pl. 1. 1850. Type, *S. tenera* Steud., the only species described. This is *Aegopogon cenchroides*.

The only species in the United States is *Aegopogon tenellus* (Cav.) Trin. (fig. 100), a Mexican species extending into southern Arizona. It is a pretty little grass, but is of no economic importance.

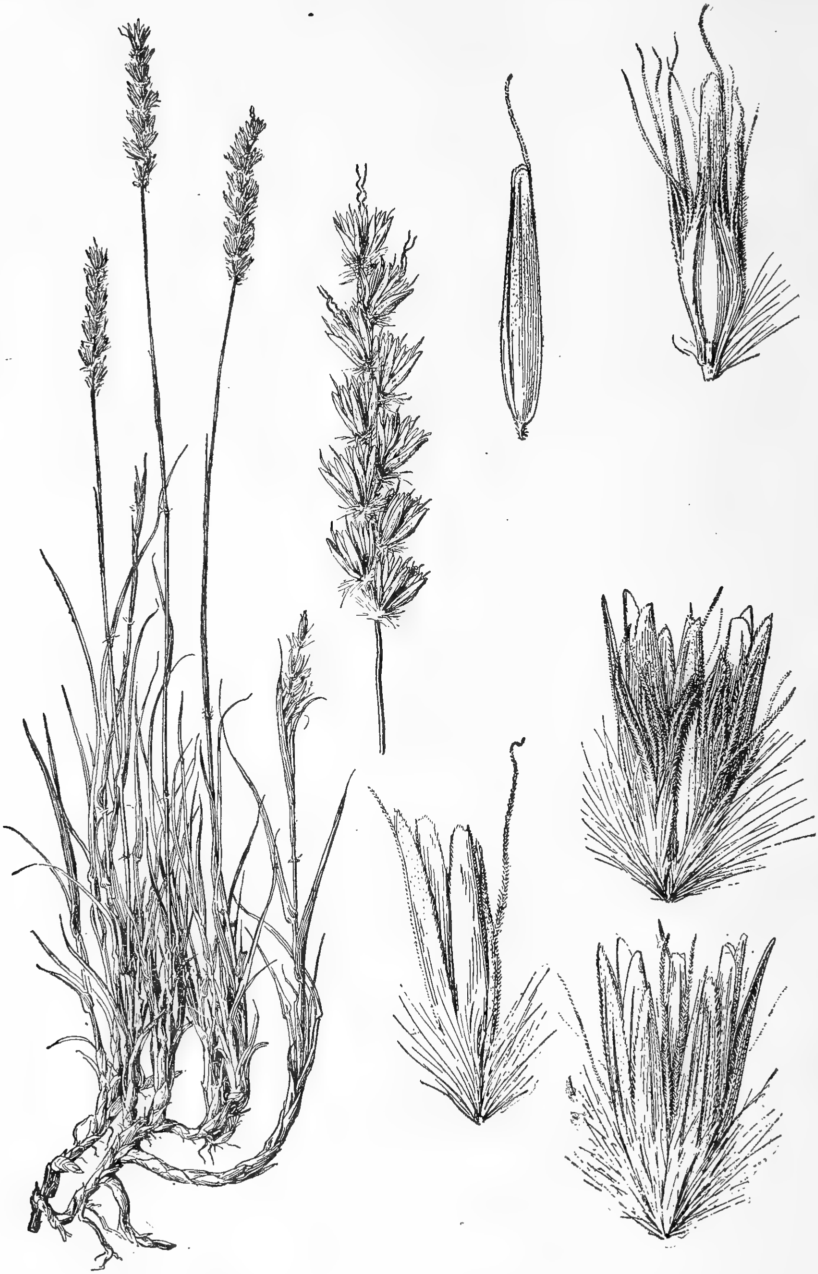

FIG. 99.—Galleta grass, *Hilaria jamesii*. Plant, × ½; single spike, × 1; two views of group of spikelets, the lower a dorsal view, the upper a ventral view, × 5; staminate spikelet (below), × 5; fertile spikelet seen from the inside and fertile floret (above), × 5.

7. CHLORIDEAE, THE GRAMA TRIBE.

82. Leptochloa Beauv.

Spikelets 2 to several flowered, sessile or short-pediceled, approximate or somewhat distant along one side of a slender rachis, the rachilla disarticulating above the glumes and between the florets; glumes unequal or nearly equal, awnless or mucronate, 1-nerved,

Fig. 100.—*Aegopogon tenellus.* Plant, × ½; group of spikelets, × 5; lateral spikelet, × 10; central (long-awned) spikelet, × 10.

usually shorter than the first lemma; lemmas obtuse or acute, sometimes 2-toothed and mucronate or short-awned from between the teeth, 3-nerved, the nerves sometimes pubescent.

Annual or perennial grasses, with flat blades and numerous spikes or racemes scattered along a common axis forming a long or sometimes short panicle. Species probably 20, in the warmer regions; 10 species in the United States, mostly in the Southern and Southwestern States.

Type species: *Cynosurus virgatus* L.

Leptochloa Beauv., Ess. Agrost. 71, 166, pl. 15, f. 1. 1812. Beauvois includes three species, *Cynosurus capillaceus*, *Eleusine filiformis*, and *E. virgata*, all of which appear in the index under Leptochloa. The third species is figured and hence is selected as the type.

Diplachne Beauv., Ess. Agrost. 80, pl. 16, f. 9. 1812. The type is *Festuca fascicularis* Lam., the only species mentioned. This is figured by Beauvois.

Rabdochloa Beauv., Ess. Agrost. 84, pl. 17, f. 3. 1812. Beauvois includes *Cynosurus monostachyos*, *C. virgatus*, *C. domingensis*, *C. cruciatus*, and *C. mucronatus*, the last two with question. The species figured, *C. domingensis*, in the explanation to the plates called *Rabdochloa domingensis*, is selected as the type.

Oxydenia Nutt., Gen. Pl. 1: 76. 1818. Only one species included, *O. attenuata*, which is *Leptochloa filiformis*.

Some authors[1] recognize Diplachne as a distinct genus, including *Leptochloa fascicularis*, *L. floribunda*, and *L. dubia*. In this group the spikelets are somewhat pediceled and are less distinctly arranged in one-sided spikes. Those who recognize the genus place it in the tribe Festuceae.

Leptochloa filiformis (Lam.) Beauv. (fig. 101) is an annual with papillate-pilose sheaths, small spikelets, the awnless florets shorter than the glumes, and numerous very slender spikes 3 to 6 inches long arranged in a panicle as much as a foot long. This is a weed in cultivated soil from Virginia to Florida and California; common also in the Tropics; sometimes called red sprangle-top.

Leptochloa fascicularis (Lam.) Gray is a smooth, erect or prostrate annual with several-flowered spikelets, the awned florets longer than the glumes; found in ditches and brackish meadows from Massachusetts to Florida and New Mexico.

The other species are more local. Two perennials, *L. domingensis* (Jacq.) Trin. and *L. virgata* (L.) Beauv., are tropical species which reach the United States in southern Florida and southern Texas, respectively. *Leptochloa dubia* (H. B. K.) Nees, a perennial with comparatively few spikes and broad lemmas notched at the apex, the nerves glabrous (the margin pubescent), is found in Florida and from Texas to New Mexico. In the Southwest it is called sprangle or sprangle-top and Texas crowfoot, and it is important as a forage grass.

For a revision of the species of Leptochloa found in the United States, see Hitchcock, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 33. 1903.

83. TRIPOGON Roth.

Spikelets several-flowered, nearly sessile, and appressed in two rows along one side of a slender rachis, the rachilla disarticulating above the glumes and between the florets; glumes somewhat unequal, acute or acuminate, narrow, 1-nerved; lemmas narrow, 3-nerved,

[1] Nash in Small, Fl. Southeast. U. S. 145, 1903; in Britt. and Brown, Illustr. Fl., ed. 2, 1: 236. 1913.

FIG. 101.—Red sprangle-top, *Leptochloa filiformis.* Plant, × ½; spikelet and floret, ×10.

bearing at the base a tuft of long hairs, bifid at the apex, the mid-nerve extending as a short awn.

Our species is a low, tufted perennial, with capillary blades and slender solitary spikes, the spikelets somewhat distant. Species about nine, East Indian and African except one American.

Type species: *Tripogon bromoides* Roth.

Tripogon Roth; Roem. and Schult., Syst. Veg. 2: 600. 1817. Only one species described.

The American species, *Tripogon spicatus* (Nees) Ekman (*Leptochloa spicata* Scribn.) (fig. 102), is found on sterile hills in Texas and northern Mexico, Cuba, and South America. It is of no importance agriculturally.

84. Eleusine Gaertn.

Spikelets few to several flowered, compressed, sessile and closely imbricate, in two rows along one side of a rather broad rachis, the latter not prolonged beyond the spikelets; rachilla disarticulating above the

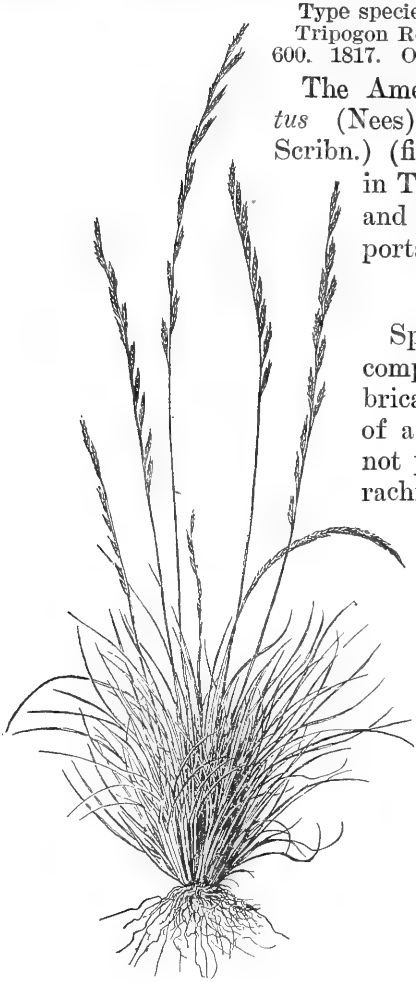

Fig. 102.—*Tripogon spicatus.* Plant, × ½; spikelet and floret, × 5.

glumes and between the florets, glumes unequal, rather broad, acute, 1-nerved, shorter than the first lemma; lemmas acute, with 3 strong green nerves close together forming a keel, the uppermost somewhat reduced; seed dark brown, roughened by fine ridges, loosely inclosed in the thin pericarp.

Annual grasses, with two to several rather stout spikes, digitate at the summit of the culms, sometimes with one or two a short distance below, or rarely with a single terminal spike. Species about six, in the warm regions of the Eastern Hemisphere, one a common introduced weed in America.

Type species: *Eleusine coracana* Gaertn.
Eleusine Gaertn., Fruct. and Sem. 1: 7, pl. 1, f. 11. 1788. Two species are described, *E. coracana* and *E. indica*. The first, being figured, is selected as the type.

Eleusine indica (L.) Gaertn. (fig. 103) is a common garden and roadside weed throughout the warmer parts of America, extending northward to Illinois and Massachusetts. It is usually spreading or prostrate, with two to several spikes, or rarely one. This species is sometimes called goose-grass and yard-grass.

The type species of the genus, *Eleusine coracana* Gaertn., is cultivated in the Tropics of the Old World for the seed, which is used for human food by the poor or primitive people. It differs from *E. indica* in its larger size, stouter, often incurved spikes, and globose seed.

85. Dactyloctenium Willd.

Spikelets 3 to 5 flowered, compressed, sessile and closely imbricate, in two rows along one side of the rather narrow flat rachis, the end projecting in a point beyond the spikelets; rachilla disarticulating above the first glume and between the florets; glumes somewhat unequal, broad, 1-nerved, the first persistent upon the rachis, the second mucronate or short-awned below the tip, deciduous; lemmas firm, broad, keeled, acuminate or short-awned, 3-nerved, the lateral nerves indistinct, the upper floret reduced; the palea about as long as the lemma; seed subglobose, ridged or wrinkled, inclosed in a thin, early-disappearing pericarp.

Annual or perennial grasses, with flat blades and two to several short thick spikes, digitate and widely spreading at the summit of the culms. Species three, in the warmer parts of the Eastern Hemisphere, one a common weed in tropical America.

Type species: *Cynosurus aegyptius* L.
Dactyloctenium Willd., Enum. Pl. 1029. 1809. Willdenow describes but one species, *D. aegyptiacum*, based on *Cynosurus aegyptius* L.

Our only species is *Dactyloctenium aegyptium* (L.) Richt. (*D. aegyptiacum* Willd.) (fig. 104), a tropical weed which extends northward to New York and Illinois. It is a prostrate annual with 2 to 5 spikes, often forming mats rooting at the nodes. Sometimes called crowfoot grass.

86. Capriola Adans.
(*Cynodon* Rich.)

Spikelets 1-flowered, awnless, sessile in two rows along one side of a slender continuous rachis, the rachilla disarticulating above the glumes and prolonged behind the palea as a slender naked bristle,

FIG. 103.—Goose-grass, *Eleusine indica*. Plant, × ½; spikelet, floret, and seed (without pericarp), × 5.

this sometimes bearing a rudimentary lemma; glumes narrow, acuminate, 1-nerved, about equal, shorter than the floret; lemma strongly

FIG. 104.—Crowfoot grass, *Dactyloctenium aegyptium*. Plant, × ½; spikelet, floret, and seed (without pericarp), × 5.

compressed, pubescent on the keel, firm in texture, 3-nerved, the lateral nerves close to the margins.

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Perennial, usually low grasses, with creeping stolons or rhizomes, short blades, and several slender spikes digitate at the summit of the upright flowering stems. Species six, of which three are Australian, one species widely distributed in the warmer regions of the globe.

Type species: *Panicum dactylon* L.

Capriola Adans., Fam. Pl. **2**: 31, 532. 1763. The genera are indicated and distinguished by Adanson in a much abbreviated and often unsatisfactory manner. The tabular arrangement of the genera of Phalarides, his first section of the grass family or Gramina, includes Capriola, with the following diagnosis, interpreting the table: Summit of leaf sheath hairy; flowers in digitate spikes; glumes laterally compressed; lemma awnless. In the index there is given as a synonym under Capriola, "Gramen dactylon Offic." The last phrase appears in the first edition of the Species Plantarum[1] in the synonymy under *Panicum dactylon* as "Gramen dactylon, radice repente. s. officinarum. Scheuch. gram. 104," thus connecting Capriola Adans. with *Panicum dactylon.*

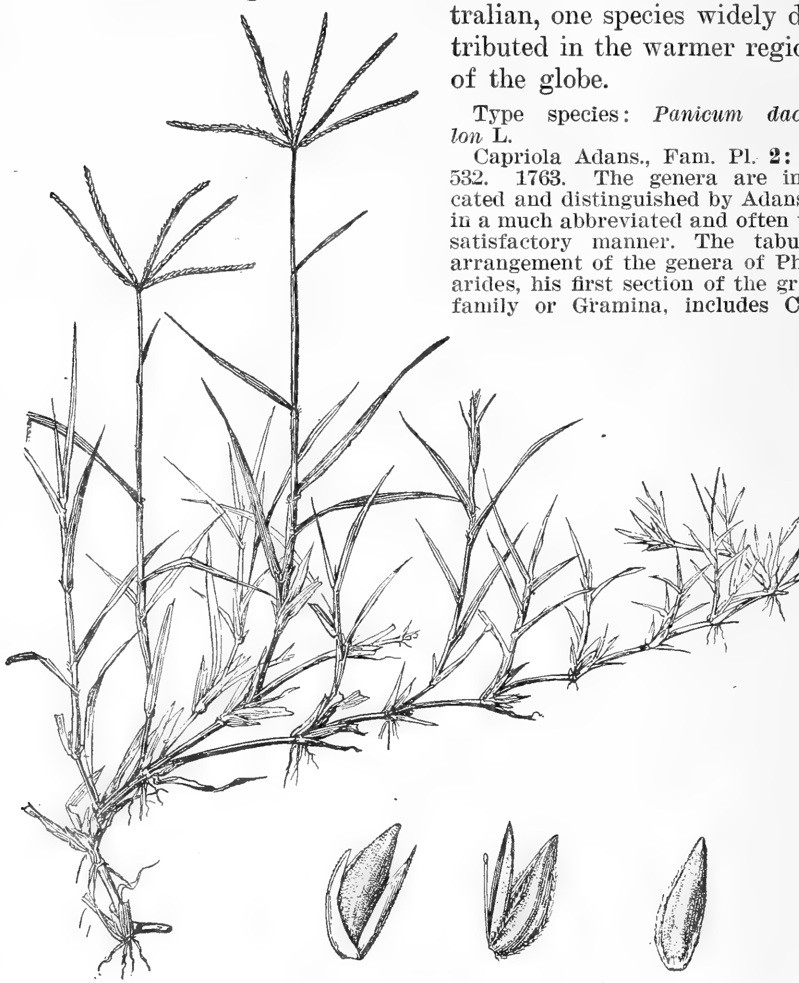

FIG. 105.—Bermuda grass, *Capriola dactylon.* Plant, × ½; spikelet and two views of floret, × 5.

Cynodon Rich.; Pers., Syn. Pl. **1**: 85. 1805. Only one species described, *C. dactylon,* based on *Panicum dactylon* L.

The only species in North America is *Capriola dactylon* (L.) Kuntze (fig. 105), commonly known as Bermuda grass. This is a

[1] L., Sp. Pl. 58. 1753.

native of the Mediterranean region, but is common in the southern United States, extending north to Maryland, southern Kansas, and the interior valleys of California.

Bermuda grass is the most important pasture grass of the Southern States, and is also widely utilized there as a lawn grass. On alluvial ground it may grow sufficiently rank to be cut for hay. It propagates readily by its rhizomes and stolons and on this account may become a pestiferous weed in cultivated fields. This grass is known also as wire-grass (especially the weedy form in fields), Bahama grass in the West Indies, and manienie in the Hawaiian Islands.

A larger form, *Capriola dactylon maritima* (H. B. K.) Hitchc. (*Cynodon maritimus* H. B. K.), is found along the seacoast of Florida.

87. Willkommia Hack.

Spikelets 1-flowered, dorsally compressed, sessile in two rows on one side of a slender rachis and appressed to it, the rachilla somewhat lengthened below and above the second glume, disarticulating just above it, not prolonged above the floret; glumes thin, the first narrow, about two-thirds as long as the second, nerveless, obtuse, the second 1-nerved, subacute; lemma about as long as the second glume, awnless, 3-nerved, the lateral nerves near the margin, the back of the lemma sparingly pubescent between the nerves, the margins densely covered with silky hairs; palea 2-nerved, the nerves densely silky hairy.

Annuals or perennials, with several short spikes scattered along a main axis; our species a low, tufted perennial. Species four; three in South Africa, one in Texas.

Type species: *Willkommia sarmentosa* Hack.

Willkommia Hack., Verh. Bot. Ver. Brandenburg **30**: 145. 1888. Hackel describes two species, *W. sarmentosa*, a perennial, and *W. annua*, an annual, both from German Southwest Africa. The first species is selected as the type.

Willkommia texana Hitchc. (fig. 106), confined to a few localities in Texas, in alkali spots in prairies and openings in woods, has no agricultural importance.

88. Schedonnardus Steud.

Spikelets 1-flowered, sessile and somewhat distant in two rows on one side of a slender, continuous 3-angled rachis, appressed to its slightly concave sides, the rachilla disarticulating above the glumes, not prolonged; glumes narrow, stiff, somewhat unequal, acuminate, 1-nerved; lemmas narrow, acuminate, a little longer than the glumes, 3-nerved.

A low, tufted perennial, with stiff, slender, divergent spikes arranged rather remotely along a common axis. Species one, on the Great Plains of the United States and in Argentina.

Type species: *Schedonnardus texanus* Steud.

Schedonnardus Steud., Syn. Pl. Glum. **1**: 146. 1854. A single species described, *S. texanus,* based on Drummond's no. 360 from Texas. This is *S. paniculatus* (Nutt.) Trel. (*Lepturus paniculatus* Nutt.).

Spirochloë Lunell, Amer. Midl. Nat. **4**: 220. 1915. Proposed for "Schedonnardus Steud . . . not thought permissible, being built on Nardus."

Schedonnardus paniculatus (fig. 107), the only species of the genus, is found on prairies and plains from Montana and Illinois to Texas. The axis of the inflorescence elongates after flowering, becoming 1 to 2 feet long, curved in a loose spiral. The whole breaks away at maturity and rolls before the wind as a tumbleweed. The species is a forage grass, but the plants are low and in the main form only an inconsiderable proportion of the total forage.

89. BECKMANNIA Host.

Spikelets 1-flowered, rarely 2-flowered, laterally compressed, subcircular, nearly sessile and closely imbricate, in two rows along one side of a slender continuous rachis, disarticulating below the glumes,

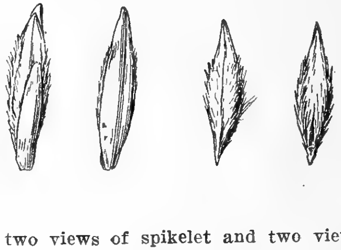

FIG. 106.—*Willkommia texana.* Plant, × ½; two views of spikelet and two views of floret, × 5.

falling entire; glumes equal, inflated, obovate, 3-nerved, rounded above but the apex apiculate; lemma narrow, 5-nerved, acuminate, about as long as the glumes; palea 2-nerved, nearly as long as the lemma.

An erect, rather stout annual, with flat blades and numerous short appressed spikes in a narrow more or less interrupted panicle. Species one, in the cooler parts of America and Eurasia.

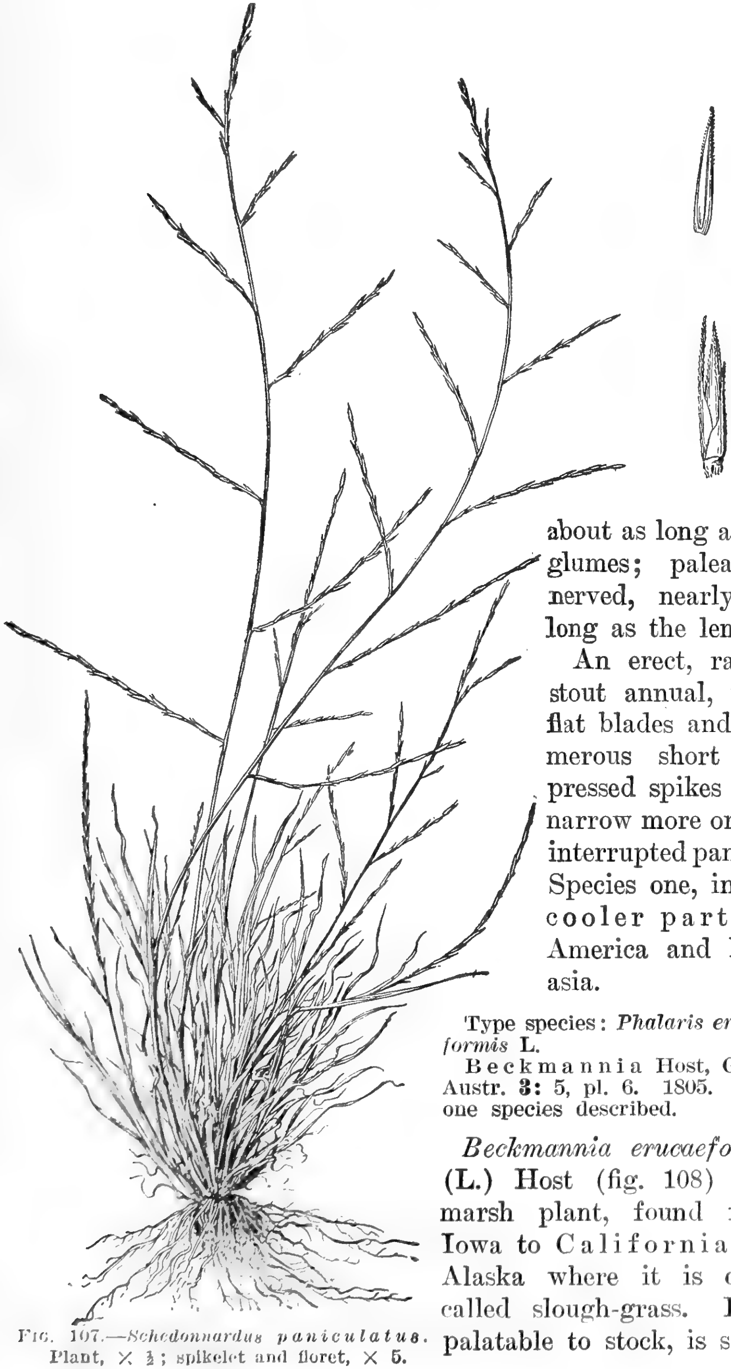

FIG. 107.—*Schedonnardus paniculatus*. Plant, × ½; spikelet and floret, × 5.

Type species: *Phalaris erucaeformis* L.

Beckmannia Host, Gram. Austr. **3:** 5, pl. 6. 1805. Only one species described.

Beckmannia erucaeformis **(L.)** Host (fig. 108) is a marsh plant, found from Iowa to California and Alaska where it is often called slough-grass. It is palatable to stock, is sometimes sufficiently abundant locally to be an important forage grass, and is not infrequently used for hay. The European form has 2-flowered spikelets.

90. SPARTINA Schreb.

Spikelets 1-flowered, much flattened laterally, sessile and usually closely imbricate, on one side of a continuous rachis, disarticulating below the glumes, the rachilla not produced beyond the floret; glumes keeled, 1-nerved,

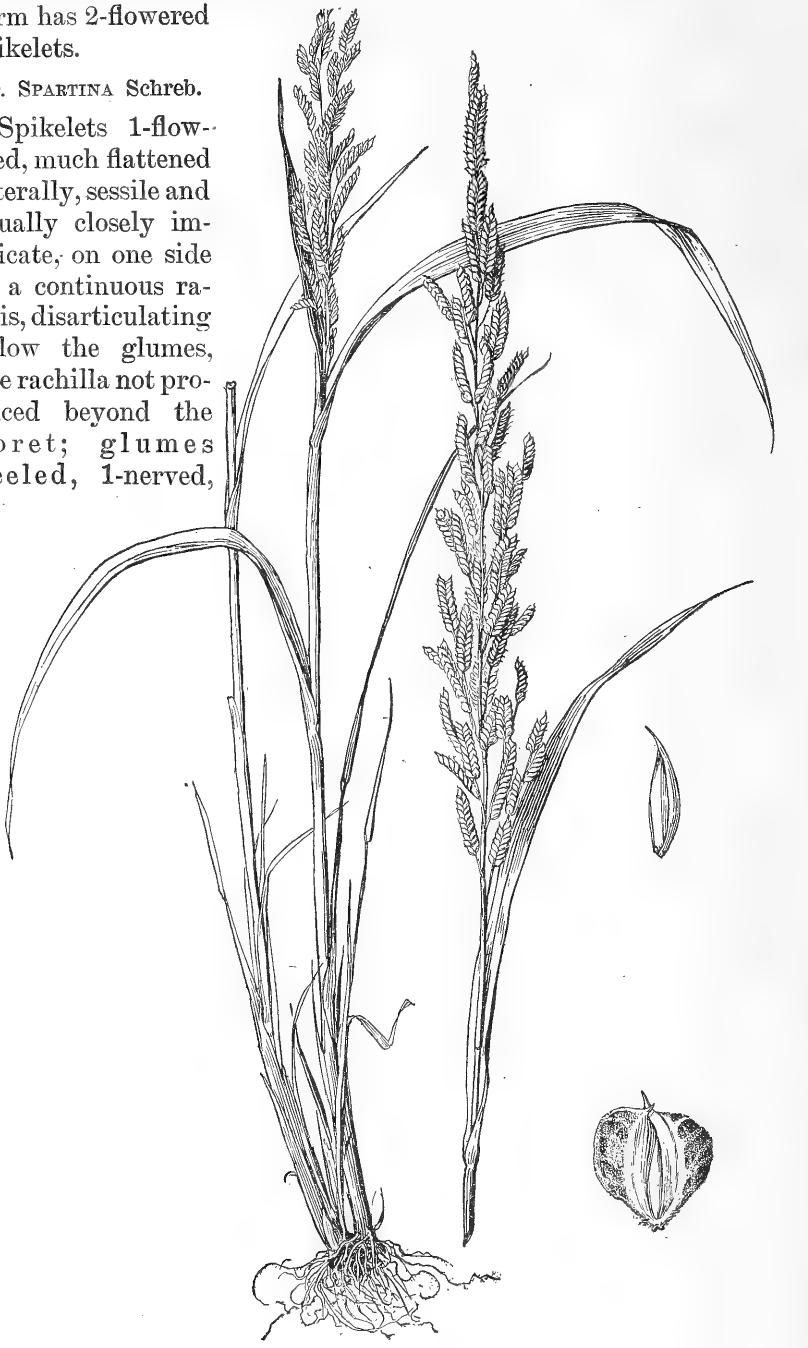

FIG. 108.—Slough-grass, *Beckmannia erucaeformis*. Plant, × ½; spikelet and floret, × 5.

acute or short-awned, the first shorter, the second often exceeding the lemma; lemma firm, keeled, the lateral nerves obscure, narrowed to a rather obtuse point; palea 2-nerved, keeled and flattened, the keel between or at one side of the nerves.

Stout, erect, often tall perennials, with usually extensively creeping, firm, scaly rhizomes, long tough blades, and two to many appressed or sometimes spreading spikes racemose on the main axis. Species about 14, all North American except two or three along the coast of Europe, Africa, and South America.

Type species: *Spartina schreberi* Gmel.

Spartina Schreb.; Gmel., Syst. Nat. ed. 13. **2**: 123. 1791. The genus was first described by Schreber in his Genera Plantarum,[1] but no species was mentioned. Gmelin merely assigns a specific name to the description given by Schreber. *Spartina schreberi* is not recognized by European botanists, but it doubtless is the common European species, *S. maritima* (Curt.) Fernald (*S. stricta* Roth).

Trachynotia Michx., Fl. Bor. Amer. **1**: 63. 1803. Type species *T. cynosuroides.* Michaux describes three species, *T. cynosuroides, T. polystachya,* and *T. juncea.* The first species described is what is now called *Spartina michauxiana* Hitchc., but the synonym, *Dactylis cynosuroides* L., from which the specific name is taken, shows that Michaux had misapplied the name. The second species, *T. polystachya,* is *Dactylis cynosuroides* L., now called *Spartina cynosuroides* (L.) Roth. Michaux remarks that this may be only a variety of the first species. It appears then that to Michaux the first species typifies the genus, and hence is selected here as the type species.

Limnetis Pers., Syn. Pl. **1**: 72. 1805. Four species are described, *L. pungens, L. juncea, L. cynosuroides,* and *L. polystachya.* The first species, which is the same as *Spartina maritima,* is selected as the type, as that is a native of Europe and is indigenous from the standpoint of the author. The other three species are American.

There are eight species in the United States. All but two are found on or near the coast. *Spartina cynosuroides* (L.) Roth, a stout grass as much as 9 feet tall, is found along the Atlantic coast. The commonest coastal species is *S. patens* (Ait.) Muhl. (including *S. juncea* Michx.), which covers vast areas of salt marsh from Newfoundland to Texas. This is a slender wiry species usually less than 3 feet tall, with only a few somewhat spreading spikes. *Spartina alterniflora* Loisel. and its two varieties, *glabra* (Muhl.) Fern. and *pilosa* (Merr.) Fern., also of the Atlantic coast, have stout stems and closely appressed spikes, forming a cylindric inflorescence. A somewhat local species, *S. spartinae* (Trin.) Merr., is found on the Texas coast. Another local species, *S. foliosa* Trin., is found on the coast of California. The only species without well-marked rhizomes is *S. bakeri* Merr., of the fresh-water marshes and low savannas of Florida and coastal Georgia. Two species are found in the interior of the United States. One, *S. michauxiana* Hitchc. (fig. 109), is common in marshes and sloughs from New England to the Great Plains. A second, *S. gracilis* Trin., is found in alkaline grassland in the Western States. The first of these is used for thatching sheds and covering hay stacks. The leaves of

[1] Schreb. Gen. Pl. **1**: 43. 1789.

FIG. 109.—Marsh-grass, *Spartina michauxiana.* Plant, × ½; spikelet and floret, × 5.

S. bakeri and *S. patens juncea* (Michx.) Hitchc. are used for making brooms. The marsh hay of the Atlantic coast, much used for bedding and packing, often consists largely of *S. patens*. The species of Spartina are too coarse for forage.

For a revision of the species found in the United States, see Merrill, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 9. 1912.

91. Campulosus Desv.
(*Ctenium* Panzer.)

Spikelets several-flowered but with only one perfect floret, sessile and closely imbricate, on one side of a continuous rachis, the rachilla disarticulating above the glumes; glumes unequal, the first small, hyaline, 1-nerved, the second as long as the lemmas, firm, 3 to 4 nerved, bearing on the back a strong divergent awn; lemmas rather papery, 3-nerved, villous on the lateral nerves and on the callus, bearing a short straight awn on the back just below the apex, the first and second lemmas empty, the third inclosing a perfect flower, the upper 1 to 3 empty and successively smaller.

Erect, slender, rather tall perennials, with usually solitary, often curved spikes. Species about 12, in the warm regions, three being in the Eastern Hemisphere and the rest in America; two species are found in the southeastern United States.

Type species: *Chloris monostachya* Michx.

Campulosus Desv., Nouv. Bull. Soc. Philom. Paris **2**: 189. 1810. Two species are mentioned, *C. gracilior* Desv. (based on *Chloris monostachya* Michx., which is *Campulosus aromaticus*), and *C. hirsutus* Desv. (based on *Chloris falcata* Swartz). The first is selected as the type. The second is now referred to Harpechloa.

Ctenium Panzer, Denkschr. Baier. Akad. Wiss. München **4**: 288, pl. 13. 1813. (Ideen Gatt. Gräser, 38.) Only one species is described, *Chloris monostachya* Michx., to which Panzer gives the name *Ctenium carolinianum*.

Monocera Ell., Bot. S. C. and Ga. **1**: 176. 1816. A single species, based on *Aegilops aromaticum* Walt., is included.

Monathera Raf., Amer. Month. Mag. **4**: 190. 1819. "Monocera Elliott . . . must be changed, because there is already a genus of shell of the same name."

Our two species are confined to the Southeastern States, one of them, *Campulosus floridanus* Hitchc., to Florida, the other, *C. aromaticus* (Walt.) Trin. (fig. 110), called toothache grass, extending from North Carolina along the Coastal Plain to Louisiana. Both species are rather infrequent and neither is of importance agriculturally.

92. Gymnopogon Beauv.

Spikelets 1 or rarely 2 or 3 flowered, nearly sessile, appressed and usually remote in two rows along one side of a slender continuous rachis, the rachilla disarticulating above the glumes and prolonged behind the one or more fertile florets as a slender stipe, bearing a rudiment of a floret, this sometimes with one or two slender awns;

glumes narrow, acuminate, 1-nerved, usually longer than the floret; lemmas narrow, 3-nerved, the lateral nerves near the margin, the

FIG. 110.—Toothache grass, *Campulosus aromaticus*. Plant, × ½; spikelet and fertile floret (palea side up), × 5.

apex minutely bifid, bearing between the teeth a slender awn, or rarely awnless.

Perennial or rarely annual grasses, with short, flat, stiff blades, numerous stiff, slender, divergent spikes loosely scattered along the upper part of the culm, or sometimes aggregate toward the summit, the spikes often deflexed at maturity. Species 10, nearly all American; 3 species in the southeastern United States.

Type species: *Andropogon ambiguus* Michx.

Gymnopogon Beauv., Ess. Agrost. 41, pl. 9, f. 3. 1812. Beauvois mentions one species, *Andropogon ambiguus* Michx., which is figured. In the description of the plate the name given is *Gymnopogon racemosus*.

Alloiatheros Ell., Bot. S. C. and Ga. 1: 146. 1816. This name is casually mentioned by Elliott in the description of *Andropogon ambiguus:* "I once intended to insert it as a distinct genus under the name of Alloiatheros, from the dissimilarity of its awns, not only in position but in figure."

Anthopogon Nutt., Gen. Pl. 1: 81. 1818. Based on *Andropogon ambiguus* Michx., which name Nuttall changes to *Anthopogon lepturoides*.

The spikelets are usually 1-flowered and awned, but in *Gymnopogon chapmanianus* Hitchc., of Florida, they are 2 to 4 flowered and awnless. This species shows in its spikelet characters a transition to Leptochloa, but in habit it closely resembles the other two species of the United States. In *G. foliosus* (Willd.) Nees, of Porto Rico and South America, the rudiment bears two long awns. Our species are perennials, with an inflorescence of scattered spikes.

Our commonest species is *Gymnopogon ambiguus* (Michx.) B. S. P. (fig. 111), found in sandy soil from New Jersey to Missouri and south to Florida and Texas. Another species, *G. brevifolius* Trin., grows from New Jersey to Florida. This species differs from the preceding in having the rachis spikelet bearing only along the upper half. The species have no agricultural importance.

93. Chloris Swartz.

Spikelets with 1 perfect floret, sessile, in two rows along one side of a continuous rachis, the rachilla disarticulating above the glumes, produced beyond the perfect floret and bearing 1 to several reduced florets consisting of empty lemmas, these often truncate, and, if more than one, the smaller ones inclosed in the lower, forming a usually club-shaped rudiment; glumes somewhat unequal, the first shorter, narrow, acute; lemma keeled, usually broad, 1 to 5 nerved, often villous on the callus and villous or long-ciliate on the keel or marginal nerves, awned from between the short teeth of a bifid apex, the awn slender or sometimes reduced to a mucro, the sterile lemmas awned or awnless.

Perennial or sometimes annual, tufted grasses, with flat blades and two to several often showy and feathery spikes aggregate at the summit of the culms. Species about 60, in the warmer regions; 15 in the southern United States.

Type species: *Agrostis cruciata* L.

Chloris Swartz, Prod. Veg. Ind. Occ. 25. 1788. Swartz describes five species, *C. cruciata*, *C. ciliata*, *C. petraea*, *C. polydactyla*, and *C. radiata*, all from the

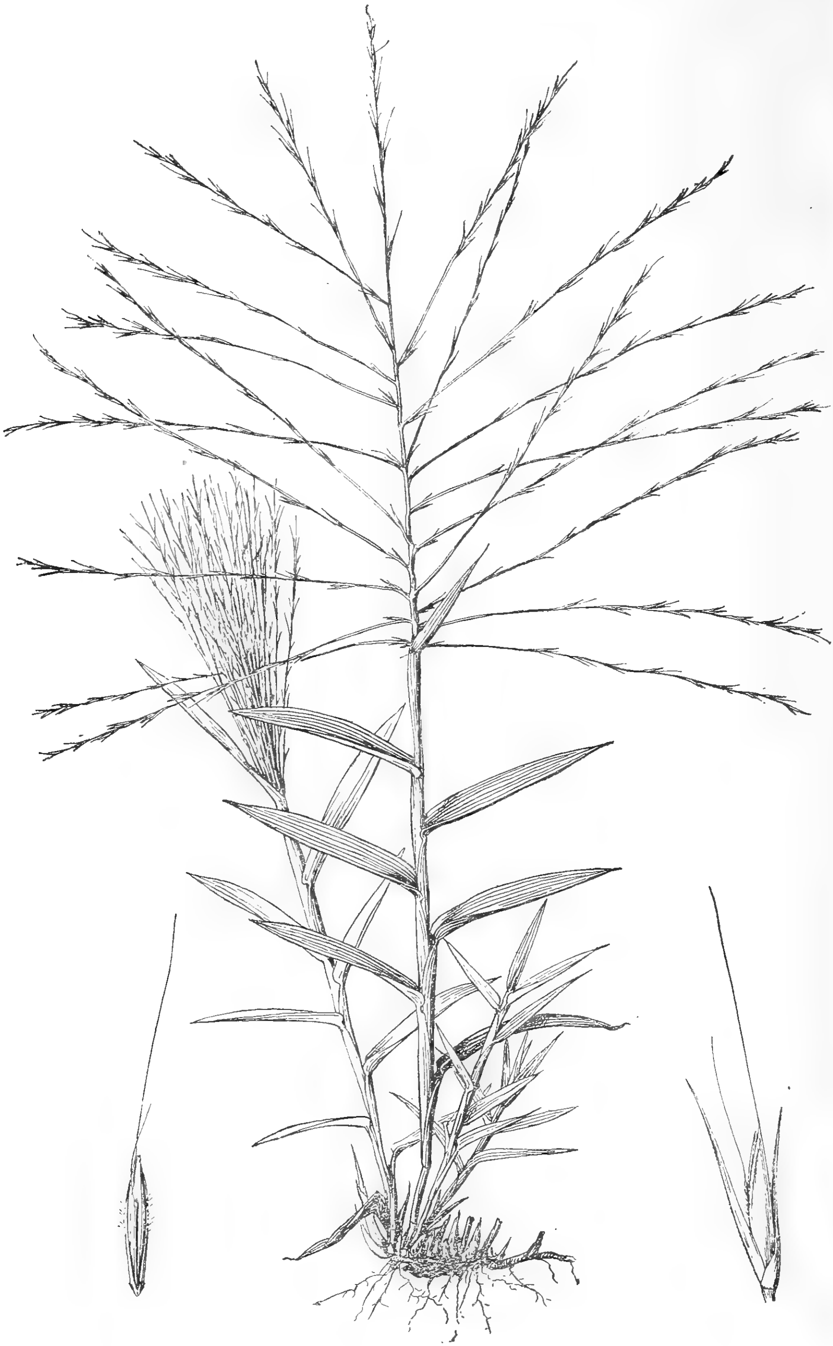

FIG. 111.—*Gymnopogon ambiguus.* Plant, × ½; spikelet and floret, × 5.

West Indies. The second and third are described as new; the others are based on Linnæan species, the first on *Agrostis cruciata*, the fourth on *Andropogon polydactylon*, and the fifth on *Agrostis radiata*. The first species is selected as the type.

Eustachys Desv., Nouv. Bull. Soc. Philom. Paris **2**: 188. 1810. One species is described, *E. petraeus*, based on *Chloris petraea* Swartz. Eustachys, recognized by some American botanists as distinct, forms a section of the genus Chloris and includes four species, *C. petraea*, *C. glauca* (Chapm.) Vasey, *C. floridana* (Chapm.) Vasey, and *C. neglecta* Nash. The group differs from Euchloris in having the lemmas short-awned or mucronate, brown, and rather firm in texture.

Chlorostis Raf., Princip. Fondament. Somiologie 26, 29. 1814. Proposed change of name for Chloris Swartz, because of Chlora L. (an animal).

Several species are found on the plains of Texas, where they form an unimportant part of the forage for grazing animals. *Chloris verticillata* Nutt. and its allies are known as windmill grasses. The mature inflorescence, consisting of several slender, divergent spikes, breaks away from the plant and rolls before the wind as a tumble-weed. In the Southwestern States is found *C. virgata* Swartz (*C. elegans* H. B. K.) (fig. 112), a tufted annual, 1 to 2 feet high, with several pale or purplish, erect, feathery spikes 1 to 2 inches long. This species invades cultivated fields and sometimes becomes a rather common weed, especially in alfalfa fields.

One species, *C. gayana* Kunth, a native of South Africa, is cultivated to a limited extent as a forage grass. This species, called Rhodes grass, has been shown to have value as a meadow grass in the Southwestern States. In the Hawaiian Islands it is used on some of the ranches in the drier regions. Rhodes grass is a perennial, 2 to 3 feet high, producing long, stout, creeping, propagating stems or stolons and bearing at the summit of the flowering stems a close fan-shaped cluster of numerous spikes 2 to 4 inches long.

For a revision of the species of Eustachys and Chloris found in the United States, see Nash, Bull. Torrey Club **25**: 432–450. 1898.

94. Trichloris Fourn.

Spikelets 1 to few flowered, nearly sessile, in two rows along one side of a continuous slender rachis, the rachilla disarticulating above the glumes and prolonged behind the uppermost perfect floret, bearing a reduced, usually awned floret; glumes unequal, acuminate, or short-awned, the body shorter than the lower lemma; lemmas narrow, 3-nerved, the marginal nerves sometimes pubescent, these and the midnerve extending into awns, the central long and slender, the lateral often much shorter.

Erect, slender, tufted perennials, with flat blades and numerous erect or ascending spikes, aggregate but scarcely digitate at the summit of the culms. Species two or three, in the dry regions of Texas and Mexico and also in Argentina.

Type species: *Trichloris pluriflora* Fourn.

Trichloris Fourn., Mex. Pl. 2: 142. 1886. Fournier includes two species, *T. fasciculata* and *T. pluriflora*, both described as new. In the generic descrip-

FIG. 112.—*Chloris virgata.* Plant × ½; glumes and floret with rudiment, × 5.

tion occurs the statement "flore summo tabescente mutico." Under the second species one finds "flore summo mutico." From this it would appear that *T. pluriflora* represented Fournier's idea of the genus; hence this species is selected as the type.

Chloropsis Hack.; Kuntze, Rev. Gen. Pl. 2: 771. 1891. The name was mentioned by Hackel[1] as a synonym under Trichloris. Hackel also mentions Chloridopsis, both names having been used by gardeners for *Trichloris blanchardiana* Hack. of Argentina. Kuntze changes the name Trichloris to Chloropsis, because of the earlier Trichlora Baker. Both Trichlora and Trichloris may be considered valid, since they have different derivations and slightly different spellings. Since Kuntze adopts Hackel's name and since Hackel mentions *Chloropsis blanchardiana*, this species is selected as the type of Chloropsis.

The two species of the United States, *Trichloris mendocina* (Phil.) Kurtz (*T. fasciculata* Fourn.) (fig. 113) and *T. pluriflora* Fourn., are found in the arid regions of northern Mexico and extend into western Texas, southern New Mexico, and southern Arizona. The first has spikelets with one perfect floret and a rudiment, each with three long awns; the second has spikelets with 3 to 5 florets, the upper one or two reduced, the lateral awns reduced or sometimes wanting. Neither is of importance agriculturally.

95. Bouteloua Lag., the grama grasses.

Spikelets 1-flowered, with the rudiments of one or more florets above, sessile, in two rows along one side of the rachis; glumes unequal, 1-nerved, acuminate or awn-tipped, the first shorter and narrower; lemma as long as the second glume or a little longer, 3-nerved, the nerves extending into short or often rather long awns, the internerves usually extending into teeth; palea 2-nerved, sometimes 2-awned; rudiment various, usually 3-awned, a second rudimentary floret sometimes present.

Perennial or sometimes annual, low or rather tall grasses, with two to several or many spikes racemose on a common axis, or sometimes solitary, the spikelets few to many in each spike, rarely solitary, pectinate or more loosely arranged and appressed, the rachis of the spike usually produced beyond the insertion of the spikelets. Species 38, all American and chiefly North American; 18 species found in the United States, mostly in open grassland of the southwestern States.

Type species: *Bouteloua racemosa* Lag.

Bouteloua Lag., Varied. Cienc. Lit. and Art. 2[4]: 134. 1805. Lagasca gives five species, *B. racemosa*, *B. hirsuta*, *B. barbata*, *B. simplex*, and *B. prostrata*. All are briefly described, except the last, which is mentioned by name only. The first species (which is the same as *B. curtipendula*) is selected as the type. In this work Lagasca spells the name of the genus "Botelua" and states that he names the genus in honor of the two brothers Boutelou. In a later work[2] Lagasca describes the genus under the name Bouteloua, and includes 10 species, the first of which is *B. hirsuta*. The spelling Bouteloua is retained because it was corrected to this form by the author to correspond to the spelling of the personal name of the brothers Boutelou, and because this second spelling has been universally accepted by botanists.

Atheropogon Muhl.; Willd., Sp. Pl. 4: 937. 1806. A single species is described, *A. apludioides Muhl.*, which is *Bouteloua curtipendula*.

Triathera Desv., Nouv. Bull. Soc. Philom. Paris 2: 188. 1810. Based on *Aristida americana* L., which is *Bouteloua americana* (L.) Scribn., a West Indian species.

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[1] In Engl. and Prantl, Pflanzenfam. 2[2]: 59. 1887.

[2] Gen. and Sp. Nov. 5. 1816.

FIG. 113.—*Trichloris mendocina.* Plant, × ½; glumes and floret with rudiment, × 5.

Heterosteca Desv., Nouv. Bull. Soc. Philom. Paris 2: 188. 1810. Based on *H. juncifolia*, which is *Bouteloua heterostega* (Trin.) Griffiths, of the West Indies.

Chondrosium Desv., Nouv. Bull. Soc. Philom. Paris 2: 188. 1810. Based on *Chloris procumbens* Durand (*Bouteloua procumbens*).

Polyodon H. B. K., Nov. Gen. and Sp. 1: 174, pl. 55. 1816. Based on a single species, *P. distichum* H. B. K.

Triaena H. B. K., Nov. Gen. and Sp. 1: 178. 1816. A single species described, *T. racemosa*, which is *Bouteloua triaena* (Trin.) Scribn.

Eutriana Trin., Fund. Agrost. 161. 1820. Trinius includes two species, *E. curtipendula* and *E. bromoides*. The first is selected as the type.

The species fall into two rather well marked divisions, those in which the spikelets are crowded and pectinate and the spikes persistent on the main axis, the florets falling, and those in which the spikelets are less crowded, ascending rather than pectinate on the rachis, and the spikes falling entire. *Bouteloua gracilis* and its allies are examples of the first group and *B. filiformis* (Fourn.) Griffiths and its allies, *B. curtipendula* and *B. aristidoides* of the second. The genus is important, since many of the species are the chief ingredient of the grazing lands of the Southwestern States.

Bouteloua gracilis Lag. (*B. oligostachya* Torr.) (fig. 114) is found on the Great Plains from Manitoba to Mexico and even southward to South America. It is the blue grama of the ranchmen and, along with buffalo grass (*Bulbilis dactyloides*) and curly mesquite (*Hilaria belangeri*), constitutes most of what is known in the Middle West as "short-grass." Blue grama is a tufted perennial, with numerous short leaves and a flower stalk about a foot high with 2 or 3 spikes about an inch long. These spikes, one at the end of the stem and the other one or two a short distance below, turn with the wind like weather vanes. An allied species, *B. hirsuta* Lag., called black grama, is found over about the same region, but is confined chiefly to rocky hills. This species differs in having shorter, more fuzzy spikes and in the prolonged end of the rachis, which forms a distinct point beyond the spikelets.

Another widely distributed species is *Bouteloua curtipendula* (Michx.) Torr. (*B. racemosa* Lag.) (fig. 115), called side-oats grama. It extends farther east than the other species, being found even as far as Connecticut. Side-oats grama is the tallest of the species, sometimes as much as 3 feet, and is further distinguished by the numerous (35 to 50) short, reflexed spikes.

In Arizona and New Mexico other species become prominent. *Bouteloua eriopoda* Torr., called here black grama and woolly-foot, is a low creeping species with woolly stem. *Bouteloua rothrockii* Vasey is the most important range grass in many parts of Arizona. It grows about a foot high and has five or six spikes to each culm. In *B. texana* S. Wats., of the Texas plains, the short triangular spikes fall from the axis entire.

Three species are annuals, *B. aristidoides* Thurb., *B. procumbens* (Durand) Griffiths (*B. prostrata* Lag.), and *B. barbata* Lag. (*B. polystachya* Torr.). These are found from Texas to Arizona, where they are called six-weeks grama. They furnish forage when young, but are of secondary importance.

For a revision of the species of Bouteloua and its allies, see Griffiths, Contr. U. S. Nat. Herb. **14:** 343–424. 1912. Economic notes and synonymy are included.

96. Cathestecum Presl.

Spikes consisting of 3 spikelets, the upper or central perfect, the 2 lateral staminate or rudimentary, the spike falling entire; central spikelet with one perfect floret below and one or more reduced florets above; glumes unequal, the first a short, thin, nerveless scale in the central spikelet, narrow and acuminate in the lateral spikelets, the second about as long as the lemma, acuminate, all usually villous; lemma 3-nerved, or rarely 5 to 7 nerved, the nerves extending into awns, and the internerves into teeth; palea 2-nerved, the nerves extending into short awns; second and third floret with

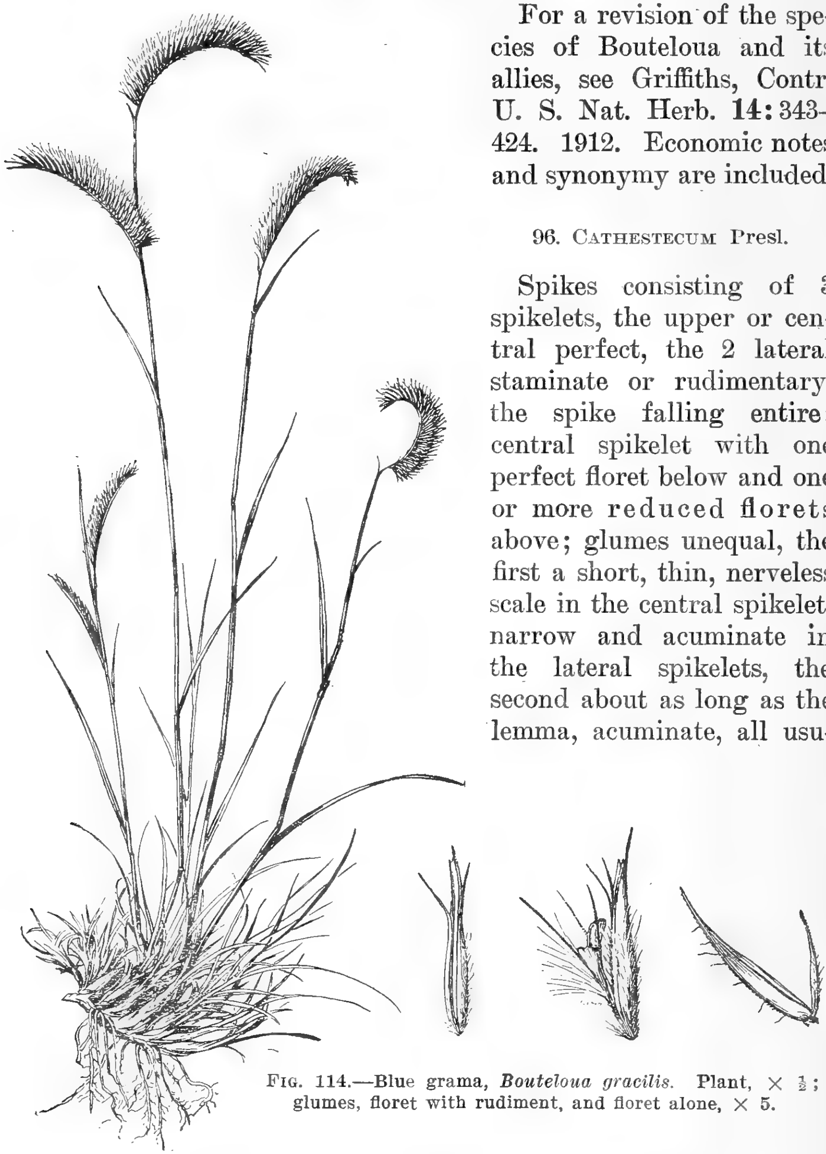

Fig. 114.—Blue grama, *Bouteloua gracilis*. Plant, × ½; glumes, floret with rudiment, and floret alone, × 5.

a fairly well developed lemma and palea, the fourth floret, if present, usually reduced.

Low cespitose or stoloniferous annuals or perennials, with short blades, and several or many short deciduous spikes scattered along the main axis. Species four, on the Mexican Plateau, one extending into western Texas.

FIG. 115.—Side-oats grama, *Bouteloua curtipendula*. Plant, × ½; spikelet and floret with rudiment, × 5.

Type species: *Cathestecum prostratum* Presl.

Cathestecum Presl, Rel. Haenk. 1: 294, pl. 42. 1830. Only one species described.

The only species found in the United States is *Cathestecum erectum* Vasey and Hack. (fig. 116), a stoloniferous perennial with the aspect of *Bouteloua texana* but more delicate. This species is known in western Texas from a very few collections, but is more common

FIG. 116.—*Cathestecum erectum.* Plant, × ½; group of spikelets (reduced spike), central spikelet, and fertile floret, × 5.

in northern Mexico. Cathestecum is placed by Bentham[1] doubtfully in the tribe Zoysieae, and by Hackel[2] in the tribe Festuceae. Griffiths[3] shows its affinity to Bouteloua and places it in the tribe Chlorideae.

[1] Benth. and Hook. Gen. Pl. 3: 1122. 1883.
[2] Engl. and Prantl, Pflanzenfam. 2^2: 65. 1887.
[3] Contr. U. S. Nat. Herb. 14: 358. 1912.

97. Munroa Torr.

Spikelets in pairs or threes on a short rachis, the lower one or two larger, 3 or 4 flowered, the upper 2 or 3 flowered, the group (reduced spikes) inclosed in the broad sheaths of short leaves, usually about 3 in a fascicle, forming a cluster or head at the ends of the branches; rachilla disarticulating above the glumes and between the florets; glumes of the lower 1 or 2 spikelets equal, 1-nerved, narrow, acute, a little shorter than the lemmas, those of the upper spikelet unequal, the first much shorter or obsolete; lemmas 3-nerved, those of the lower spikelet coriaceous, acuminate, the points spreading, the midnerve extended into a mucro, those of the upper spikelet membranaceous; palea narrow, 2-nerved, inclosing the oval, dorsally compressed caryopsis.

Low spreading, much-branched annuals, the short, flat, pungent leaves in fascicles. Species three, plains of America; two in Argentina, one in the western United States.

Type species: *Crypsis squarrosa* Nutt.

Munroa Torr., U. S. Rep. Expl. Miss. Pac. 4: 158. 1856. One species described, *M. squarrosa* (Nutt.) Torr. Torrey spells the genus Monroa, naming it in honor of Munro, whom he refers to erroneously as Major "Monro."

The prophylla are prominent in the fascicles of leaves, the two nerves extending into long, green tips. The lower spikelet is bulged out on the lower side, throwing the glumes forward; thus they appear somewhat asymmetric. This genus has hitherto been placed in Festuceae, but the structure of the spikelet and spike show closer affinity to genera of Chlorideae.

Munroa squarrosa (fig. 117) is common on the Great Plains from Montana to northern Mexico, usually in new soil and open ground. It has little or no importance as a forage grass. It is sometimes abundant on recently broken sod. *Munroa mendocina* Phil., of Argentina, has been referred to *M. squarrosa*, but it is a distinct species.

98. Bulbilis Raf.
(*Buchloë* Engelm.)

Plants unisexual. Staminate spikelets 2-flowered, sessile and closely imbricate, in two rows on one side of a slender rachis forming a short spike; glumes somewhat unequal, rather broad, 1-nerved, acutish; lemmas longer than the glumes, 3-nerved, rather obtuse, whitish; palea as long as its lemma, 2-nerved. Pistillate spikelets mostly 3 to 5 in a short spike or head, this falling entire, usually 2 heads to the inflorescence, the common peduncle short and included in the somewhat inflated sheaths of the upper leaves, the thickened somewhat woody rachis and the 2 or 3 outer (second) glumes appearing like an involucre; glumes very unequal, the first inside relative to the cluster, thin, 1-nerved, keeled, the nerve extending into a point or awn, as long as the lemma or reduced in some of the spikelets or wanting, the second glume firm, thick and woody, almost surrounding the remainder of the spikelet, rounded on the back, white or yellowish, obscurely nerved, the margins inflexed, thin, ciliate, the upper part greenish, acuminate, spreading, with one or two teeth at the sides; lemma firm-membranaceous, 3-nerved, dorsally compressed, broad below, narrowed into a 3-lobed green summit, the middle lobe much the larger; palea 2-nerved, broad, obtuse, about as long as the body of the lemma, enveloping the caryopsis.

FIG. 117.—*Munroa squarrosa.* Plant, × ½; group of spikelets (reduced spike), spikelet, and floret, × 5.

A low stoloniferous perennial, with short curly blades, the staminate flowers in two or three short spikes on slender, erect culms, the pistillate in sessile clusters partly hidden among the leaves. Species one, on the Great Plains from Montana to Mexico.

Type species: *Sesleria dactyloides* Nutt.

Bulbilis Raf., Amer. Month. Mag. **4**: 190. 1819. Rafinesque gives a review of Nuttall's Genera of North American Plants. The part relating to Bulbilis is, "Sesleria dactyloides must form a peculiar genus by Mr. N's own account, it may be called Bulbilis."

Calanthera Kunth, in Hook. Kew Journ. **8**: 18. 1856. A single species included, "C. dactyloides Kth.—Nutt. Sesleria . . . Buffalo grass."

Buchloë Engelm., Trans. Acad. St. Louis 1: 432. 1859. Based on *Sesleria dactyloides*. Engelmann gave the first description of the genus. Nuttall's description of *Sesleria dactyloides* was based on the staminate plant.

The species is usually described as diœcious [1] because the staminate and pistillate flowers are found on different individuals. Experiments in growing the plants from seed show that they are monœcious, the two kinds of flowers arising from distinct branches which propagate vegetatively, each branch producing its own kind.[2] Plank [3] observed that seedlings were monœcious.

Bulbilis dactyloides (Nutt.) Raf. (*Buchloë dactyloides* Engelm.) (fig. 118), commonly known as buffalo grass, is one of the chief constituents of the sod on the Great Plains. It forms, when unmixed with other grasses, a close, soft, grayish green turf. Buffalo grass is dominant over large areas on the uplands, colloquially known as the "short-grass country," and is one of the most important grazing grasses of this region. The sod houses of the early settlers were made mostly from the sod of this grass.

8. PHALARIDEAE, THE CANARY-GRASS TRIBE.

99. Torresia Ruiz and Pav.
(*Hierochloë* R. Br., *Savastana* Schrank.)

Spikelets with one terminal perfect floret and two staminate florets, disarticulating above the glumes, the staminate florets falling attached to the fertile one; glumes equal, broad, thin and papery, smooth, acute; sterile lemmas about as long as the glumes, mostly somewhat appressed-hispid, sometimes awned from between two lobes; fertile lemma somewhat indurate, about as long as the others, smooth or nearly so, awnless; palea 3-nerved, rounded on the back.

Perennial, low, erect, sweet-smelling grasses, with small panicles of bronze-colored spikelets. Species about 17, confined to cool and alpine regions; 3 species in the United States.

Type species: *Torresia utriculata* Ruiz and Pav.

Savastana Schrank, Baier. Fl. 1: 100, 337, 1789, not Savastania Scop., 1777. Type, *S. hirta* Schrank, the only species described.

Torresia Ruiz and Pav., Syst. Veg. Peruv. Chil. 251. 1798. A single species described.

Hierochloë R. Br., Prodr. Fl. Nov. Holl. 208. 1810. Type, *Disarrenum antarcticum* Labill. upon which is based the only species described (*H. antarctica*). Later authors have often spelled this Hierochloa.

Dimesia Raf., Amer. Month. Mag. 2: 175. 1818. Based on "*Holcus fragrans* of Pursh's Flora." This is the same as *Torresia odorata*.

The common species, *Torresia odorata* (L.) Hitchc. (*Hierochloë odorata* Wahl., *H. borealis* Roem. and Schult.) (fig. 119), called holy grass, vanilla grass, or Seneca grass, grows in Canada and the northern part of the United States. Like all the species of the genus and the allied genus Anthoxanthum, it is sweet scented, owing to the

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[1] Pilger discusses this and other species in a paper on monœcious and diœcious grass genera. Bot. Jahrb. Engler 34: 377. 1904.

[2] Hitchcock, Bot. Gaz. 20: 464. 1895.

[3] Bull. Torrey Club 19: 303. 1892.

FIG. 118.—Buffalo grass, *Bulbilis dactyloides.* Pistillate plant (above), × ½; group of pistillate spikelets (reduced spike), and floret, × 5; staminate plant (below), × ½; staminate spikelet, × 5.

presence of coumarin. The Indians use the grass to make fragrant baskets.

Torresia alpina (Swartz) Hitchc., with small, condensed panicles and awned staminate florets, is arctic and extends to the alpine peaks of New York and New England; *T. macrophylla* (Thurb.) Hitchc., with broad blades, is Californian.

100. ANTHOXANTHUM L.

Spikelets with 1 terminal perfect floret and 2 sterile lemmas, the rachilla disarticulating above the glumes, the sterile lemmas falling attached to the fertile floret; glumes unequal, acute or mucronate; sterile lemmas shorter than the glumes, empty, awned from the back; fertile lemma shorter than the sterile ones, awnless; palea 1-nerved, rounded on the back, inclosed in the lemma.

Sweet-smelling annual or perennial grasses, with flat blades and spikelike panicles. Species about four, Europe and Asia; two introduced into the United States.

Type species: *Anthoxanthum odoratum* L.

Anthoxanthum L., Sp. Pl. 28, 1753; Gen. Pl., ed. 5, 17. 1754. Linnæus describes three species, *A. odoratum*, *A. indicum*, and *A. paniculatum*. The first is chosen as the type. The second species is now referred to Perotis and the third to Festuca.

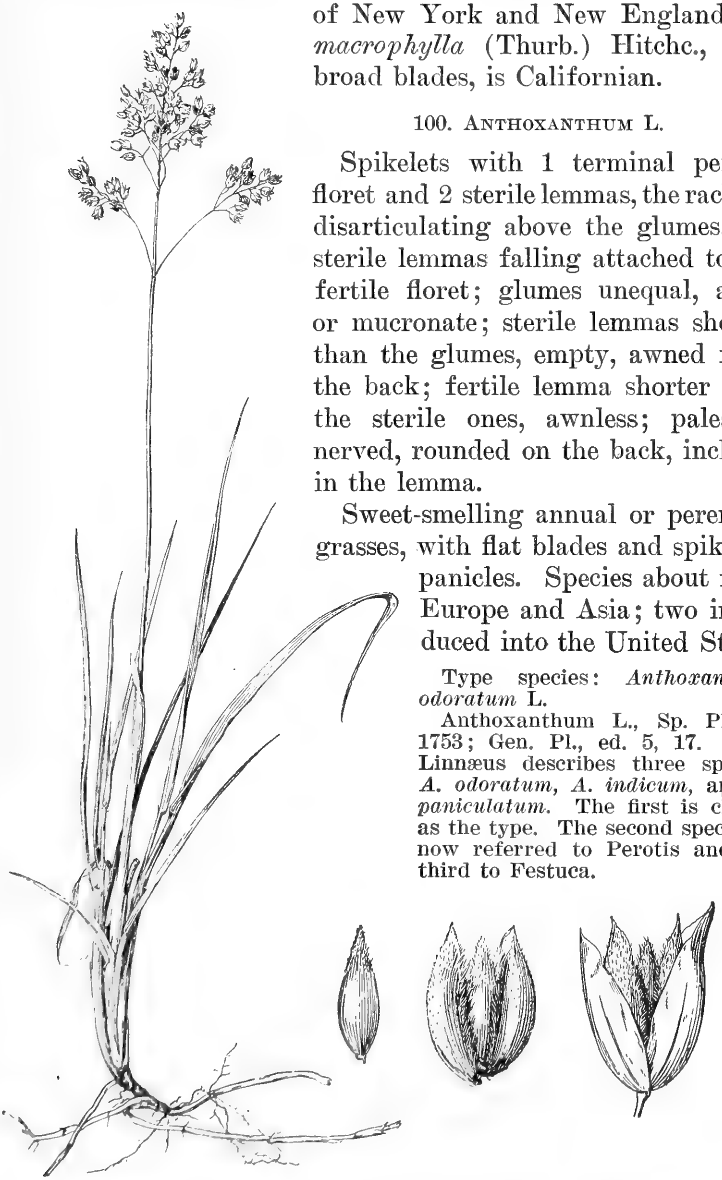

FIG. 119.—Vanilla grass, *Torresia odorata*. Plant, × ½; spikelet, florets with the glumes removed, and fertile floret, × 5.

Anthoxanthum odoratum, sweet vernal grass (Pl. XV; fig. 120), is sometimes included in meadow mixtures to give fragrance to the hay.

The grass has no forage value. It is now common along roadsides and in grassland throughout the Eastern States. Like the species of Torresia it has an aromatic odor due to the presence of coumarin. Sweet vernal grass is an erect perennial, about a foot high. Another species, *A. aristatum* Boiss. (*A. puellii* Lec. and Lam.), a low annual, is introduced at a few localities.

101. PHALARIS L.

Spikelets laterally compressed, with 1 terminal perfect floret and 2 sterile lemmas below, disarticulating above the glumes, arranged in usually dense spikelike panicles; glumes equal, boat shaped, often winged on the keel; sterile lemmas reduced to 2 small scales (rarely only 1); fertile lemma coriaceous, shorter than the glumes, inclosing the faintly 2-nerved palea.

Annual or perennial erect grasses, with flat blades. Species about 20, in temperate regions of Europe and America. Nine species are found in the United States, four being introduced from Europe.

Type species: *Phalaris canariensis* L.

Phalaris L., Sp. Pl. 54, 1753; Gen. Pl., ed. 5, 29. 1754. Five species are described, *P. canari-*

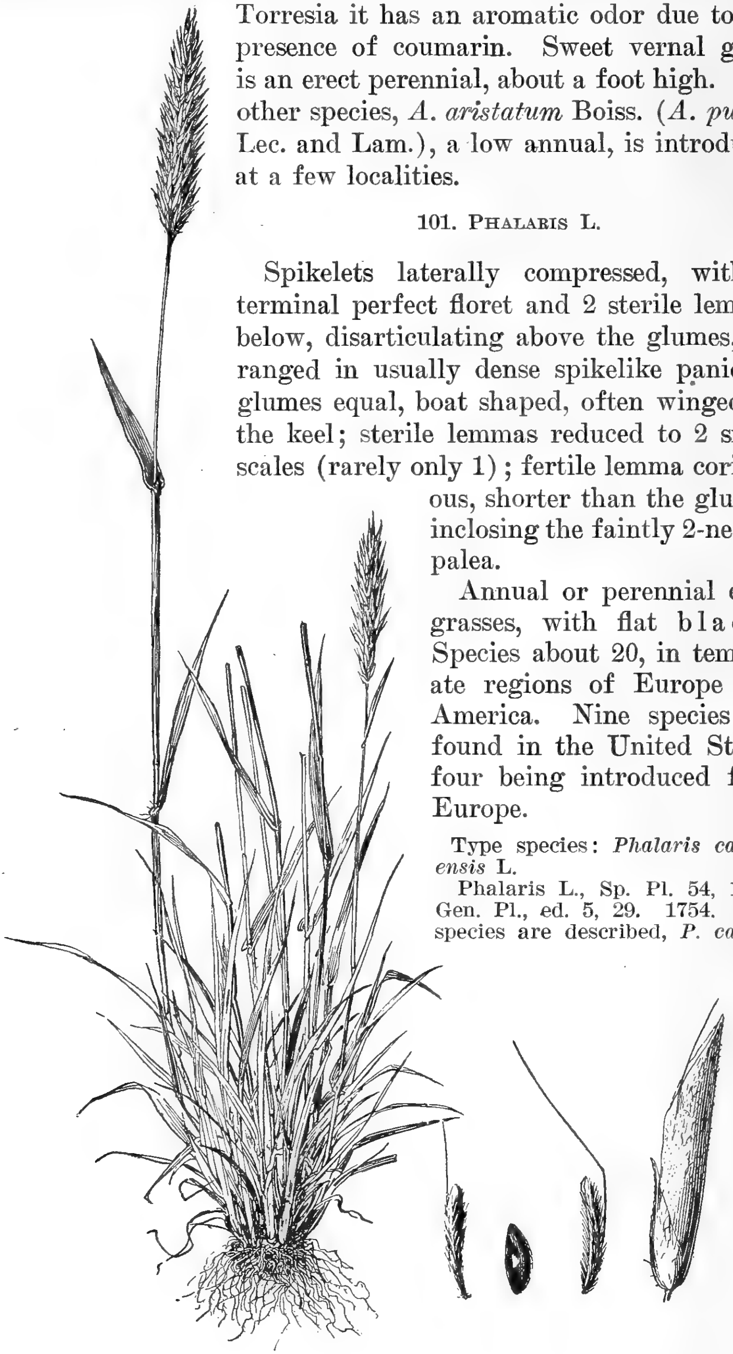

FIG. 120.—Sweet vernal grass, *Anthoxanthum odoratum*. Plant, × ½; spikelet, two sterile lemmas, and fertile floret, × 5.

SWEET VERNAL GRASS (ANTHOXANTHUM ODORATUM).

INDIAN RICE (ZIZANIA PALUSTRIS).

Along the Anacostia River, Washington, D. C. The plants below are pickerel weed (*Pontederia cordata*) at right and arrowleaf (*Sagittaria latifolia*) at left.

ensis, *P. phleoides*, *P. arundinacea*, *P. erucaeformis*, and *P. oryzoides*. The second species is now referred to Phleum, the fourth to Beckmannia, and the fifth to Homalocenchrus. The first species is chosen as the type, because this is the one that best corresponds to the description of the genus

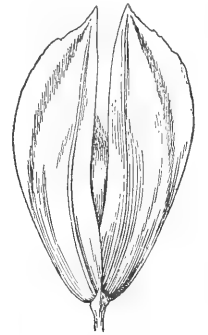

Fig. 121.—Canary grass, *Phalaris canariensis*. Plant, × ½; spikelet and fertile floret with the two sterile lemmas, × 5.

in the Genera Plantarum (e. g., gluma obtusa) and is moreover the only one of the five species mentioned above that was known by the name of Phalaris to the older authors, such as Bauhin.

Typhoides Moench, Meth. 201. 1794. A single species, *T. arundinacea*, based on *Phalaris arundinacea* L., is included.

Digraphis Trin., Fund. Agrost. 127. 1820. A single species, *D. arundinacea*, based on *Phalaris arundinacea* L., is included.

Endallax Raf., Bull. Bot. Seringe **1**: 220. 1830. *Phalaris arundinacea* is the only species given.

The most important species of the genus in the United States is *Phalaris arundinacea* L., reed canary grass, a native perennial found in wet ground in the cooler parts of the Northern Hemisphere. The inflorescence is a rather loose spikelike panicle 2 to 6 inches long. It is an important constituent of lowland hay in the region from Montana to Wisconsin. A variety (*picta* L.) with blades striped with white is grown for ornament in gardens under the name of ribbon grass or gardener's garters.

Phalaris canariensis L. (fig. 121), canary grass, is an annual with ovoid heads, the large spikelets white with green nerves. This species is introduced from Europe, where it is grown for seed, which furnishes the canary seed of commerce.[1] *Phalaris caroliniana* Walt., a perennial of the southern United States, with oblong compact heads, is sometimes cultivated for winter forage.

9. ORYZEAE, THE RICE TRIBE.

102. Oryza L.

Spikelets 1-flowered, laterally compressed, disarticulating below the glumes; glumes 2, much shorter than the lemma, narrow; lemma rigid, keeled, 3-nerved, sometimes awned; palea similar to the lemma, narrower, keeled, but with no midnerve on the back, 2-nerved close to the margins.

Annual or sometimes perennial swamp grasses, often tall, with flat blades and spikelets in open panicles. Species about seven, one in tropical America, the others in tropical Africa and Asia.

Type species: *Oryza sativa* L.

Oryza L., Sp. Pl. 333, 1753; Gen. Pl., ed. 5, 155. 1754. A single species, *O. sativa,* is described.

The only important species is *Oryza sativa* L. (fig. 122), or rice. This is cultivated in all tropical and warm countries and is one of the important food plants of the world. There are a large number of varieties, some with awned, some with awnless spikelets. In the United States rice is grown under irrigation on the lowland along the Atlantic coast of the Southern States, especially in South Carolina and Georgia, and more extensively along the Mississippi River in Louisiana and on the prairies of southwestern Louisiana and southeastern Texas.

103. Homalocenchrus Mieg.
(*Leersia* Swartz.)

Spikelets 1-flowered, strongly compressed laterally, disarticulating from the pedicel; glumes wanting; lemma chartaceous, broad, oblong, boat shaped, usually 5-nerved, the lateral pair of nerves close to the margins, these and the keel often hispid-ciliate, the intermediate nerves sometimes faint; palea as long as the lemma, much narrower, usually 3-nerved, the keel usually hispid-ciliate, the lateral nerves close to the margins, the margins firmly held by the margins of the lemma; stamens six or fewer.

Perennial grasses, usually with creeping rhizomes, with flat, scabrous blades and open panicles, the spikelets nearly sessile along one

[1] The commercial seed may also contain seed of *Panicum miliaceum.* The seed of *Phalaris canariensis* is pale yellow, equally convex on both sides, compressed, and somewhat pubescent. The seed of *Panicum miliaceum* is brownish or reddish, much more plump, dorsally flattened on one side, smooth, and faintly nerved.

side of the branchlets. Species ten, tropical and temperate regions; five species in the United States, mostly swamp grasses.

Type species: *Phalaris oryzoides* L.

Homalocenchrus Mieg, Act. Helv. Phys. Math. 4: 307. 1760. One species is referred to the genus with certainty, another being doubtfully referred to it. No specific names are used, but under the first there are two citations which appear in the Species Plantarum under *Phalaris oryzoides*.

Leersia Swartz, Prod. Veg. Ind. Occ. 21. 1788. Three species are described, *L. monandra*, *L. hexandra*, and *L. oryzoides*. *Phalaris oryzoides* L., the basis of the third species, is selected as the type, as this is the oldest historically.

FIG. 122.—Rice, *Oryza sativa*. Plant, × ½; spikelet, × 5.

Endodia Raf., Neogenyt. 4. 1825. Based on *Leersia lenticularis*, the only species mentioned.

Aplexia Raf., Bull. Bot. Seringe 1: 220. 1830. A single species, *Leersia virgata* (probably a misprint for *L. virginica*) is included.

All the species of the United States except *Homalocenchrus monandrus* (Swartz) Kuntze, a plant of rich woods in southern Florida and southern Texas, have creeping rhizomes. Most of them are marsh grasses. *Homalocenchrus monandrus* differs from the other species also in having small glabrous spikelets in which the palea is rounded on the back and lacks the midnerve, as in rice. In the other species the palea is strongly compressed-keeled and appears to represent a bract rather than a prophyllum.

Homalocenchrus virginicus (Willd.) Britton and *H. oryzoides* (L.) Poll. (fig. 123) are common throughout the eastern United States in moist soil, the latter often forming distinct zones of vegetation in marshes. The first has spikelets about 3 mm. long and the main panicle branches solitary; the second has spikelets about 5 mm. long and the lower main panicle branches more than one at the node. These species, because of the very scabrous, adhesive blades, are called rice cut-grass. The species have no economic importance.

10. ZIZANIEAE, THE INDIAN-RICE TRIBE.

104. ZIZANIOPSIS Doell and Aschers.

Spikelets unisexual, 1-flowered, disarticulating from the pedicel, mixed on the same branches of the panicle, the staminate below; first glume wanting; second glume 7-nerved, short-awned in the pistillate spikelets; lemma 3-nerved; palea wanting; stamens six; styles rather long, united; caryopsis obovate, free, coriaceous, smooth and shining, beaked with the persistent style.

Robust perennial marsh grasses, with stout creeping rhizomes, broad flat blades, and large open panicles. Species three; two in South America, one in the United States.

Type species: *Zizania microstachya* Nees.

Zizaniopsis Doell and Aschers.; Doell in Mart. Fl. Bras. 2^2: 12, pl. 3. 1871. A single species described.

The only species in the United States is *Zizaniopsis miliacea* (Michx.) Doell and Aschers. (fig. 124), growing in swamps from Virginia to Florida and Texas. Like *Zizania palustris*, which it somewhat resembles, this species may be gregarious over wide areas. It has no economic importance except as it may furnish shelter and food to water birds.

105. ZIZANIA L.

Spikelets unisexual, 1-flowered, disarticulating from the pedicel; staminate spikelet soft, the first glume wanting, the second 5-nerved, membranaceous, linear, acuminate or awn-pointed; lemma about as long as the glume, 3-nerved; palea wanting; stamens 6; pistillate

FIG. 123. Rice cut-grass, *Homalocenchrus oryzoides*. Plant, × ½; spikelet, × 5.

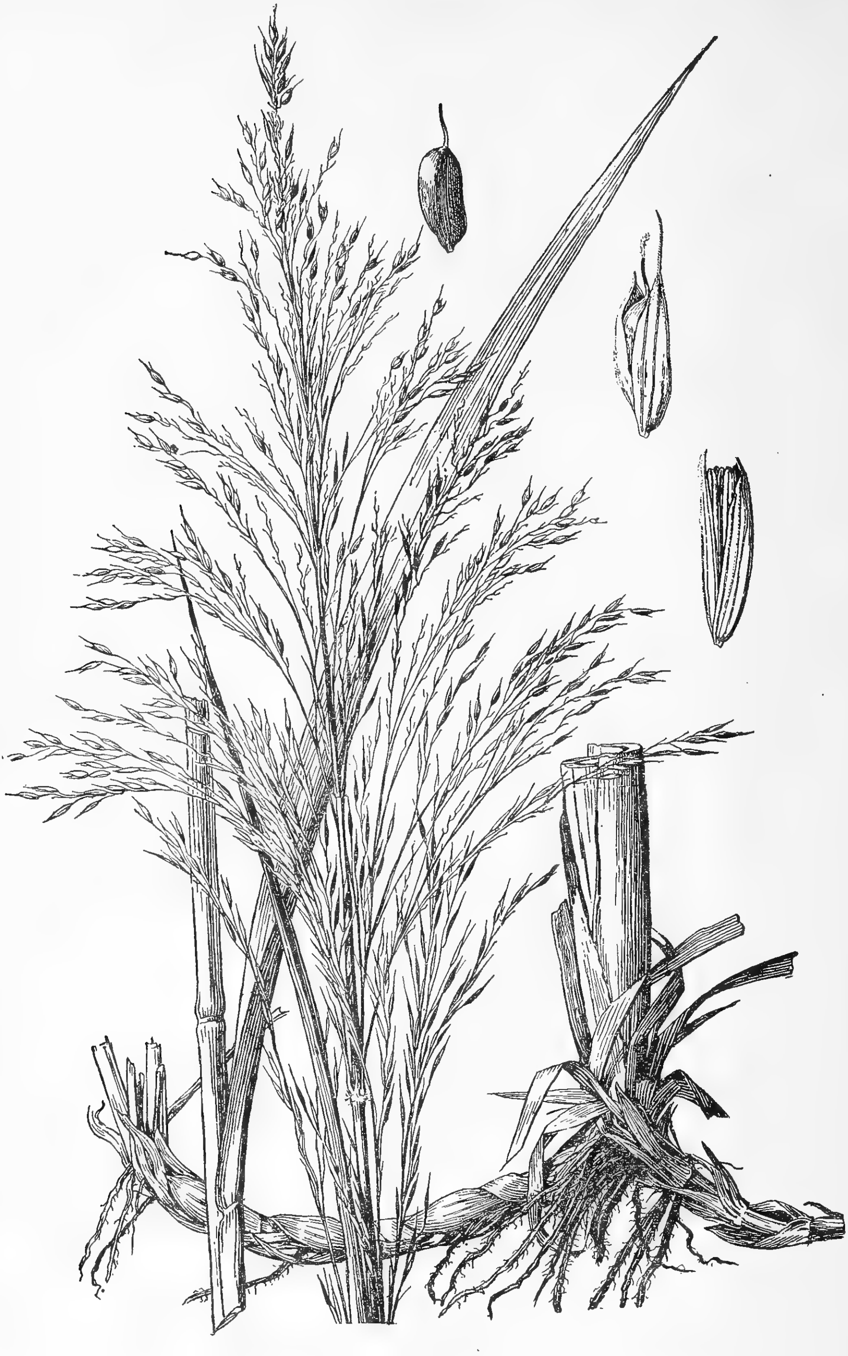

FIG. 124.—*Zizaniopsis miliacea.* Plant, × ½; staminate spikelet, pistillate spikelet, and ripe caryopsis, × 5.

spikelet terete, angled at maturity: glumes wanting; lemma chartaceous, 3-nerved, tapering into a long slender awn; palea 2-nerved, closely clasped by the lemma; grain cylindric, as much as 2 cm. long.

Tall annual or perennial aquatic grasses, with flat blades and large terminal panicles, the lower branches spreading, bearing the pendulous staminate spikelets, the upper branches ascending, at maturity erect, bearing appressed pistillate spikelets, the staminate spikelets early deciduous, the pistillate spikelets tardily deciduous. Species three, one in eastern Asia, two in North America.

Type species: *Zizania aquatica* L.

Zizania L., Sp. Pl. 991, 1753; Gen. Pl., ed. 5, 427. 1754. Linnæus describes two species, *Z. aquatica* and *Z. terrestris*. The citation in the Genera Plantarum is to Gronovius. "Zizania Gron. virg. 189" is given as a synonym by Linnæus under *Z. aquatica;* hence the latter is the type species. The second species, from Malabar, does not belong to Zizania. The director of the Kew Royal Botanic Gardens states that the plate upon which it is based (Rheede, Hort. Malab. **12:** pl. 60) represents *Scleria elata* Thwaites.

Fartis Adans., Fam. Pl. **2:** 37, 557. 1763. Based on Zizania L., which was not Zizania of the ancients.

Hydropyrum Link, Hort. Berol. **1:** 252. 1827. A single species, *H. esculentum*, based on *Zizania palustris* L., is included.

Melinum Link, Handbuch Erkenn. Gewächse **1:** 96. 1829. A single species, *M. palustre*, based on *Zizania palustris* L., is included.

Ceratochaete Lunell, Amer. Midl. Nat. **4:** 214. 1915. A new name proposed for Zizania L., "not Zizanion of the New Testament," which is the tares of Scripture.

Zizania palustris L. (Pl. XVI; fig. 125), Indian or wild rice, is an annual marsh grass growing in the Eastern and Northern States, often over extensive areas. The seeds were used by the aborigines for food and are still used to some extent by some of the northern tribes of Indians. Wild rice is important as a food and shelter for water birds. It is sometimes planted for this purpose in marshes on game preserves. *Zizania aquatica* L. differs in having narrower blades, shorter culms, and less spreading panicles. This form, found from Maine to Minnesota, may be a variety rather than a distinct species.[1] At first Linnæus did not distinguish between the narrow-leaved and broad-leaved forms, but based the name *aquatica* on a specimen [2] of the narrow-leaved form. Later (1771) he described the broad-leaved form as *Zizania palustris*. The Asiatic *Z. latifolia* Turcz. is a perennial with rhizomes and stolons.

106. Luziola Juss.

Spikelets unisexual, 1-flowered, disarticulating from the pedicel, the staminate and pistillate flowers in separate panicles on the same plant; first glume and palea wanting; second glume and lemma about equal, thin, several to many nerved, lanceolate or oblong; stamens several ("6 to 18"); stigmas long, plumose; grain free, globose, smooth.

[1] See Smiths. Misc. Coll. 68^{12}: 35. 1918.

[2] See Hitchcock, Contr. U. S. Nat. Herb. **12:** 124. 1908.

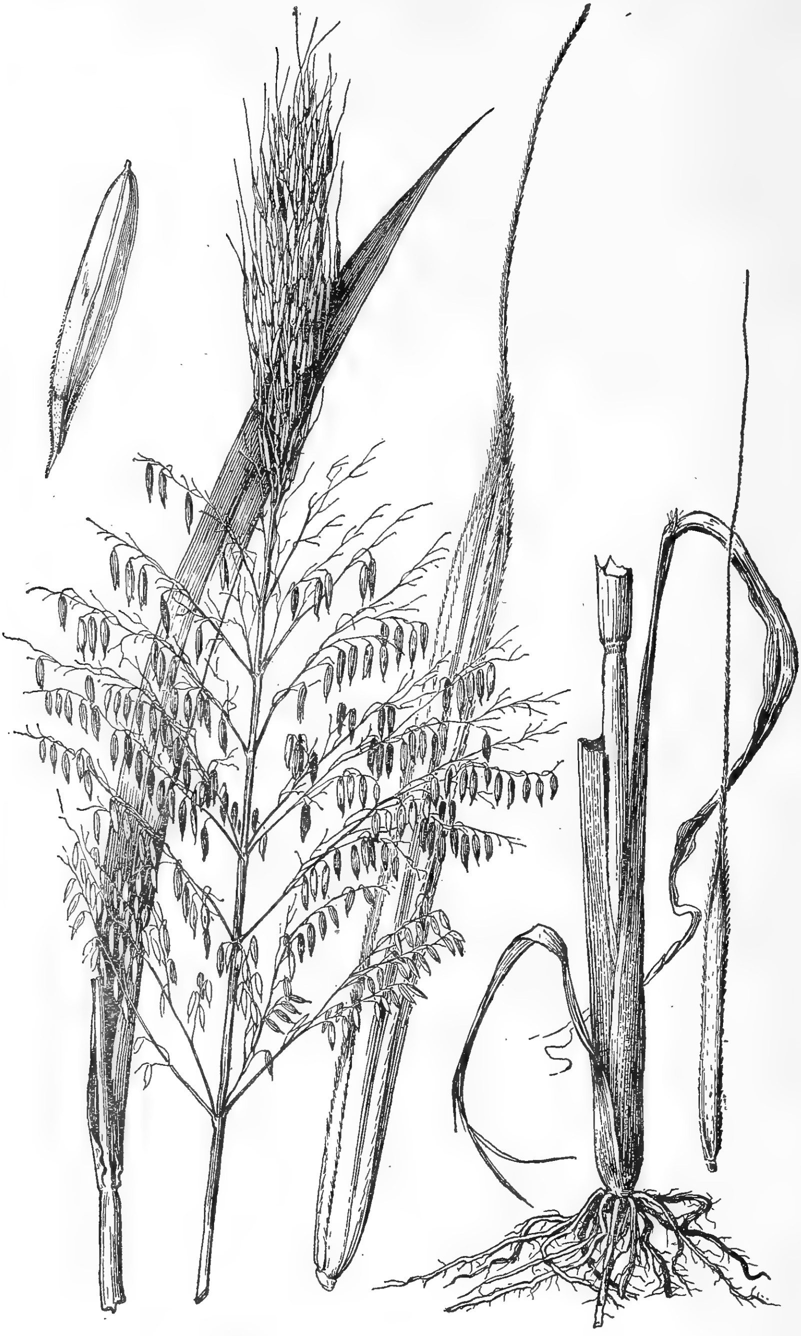

FIG. 125.—Wild rice, *Zizania palustris.* Plant, × ½; pistillate spikelet, × 2; a second view, × 5; staminate spikelet, × 5.

Perennial, creeping, low or delicate grasses, with narrow, flat blades and terminal and axillary panicles. Species about six, in tropical America; two species in the southern United States.

Type species: *Luziola peruviana* Gmel.
Luziola Juss.; Gmel. Syst. Nat. 2: 637. 1791. The genus is first described by Jussieu in his Genera Plantarum (1789), but no specific name is mentioned. Gmelin assigns a specific name to the species described by Jussieu.

There are two species in the United States, *Luziola peruviana* (fig. 126), with fruit 2 mm. long, and *L. alabamensis* Chapm., with fruit 4 mm. long, the former from Florida to Louisiana and the latter from Alabama. They have no economic importance.

107. Hydrochloa Beauv.

Spikelets unisexual, 1-flowered, awnless, disarticulating from the pedicel, the plants monœcious; staminate spikelets with a thin 7-nerved lemma, a 2-nerved palea, and 6 stamens, the glumes wanting; pistillate spikelets with a thin 3-nerved second glume and 5-nerved lemma, the first glume and the palea wanting, the stigmas long and slender.

A slender, branching, aquatic grass, probably perennial, the leaves floating; staminate flowers in a small few-flowered terminal spike; pistillate flowers in few-flowered spikes in the axils of the leaves. Species one, in the southeastern United States.

Type species: *Hydrochloa carolinensis* Beauv.
Hydrochloa Beauv., Ess. Agrost. 135, pl. 24, f. 4. 1812. Beauvois figures one species, which he names *H. carolinensis*. The species was first described as *Zizania fluitans* Michx., but this name can not be transferred to Hydrochloa because of *H. fluitans* Host.

The spikelets of each sex possess but two bracts. From the appearance and nervation it is assumed that the palea is present in the staminate spikelets and wanting in the pistillate.

Hydrochloa carolinensis Beauv. (fig. 127) is found in streams and ponds from South Carolina to Florida and Louisiana, sometimes in sufficient abundance to become troublesome. It has no economic importance.

Pharus L., Syst. Nat., ed. 10, 2:1269. 1759. A tropical American genus, one species of which, *P. latifolius* L., was included by Chapman in his Flora of the Southern States. The locality given is "Orange Lake, Florida (Herb. Thurber)." This West Indian species has not been observed by others in Florida and it should be credited to the United States with doubt.

Rather tall monœcious perennials, with broad elliptic or oblanceolate, petiolate blades and terminal panicles, the large terete pistillate spikelets appressed along the rather few stiffly spreading branches, these disarticulating at the base and easily detached, the uncinate fruits acting like burs.

FIG. 126.—*Luziola peruviana.* Plant, × ½; pistillate and staminate spikelets, × 5.

11. MELINIDEAE, THE MOLASSES-GRASS TRIBE.

Melinis Beauv., Ess. Agrost. 54, pl. 11, f. 4. 1812. A Brazilian genus. *Melinis minutiflora* Beauv. (molasses grass) is cultivated in the Tropics for forage. It has been tried in the warmer parts of the South. Molasses grass is a rather stout perennial, with viscid-pubescent foliage, and narrow many-flowered panicles of very small awned spikelets.

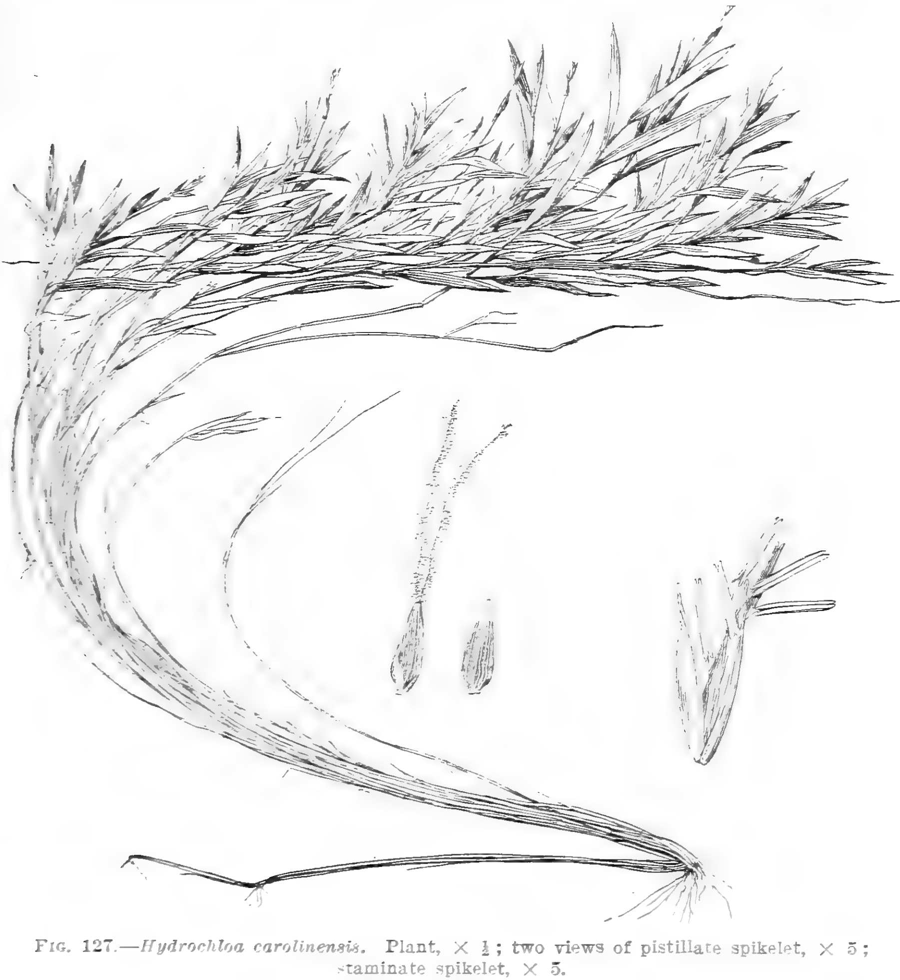

FIG. 127.—*Hydrochloa carolinensis.* Plant, × ½; two views of pistillate spikelet, × 5; staminate spikelet, × 5.

12. PANICEAE, THE MILLET TRIBE.

108. ANTHAENANTIA Beauv.[1]

Spikelets obovoid; first glume wanting; second glume and sterile lemma about equal in length, broad, 5-nerved, villous, the sterile lemma with a small palea and sometimes with a staminate flower; fertile lemma cartilaginous, boat shaped, 3-nerved, subacute, chest-

[1] For a discussion of this and the following genera of this tribe, see Chase, Proc. Biol. Soc. Washington, 19: 183–192, 1906; 21: 1–10, 1908; 21: 175–188, 1908; 24: 103–160, 1911.

nut brown, as long as the glume, the pale margins very narrow, infolding the palea its entire length.

Perennial erect grasses with short creeping rhizomes, narrow, firm, flat blades, the uppermost much reduced, and narrow panicles, the slender branches ascending or appressed. Species two, on the Coastal Plain of the southeastern United States.

Type species: *Phalaris villosa* Michx.

Anthaenantia Beauv., Ess. Agrost. 48, pl. 10, f. 7. 1812. *Phalaris villosa* is the only species mentioned.

Aulaxanthus Ell., Bot. S. C. and Ga. **1:** 102. 1816. Two species are described, *A. ciliatus* and *A. rufus*. The first, which is the same as *Anthaenantia villosa*, is accepted as the type.

Aulaxia Nutt., Gen. Pl. **1:** 47. 1818. Nuttall changes Elliott's name Aulaxanthus to Aulaxia.

Anthaenantia villosa (Michx.) Beauv. (fig. 128), with comparatively short, spreading blades and usually pale panicle, and *A. rufa* (Ell.) Schult., with long erect blades and usually purple panicle, are of no economic importance.


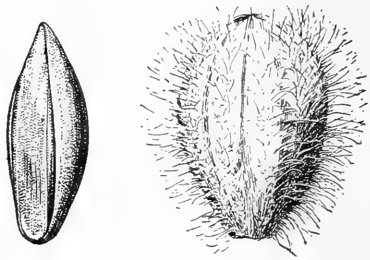

FIG. 128.—*Anthaenantia villosa*. Plant, × ½; spikelet and fertile floret, × 10.

109. VALOTA Adans.

Spikelets lanceolate, in pairs, short-pediceled, in two rows along one side of a narrow rachis; first glume minute, glabrous;

second glume and sterile lemma about as long as the fruit, 3 to 5 nerved, copiously silky; fertile lemma cartilaginous, lanceolate, acuminate, usually brown, the flat white hyaline margins broad.

Perennial grasses, the slender racemes erect or nearly so, aggregate along the upper part of the main axis, forming a white or brownish woolly panicle. Species about 12, in the warmer parts of America and in Australia; 3 species in the southern United States.

Type species: *Andropogon insularis* L.

Valota Adans., Fam. Pl. **2**: 495. 1763. The citation given by Adanson is to "Sloan. t. 14. f. 2." which is also given by Linnæus under his *Andropogon insularis*,[1] which fixes this species as the type.

Trichachne Nees, Agrost. Bras. 85. 1829. Nees describes five species, the first of which, *T. insularis*, based on *Andropogon insularis*, is taken as the type.

Valota is closely allied to Syntherisma, differing chiefly in the acuminate fruit and the silky spikelets.

Valota insularis (L.) Chase (*Panicum lanatum* Rottb., *P. leucophaeum* H. B. K.) (fig. 129), common in the American Tropics, with brown or tawny inflorescence, is found in southern Florida. *Valota hitchcockii* Chase, with short blades and short-pubescent spikelets is a rare species from Texas and Mexico. *Valota saccharata* (Buckl.) Chase (*Panicum lachnanthum* Torr.), with copiously long, silky white spikelets, is common in the Southwestern States on rocky soil. The first-mentioned species is not relished by cattle and in the West Indies is called sour-grass. The third species is a constituent of the ranges of the Southwest, but furnishes only fair forage.

110. Syntherisma Walt., the crab-grasses.
(*Digitaria* Hall., not Heist.)

Spikelets solitary or in twos or threes, subsessile or short-pediceled, alternate in two rows on one side of a three-angled winged or wingless rachis; spikelets lanceolate or elliptic, plano-convex; first glume minute or wanting; second glume equaling the sterile lemma or shorter; fertile lemma cartilaginous, the hyaline margins pale.

Annual or sometimes perennial, erect or prostrate grasses, the slender racemes digitate or somewhat scattered, but aggregate along the upper part of the culms. Species about 60, in the warmer parts of the world; 12 species in the United States, mostly in the southeastern part.

Type species: *Syntherisma praecox* Walt.

Digitaria Hall., Stirp. Helv. **2**: 244, 1768, not Adans., 1763, nor Heist., 1759. Haller describes two species. No specific names are used, but the first species is associable by citation with *Panicum sanguinale* L. (*Syntherisma sanguinalis*) and the second with *Panicum dactylon* L. (*Capriola dactylon*). The first is chosen as the type.

Syntherisma Walt., Fl. Carol. 76. 1788. Walter describes three species, *S. praecox*, *S. serotina*, and *S. villosa*. The first of these is selected as the type. This is the same as *S. sanguinalis*.

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[1] Syst. Nat., ed. 10, **2**: 1304. 1759.

FIG. 129.—Sour-grass, *Valota insularis.* Plant, × ½; spikelet and fertile floret, × 10.

Syntherisma is included in Panicum by some botanists and in Paspalum by others. It differs from both in the cartilaginous rather

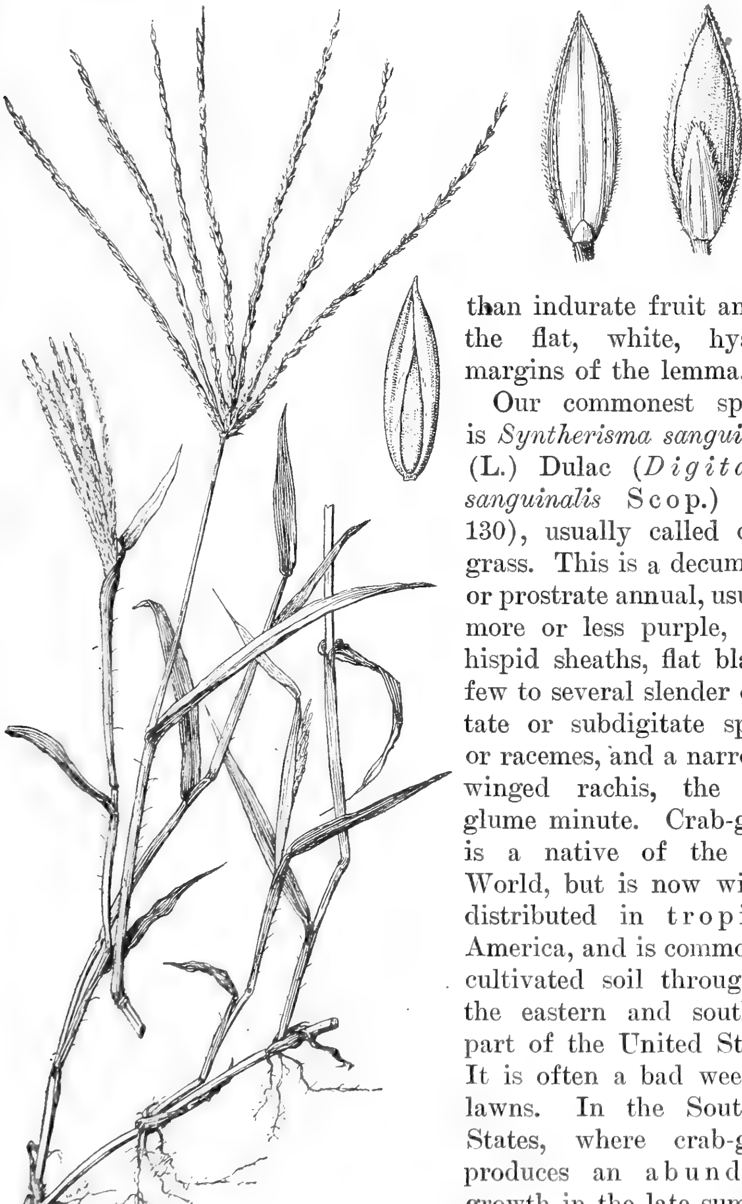

FIG. 130.—Crab-grass, *Syntherisma sanguinalis*. Plant, × ½; two views of spikelet and fertile floret, × 10.

than indurate fruit and in the flat, white, hyaline margins of the lemma.

Our commonest species is *Syntherisma sanguinalis* (L.) Dulac (*Digitaria sanguinalis* Scop.) (fig. 130), usually called crab-grass. This is a decumbent or prostrate annual, usually more or less purple, with hispid sheaths, flat blades, few to several slender digitate or subdigitate spikes or racemes, and a narrowly winged rachis, the first glume minute. Crab-grass is a native of the Old World, but is now widely distributed in tropical America, and is common in cultivated soil throughout the eastern and southern part of the United States. It is often a bad weed in lawns. In the Southern States, where crab-grass produces an abundant growth in the late summer on the fields from which crops have been gathered, it is utilized for forage and is sometimes cut for hay.

Syntherisma ischaemum (Schrad.) Nash (*Digitaria humifusa* Pers., *Panicum glabrum* Gaud.), also introduced, is darker green and glabrous, and has dark pubescent spikelets, the first glume wanting. This is a common weed in lawns. *Syntherisma filiformis* (L.) Nash is an erect native annual with erect racemes, the rachis not winged. Several other species are found in Florida. Nearly all the species of Syntherisma are weedy grasses or tend to become weeds.

For a revision of the species of Syntherisma found in the United States, see Nash, Bull. Torrey Club **25**: 289–303. 1898.

111. Leptoloma Chase.

Spikelets on slender pedicels; first glume minute or obsolete; second glume 3-nerved, nearly as long as the 5 to 7 nerved sterile lemma, a more or less prominent stripe of appressed silky hairs down the internerves and margins of each, the sterile lemma empty or inclosing a minute nerveless rudimentary palea; fertile lemma cartilaginous, elliptic, acute, brown, the delicate hyaline margins inclosing the palea.

Perennial branching grasses, with brittle culms, felty pubescent at base, flat blades, and open or diffuse panicles, these breaking away at maturity, becoming tumbleweeds. Species four; one in the United States, the others in Australia.

Type species: *Panicum cognatum* Schult.
Leptoloma Chase, Proc. Biol. Soc. Washington **19**: 191. 1906. The type is designated.

The only species found in our country is *Leptoloma cognatum* (Schult.) Chase (*Panicum autumnale* Bosc, *P. divergens* Muhl.) (fig. 131) growing in sandy soil from New England to Florida and from Minnesota to Texas. This genus differs from Syntherisma chiefly in the form of the inflorescence, being an open panicle rather than an aggregation of slender spikes. It is of no economic importance.

112. Stenotaphrum Trin.

Spikelets embedded in one side of an enlarged and flattened corky rachis disarticulating at maturity, the spikelets remaining attached; first glume small; second glume and sterile lemma about equal, the latter with a palea or staminate flower; fertile lemma chartaceous.

Creeping stoloniferous perennials, with short flowering stems, rather broad and short obtuse blades, and terminal and axillary spikes. Species about five; islands of the Pacific; one in the southern United States.

Type species: *Panicum dimidiatum* L.
Stenotaphrum Trin., Fund. Agrost. 175. 1820. A single species is mentioned, *S. glabrum* Trin., based on *Rottboellia dimidiata* L., which in turn is based on *Panicum dimidiatum* L.

Our species is *Stenotaphrum secundatum* (Walt.) Kuntze (*S. americanum* Schrank) (fig. 132), found near the coast from North Carolina to Florida and Texas, and southward, growing especially in alluvial or mucky soil. It is cultivated as a lawn grass in the coastal cities under the name of St. Augustine grass. The lawns of this grass have a coarse texture but are otherwise satisfactory. The grass is propagated by setting out cuttings or pieces of the stolons bearing shoots.


FIG. 131.—*Leptoloma cognatum*. Plant, × ½; two views of spikelet and fertile floret, × 10.

113. ERIOCHLOA H. B. K.

Spikelets dorsally compressed, more or less pubescent, solitary or sometimes in pairs, short-pediceled or subsessile, in two rows on one side of a narrow, usually hairy rachis, the pedicels often clothed with long, stiff hairs, the back of the fertile lemma turned from the rachis; lower rachilla joint thickened, forming a more or less ringlike, usually dark-colored callus below the second glume, the first glume reduced to a minute sheath about this and adnate to it; second glume and sterile lemma about equal, acute or acuminate, the lemma usually inclosing a hyaline palea or sometimes a staminate flower; fertile lemma indurate, minutely papillose-rugose, mucronate or awned, the awn often readily deciduous, the margins slightly inrolled.

Annual or perennial, often branching grasses, with terminal panicles consisting of several or many spreading or appressed racemes, usually rather closely arranged along the main axis. Species about 15, in the warmer parts of the world, mostly in America; 6 species in the United States, in the Southern and Southwestern States.

Type species: *Eriochloa distachya* H. B. K.

Eriochloa H. B. K., Nov. Gen. and Sp. **1:** 94, pls. 30 and 31. 1816. Two species are described, *E. distachya* and *E. polystachya,* and both are figured. The first is chosen as the type.

Helopus Trin., Fund. Agrost. 103, pl. 4. 1820. The only species mentioned is *H. pilosus,* which is the same as *Eriochloa punctata.* Trinius incorrectly cites *Milium ramosum* Retz. as a synonym of *Helopus pilosus.*

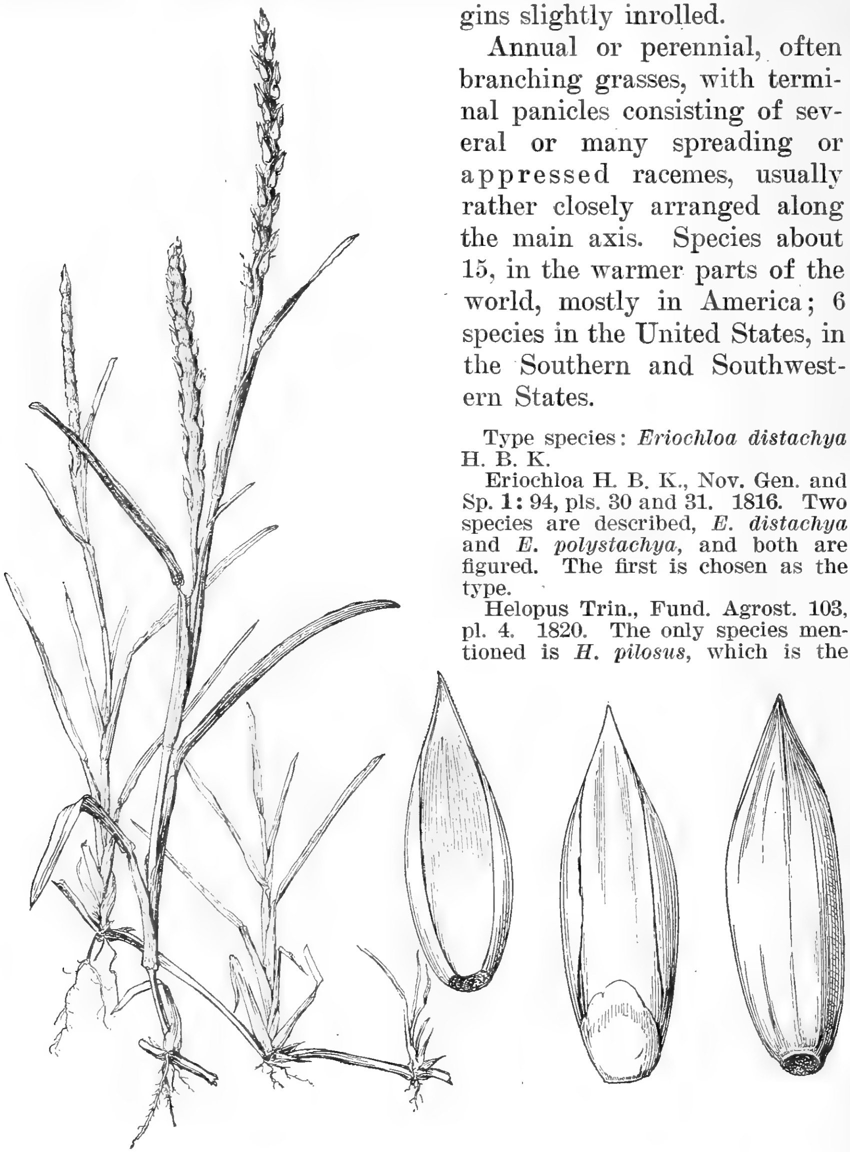

FIG. 132.—St. Augustine grass, *Stenotaphrum secundatum.* Plant, × ½; two views of spikelet and fertile floret, × 10.

Oedipachne Link, Hort. Berol. **1:** 51. 1827. The only species mentioned is *Milium punctatum* L. (*Eriochloa punctata* (L.) Hamilt.), upon which *Oedipachne punctata* is based.

Our commonest species is *Eriochloa acuminata* (Presl) Kunth, an annual, 1 to 2 feet tall, with spikelets about 5 mm. long, the fertile lemma apiculate. This is found from Kansas to Texas and Arizona, in open ground, often a weed in cultivated soil. In some books this is called *E. polystachya* H. B. K., a species described from Ecuador. A West Indian species, *E. punctata* (L.) Hamilt. (fig. 133), extends into Louisiana and Texas.

Our species appear to be of no agricultural importance. One species of the West Indies (*E. subglabra*), called in Porto Rico malojilla, is used for forage. This has been tried along the Gulf coast from Florida to southern Texas, and has given excellent results in southern Florida and at Biloxi, Miss. Carib grass, as it is proposed to call this species, is similar in habit to Para grass, producing runners, but less extensively, and is suited to grazing and will furnish a good quality of hay. It will not withstand either cold or drought.

114. Brachiaria (Trin.) Griseb.

Spikelets dorsally compressed, solitary, rarely in pairs, subsessile, in two rows on one side of a 3-angled, sometimes narrowly winged rachis, the first glume turned toward the axis; first glume short or nearly as long as the spikelet; second glume and sterile lemma about equal, 5 to 7 nerved, the lemma inclosing a hyaline palea and sometimes a staminate flower; fertile lemma indurate, usually papillose-rugose, the margins inrolled, the apex rarely mucronate or bearing a short awn.

Annual or perennial, branching and spreading grasses, with linear blades and terminal inflorescence consisting of several spreading or appressed racemes along a common axis. Species about 15, in the warmer regions of both hemispheres; 3 species in the United States, 2 native along our southern border, 1 introduced.

Type species: *Panicum erucaeforme* J. E. Smith.

Brachiaria Griseb., in Ledeb. Fl. Ross. 4: 469. 1853. Only one species is mentioned, *B. erucaeformis*.

From those species of Panicum with spikelets in one-sided spike-like racemes, this genus differs in having the spikelets in the reverse position relative to the rachis, that is, with the first glume toward the rachis.

The three species, none of which has economic importance, are *Brachiaria erucaeformis* (J. E. Smith) Griseb., an annual, with pubescent spikelets, occasionally introduced from Europe, *B. platyphylla* (Griseb.) Nash (fig. 134), an annual, with glabrous spikelets, growing in Louisiana and Texas, and *B. ciliatissima* (Buckl.) Chase (*Panicum ciliatissimum* Buckl.), a perennial, with silky spikelets, growing in Arkansas and Texas.

Fig. 133.—*Eriochloa punctata*. Plant, × $\frac{1}{2}$; two views of spikelet and fertile floret, × **10**.

115. Axonopus Beauv.
(*Anastrophus* Schlecht.)

Spikelets depressed biconvex, not turgid, oblong, usually obtuse, solitary, sessile, and alternate, in two rows on one side of a 3-angled rachis, the back of the fertile lemma turned from the axis; first glume wanting; second glume and sterile lemma equal, the lemma without a palea; fertile lemma and palea indurate, the lemma oblong-elliptic, usually obtuse, the margins slightly inrolled.

Stoloniferous or tufted perennials, rarely annuals, with usually flat or folded, abruptly rounded or somewhat pointed blades, and few or numerous, slender, spikelike racemes, digitate or racemose along the main axis. Species about 30, tropical America, 1 or 2 introduced into the Tropics of the Old World; 2 species in the United States, in moist soil in the Southeastern States.

Type species: *Milium compressum* Swartz.

Axonopus Beauv., Ess. Agrost. 12, 154. 1812. Beauvois mentions several diverse species that belong to his new genus, the first being *Milium compressum,* which


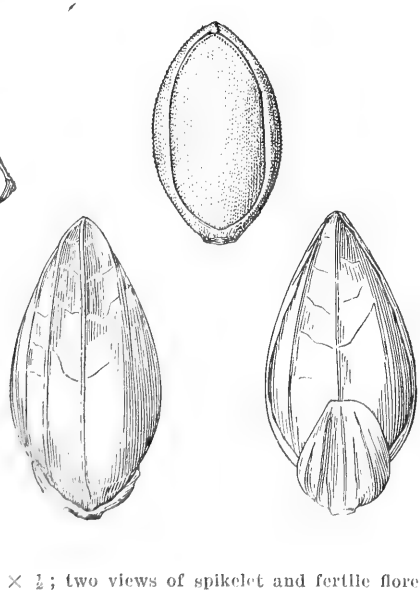

Fig. 134.—*Brachiaria platyphylla.* Plant, × ½; two views of spikelet and fertile floret, × 10.

is chosen as the type, since it is the only species that agrees with his description of the genus in having solitary spikelets. The other species that he mentions are now referred to other genera, *Milium digitatum* to Syntherisma, *M. cimicinum* to Coridochloa, *M. paniceum* to Syntherisma. In a subsequent paragraph the author briefly describes a new species, *A. aureus*, which he thinks ought to belong to this genus. Nash[1] selects *A. aureus* as the type of Axonopus.

Cabrera Lag., Gen. and Sp. Nov. 5. 1816. The type is *C. chrysoblepharis* Lag., the only species mentioned. To this group belongs *Axonopus aureus* mentioned above.

Anastrophus Schlecht., Bot. Zeit. **8**: 681. 1850. The type is *Paspalum platyculmum* Du Petit-Thou., the first of several species referred to the genus. This is probably the same as *Axonopus compressus*, or at least closely allied to that species.

Lappagopsis Steud., Syn. Pl. Glum. **1**: 112. 1854. The type is *L. bijuga* Steud., the only species described.

The most important species of the genus in the United States is *Axonopus compressus* (Swartz) Beauv. (fig. 135), usually called carpet grass in the South. This is a stoloniferous perennial, with compressed stems, comparatively short, flat, broadly linear, abruptly pointed blades, and slender spikes somewhat digitate at the summit of the culms. Carpet grass is common in the Tropics and extends in the United States from Virginia to Florida and Texas in the lowland along the coast. It thrives particularly in alluvial or mucky open ground, where it becomes the dominant

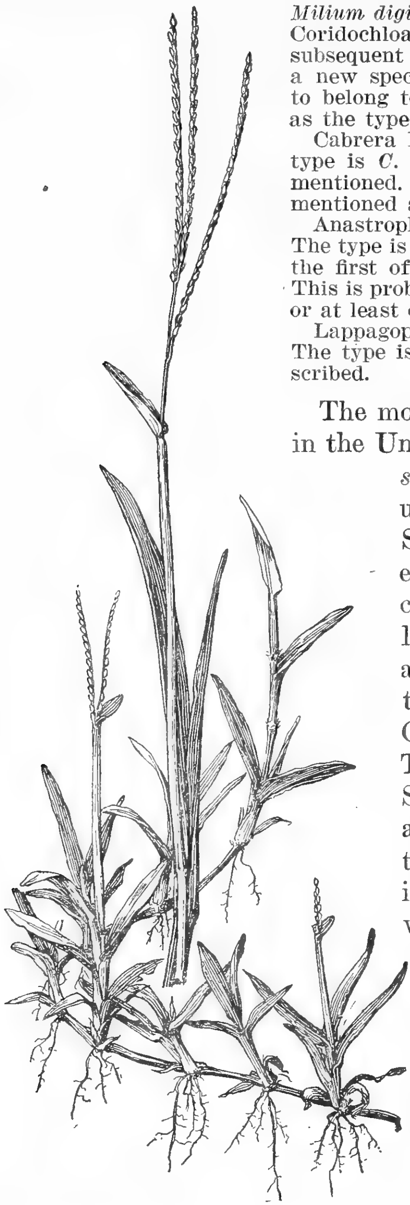

FIG. 135.—Carpet grass, *Axonopus compressus*. Plant, × ½; two views of spikelet and fertile floret, × 10.

grass. Carpet grass is the predominant pasture grass in the region mentioned, but is of little importance on sandy soil and does not thrive on the uplands. In the region where it thrives as a pasture grass

[1] N. Amer. Fl. **17**: 165. 1912.

it may be utilized as a lawn grass. For this purpose it is propagated by setting out pieces of the stolons. It soon spreads and occupies the space between.

A second species of the genus, *A. furcatus* (Flügge) Hitchc., is found over about the same range as the preceding, but confined to the United States. This is infrequent and is usually of no economic importance, but is a valuable pasture grass in the Kissimmee region, Fla. It is distinguished by its larger spikelets, 4 to 6 mm. long.

116. Reimarochloa Hitchc.
(*Reimaria* of authors.)

Spikelets strongly dorsally compressed, lanceolate, acuminate, rather distant, subsessile, and alternate in two rows along one side of a narrow, flattened rachis, the back of the fertile lemma turned toward it; both glumes wanting, or the second sometimes present in the terminal spikelet; sterile lemma about equaling the fruit, the sterile palea obsolete; fertile lemma scarcely indurate, faintly nerved, acuminate, the margins inrolled at the base only, the palea free nearly half its length.

Spreading or stoloniferous perennials, with flat blades and slender spikes, these subdigitate or racemose along the upper part of the culm, stiffly spreading or reflexed at maturity. Species about four; in the American Tropics, one extending into Florida.

Type species: *Reimaria acuta* Flügge.

Reimarochloa Hitchc., Contr. U. S. Nat. Herb. **12**: 198. 1909. The type is designated. The genus includes most of the species that have been assigned to Reimaria Flügge, the type of which is *R. candida*, a species of Paspalum.

Only one species is found in the United States, *Reimarochloa oligostachya* (Munro) Hitchc. (fig. 136), confined to Florida and Cuba. It has no economic importance.

117. Paspalum L.

Spikelets plano-convex, usually obtuse, subsessile, solitary or in pairs, in two rows on one side of a narrow or dilated rachis, the back of the fertile lemma toward it; first glume usually wanting; second glume and sterile lemma commonly about equal, the former rarely wanting; fertile lemma usually obtuse, chartaceous-indurate, the margins inrolled.

Mostly perennials, with one to many spikelike racemes, these single or paired at the summit of the culms or racemosely arranged along the main axis. Species numerous, probably as many as 200, widely distributed in the warmer parts of both hemispheres; about 50 species in the United States, mostly in the Southeastern States.

Type species: *Paspalum dimidiatum* L.

Paspalum L., Syst. Nat. ed. 10. **2**: 855, 1759. Four species are described, *P. dimidiatum* (of which "Panicum dissectum sp. pl. 57 n. 6" is cited as a synonym), *P. virgatum*, *P. paniculatum*, and *P. distichum*. The first is selected as the type. All are still retained in the genus.

FIG. 136.—*Reimarochloa oligostachya*. Plant × ½; two views of spikelet and fertile floret, × 10.

Ceresia Pers., Syn. Pl. **1**: 85. 1805. A single species, *C. elegans* Pers., is included. This is one of the species having a broad-winged rachis.

Reimaria Flügge, Gram. Monogr. 213. 1810. Three species are included, *R. candida* Humb. and Bonpl., *R. elegans*, and *R. acuta*. The first two are species of Paspalum in which both glumes are wanting, the third, to which the generic description less aptly applies, is a species of Reimarochloa. *Reimaria candida* is taken as the type.

Cymatochloa Schlecht., Bot. Zeit. **12**: 817, 821. 1854. Two names, "*C. fluitans* (*Ceresia fluitans* Ell.)" and "*C. repens* (*Paspalum repens* Berg.)" are given. Both names apply to the same species, *Paspalum repens* Berg.

Dimorphostachys Fourn., Compt. Rend. Acad. Sci. (Paris) 80: 441. 1875. The type is *Panicum monostachyum* H. B. K., the first of four species mentioned.

Paspalum is closely allied to Panicum, differing chiefly in the strictly racemose inflorescence and the plano-convex spikelets in which the first glume is wanting. In a few species (section Dimorphostachys, in *Paspalum distichum* and in *P. bifidum* (Bertol.) Nash) the first glume is present on at least a part of the spikelets. In *P. pulchellum* Kunth of tropical America and a few other species both glumes are wanting.

In spite of the large number of species in this genus, very few are of economic importance. Most of the species make a sparse growth in moist pine barrens and old fields and are not grazed to any extent. A few species inhabiting meadows and savannas furnish a limited amount of forage. Among these may be mentioned *P. laeve* Michx. (fig. 137) and *P. ciliatifolium* Michx., and the allies of these species. *Paspalum laeve*, with 2 or 3 racemes and spikelets 2.5 mm. long, is common from Maryland to Florida and Texas. *Paspalum ciliatifolium* and its allies, besides the one to few slender racemes on the main culm, have several naked branches from the upper sheaths, each branch usually bearing a single raceme.

Paspalum distichum L., with creeping stolons and racemes in pairs at the summit of the culms, is widely distributed along muddy coasts and ditch banks from Virginia to Florida and thence across the continent to California and Washington. Where abundant it furnishes some forage.

Paspalum dilatatum Poir. has been tried as a forage grass in the Southern States, where it has been cultivated under the name of water grass. It has little to recommend it here, but in the Hawaiian Islands it gives much promise as a pasture grass. In tropical America species of Paspalum form an important element in the grazing land of the savannas, *P. notatum* Flügge being one of the most abundant.

118. Panicum L.

Spikelets more or less compressed dorsiventrally, arranged in open or compact panicles, rarely racemes; glumes 2, herbaceous, nerved, usually very unequal, the first often minute, the second typically equaling the sterile lemma, the latter of the same texture and simulating a third glume, bearing in its axil a membranaceous or hyaline palea and sometimes a staminate flower, the palea rarely wanting;

fertile lemma chartaceous-indurate, typically obtuse, the nerves obsolete, the margins inrolled over an inclosed palea of the same tex-

FIG. 137.—*Paspalum laeve.* Plant, × ½; two views of spikelet and fertile floret, × 10.

ture, a lunate line of thinner texture at the back just above the base, the rootlet protruding through this at germination.

Annual or perennial grasses, of various habit. Species probably about 500, mostly confined to the warmer regions of both hemispheres, about 150 species being found in the United States.

Type species: *Panicum miliaceum* L.

Panicum L., Sp. Pl. 55, 1753; Gen. Pl., ed. 5, 29. 1754. Twenty species are described. The first ten and the fifteenth are now referred to other genera. Of the species considered typical by Linnæus, as indicated by the description in his Genera Plantarum, *Panicum miliaceum* is the only one cultivated and is therefore chosen as the type.[1]

Eatonia Raf., Journ. de Phys. **89**: 104. 1819. A single species, *E. purpurascens*, which is the same as *Panicum virgatum*, is included.

Steinchisma Raf., Bull. Bot. Seringe **1**: 220. 1830. "*Panicum divaricatum, P. hians*" are cited, both names applying to the same species, *P. hians* Ell.

Phanopyrum (Raf.) Nash, in Small, Fl. Southeast. U. S. 104. 1903. Based on "Panicum, subgenus Phanopyrum Raf.," with a single species, *P. gymnocarpon* (Ell.) Nash.

Chasea Nieuwl., Amer. Midl. Nat. **2**: 64. 1911. A new name proposed for "Panicum of the authors not of Linnæus or only in part," the name Panicum being applied to Chaetochloa.

Among the species of the United States two subgenera are recognized, besides Panicum proper.

Subgenus Paurochaetium Hitchc. and Chase. Perennials with tufted culms, erect narrow blades, narrow, more or less spikelike inflorescence, the ultimate branchlets produced beyond the uppermost spikelets as a bristle 1 to 6 mm. long, the apiculate fruits transversely rugose. There are four species within our limits, one from Florida, three from Texas. This subgenus shows a transition to Chaetochloa.

Subgenus Dichanthelium Hitchc. and Chase. Perennials forming a usually well-marked rosette of winter leaves, having a vernal phase of simple culms and terminal panicles of small, perfect, but usually sterile spikelets, and an autumnal phase produced by the branching of the culms after the maturity of the primary panicles, the secondary leaves and panicles usually much reduced, the spikelets cleistogamous and fruitful, sometimes hidden in the sheaths. There are 105 species within our limits, the species being especially abundant on the Atlantic Coastal Plain. A representative of this subgenus is *Panicum dichotomum* L. (fig. 138). A common species in the Eastern States is *P. clandestinum* L. (Pl. XVII), one of the most robust representatives of the group. This has bristly sheaths and cordate clasping blades as much as an inch wide. It grows in moist soil and furnishes a moderate amount of forage.

The remaining species belong for the most part to true Panicum, called by some the subgenus Eupanicum. The more important of these are the following: *Panicum barbinode* Trin., Para grass, a perennial with stout stolons as much as 15 feet long, culms 3 to 6 feet tall from a creeping base, bearded nodes, and panicles 4 to 6 inches long, consisting of several spikelike racemes of glabrous spikelets

[1] For a full discussion of the type species of Panicum, see Hitchcock and Chase, Contr. U. S. Nat. Herb. 15: 13. 1910.

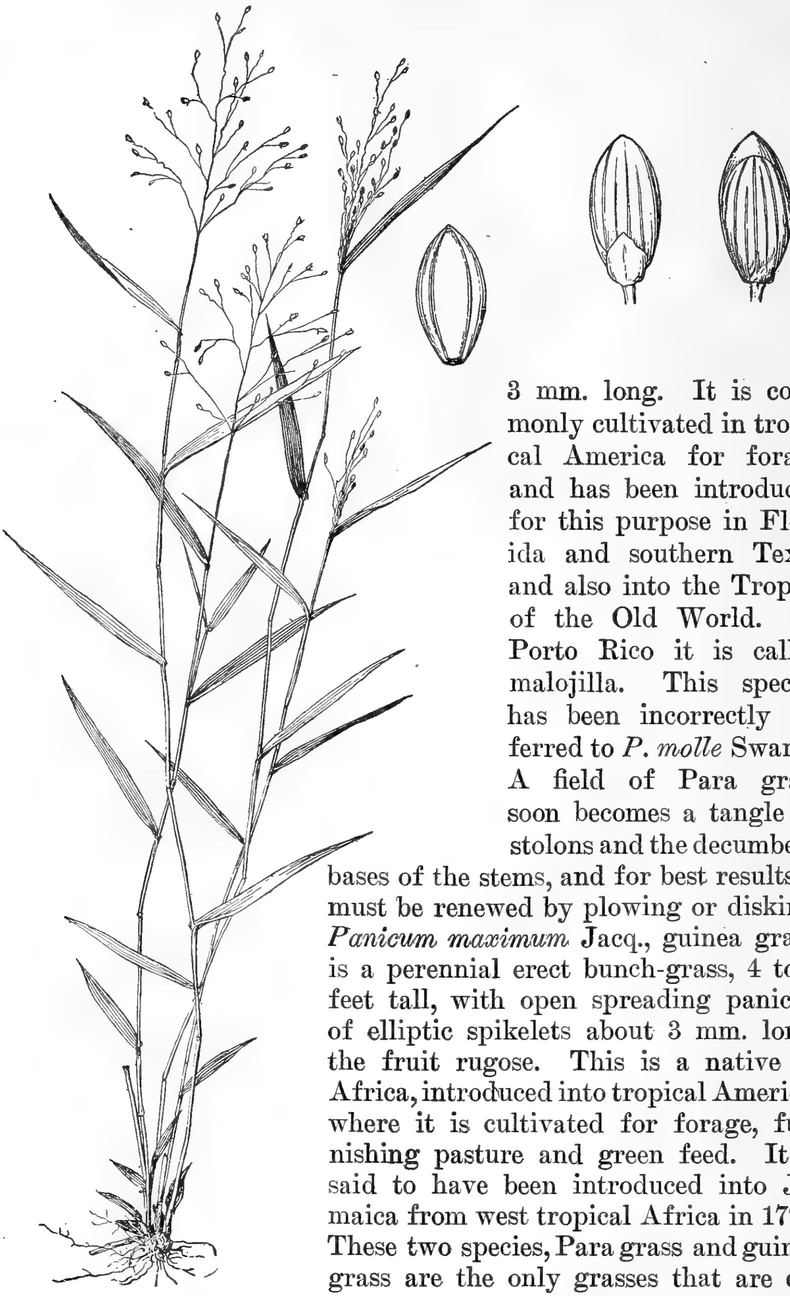

FIG. 138.—*Panicum dichotomum.* Plant, × ½; two views of spikelet and fertile floret, × 10.

3 mm. long. It is commonly cultivated in tropical America for forage and has been introduced for this purpose in Florida and southern Texas and also into the Tropics of the Old World. In Porto Rico it is called malojilla. This species has been incorrectly referred to *P. molle* Swartz. A field of Para grass soon becomes a tangle of stolons and the decumbent bases of the stems, and for best results it must be renewed by plowing or disking. *Panicum maximum* Jacq., guinea grass, is a perennial erect bunch-grass, 4 to 6 feet tall, with open spreading panicles of elliptic spikelets about 3 mm. long, the fruit rugose. This is a native of Africa, introduced into tropical America, where it is cultivated for forage, furnishing pasture and green feed. It is said to have been introduced into Jamaica from west tropical Africa in 1774. These two species, Para grass and guinea grass are the only grasses that are extensively cultivated for forage in tropical America. *Panicum miliaceum* L., proso millet, broom-corn millet, hog millet, an erect annual 2 to 3 feet tall, with a drooping panicle, is cultivated in Europe for the seed, which is used for food. It is sparingly cultivated in this country for forage.

PANICUM CLANDESTINUM.

Common in moist woods. Useful for forage and for ornament.

EULALIA (MISCANTHUS SINENSIS). GROWN FOR ORNAMENT

Panicum virgatum L. (fig. 139) switch-grass, an erect perennial 3 to 5 feet tall, with open spreading panicle, is common in the eastern half

Fig. 139.—Switch-grass, *Panicum virgatum*. Plant, × ½; two views of spikelet and fertile floret, × 10.

of the United States. It is a constituent of prairie hay. *Panicum bulbosum* H. B. K., of the Southwest develops well-marked corms at the base of the culms. *Panicum texanum* Buckl., Texas millet, Colorado grass, is an annual rather weedy grass of Texas that has been utilized for hay. It has been called Colorado grass because it grows in the valley of the Colorado River. *Panicum dichotomiflorum* Michx. is a smooth, annual, much-branched, rather succulent weed, common in the eastern United States in the autumn. The first glume is very short and truncate. *Panicum capillare* L. (fig. 140), old-witch grass, is an annual weed, with hirsute sheaths and a relatively large open capillary panicle with small spikelets. At maturity the panicle breaks away and is blown about by the wind as a tumble grass. *Panicum geminatum* Forsk. (fig. 141), a common tropical species, extends into Florida and Texas.

Besides the two subgenera there are a few species that can not be included in true Panicum. Two of these within our range are of some importance. *Panicum obtusum* H. B. K. (fig. 142), a forage grass of the Southwest, producing long wiry stolons with bearded, swollen nodes, and short, erect, fertile culms with narrow panicles of obtuse spikelets, is called grapevine mesquite, because of the long, tough stolons, and adobe grass, because it is found on slightly alkaline soil. This species differs from Eupanicum in the long first glume and the racemose branches of the inflorescence. *Panicum hemitomon* Schult., maiden cane, is found in moist soil, often in the water, from Texas to Florida and Delaware near the coast. It produces extensively creeping rhizomes and numerous sterile shoots. The panicle is narrow, with short appressed branches. On account of the rhizomes it becomes a troublesome weed in cultivated soil, especially in Florida. This species differs from Eupanicum in the less chartaceous fruit with the palea free at the tip. The seeds of *Panicum sonorum* Beal are used for food by the Cocopa Indians.

See Williams, U. S. Dept. Agr., Farmers' Bull. 101, 1899; Scribner, U. S. Dept. Agr., Div. Agrost. Bull. 20, fig. 23, 1900; Hitchcock and Chase, Contr. U. S. Nat. Herb. 15, 1910. The last work is a revision of the genus Panicum in North America and gives full descriptions and synonymy of all the species.

119. Lasiacis (Griseb.) Hitchc.

Spikelets subglobose, placed obliquely on their pedicels; first glume broad, somewhat inflated-ventricose, usually not over one-third the length of the spikelet, several-nerved; second glume and sterile lemma about equal, broad, abruptly apiculate, papery-chartaceous, shining, many-nerved, glabrous, or lanose at the apex only, the lemma inclosing a membranaceous palea and sometimes a staminate flower; fertile lemma white, bony-indurate, obovoid, obtuse, this and the palea of the same texture, bearing at the apex in a slight crateriform

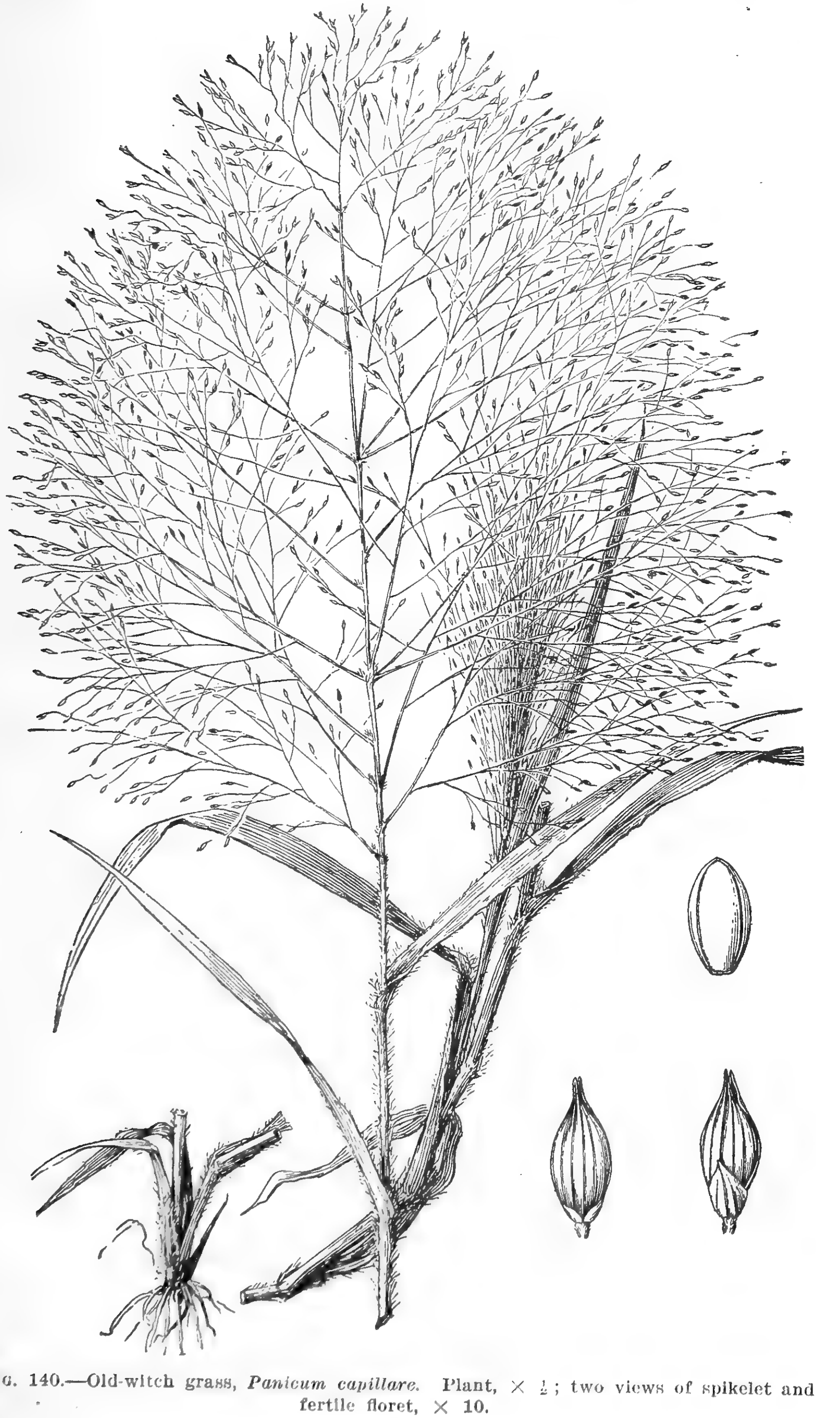

FIG. 140.—Old-witch grass, *Panicum capillare*. Plant, × ½; two views of spikelet and fertile floret, × 10.

depression a tuft of woolly hairs, the palea concave below, gibbous above, the apex often free at maturity.

FIG. 141.—*Panicum geminatum.* Plant, × ½; two views of spikelet and fertile floret × 10.

Large branching perennials, with woody culms often clambering several feet high into shrubs or trees, the blades firm, flat, usually lanceolate and narrowed into a petiole, the spikelets in an open panicle. Species about 20; in the American Tropics, one extending into southern Florida.

FIG. 142.—Grapevine mesquite, *Panicum obtusum*. Plant, × ½; spikelet and fertile floret, × 10.

Type species: *Panicum divaricatum* L.

Panicum, section Lasiacis Griseb, Fl. Brit. W. Ind. 551. 1864. Five species included, the first of which is *P. divaricatum.*

Lasiacis Hitchc., Contr. U. S. Nat. Herb. **15**:16. 1910. The type is designated. This genus was previously included as a section in Panicum, from which it differs in habit, the woody culms resembling those of bamboos, and in the oblique spikelets with the woolly apex of the fruit and the gibbous fertile palea.

The only species in the United States is *Lasiacis divaricata* (L.) Hitchc. (fig. 143) of southern Florida. It has no economic value.

120. Sacciolepis Nash.

Spikelets oblong-conic; first glume small, much shorter than the spikelet; second glume broad, inflated-

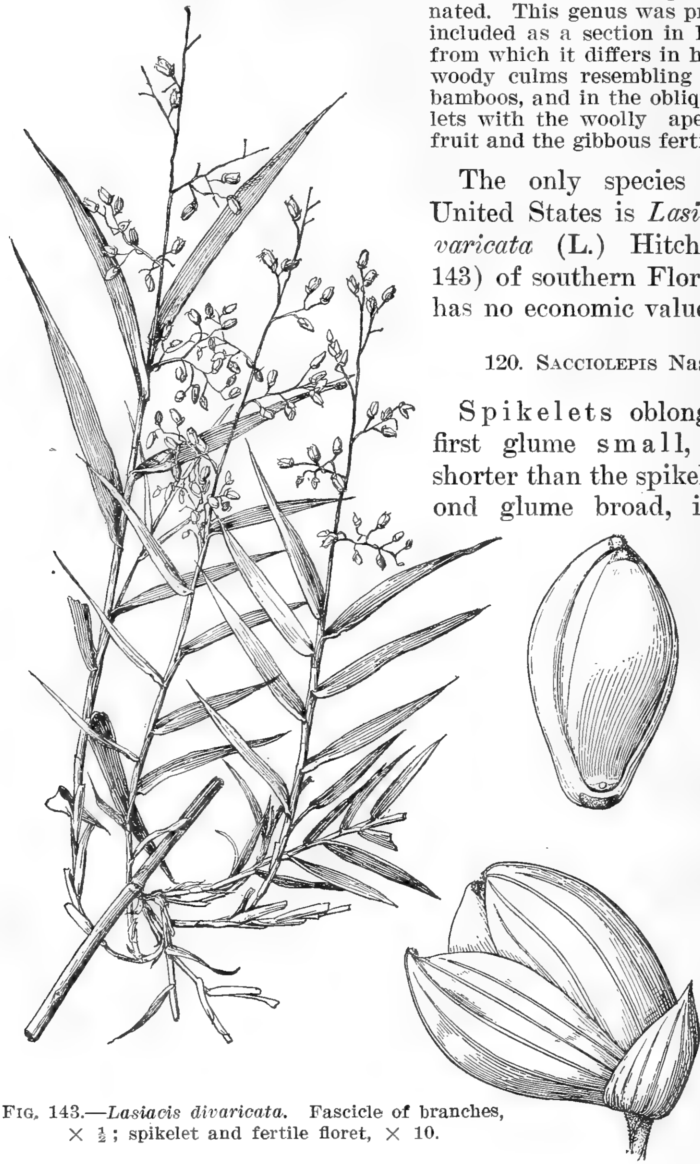

Fig. 143.—*Lasiacis divaricata.* Fascicle of branches, × ½; spikelet and fertile floret, × 10.

saccate, strongly many-nerved; sterile lemma narrower, flat, fewer nerved, its palea nearly as long, often subtending a staminate flower; fertile lemma stipitate, elliptic, chartaceous-indurate, the margins inrolled, the palea not inclosed at the summit.

Annuals or perennials, of wet soil, usually branching, the inflorescence a dense, usually elongate, spikelike panicle. Species about 12; in the Tropics of both hemispheres, 1 extending into the southeastern United States.

Type species: *Panicum gibbum* Ell.
Sacciolepis Nash, in Britton, Man. 80. 1901. Only one species is described.

Sacciolepis striata (L.) Nash (*Holcus striatus* L., *Panicum gibbum* Ell.) (fig. 144) is a stoloniferous marsh grass found from Virginia to Oklahoma and southward. It has no economic value.

121. OPLISMENUS Beauv.

Spikelets terete or somewhat laterally compressed, subsessile, solitary or in pairs, in two rows crowded or approximate on one side of a narrow scabrous or hairy rachis; glumes about equal, emarginate or 2-lobed, awned from between the lobes; sterile lemma exceeding the glumes and fruit, notched or entire, mucronate

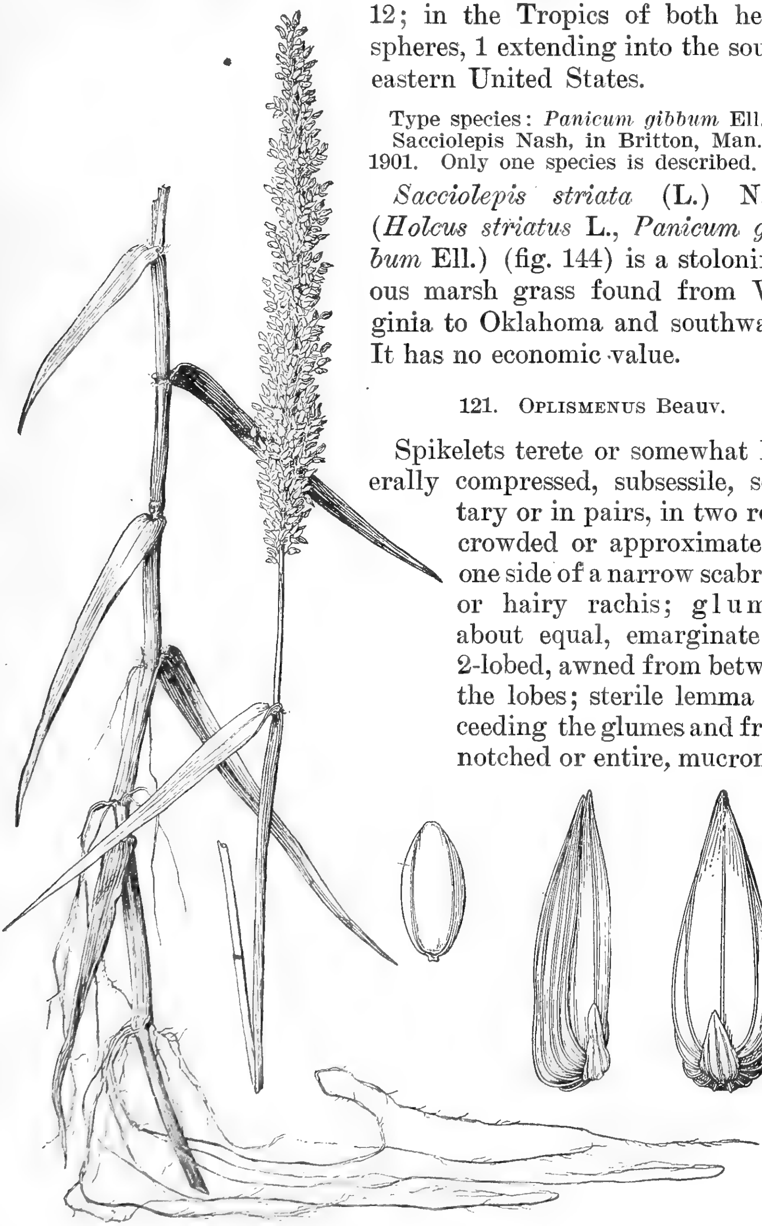

FIG. 144.—*Sacciolepis striata.* Plant, × ½; two views of spikelet and fertile floret, × 10.

or short-awned, inclosing a hyaline palea; fertile lemma elliptic, acute, convex or boat shaped, the firm margins clasping the palea, not inrolled.

Freely branching, creeping, shade-loving annuals or perennials, with erect flowering shoots, flat, thin lanceolate or ovate blades, and several one-sided, thickish, short spikes rather distant on a main axis. Species about 10, in the Tropics of both hemispheres, 1 extending into the Southern States.

Type species: *Oplismenus africanus* Beauv.

Oplismenus Beauv., Fl. Owar. **2**: 14, pl. 58, f. 1. 1809. A single species is described.

Orthopogon R. Br., Prodr. Nov. Holl. 194. 1810. Four species are described, *O. compositus, O. aemulus, O. flaccidus*, and *O. imbecillis. Panicum compositum* L. is chosen as the type, this being the basis of the first species of Orthopogon.

The only species in the United States is *Oplismenus setarius* (Lam.) Roem. and Schult. (fig. 145), found in shady places from Florida to Texas. This is grazed by stock, but is not sufficiently abundant to be of importance.

122. Echinochloa Beauv.

Spikelets plano-convex, often stiffly hispid, subsessile, solitary or in irregular clusters on one side of the panicle branches; first glume about half the length of the spikelet, pointed; second glume and sterile lemma equal, pointed, mucronate, or the glume short-awned and the lemma long-awned, sometimes conspicuously so, inclosing a membranaceous palea and sometimes a staminate flower; fertile lemma plano-convex, smooth and shining, acuminate-pointed, the margins inrolled below, flat above, the apex of the palea not inclosed.

Coarse, often succulent, annual, or sometimes perennial, grasses, with compressed sheaths, linear flat blades, and rather compact panicles composed of short, densely flowered racemes along a main axis. Species about 10, in the warm and temperate regions of both hemispheres; 4 species in the United States.

Type species: *Panicum crusgalli* L.

Echinochloa Beauv., Ess. Agrost. 53, pl. 11, f. 2. 1812. The species figured is selected as the type.

With the exception of *Echinochloa colonum* (L.) Link, the species of Echinochloa have distinctly awned or awn-pointed spikelets. In that cosmopolitan species the spikelets are merely apiculate or mucronate, and the racemes are simple and rather remote.

Echinochloa crusgalli (L.) Beauv. (fig. 146), barnyard grass, is a common weedy annual found throughout the country except at higher altitudes. The panicles vary much in the size and length of the awns, and in color vary from green to dark purple. In fields and waste places the plants are usually spreading, but in water or wet places may be stout and erect. An erect short-awned form, with short, ascending racemes, found in the Southwestern States, is the Mexican *E. crusgalli zelayensis* (H. B. K.) Hitchc. (*Oplismenus zelayensis* H. B. K.). *E. crusgalli edulis* (*Panicum frumentaceum* Roxb., 1820, not Salisb., 1796) is a form that has been cultivated in tropical Asia for the seeds, which are used for food. It differs in having short, compact, appressed, somewhat incurved racemes and nearly awnless spikelets. This form has been advertised by seeds-

FIG. 145.—*Oplismenus setarius*. Plant, × ½; two views of spikelet and fertile floret, × 10.

men in this country as billion-dollar grass and recommended for forage. It has some forage value, but requires considerable moisture to produce abundantly, and is rather too succulent to make good hay.

In these forms the sheaths are smooth. *Echinochloa walteri* (Pursh) Heller is a closely allied native species with hirsute sheaths and long-awned spikelets.

All the species of Echinochloa are grazed by horses and cattle, but usually grow in situations where they can not well be utilized.

FIG. 146.—Barnyard grass, *Echinochloa crusgalli*. Plant, × ½; two views of spikelet and fertile floret, × 10.

123. TRICHOLAENA Schrad.

Spikelets on short capillary pedicels; first glume small, much shorter than the spikelet, villous; second glume and sterile lemma equal, raised on a stipe above the first glume, emarginate or slightly lobed, short-awned, covered, except toward the apex, with long silky hairs, the palea of the sterile lemma well developed; fertile lemma shorter than the spikelet, cartilaginous, smooth, boat shaped, obtuse, the margins thin, not inrolled, inclosing the margins of the palea.

Perennial or annual grasses, with rather open panicles of silky spikelets. Species about 15, in the Eastern Hemisphere, mostly in Africa, one cultivated in the United States.

Type species: *Tricholaena micrantha* Schrad.

Tricholaena Schrad.; Schult., Mant. **2**: 163. 1824. Three species are described, but the second and third are included in the genus with a question. The first species is taken as the type.

Tricholaena rosea Nees (fig. 147), Natal grass, is becoming an important forage grass in the sandy lands of Florida, where it has been recently introduced. It is an upright, rather slender perennial, 2 to 4 feet tall, with beautiful purple panicles, 4 to 10 inches long. The color varies from light purple or pink to wine color. Although a perennial, it is usually cultivated as an annual, as it will not survive temperatures below freezing.

124. CHAETOCHLOA Scribn.
(*Setaria* Beauv.)

Spikelets subtended by one to several bristles (sterile branchlets), falling free from the bristles, awnless; first glume broad, usually less than half the length of the spikelet, 3 to 5 nerved; second glume and sterile lemma equal, or the former shorter, several-nerved; fertile lemma coriaceous indurate, smooth or rugose.

Annual or perennial grasses, with narrow terminal panicles, these dense and spikelike or somewhat loose and open. Species about 65, in the tropical and warm temperate regions of both hemispheres; 18 species in the United States.

Type species: *Panicum viride* L.

Setaria Beauv., Ess. Agrost. 51, pl. 13, f. 3, 1812, not Acharius, 1789, nor Michaux, 1803. Fourteen species are listed, *S. viridis* being illustrated. *Panicum viride* L., on which this species is based, is taken as the type.

Chaetochloa Scribn., U. S. Dept. Agr., Div. Agrost. Bull. **4**: 38. 1897. Scribner proposes the name Chaetochloa for Setaria Beauv., stating that the name Setaria was first used by Beauvois (Fl. Owar. 1809)[1] for a species of Pennisetum. Scribner himself applies the name Chaetochloa to the species allied to *Panicum viride*. Hence it seems that he wished to substitute Chaetochloa for Setaria as used by Beauvois in his Essai (Ess. Agrost. 51, pl. 13, f. 3, 1812). The figured species, *Setaria viridis* (L.) Beauv., becomes the type.

The name Ixophorus Schlecht. was applied to this genus by Nash,[2] but that is based on a Mexican species not congeneric with ours.

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[1] According to Dr. J. H. Barnhart the part containing Setaria (Fl. Owar. **2**: 80) was not published until 1818.

[2] Britton and Brown, Illustr. Fl. **1**: 125. 1896.

FIG. 147.—Natal grass, *Tricholaena rosea*. Plant, × ½; spikelet and fertile floret, × 10.

Beal[1] applied the name Chamaeraphis R. Br. to American species of Chaetochloa, but that is an Australian genus in which the articulation is below the spikelet-bearing branches, as in Pennisetum.

One group of this genus, section Ptychophyllum, has broad, often plaited, blades and loose or open panicles, the bristles solitary and at the base of only the uppermost spikelets on the short branchlets. This section has usually been referred to Panicum, but shows a closer relationship to Chaetochloa. Two species of this group, both perennials, are cultivated in greenhouses or in the open in the Tropics for ornament, chiefly on account of the broad plaited blades that resemble those of young palms. *Chaetochloa sulcata* (Aubl.) Hitchc. (*Panicum sulcatum* Aubl.) has narrow, rather dense panicles, 1 to 2 feet long, and blades about 2 inches wide. *Chaetochloa palmifolium* (Willd.) Hitchc. and Chase has large open panicles and broader blades. This has been known in cultivation as *Panicum plicatum*, but is not *P. plicatum* Lam. It is sometimes called palm-grass.

Of the species of Chaetochloa proper[2] (Setaria Beauv.) several are weeds in cultivated soil. Two annual species are common in the eastern United States, where they are known as foxtail or pigeon grass. *Chaetochloa viridis* (L.) Scribn., green foxtail, has a green, somewhat pointed head, with untwisted blades. *Chaetochloa lutescens* (Weigel) Stuntz (*Setaria glauca* of most authors, not *Panicum glaucum* L.) (fig. 148), yellow foxtail, has cylindric yellow obtuse heads and blades twisted in a half spiral so that toward the end the upper surface is beneath.

Another annual species common in waste places is *Chaetochloa verticillata* (L.) Scribn., in which the bristles are backwardly roughened, the heads thus sticking readily to clothing. *Chaetochloa geniculata* (Lam.) Millsp. and Chase is a perennial species resembling yellow foxtail. This is common in the Southern States and throughout the Tropics. *Chaetochloa magna* (Griseb.) Scribn., a robust annual as much as 9 feet high, with a dense panicle or head as much as a foot long and 2 inches in diameter, is found in marshes from Maryland to the West Indies.

Chaetochloa macrostachya (H. B. K.) Scribn. and Merr. (heretofore commonly confused with the South American *C. composita* (H. B. K.) Scribn.), is of some importance as a range grass from Texas to Arizona. It is a pale perennial, with somewhat pointed spikelike panicles. The two annuals, *C. viridis* and *C. lutescens*, are often sufficiently abundant to furnish considerable forage.

The most important species of the genus is *Chaetochloa italica* (L.) Scribn. (*Setaria italica* Beauv.). This is called millet, or, to distinguish it from other kinds of millet, foxtail millet. Millet is an

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[1] Grasses N. Amer. 2: 150. 1896.

[2] The genus was revised by Scribner and Merrill, U. S. Dept. Agr., Div. Agrost. Bull. 21. 1900.

erect annual, 2 to 4 feet tall, with a dense, bristly, yellow or purple head. There are many varieties in cultivation, differing in the size and lobing of the head, the length and color of the bristles, and the color of the seed. Small forms resemble *C. viridis*, but may be distinguished by the articulation of the seed. In *C. viridis* the seed (fruit, that is, the fertile floret) falls from the pedicel inclosed within the glumes. In *C. italica* the seed readily separates from the glumes by an articulation above the sterile lemma. A ripe head of *C. italica* rubbed between the palms yields free seed. A head of *C. viridis* will yield entire spikelets.

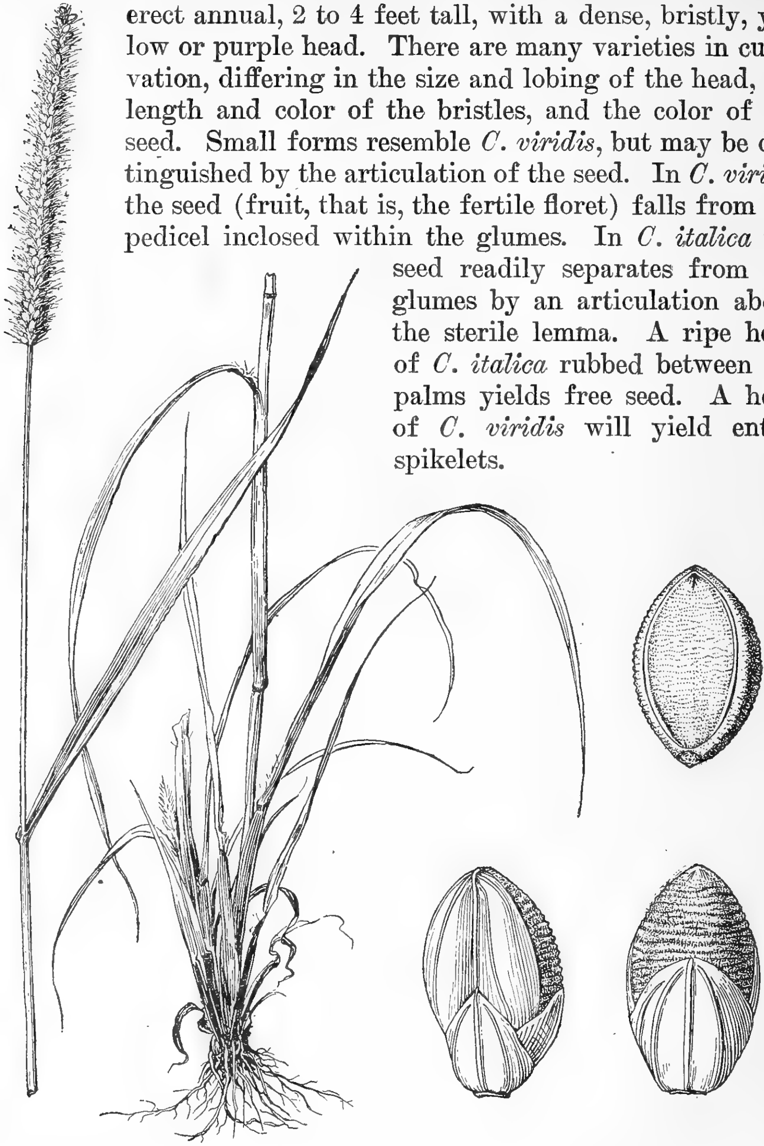

FIG. 148.—Yellow foxtail, *Chaetochloa lutescens*. Plant, × ½; two views of spikelet and fertile floret, × 10.

The varieties of *Chaetochloa italica* cultivated in the United States have been classified as follows[1] (under *Setaria italica*):

Fruit dark colored (reddish or orange to blackish or brownish black).
    Fruit reddish or orange .... *rubrofructa.*
    Fruit blackish, brownish black, or purplish black with pale yellowish straw lines intermingled, these sometimes predominating .... *nigrofructa.*

[1] See Hubbard, Amer. Journ. Bot. 2: 187. 1915.

Fruit pale (yellowish to straw or light brown).
Bristles green.
Panicle more or less open-lobulate .... *stramineofructa.*
Panicle dense or slightly lobulate at base .... *germanica.*
Bristles brown or purple.
Bristles brown .... *brunneoseta.*
Bristles purple.
Panicle more or less lobulate .... *hostii.*
Panicle dense or slightly lobulate at base .... *metzgeri.*

Subsp. *rubrofructa* Hubb.: The only forms cultivated in the United States are var. *purpureoseta* Hubb., Turkish millet, with purple bristles and a large lobulate head; and subvar. *violacea* (Alef.) Hubb., Kursk millet or Siberian millet, with purple bristles and a smaller dense head.

Subsp. *nigrofructa* Hubb.: The common form cultivated in the United States is var. *atra*, or Hungarian grass. This has small dense heads 1 to 3 inches long with purple bristles.

Subsp. *stramineofructa* Hubb., German millet: Plants robust with heads 4 to 12 inches long and as much as 2 inches wide, the bristles noticeably longer than the spikelets. Forma *breviseta* (Doell) Hubb., Golden Wonder millet, differs in having bristles shorter than the spikelets or barely exceeding them.

Subsp. *germanica* (Mill.) Hubb., common millet: Heads mostly 2 to 3 inches long, one-fourth to one-half an inch thick, the bristles noticeably longer than the spikelets; forma *mitis* (Alef.) Hubb. with bristles shorter than the spikelets or barely exceeding them. There has been an unfortunate misapplication of the name German millet. The forms cultivated under this name are not the subspecies *germanica* as one would suppose (see the preceding subspecies).

Var. *brunneoseta* Hubb., Aino millet: Head large, lobulate, brown. Subvar. *densior* Hubb. has a compact scarcely lobulate head.

Var. *hostii* Hubb., German millet: Head large, lobulate, purple; differs from the other form of German millet (subsp. *stramineofructa*) in having purple bristles.

Var. *metzgeri* (Körnicke) Hubb., common millet: Bristles noticeably longer than the spikelets; differs from the other form of common millet (subsp. *germanica*) in having purple bristles; sometimes called Hungarian grass, a name which should be applied to subsp. *nigrofructa*.

125. Pennisetum Rich.

Spikelets solitary or in groups of two or three, surrounded by an involucre of bristles, these not united except at the very base, often plumose, falling attached to the spikelets; first glume shorter than the spikelet, sometimes minute or wanting; second glume shorter than or equaling the sterile lemma; fertile lemma chartaceous, smooth, the margin thin, inclosing the palea.

Annual or perennial, often branched grasses, with usually flat blades and dense spikelike panicles. Species about 50, in the tropical regions of both hemispheres; 1 species in southern Florida.

Type species: *Pennisetum typhoideum* Rich.

Pennisetum Rich., in Pers. Syn. Pl. 1: 72. 1805. Five species are described, *P. typhoideum*, *P. setosum*, *P. cenchroides*, *P. orientale*, and *P. violaceum*. *Pennisetum typhoideum*, being a well-known economic species, is chosen as the type.

Penicillaria Willd., Enum. Pl. 2: 1036. 1809. A single species, *P. spicatus*, based on *Holcus spicatus* L., is described.

Gymnothrix Beauv., Ess. Agrost. 59, pl. 13. f. 6. 1812. The type species is *G. thourii*, the one figured. Beauvois distinguished Gymnothrix from Pennisetum by the glabrous (not plumose) bristles.

The most important species of the genus is *Pennisetum glaucum* (L.) R. Br. (*P. typhoideum* Rich., *P. americanum* (L.) Schum., *Penicillaria spicata* (L.) Willd.), called in this country pearl millet (fig. 149). This is a robust annual, 4 to 8 feet tall, with broad blades like those of corn or sorghum, and a dense, erect, cylindric spikelike panicle as much as a foot long, the stem woolly below the spike, the involucre containing usually two spikelets about as long as the bristles. Pearl millet differs from the other Paniceae in having an enlarged caryopsis bursting through its lemma and palea. The caryopsis, or "seed," is deciduous by an articulation above the fertile lemma, the bristles and the floral bracts remaining on the spike. Pearl millet is widely cultivated in tropical Africa and Asia, the seed being used for human food. The species has been cultivated since pre-

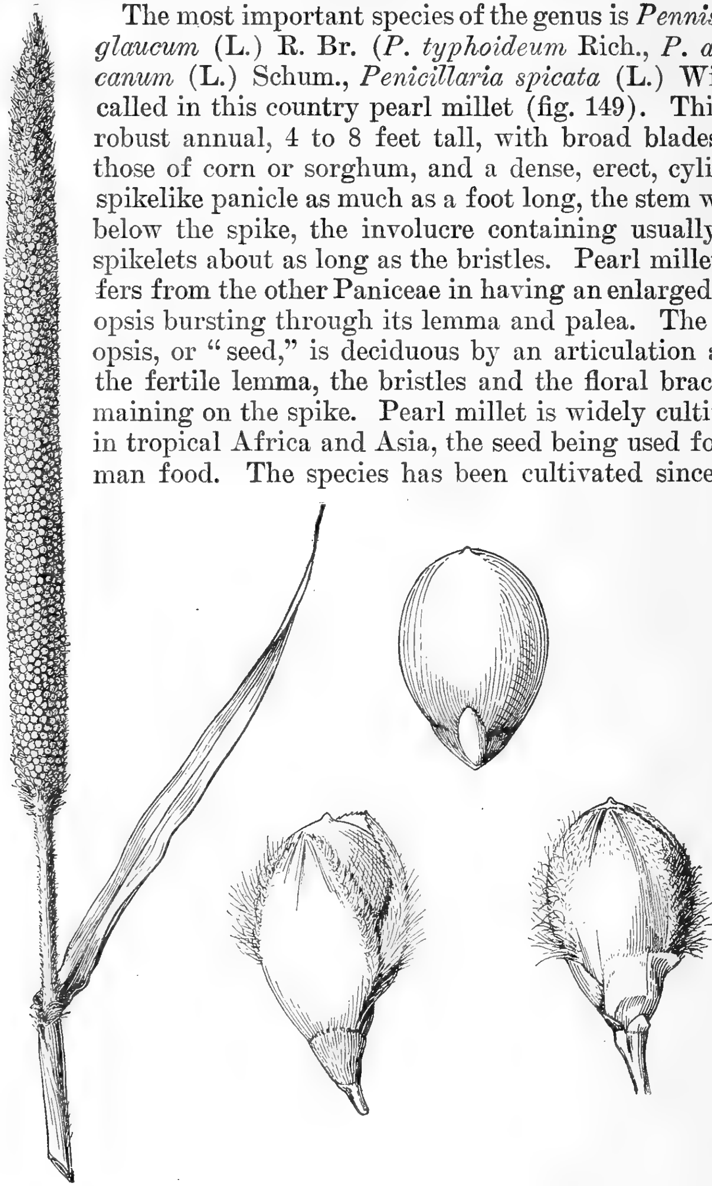

FIG. 149.—Pearl millet, *Pennisetum glaucum*. Inflorescence, × ½; two views of spikelet and caryopsis, × 10.

historic times, its wild prototype being unknown. In the United States pearl millet is used to a limited extent in the Southern States for forage, especially for soiling.

Panicum glaucum L. (Sp. Pl. 56. 1753), on which was based *Pennisetum glaucum*, was itself based on a citation from the Flora Zeylanica (Panicum spica tereti, involucris bifloris fasciculato-pilosis L. Fl. Zeyl. 18. 1747), which refers to the species afterwards described as *Pennisetum typhoideum*. Linnæus described two varieties of *Panicum glaucum*, these being now called *Chaetochloa viridis* and *C. lutescens*. Through an error the name *Panicum glaucum* has been applied by nearly all botanists to the latter species. When the species was transferred to Setaria and to Chaetochloa the error was perpetuated. Robert Brown transferred *Panicum glaucum* to Pennisetum but used the name in the erroneous sense, as is shown by his description. Nevertheless, Robert Brown must be credited with the name *Pennisetum glaucum* even though he described the wrong species. The only species of Pennisetum found native in the United States is *P. setosum* (Swartz) Rich. (fig. 150), of tropical America, which extends into southern Florida. Two species are cultivated for ornament. *Pennisetum villosum* R. Br. (*P. longistylum* of florists, not Hochst.) is a slender perennial 1 or 2 feet tall with a pale feathery head 2 to 4 inches long, the bristles 1 to 2 inches long. *Pennisetum ruppelii* Steud., fountain grass, with beautiful pink or purple nodding spikes, longer and more graceful than those of the preceding, is used for borders. An African species, Napier grass (*P. purpureum* Schum.), has been tested recently in the Southern States as a forage plant. It is a coarse perennial 8 to 12 feet tall.

126. Cenchrus L.

Spikelets solitary or few together, surrounded and inclosed by a spiny bur composed of numerous coalescing bristles (sterile branchlets), the bur globular, the peduncle short and thick, articulate at base, falling with the spikelets and permanently inclosing them, the seed germinating within the old involucre, the spines usually retrorsely barbed.

Annual or sometimes perennial, commonly low branching grasses, with flat blades and racemes of burs, the burs readily deciduous. Species about 25, in the warmer parts of both hemispheres, but chiefly in America; 7 species in the United States, chiefly in the southern portion.

Type species: *Cenchrus echinatus* L.

Cenchrus L., Sp. Pl. 1049, 1753; Gen. Pl., ed. 5, 471. 1754. Linnæus describes five species, *C. racemosus*, *C. capitatus*, *C. echinatus*, *C. tribuloides*, and *C. frutescens*. The reference in the Genera Plantarum is to Panicastrella Mich. 31, that is, to plate 31 of Micheli's Nova Plantarum Genera, published in 1729. The account of the genus Panicastrella is on page 36. The two species here described are cited as synonyms by Linnæus, under *Cenchrus echinatus* and *C. tribuloides*, both being based on descriptions in Sloane's History of Jamaica. The first species, *C. echinatus*, is chosen as the type. *Cenchrus racemosus* is now referred to Nazia; *C. capitatus* to Echinaria. *Cenchrus frutescens*, of which there is no specimen in the Linnæan Herbarium, is uncertain. It is stated to come from America, but this is a misprint for Armenia, as is shown by the second edition of the Species Plantarum.

FIG. 150.—*Pennisetum setosum.* Plant, × ½; two views of spikelet and fertile floret, × 10.

Rarum Adans., Fam. Pl. 2: 35, 597. 1763. Of the four pre-Linnæan citations two are given by Linnæus under *Cenchrus echinatus*, which is taken as the type.

Cenchropsis Nash, in Small, Fl. Southeast. U. S. 109. 1903. *Cenchrus myosuroides* H. B. K. is designated as the type.

Nastus Lunell, Amer. Midl. Nat. 4: 214. 1915. The name is ascribed to Dioscorides and "*Cenchrus frutescens* Linn." given as the type. Lunell intends to apply the name to Cenchrus, but the designated type is unidentifiable and certainly is not a grass.

Most of the species of the United States are annual. *Cenchrus myosuroides* H. B. K. differs from our other species in the involucre, or bur, with bristles united only at the base. Were it not for certain species of Australasia which are intermediate, this species might be segregated under a distinct genus, as was done by Nash.[1] The original *C. tribuloides* L. (fig. 151) is a dune grass of the Atlantic coast, with large villous burs. The common sand bur of the interior found in sandy fields across the continent is *C. pauciflorus* Benth. This was formerly confused with *C. tribuloides* and more recently has been called *C. carolinianus* Walt., which proves to be a different species. *Cenchrus echinatus*, a common tropical species extending into the Southern States, has a less prickly bur, with a ring of slender bristles at the base of the stout prickles. The species of Cenchrus, especially the last two, are excellent forage grasses before the burs are formed. The genus has been revised by Nash.[2]

127. Amphicarpon Raf.

Spikelets of two kinds on the same plant, one in a terminal panicle, perfect but not fruitful, the other cleistogamous on slender leafless subterranean branches from the base of the culm or sometimes also from the lower nodes; first glume of the aerial spikelets variable in size, sometimes obsolete; second glume and sterile lemma about equal; lemma and palea indurate, the margins of the lemma thin and flat; fruiting spikelets much larger, the first glume wanting; second glume and sterile lemma strongly nerved, subrigid, exceeded at maturity by the turgid, elliptic, acuminate fruit with strongly indurate lemma and palea, the margins of the lemma thin and flat; stamens with small anthers on short filaments.

Annual or perennial erect grasses, with flat blades and narrow terminal panicles. Species two, in the Atlantic Coastal Plain region of the United States.

Type species: *Milium amphicarpum* Pursh.

Amphicarpon Raf., Amer. Month. Mag. 2: 175. 1818. In a review of Pursh's Flora of North America, Rafinesque indicates that *Milium amphicarpon* should be a new genus, Amphicarpon Raf. Kunth[3] published the genus Amphicarpum, based on the same type, apparently ignorant of Rafinesque's proposed name.

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[1] *Censhropsis myosuroides* (H. B. K.) Nash, in Small, Fl. Southeast, U. S. 109. 1903.

[2] Bull. Torrey Club 22: 298–301. 1895.

[3] Rev. Gram. 1: 28. 1829.

The two species are *Amphicarpon purshii* Kunth (*A. amphicarpon* (Pursh) Nash), an annual (fig. 152), with hirsute blades, found

FIG. 151.—*Cenchrus tribuloides.* Plant, × ½; two views of spikelet and fertile floret, × 10.

from New Jersey to Florida, and *A. floridanum* Chapm., a stoloniferous perennial, with glabrous blades, confined to Florida. The latter often provides abundant pasture.

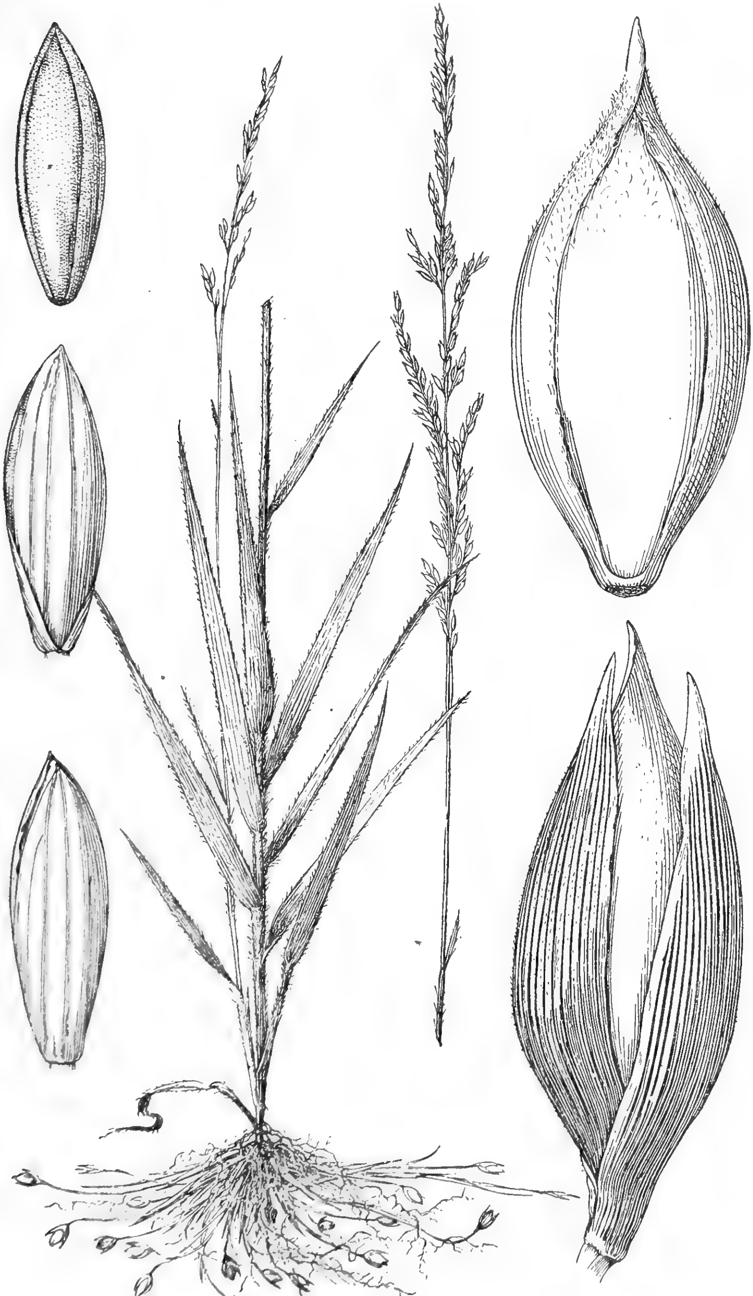

FIG. 152.—*Amphicarpon purshii.* Plant, × ½; two views of aerial spikelet and floret and the subterranean spikelet and fertile floret, × 10.

Olyra L., Syst. Nat., ed. 10, 2:1261. 1759. A tropical American genus, one species of which, *O. latifolia* L. (fig. 153) is credited to Florida by Small in his Flora of the Southeastern United States. The record is doubtful.

A glabrous perennial, bamboolike in aspect, as much as 15 feet tall, the branches straggling over shrubs; blades petiolate, asymmetrically lanceolate-oblong, as much as 8 inches long and 2 inches wide; panicles 4 to 6 inches long, the branches stiffly ascending or spreading, each bearing a single, large, long-acuminate, pistillate spikelet at the thickened summit and several small slender-pediceled staminate spikelets along the branch.

13. ANDROPOGONEAE, THE SORGHUM TRIBE.

128. Imperata Cyrillo.

Spikelets all alike, awnless, in pairs, unequally pedicellate on a slender continuous rachis, surrounded by long silky hairs; glumes about equal, membranaceous; sterile lemma, fertile lemma, and palea thin and hyaline.

Perennial, slender, erect grasses, with terminal narrow woolly panicles. Species seven, in the tropical regions of both hemispheres; two species in the United States, three others in tropical America.

Type species: *Lagurus cylindricus* L.

Imperata Cyrillo, Pl. Rar. Neap. 2: 26. 1792. A single species is described, *I. arundinacea* Cyrillo, but the genus is based upon *Lagurus cylindricus* L.[1]

Our species are *Imperata brasiliensis* Trin., in southern Florida, and *I. hookeri* Rupr. (fig. 154), from western Texas to southern California. They are not found in sufficient abundance to be of agricultural value.

129. Miscanthus Anderss.

Spikelets all alike, in pairs unequally pedicellate along a slender continuous rachis; glumes equal, membranaceous or somewhat coriaceous; sterile lemma a little shorter than the glumes, hyaline; fertile lemma hyaline, smaller than the sterile lemma, extending into a delicate bent and flexuous awn; palea small and hyaline.

Robust perennials, with long flat blades and terminal panicles of aggregate spreading slender racemes, our species with a tuft of silky hairs at the base of the spikelet, surrounding it and of about the same length as the glumes, the palea of the short-pedicellate spikelet about one-fourth as long as the lemma, the palea of the long-pedicellate spikelet obsolete. Species about eight, in southeastern Asia and South Africa; one cultivated in the United States.

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[1] Cyrillo gives the generic heading thus: "Imperata. *Lagurus cylindricus* Linn., Sp. Pl. 120, n. 2."

FIG. 153.—*Olyra latifolia.* Plant, × ½; pistillate spikelet, fertile floret, and staminate spikelet, × 5.

Type species: *Miscanthus japonicus* Anderss.

Miscanthus Anderss., Ofv. Svensk. Vet. Akad. Forh. **1855:** 165. 1856. Andersson describes five species, *M. capensis*, *M. japonicus*, *M. luzonensis*, *M. sinensis*, and *M. purpurascens*. Andersson states that *M. capensis* is a transition from

FIG. 154.—*Imperata hookeri*. Plant, × ½; spikelet, × 5.

this group to the other genera of the tribe; hence this species may be excluded from consideration in selecting the type of the genus. The second species, *M. japonicus*, is therefore selected as the type.

Xiphagrostis Coville, Contr. U. S. Nat. Herb. **9:** 399, pl. 69. 1905. Two species are included, *X. floridula* (Labill.) Coville and *X. japonica* (Thunb.) Coville. *Saccharum floridulum* Labill., on which the first species is based, is designated as the type. Coville assumed *M. capensis* to be the type of Miscanthus, as it was the first species described (see Miscanthus, p. 254), and referred *Miscanthus sinensis* and its allies, which were not congeneric with *M. capensis*, to Xiphagrostis.

Miscanthus sinensis Anderss. (Pl. XVIII; fig. 155) is cultivated in the United States as an ornamental. Commercially it is known as *Eulalia japonica* or merely eulalia. This is a reedy grass 4 to 8 feet high, growing in large bunches, with flat mostly basal blades, 2 to 3 feet long and about half an inch wide, gradually narrowed to a slender point, the panicle somewhat fan shaped, consisting of numerous silky racemes 4 to 8 inches long, aggregate at the summit of the culm. Eulalia has escaped from cultivation and is found growing wild in some localities. There are two varieties of *Miscanthus sinensis* with variegated leaves, var. *variegatus* Beal, with striped blades, and var. *zebrinus* Beal, with banded blades. *Miscanthus sinensis gracillimus* is a variety with very narrow blades. Another species, *M. nepalensis* (Trin.) Hack., is occasionally cultivated under the name of Himalaya fairy grass. This has spikelets about one-fourth as long as the hairs at their base.

130. Saccharum L.

Spikelets in pairs, one sessile, the other pedicellate, both perfect, awnless, arranged in panicled racemes, the axis disarticulating below the spikelets; glumes somewhat indurate, sterile lemma similar but hyaline; fertile lemma hyaline, sometimes wanting.

Perennial grasses of tropical regions, including about 10 species.

Type species: *Saccharum officinarum* L.

Saccharum L., Sp. Pl. 54. 1753; Gen. Pl., ed. 5, 28. 1754. Two species are described. The first is chosen as the type, because it is a well-known economic species. The second species, *S. spicatum*, is now referred to the genus Imperata.

Saccharum officinarum (fig. 156), the sugar cane, is cultivated in Louisiana and to a limited degree in some of the other Gulf States. It is a tall stout grass, 8 to 15 feet tall or even taller, with solid juicy stems, broad flat blades, and large plumelike panicles 1 to 2 feet long, with numerous small spikelets about 3 mm. long, each surrounded at the base by a tuft of silky hairs two or three times as long as the spikelet. The glumes and the delicate sterile lemma are about the same length, the fertile lemma and palea being absent. Sugar cane is cultivated chiefly for the production of sugar and molasses; but, especially in the Gulf States outside of Louisiana, it is also used for forage.

131. Erianthus Michx.

Spikelets all alike, in pairs along a slender axis, one sessile, the other pedicellate, the rachis disarticulating below the spikelets, the rachis

FIG. 155.—Eulalia, *Miscanthus sinensis*. Sketch of several stems, much reduced; branch of panicle, × ½; spikelet, × 5.

FIG. 156.—Sugar cane, *Saccharum officinarum*. Sketch of three stems, much reduced; a few branches of panicle, × ½; spikelet with pedicel of second spikelet (the shorter) and joint of rachis, × 5.

joint and pedicel falling attached to the sessile spikelet; glumes coriaceous, equal, usually copiously clothed, at least at the base, with long silky spreading hairs; sterile lemma thin and hyaline; fertile lemma hyaline, the midnerve extending into a slender awn; palea small and hyaline.

Perennial reedlike grasses, with flat blades and terminal oblong, usually dense silky panicles. Species about 20, in the warmer regions of both hemispheres; five in the United States, mostly in the Atlantic Coastal Plain.

Type species: *Erianthus saccharoides* Michx.

Erianthus Michx., Fl. Bor. Amer. **1**: 54. 1803. Michaux describes two species, *E. saccharoides* and *E. brevibarbis*. He derives the name of the genus from two Greek words which mean hairy flower, because of the very densely villous involucre below the spikelets, and he remarks that the genus is closely allied to Saccharum. The first species, with long involucral hairs, he names *saccharoides*, and the second, with short hairs, *brevibarbis*. The first species, better representing Michaux's idea of the genus, is chosen as the type.

The commonest native species is *Erianthus saccharoides* (fig. 157), with straight awns and woolly panicles. *Erianthus divaricatus* (L.) Hitchc., with pale panicles, and *E. contortus* Baldw., with dark panicles, have flat, twisted awns. *Erianthus strictus* Baldw. has naked spikelets, and *E. brevibarbis* Michx. has short hairs at the base of the spikelets. The plants are too coarse to be of value for grazing, but some of our native species might well be cultivated for ornament.

One species, *E. ravennae* (L.) Beauv., a native of the Mediterranean region, is occasionally cultivated for ornament because of the silky plumes. It is called Ravenna grass and also by the less distinctive names, plume-grass and hardy pampas grass. The culms are several feet high, growing in large clumps, with blades about half an inch wide, tapering into a long slender point, the plume being as much as 2 feet long.

132. Andropogon L.

Spikelets in pairs at each node of an articulate rachis, one sessile and perfect, the other pedicellate and either staminate, neuter, or reduced to the pedicel, the rachis and the pedicels of the sterile spikelets often villous, sometimes conspicuously so; glumes of the fertile spikelet coriaceous, narrow, awnless, the first rounded, flat, or concave on the back, several-nerved, the median nerve weak or wanting; sterile lemma shorter than the glumes, empty, hyaline; fertile lemma hyaline, narrow, entire or bifid, usually bearing a bent and twisted awn from the apex or from between the lobes; palea hyaline, small or wanting; pedicellate spikelet awnless, sometimes staminate and about as large as the sessile spikelet, sometimes consisting of one or more reduced glumes, sometimes wanting, only the pedicel present.

Rather coarse perennials (in the United States), with solid culms, the spikelets arranged in racemes, these numerous, aggregate on an

FIG. 157.—Plume-grass, *Erianthus saccharoides*. Plant, × ½; spikelet with pedicel (at right) and joint of rachis, × 5.

exserted peduncle, or single, in pairs, or sometimes in threes or fours, the common peduncle usually inclosed by a spathelike sheath, these sheaths often numerous, forming a compound inflorescence, usually narrow, but sometimes in dense subcorymbose masses. Species about 150, in all warmer parts of the world; about 30 species in the United States, mostly in the South.

Type species *Andropogon virginicus* L.

Andropogon L., Sp. Pl 1045, 1753; Gen. Pl., ed. 5, 468. 1754. Linnæus describes 12 species. The reference in the Genera Plantarum is to "Roy. lugdb. 52." In this work, Flora Leydensis, published in 1740, Royen describes two species, the first of these is later (Species Plantarum) named *Andropogon hirtum* by Linnæus, and the second *A. virginicum.* The type should be chosen from these two. The two species appear to be equally familiar to Royen and to Linnæus, though *A. virginicus* is more fully described and has priority of position in the Species Plantarum. *Andropogon virginicus* is chosen as the type, as this choice retains the generic name for its usual signification. Of the 12 species originally described, 4 are retained in Andropogon, *A. distachyos, A. virginicus, A. bicornis,* and *A. ischaemum. Andropogon contortus* is now referred to Heteropogon, *A. divaricatus* to Erianthus, *A. nutans* to Sorghastrum, *A. alopecuroides* to Erianthus, *A. schoenanthus, A. hirtus,* and *A. nardus* to Cymbopogon. *Andropogon fasciculatus,* the last species, is unidentifiable.

Schizachyrium Nees, Agrost. Bras. 331. 1829. The type species is *Andropogon condensatus* H. B. K., upon which is based *S. condensatum,* first of the six species described. Nees states, in a paragraph at the end of the generic description, that besides the species he enumerates *Andropogon brevifolius* belongs to Schizachyrium. Because of this statement Nash[1] chooses the latter species as the type. This group includes the species of Andropogon with racemes single at the ends of the branches.

Dimeiostemon Raf., Bull. Bot. Seringe **1**: 221. 1830. "Andropogon vaginatus Ell., A. sessiliflorus [nomen nudum], A. macrurus, A. vaginatus [repeated], A. tetrastachys" are listed. *Andropogon vaginatus* Ell., which is the same as *A. virginicus* L., is taken as the type.

Amphilophis Nash, in Britton, Man. 71. 1901. Only one species described, *Andropogon torreyanus* Steud. This group includes the species of Andropogon with numerous racemes in a naked panicle. Amphilophis was first used by Trinius[2] as a section of Andropogon.

Our species are divided into three groups: One (constituting the genus Schizachyrium of some authors) with the racemes single on each peduncle; two, with the racemes in pairs, or sometimes in threes or fours, on each peduncle; three, with the racemes aggregate toward the naked summit of the culms and branches. The commonest representative in the United States of the first group is *Andropogon scoparius* Michx. (fig. 158). This is an erect bunch-grass 2 to 4 feet high, the racemes scattered along the upper part of the stem. It is common throughout the eastern half of the United States. It is a fairly good forage grass and forms a part of the wild prairie hay in the eastern portion of the Great Plains, where it is called little bluestem. The second group is represented by numerous species in the Southern States. One of these, *A. virginicus* L. (fig. 159) is found in old fields, open woods, and sterile ground from Massachusetts to Texas and Florida. This is called broom sedge, though the name is also applied to some of the other species of Andropogon. *Andropogon virginicus* is a

[1] N. Amer. Fl. **17**: 100. 1912.

[2] Mém. Acad. St. Pétersb. VI. **2**: 285. 1832.

bunch-grass with tall slender culms, the feathery racemes in pairs, the rachis flexuous, the short common peduncle and usually the lower part of the racemes inclosed in the inflated sheathing bract,

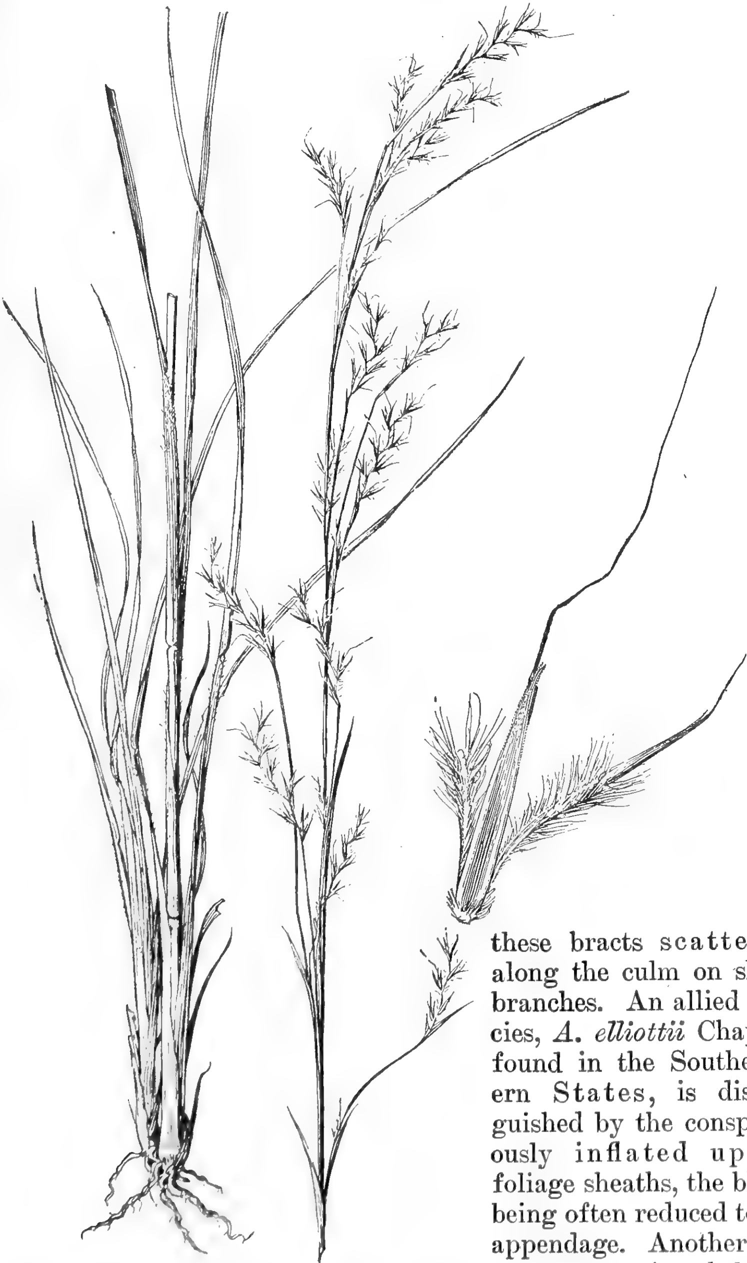

FIG. 158.—Little bluestem, *Andropogon scoparius.* Plant, × ½; pair of spikelets with joint of rachis (at left), × 5.

these bracts scattered along the culm on short branches. An allied species, *A. elliottii* Chapm., found in the Southeastern States, is distinguished by the conspicuously inflated upper foliage sheaths, the blade being often reduced to an appendage. Another important species, belonging to this group but differing in aspect from the

FIG. 159.—Broom sedge, *Andropogon virginicus*. Plant × ½; pair of spikelets with joint of rachis (at left), the second spikelet obsolete, the hairy pedicel only present, × 5.

last, is *A. furcatus* Muhl. (Pl. XIX; fig. 160). This grows throughout the eastern half of the United States and is an important forage grass in the western portion of its range. Here it is the chief constituent of prairie hay and is known as big bluestem. It is a tall, usually purplish bunch-grass, the racemes only slightly hairy, borne in twos to fours at the ends of the culms and the short branches, the rachis strict. In the Great Plains, grasses are popularly divided into tall grasses and short grasses. The former, of which *A. furcatus* is the most important, are found chiefly in the valleys and draws; the latter, including buffalo grass and grama grass, are found on the uplands. The third group of Andropogon is represented in this country by only three species, all extending northward from Mexico into the Southwestern States. The very hairy or feathery racemes are crowded in an oblong or somewhat flabellate white panicle terminating the main culm and its branches. One of these, *A. saccharoides* Swartz (fig. 161) (*A. argenteus* DC., *A. barbinodis* Lag.), is distinguished by the bearded nodes. *Andropogon saccharoides laguroides* (DC.) Hack. (*A. torreyanus* Steud.), with more slender culms and smooth nodes, is found as far north as Kansas. Another species of the group, *A. perforatus* Trin., of Mexico, rare in this country, differs in having a little pinhole or pit in the first glume.

An allied group of grasses is of importance in tropical parts of the Old World because of the essential oils obtained from them. They are included in Andropogon by some authors, but are referred by others to Cymbopogon. A full account of these grasses is given by Stapf.[1] The most important are citronella grass (*Andropogon nardus* L.; *Cymbopogon nardus* Rendle) and lemon grass (*Andropogon citratus* DC., *Cymbopogon citratus* Stapf). These are robust grasses with large compound inflorescences, the small racemes in pairs, each pair partly included in a sheathing spathe.

An allied genus, Anatherum Beauv., is represented by a single species, *A. zizanioides* (L.) Hitchc. and Chase (*Andropogon muricatus* Retz.; *Vetiveria zizanioides* Nash). This Old World grass is frequently cultivated in tropical America for hedges and for the aromatic roots, which are used for making screens and mats to perfume the air of houses. These roots readily impart perfume when wet. The grass is called vetiver, khus-khus, and khas-khas. It has escaped from cultivation in Louisiana. Vetiver is a robust grass with a large erect panicle, the slender whorled branches ascending, naked at the base, the awnless spikelets muricate.

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[1] Bull. Misc. Inf. Kew **1906**: 297. 1906.

FIG. 160.—Big bluestem, *Andropogon furcatus*. Plant, × ½; pair of spikelets with joint of rachis, × 5.

BLUESTEM (ANDROPOGON FURCATUS).

Rocky banks of the Potomac. A valuable forage grass on the prairies of the Mississippi Valley.

GAMA GRASS (TRIPSACUM DACTYLOIDES). NEAR WASHINGTON, D. C.

FIG. 161.—*Andropogon saccharoides.* Plant, × ½; pair of spikelets with joint of rachis (at left), the pedicellate spikelet showing a little at right, × 5.

Arthraxon Beauv., Ess. Agrost. 111. 1812. Type species, *A. ciliaris* Beauv. This Old World genus is represented in North America by *A. quartinianus* (A. Rich.) Nash, introduced into Jamaica and Guadaloupe, and by *A. ciliaris cryptatherus* Hack., established in the vicinity of Washington, D. C. The latter is a creeping slender grass with thin cordate-lanceolate blades, the inflorescence of several slender racemes in a cluster.

133. Holcus L.
(*Sorghum* Pers.)

Spikelets in pairs, one sessile and fertile, the other pedicellate, sterile but well developed, usually staminate, the terminal sessile spikelet with two pedicellate spikelets.

Annual or perennial, tall or moderately tall grasses, with flat blades and terminal panicles of 1 to 5 jointed tardily disarticulating racemes. Species about six, one Mexican, the others in the Old World; two cultivated or introduced into America.

Type species: *Holcus sorghum* L.

Holcus L., Sp. Pl. 1047, 1753; Gen. Pl., ed. 5, 469. 1754. Linnæus describes seven species, *H. sorghum*, *H. saccharatus*, *H. halepensis*, *H. lanatus*, *H. odoratus*, *H. laxus*, and *H. striatus*. The selection of the type species is of particular importance in this genus, because it affects the generic name of the group containing the cultivated sorghums. The first three of the original seven species were segregated from the others in 1763 by Adanson, who applied to them the old name sorghum, used by Bauhin and other pre-Linnæan authors for the cultivated sorghums. This name was accepted by most of those subsequent authors who recognized the group as a genus distinct from Andropogon, and as a subgeneric name by those who held it to be a subgenus of Andropogon. Of the remaining four of the original seven species of Holcus all but *H. lanatus* were early assigned to other genera, leaving *H. lanatus* in possession of the generic name and in effect making this residual species the type of the genus. Linnæus, however, in all the editions of the Genera Plantarum and in the Hortus Cliffortianus and the Hortus Upsaliensis used the name Holcus for sorghum only. The description and the synonymy in all cases apply only to the first three of the seven species included in the Species Plantarum. Moreover, in all the editions of the Genera Plantarum Linnæus cites "Sorgum Mich." While Micheli[1] gives no description or figure of the genus, we know from Bauhin and others that Sorgum or Sorghum was in common use for the group in question. Linnæus uses the old name Sorghum for the trivial or specific name of the first species, and cites Sorghum of Bauhin as a synonym. It is clear that the Holcus of Linnæus is the old Sorghum, the other four diverse species (which do not agree with the generic descriptions in any of the works cited), evidently being appended for want of a place to put them. According to the American Code the genera of Linnæus's Species Plantarum are to be typified through citations given in his Genera Plantarum of 1754. The reference to Micheli, the use of sorghum as a specific name, and the descriptions all point to *H. sorghum* as the type of the genus Holcus. *Holcus lanatus* is now referred to Notholcus, *H. odoratus* to Torresia (Hierochloë, Savastana), *H. laxus* to Uniola, and *H. striatus* to Sacciolepis. By many authors the genus Holcus as here understood is included under Andropogon.

Blumenbachia Koel., Descr. Gram. 28. 1802. A single species, "B. halepensis," based on "Holcus Haleppensis Linn." is included.

Sorghum Pers., Syn. Pl. **1**: 101. 1805. Four species are included. *Holcus sorghum* L., upon which *S. vulgare* Pers. is based, is taken as the type.

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[1] Nov. Plant. Gen. 35. 1729.

Holcus sorghum L. (*Andropogon sorghum* Brot.; *Sorghum vulgare* Pers.) has been cultivated from prehistoric times[1] for the seed, which has been used for food, for the sweet juice, and for forage. In the United States it is cultivated under the general name of sorghum or sorgo. There are many races and varieties, the chief of which are sorgo, kafir, milo, broom corn, shallu, kaoliang, and durra. Sorgo includes the varieties with sweet juice, these varieties often being known collectively as saccharine sorghums.

In this country sorgo is cultivated, chiefly in the region from Kansas to North Carolina, for the juice which is made into sirup and for foliage which is used for fodder in the Southern States, especially in the region from Kansas to Texas, where it is often called "cane." The other races of sorghum are often classed together as nonsaccharine sorghums. The large panicles of one race, broom corn, grown especially in Illinois, furnish the material for brooms. The other races are used for forage or for the seed, which is used for feed. Kafir, milo, and a recently introduced variety, feterita, are of especial value in the southern part of the Great Plains and other semiarid regions where dry-land farming is practiced. Kafir, or Kafir corn, is a rather low form with compact cylindric heads and awnless spikelets. Milo, or milo maize, is a usually taller form, with ovate heads, a straight or recurved peduncle, awned spikelets, and larger seeds. Durra differs from milo in having densely pubescent grayish or greenish glumes (instead of brown or black and slightly pubescent), and strongly flattened seeds. Some of these forms are called Egyptian corn, chicken corn, and Jerusalem corn. The name chicken corn should be restricted to a variety spontaneous in Louisiana and Mississippi (*Holcus sorghum drummondii* (Nees) Hitchc., *Andropogon drummondii* Nees, *A. sorghum drummondii* Hack.). A recently introduced variety, *Holcus sorghum sudanensis* (Piper) Hitchc. (*Andropogon sorghum sudanensis* Piper), is now extensively cultivated for hay in the semiarid regions under the name of Sudan grass. This is a rather slender annual, 6 to 9 feet tall, the panicle open and spreading. The absence of rhizomes shows its affinity to sorgo. Tunis grass is an allied variety (*Holcus sorghum exiguus* (Forsk.) Hitchc., *Holcus exiguus* Forsk., *Andropogon sorghum exiguus* Piper) that has been tried in our Southern States.

The second species of Holcus found in the United States is *H. halepensis* L. (fig. 162), known as Johnson grass. This is a perennial with stout creeping rhizomes. The panicle is open and spreading, the spikelets awned or awnless. Johnson grass is not so tall as the open-panicled forms of sorghum, being usually 3 to 5 feet tall, and

[1] For a history and classification of sorghum, see Ball, U. S. Dept. Agr., Bur. Pl. Ind. Bull. 175. 1910.

FIG. 162.—Johnson grass, *Holcus halepensis*. Plant, × ½; two views of terminal raceme, one of the pedicellate spikelets fallen, × 5.

has narrower blades than plants of sorghum of the same height. The characteriscic difference is the presence of the creeping rhizomes in the former. Johnson grass is a native of the Mediterranean region, but is now widely distributed in the warmer parts of America. In the United States it is common throughout the South, where it is often a troublesome weed. It is an excellent and much-used forage grass, but the difficulty of eradicating it from ground that it has once occupied offsets its forage value. Johnson grass has become an especially pernicious weed on the Black Lands of Alabama and Texas.[1]

The sorghums and Johnson grass sometimes produce hydrocyanic acid in sufficient abundance, especially in second growth, to poison grazing animals.

134. Sorghastrum Nash.

Spikelets in pairs, one nearly terete, sessile, and fertile, the other wanting, only the hairy pedicel being present; glumes coriaceous, brown or yellowish, the first hirsute, the edges inflexed over the second; sterile and fertile lemmas thin and hyaline, the latter extending into a usually well-developed bent and twisted awn.

Perennial, erect, rather tall grasses, with narrow flat blades and narrow terminal panicles of one to few jointed racemes. Species about 10 in the warmer parts of the Western Hemisphere, and a few in Africa; 3 species in the United States east of the Rocky Mountains.

Type species: *Andropogon avenaceus* Michx.

Poranthera Raf., Bull. Bot. Seringe **1**: 221, 1830, not Rudge, 1811. "Andropogon nutans [L.] et ciliatus [Ell.])" are cited. These names apply to the same species, *Sorghastrum nutans* (L.) Nash.

Sorghastrum Nash, in Britton, Man. 71. 1901. Only one species described. *S. avenaceum* (Michx.) Nash.

Chalcoelytrum Lunell, Amer. Midl. Nat. **4**: 212. 1915. The name proposed to replace Sorghastrum Nash, which, being built on Sorghum, is considered undesirable.

The units of the inflorescence are racemes reduced to one or two joints, or in *Sorghastrum nutans* sometimes four or five. The slender, villous rachis disarticulates at the top of each joint, the spikelets falling with two villous stalks attached, one the rachis joint, the other the pedicel of the obsolete sterile spikelet. The articulation is more or less oblique, leaving a bearded blunt callus or, in some South American species, a long, sharp callus. In *S. nutans* the racemes not infrequently occur in pairs with a sessile spikelet in the fork, that is, the pedicel of the sterile spikelet of the lowest joint has been replaced by a short raceme of one or two joints.

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[1] For methods of eradication, see Cates and Spillman, U. S. Dept. Agr., Farmers' Bull. 279. 1907.

The commonest species of the genus in the United States is *Sorghastrum nutans* (L.) Nash (fig. 163), sometimes called Indian reed or Indian grass. This is a tall, erect grass with handsome bronze-colored panicles as much as a foot long, the awns about half an inch long, the anthers brilliant yellow. The species is found in prairies and open woods throughout the eastern United States and southwestward to Arizona and Mexico. It is a common constituent of prairie hay in the eastern part of the Great Plains region.

Two other species are found in the Southern States, both with awns about an inch long, *Sorghastrum elliottii* (C. Mohr) Nash, with pedicels villous only at the very tip, and *S. secundum* (Chapm.) Nash, with a one-sided panicle and pedicels villous along the upper portion.

135. Rhaphis Lour.

Spikelets in threes, one sessile and perfect, the other two pedicellate and sterile, or sometimes a pair below, one fertile and one sterile; fertile spikelet terete, the glumes coriaceous; sterile and fertile lemmas thin and hyaline, the latter long-awned.

Perennial grasses, or our species annual, with open panicles, the three spikelets (reduced racemes) borne at the ends of long, slender, naked branches. Species about 20, all in the tropical regions of the Eastern Hemisphere except the 1 found in the southern United States.

Type species: *Rhaphis trivialis* Lour.

Rhaphis Lour., Fl. Cochinch. 553. 1790. Only one species described, which is the same as *Andropogon aciculatus* Retz. Some authors have thought the name Rhaphis was invalidated by the earlier Rhapis L. f. (1789), a genus of palms. The names have a different derivation and a different pronunciation, and the one does not invalidate the other.

Pollinia Spreng., Pugill. 2: 10, 1815, not Pollinia Trin., 1832. Type species, *P. gryllus* Spreng. (*Andropogon gryllus* L.). Several species are described, but the generic characters are given under the first species.

Centrophorum Trin., Fund. Agrost. 106, pl. 5. 1820. Type species, *C. chinense* Trin. (*Andropogon aciculatus* Retz.), the only one described.

Chrysopogon Trin., Fund. Agrost. 187. 1820. Type species, *Andropogon gryllus* L. Two species are mentioned, *C. gryllus* and *C. aciculatus*, but an illustration of the first is cited.

The only species occurring in the United States is *Rhaphis pauciflora* (Chapm.) Nash (fig. 164), an annual found in Florida and Cuba. This has the aspect of a species of Stipa, the spikelets with their long awns and barbed callus resembling the fruit of *Stipa spartea.* The long slender branches of the few-flowered panicle bear a terete, brown, sessile fertile spikelet and two slender sterile pedicels, each with a slender glume. The peduncle disarticulates by a long oblique line through the thickened villous end, the portion separating with the spikelet being densely brown-villous, this forming a long sharp callus. The glumes are coriaceous and at maturity separate somewhat, the spikelet gaping at the apex. The palea is present, but

FIG. 163.—Indian grass, *Sorghastrum nutans*. Plant, × ½; spikelet with pedicel at left and rachis joint at right, × 5.

FIG. 164.—*Rhaphis pauciflora.* Plant with old spikelet still attached to roots, × ½; fruiting fertile spikelet, × 5.

much shorter than the very thin sterile and fertile lemmas. The awn is about 6 inches long, twisted and bent. The species before maturity furnishes forage on the grassy pinelands of southern Florida.

136. HETEROPOGON Pers.

Spikelets in pairs, one sessile, the other pedicellate, both of the lower few to several pairs staminate or neuter, the remainder of the sessile spikelets perfect, terete, long-awned, the pedicellate spikelets, like the lower, staminate, flat, conspicuous, awnless; glumes of the fertile spikelet equal, coriaceous, the first brown-hirsute, infolding the second; lemmas thin and hyaline, the fertile one narrow, extending into a strong bent and twisted brown awn; palea wanting; glumes of the staminate spikelet membranaceous, the first green, faintly many nerved, asymmetric, one submarginal keel rather broadly winged, the other wingless, the margins inflexed, the second glume narrower, symmetric; lemmas hyaline; palea wanting.

Annual or perennial, often robust grasses, with flat blades and solitary racemes terminal on the culms and branches; rachis slender, the lower part, bearing the pairs of staminate spikelets, continuous, the remainder disarticulating obliquely at the base of each joint, the joint forming a sharp barbed callus below the fertile spikelet, the pedicellate spikelet readily falling, its pedicel remaining, obscured in the hairs of the callus. Species about seven, in the warmer regions of both hemispheres; two in the United States, from Florida to Arizona.

Type species: *Heteropogon glaber* Pers.

Heteropogon Pers., Syn. Pl. 2: 533. 1807. Persoon describes two species, *H. glaber*, of which he gives as synonyms *Andropogon allioni* DC. and *A. contortus* All., and *H. hirtus*, of which he gives as a synonym *Andropogon contortus* L. The first is selected as the type.

Spirotheros Raf., Bull. Bot. Seringe 1: 221. 1830. A single species, "*Stipa melanocarpa* Muhl., *Andropogon melanocarpus* Ell.," is given.

The two species in the United States are *Heteropogon contortus* (L.) Beauv. (fig. 165), a perennial, 1 to 3 feet tall, the first glume of the staminate spikelets papillose-pilose, sometimes sparsely so, and *H. melanocarpus* (Ell.) Benth., an annual, 4 to 7 feet tall and often much branched, the first glume of the staminate spikelets bearing a row of glands along the back. The first species is found in rocky places from Texas to Arizona. The second is found in Florida, Georgia, and Alabama; also in Arizona. The oil glands on the inflorescence of the latter give the plant an odor like that of citronella oil.

Heteropogon contortus is an important forage grass but does not extend far into the United States. In the Hawaiian Islands, where it is called pili, it is an important range grass on the drier areas. It was used by the natives to thatch their grass huts. The mature fruits are injurious to sheep.

FIG. 165.—*Heteropogon contortus*. Plant, × ½; fruiting fertile spikelet, × 5.

137. Trachypogon Nees.

Spikelets in pairs, along a slender continuous rachis, one nearly sessile, staminate, awnless, the other pedicellate, perfect, long-awned; the pedicel of the perfect spikelet obliquely disarticulating near the base, forming a sharp barbed callus below the spikelet; first glume firm-membranaceous, rounded on the back, several-nerved, obtuse; second glume firm, obscurely nerved; fertile lemma narrow, extending into a stout twisted and bent or flexuous awn; palea obsolete; sessile spikelet persistent, as large as the fertile spikelet and similar but awnless.

Perennial, moderately tall grasses, with terminal spikelike racemes, these single or clustered. Species about seven, Mexico to South America, one extending into the southwestern United States.

Type species: *Andropogon montufari* H. B. K.
Trachypogon Nees, Agrost. Bras. 341. 1829. The first of the 13 species described, *T. montufari*, based on *Andropogon montufari*, is selected as the type. The first five species are all that are now retained in Trachypogon.

Our only species is *Trachypogon montufari* (H. B. K.) Nees (fig. 166), found in southern Arizona and southwestern New Mexico, an erect slender perennial with solitary racemes, the feathery awns about 1½ inches long. It is an important constituent of the grazing areas of Central and South America.

138. Elyonurus Humb. and Bonpl.

Spikelets in pairs along a somewhat tardily disarticulating rachis, the joints and pedicels thickened and parallel, the sessile spikelets appressed to the concave side, the pedicellate spikelet staminate, similar to the sessile one, both awnless, the pair falling with a joint of the rachis; first glume firm, somewhat coriaceous, depressed on the back, the margins inflexed around the second glume, a line of balsam glands on the marginal nerves, the apex entire and acute or acuminate, or bifid with aristate teeth; second glume similar to the first; sterile and fertile lemmas thin and hyaline; palea obsolete.

Erect, moderately tall perennials, with solitary spikelike, often woolly racemes. Species about 15, in the warmer regions of both hemispheres; two species extending into our Southern States.

Type species: *Elyonurus tripsacoides* Humb. and Bonpl.
Elyonurus Humb. and Bonpl., Willd. Spec. Pl. 4: 941. 1806. Only one species is described.

Elyonurus tripsacoides (fig. 167), with inconspicuously hairy spikes, extends from Florida to Texas, and *E. barbiculmis* Hack., with conspicuously woolly spikes, is found from western Texas to Arizona. The species of Elyonurus are important grazing grasses in the savannas and plains of tropical America.

FIG. 166.—*Trachypogon montufari.* Plant, × ½; fruiting fertile spikelet, × 5.

FIG. 167.—*Elyonurus tripsacoides.* Plant, × ½; two views of a pair of spikelets with a joint of the rachis, × 5.

139. MANISURIS L.
(*Rottboellia* L. f.)

Spikelets awnless, in pairs at the nodes of a thickened articulate rachis, one sessile and fertile, the other pedicellate and sterile, the pedicel thickened and appressed to the rachis, the sessile spikelet fitting closely against the rachis, forming a cylindric or subcylindric spike; glumes obtuse, awnless, the first coriaceous, fitting over the hollow containing the spikelet, the second less coriaceous than the first; sterile lemma, fertile lemma, and palea thin and hyaline, inclosed within the glumes; pedicellate spikelet reduced, often rudimentary.

Perennial slender, moderately tall, or tall grasses, with usually numerous smooth cylindric or flattened spikes, single on the culms and branches. Species about 30, in the warm regions of both hemispheres; 5 in the southern United States.

Type species: *Manisuris myuros* L.

Manisuris L., Mant. Pl. 2: 164. 1771. Only one species described.

Rottboellia L. f., Nov. Gram. Gen. 22, pl. 1, 1779 (Amoen, Acad. 10. 1790), not Scop., 1777. In a note appended to the description of the genus is the statement, "Huc pertinent Aegilops Incurvata & Exaltata S. N., p. 762, aeque ac Panicum Dimidiatum S. N., p. 90." The second species, being the one illustrated, is the type.

Stegosia Lour., Fl. Cochinch. 1: 51. 1790. Type, *S. cochinchinensis* Lour., the only species described.

Hemarthria R. Br., Prodr. Fl. Nov. Holl. 207. 1810. Two species described, *H. compressa* and *H. uncinata.* The first species, based upon *Rottboellia compressa* L. f., is chosen as the type.

Lodicularia Beauv., Ess. Agrost. 108, pl. 21, f. 6. 1812. A single species is included, *L. fasciculata*, based on *Rottboellia fasciculata* Desf. (*R. fasciculata* Lam. evidently intended).

Coelorhachis Brongn., in Duperr. Bot. Voy. Coquille 64. 1829. The type is *Aegilops muricata* Retz., on which is based *Coelorhachis muricata*, the only species described.

The species of Manisuris found in the United States are nowhere abundant and are of little economic importance, though they may furnish some forage. *Manisuris fasciculata* (Lam.) Hitchc. has flattened spikes. The other three species have cylindric spikes. In these the first glume is variously marked, being somewhat pitted in *M. cylindrica* (Michx.) Kuntze (fig. 168), tessellate in *M. tessellata* (Steud.) Scribn., and transversely wrinkled in *M. rugosa* (Nutt.) Kuntze.

140. RYTILIX Raf.
(*Hackelochloa* Kuntze, *Manisuris* of authors.)

Spikelets awnless, in pairs, the rachis joint and pedicel grown together, the two clasped between the edges of the globose alveolate first glume of the sessile spikelet; pedicellate spikelet conspicuous, staminate.

A much-branched annual with flat blades, the numerous spikes single and more or less inclosed in the sheathing bract, these some-

FIG. 168.—*Manisuris cylindrica.* Plant, × ½; sessile spikelet and joint of rachis, × 5; joint of rachis with sterile pedicel and rudimentary spikelet, the fertile spikelet at right, × 5.

what clustered in the axils of the foliage leaves. Species one, in the tropical regions of the world.

Type species: *Manisuris granularis* Swartz.

Rytilix Raf., Bull. Bot. Seringe **1**: 219. 1830. Rafinesque cites "Manisuris granularis et Myurus Auct." and lists one species *Rytilix glandulosa.* The first species cited is chosen as the type.

Hackelochloa Kuntze, Rev. Gen. Pl. **2**: 776. 1891. Kuntze restores Manisuris to its Linnæan sense and, overlooking Rytilix Raf., proposes Hackelochloa for Manisuris Swartz, with *H. granularis*, based on *Cenchrus granularis*, as the type.

Rytilix granularis (L.) Skeels (fig. 169) is a tropical weed which extends into the United States from Florida to Arizona. The little pitted globose spikelets are very characteristic.

FIG. 169.—*Rytilix granularis.* Plant, × ½; a single raceme, × 2; two views of a pair of spikelets with joint of rachis and pedicel grown together, × 5.

14. TRIPSACEAE, THE CORN TRIBE.

141. Tripsacum L.

Spikelets unisexual; staminate spikelets 2-flowered, in pairs on one side of a continuous rachis, one sessile, the other sessile or pedicellate, similar to those of Zea, the glumes firmer; pistillate spikelets single and on opposite sides at each joint of the thick, hard articulate lower part of the same rachis, sunken in hollows in the joints, consisting of one perfect floret and a sterile lemma; first glume coriaceous, nearly infolding the spikelet, fitting into and closing the hollow of the rachis; second glume similar to the first but smaller, infolding the remainder of the spikelet; sterile lemma, fertile lemma, and palea very thin and hyaline, these progressively smaller.

Robust perennial grasses, with usually broad flat blades and monœcious terminal and axillary inflorescences of 1 to 3 spikes, the pistillate part below, breaking up into bony, seedlike joints, the staminate above on the same rachis, deciduous as a whole. Species about seven, all American, extending from the middle United States to northern South America; three species in the United States.

Type species: *Coix dactyloides* L.

Tripsacum L., Syst. Nat., ed. 10, **2**: 1261. 1759. Type the first of the two species described, *T. dactyloides*, based on *Coix dactyloides* L., and *T. hermaphroditum*. The second species, based on "Cenchrus 2, Brown. Jam. 367," is now referred to Anthephora.

Dactylodes Zanoni-Monti; Kuntze, Rev. Gen. Pl. **2**: 772. 1891. Two species are included, *D. angulatum*, based on *Coix angulatus* Mill., and *D. fasciculatum*, based on *Tripsacum fasciculatum* Trin. *Coix angulatus*, which is the same as *Tripsacum dactyloides*, is taken as the type.

The common species in the United States is *Tripsacum dactyloides* (Pl. XX; fig. 170), a robust perennial, 3 to 6 feet tall, with broad blades, the terminal spikes mostly in threes, the axillary spikes mostly solitary. This species, called gama grass, is found in moist places from Connecticut to Texas and Florida. It is a good forage grass, but is usually not abundant enough to be of much importance. A second species, *T. floridanum* Porter, with narrow blades, is found in southern Florida, and a third species, *T. lemmoni* Vasey, with pilose lower sheaths, is found in Arizona.

142. Euchlaena Schrad.

Staminate spikelets as in Zea; pistillate spikelets single, on opposite sides, sunken in cavities in the hardened joints of an obliquely articulate rachis, the indurate first glume covering the cavity; second glume membranaceous, the lemmas hyaline. Spikes infolded in foliaceous bracts or husks, 2 to several of these together inclosed in the leaf sheaths.

The one species generally recognized is *Euchlaena mexicana* Schrad., a tall annual with somewhat the aspect of corn (*Zea mays*), a native of Mexico.

Type species: *Euchlaena mexicana* Schrad.

Euchlaena Schrad., Ind. Sem. Hort. Goettingen. 1832. Only one species described. The specimen was collected by Dr. Mühlenfordt in Mexico.

The genus is little known. Several species have been proposed, but they are doubtfully distinct from *Euchlaena mexicana*. An un-

FIG. 170.—Gama grass, *Tripsacum dactyloides.* Rhizome, leaves, and inflorescence, × ½; pistillate spikelet and joint of rachis, × 5; pair of staminate spikelets with joint of rachis, × 5.

described species from Mexico is a perennial with simple culms and creeping rhizomes. A form which is supposed to be the original *E. mexicana* is cultivated occasionally in our Southern States, where it is known as teosinte (fig. 171). This is a tall, stout grass, usually branching at the base and forming large clumps. The tassel is like that of corn, and the fascicles of spikes, inclosed in husks with the long styles or silk hanging from the apex, bear a superficial resemblance to the ears of corn. Teosinte is cultivated chiefly for soiling. It has sometimes been called *Reana luxurians* Durieu.

143. Zea L., maize, Indian corn.

Spikelets unisexual; staminate spikelets 2-flowered, in pairs, on one side of a continuous rachis, one nearly sessile, the other pedicellate; glumes membranaceous, acute; lemma and palea hyaline; pistillate spikelets sessile, in pairs, consisting of one fertile floret and one sterile floret, the latter sometimes developed as a second fertile floret; glumes broad, rounded or emarginate at apex; sterile lemma similar to the fertile, the palea present; style very long and slender, stigmatic along both sides well toward the base.

A tall annual grass, with broad, conspicuously distichous blades, monœcious inflorescences, the staminate flowers in spikelike racemes, these numerous, forming large spreading panicles (tassels) terminating the stems, the pistillate inflorescence in the axils of the leaves, the spikelets in 8 to 16 or even as many as 30 rows on a thickened, almost woody axis (cob), the whole inclosed in numerous large foliaceous bracts (husks), the long styles (silk) protruding from the top as a silky mass of threads. In the common varieties of corn the floral bracts are much shorter than the kernel and remain on the cob when the kernels are shelled.[1] Species one.

Type species: *Zea mays* L.

Zea L., Sp. Pl. 971, 1753; Gen. Pl., ed. 5, 419. 1754. *Zea mays* is the only species described.

Mays Tourn., in Gaertn. Fruct. and Sem. **1**: 6, pl. 1. 1788. The single species, *M. zea* Gaertn., is the same as *Zea mays* L.

Mayzea Raf., Med. Fl. **2**: 241. 1830. Two species included. *Zea mays* L., on which the first species, *M. cerealis*, is based, is taken as the type.

In the United States *Zea mays* L. (figs. 172, 173) is usually called corn; in Europe and sometimes in America, especially in literature, it is called maize. Corn is one of the important economic plants of the world, being cultivated for food for man and domestic animals and for forage. It originated[2] in America, probably on the Mexican Plateau, and was cultivated from prehistoric times by the early

[1] For note on the structure of the maize ear as indicated in Zea-Euchlaena hybrids, see Collins, Journ. Agr. Res. **17**: 127–135. 1919.

[2] For a note on the origin of maize, see Collins, Journ. Washington Acad. Sci. **2**: 520. 1912.

FIG. 171.—Teosinte, *Euchlaena mexicana*. Sketch of plant, much reduced; pistillate inflorescence inclosed in bract (*a*) and with portion of bract removed (*b*), × 1; lateral view of joint of rachis and the fertile spikelet (*c*), × 2; dorsal view of same, showing first glume (*d*), × 2.

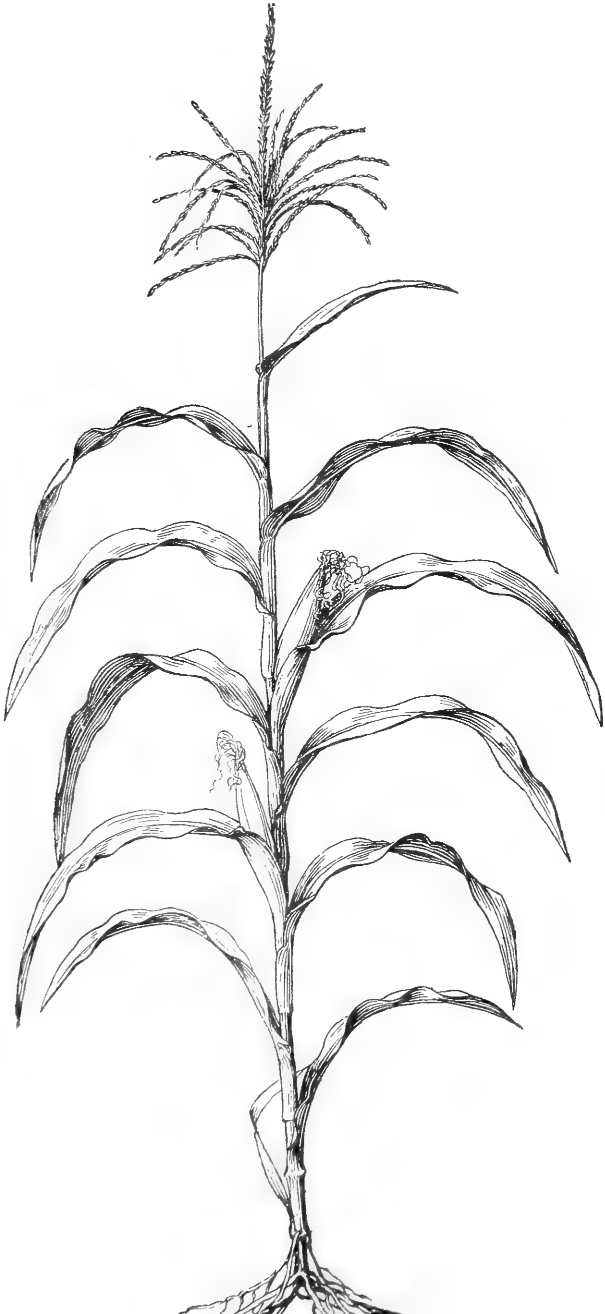

FIG. 172.—Corn, *Zea mays*. Sketch of plant, much reduced.

FIG. 173.—Corn, *Zea mays*. Pistillate inflorescence (ear) and two branches of staminate inflorescence (tassel), × ½; pair of pistillate spikelets attached to rachis (cob) with mature caryopses (grains), the second glume showing, × 2; single pistillate spikelet soon after flowering showing first (at left) and second glumes and young grain, × 2; staminate spikelet, × 2.

races of American aborigines, from Peru to middle North America. Several races of corn are grown in the United States,[1] the most important being dent, the common commercial field sort, flint, sweet, and pop. Pod corn (*Z. mays tunicata* Larr.), occasionally cultivated as a curiosity, is a variety in which each kernel is enveloped in the elongate floral bracts. A variety with variegated leaves (*Z. mays japonica* Körn.) is cultivated for ornament.

144. Coix L.

Spikelets unisexual; staminate spikelets 2-flowered, in twos or threes on the continuous rachis, the normal group consisting of a pair of sessile spikelets with a single pedicellate spikelet between, the latter sometimes reduced to a pedicel or wanting; glumes membranaceous, obscurely nerved; lemma hyaline, nearly as long as the glumes, awnless, 5-nerved; palea hyaline, a little shorter than the lemma; stamens 3; pistillate spikelets 3 together, 1 fertile and 2 sterile at the base of the inflorescence; fertile spikelet consisting of 2 glumes, 1 sterile lemma, a fertile lemma, and a palea; glumes several-nerved, hyaline below chartaceous in the upper narrow pointed part, the first very broad, infolding the spikelet, the margins infolded beyond the 2 lateral stronger pair of nerves, the second glume narrower than the first, keeled; sterile lemma about as long as the second glume, similar in shape but a little narrower, hyaline below, somewhat chartaceous above; fertile lemma hyaline, narrow, somewhat shorter than the sterile lemma; palea hyaline; narrow, shorter than the lemma; sterile spikelets consisting of a single narrow tubular glume as long as the fertile spikelet, somewhat chartaceous.

Fig. 174.—Job's-tears, *Coix lachryma-jobi.* Upper portion of plant, × 1.

[1] See Montgomery, The Corn Crops, 15, 1913: Sturtevant, U. S. Dept. Agr., Off. Exp. Sta. Bull. 57. 1899.

Tall branched grasses with broad flat blades, the monœcious inflorescences numerous on long, stout peduncles, these clustered in the axils of the leaves, each inflorescence consisting of an ovate or oval, pearly white or drab, beadlike, very hard, tardily deciduous involucre (much modified sheathing bract) containing the pistillate lower portion of the inflorescence, the points of the pistillate spikelets and the slender axis of the staminate portion of the inflorescence protruding through the orifice at the apex, the staminate upper portion of the inflorescence 2 to 4 cm. long, soon deciduous, consisting of several clusters of staminate spikelets. Species about four, one widely distributed in tropical countries, the others in the East Indies.

Type species: *Coix lachryma-jobi* L.

Coix L., Sp. Pl. 972, 1753; Gen. Pl., ed. 5, 419. 1754. Linnæus describes two species, *C. lachryma-jobi* and *C. dactyloides*. The reference in the Genera Plantarum (above cited) is to Tournefort's plate 302, which represents the first species.

Coix lachryma-jobi L. (fig. 174), known as Job's-tears and sometimes as Christ's-tears, is cultivated in all tropical countries for ornament and has escaped into waste places, especially around dwellings. It is also cultivated in greenhouses and sometimes in the open in warm temperate regions. The name Job's-tears comes from the fancied resemblance of the fruit to tears. The fruits, or so-called seeds, are used for a variety of purposes, such as beads, and for rosaries.

LIST OF NEW SPECIES AND NEW NAMES.

INDEX.

[Synonyms are in *italic* type. The page numbers of the principal entries are set in **heavy-face** type.]

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BULLETIN No. 773

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. PROFESSIONAL PAPER May 29, 1919

CHEMICAL ANALYSES OF LOGAN BLACKBERRY (LOGANBERRY) JUICES.

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CONTENTS.

THE LOGAN BLACKBERRY (LOGANBERRY).

The Logan blackberry, which is generally known as the Loganberry, originated in 1881, on the grounds of Judge J. H. Logan, of Santa Clara, Cal., who grew it from the seed of the Aughinbaugh blackberry. The seedling was supposed to be the result of hybridization between the blackberry and a red raspberry, presumably the Red Atwerp, which grew beside the blackberry parent [2, 3, 4]. Recent investigations, however, throw doubt on this view and indicate that it is a variety of the trailing blackberry common to the Pacific coast.[5] The plant is an exceedingly robust grower, showing unique foliage and cane growth, as well as fruit. The fruit, shaped like the common blackberry, is sometimes as long as 1¼ inches and of a dark color, similar to that of a dark red raspberry.[2] The berry has a characteristic flavor, resembling that of raspberries, both red and black, but more acid than either. A closely-related berry, introduced by Burbank,[2] is the "Phenomenal," which is very similar to the Logan blackberry,

[1] Credit is due R. W. Clough, of the Bureau of Chemistry, for the analytical work on the Washington Logan blackberry juices reported in this bulletin.

[2] Wickson, E. J. The California Fruits and How to Grow Them (1914), p. 417.

[3] Shinn, C. H. Garden and Forest (1894), 7: 465-6.

[4] Gardner, V. R. Biennial Crop Pest and Horticultural Report, 1911-12, pp. 59-65. Oreg. Agr. Exp. Sta.

[5] Is the Hybrid Origin of the Loganberry a Myth? Journal of Heredity (1916), 7: 504-7.

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although considered less desirable in some respects. Another trailing berry, well known on the California markets, is the Mammoth blackberry, often called a "black Loganberry." Its color is black, however, whereas the color of the Logan blackberry is red, approaching purple when very ripe. Information on the culture of the Logan blackberry and related species is given in Farmers' Bulletin 998 of this department.

As the ripe Logan blackberry is very tender and does not ship well, it usually is picked when more or less immature, thus insuring a better condition for it when shipped for retail consumption. Somewhat riper fruit may be sent to the canning factories, which, as a rule, are nearer the sources of supply.

USES OF THE LOGAN BLACKBERRY.

Because of its pleasant flavor, Logan blackberry juice is very popular as a beverage, and the berry is also used in making jams, jellies, and soda-fountain sirups. Methods of extracting and treating the juice are constantly being perfected, and this industry, already large, is growing rapidly.

Logan blackberry juice is naturally so sour that it is necessary both to dilute and to sweeten it to obtain a potable article. The addition of sugar in sufficient quantities to mask the acidity makes a product too sirupy to drink, unless the juice is at the same time diluted. The flavor and color of Logan blackberry juice permit a dilution with from 2 to 3 parts of water, and the addition of 1 part of sugar. As a rule, the sirups prepared for soda-fountain use are made by adding sugar to undiluted juices, the composition running from about 1 part of juice and 1 part of sugar to, roughly, 3 parts of juice and 1 part of sugar.

MANUFACTURE OF LOGAN BLACKBERRY JUICE.

The manufacturing processes are practically the same in all the factories inspected.

The berries are collected from the fields near the factories, and crushed as soon thereafter as possible, to prevent any molding. The crushers consist essentially of wooden rollers which run at different speeds, thus giving a tearing motion. From the crushers the pulp is delivered directly to the press cloths, in which it is folded and piled in the presses, which are of the hydraulic type. In many factories only one pressing is made, the refuse pulp being destroyed. Two systems of making a second pressing, however, are employed. In one sufficient cold water to make a workable mixture is added, and, after standing for 24 hours, this pulp-water mixture is pressed again. By the other method, the pomace is steamed in an open tank from 5 to 10 hours, which cooks it sufficiently to make a soft mass. This material is then pressed like fresh pulp. The second-pressing juices thus obtained have a high color, and are used with first-pressing juice for further blending. Often the juice from the presses is passed through a continuous sterilizer and placed in cans for storage.

Because of variations in the flavor and character of the juice at different periods of the season, all juices are blended before being bottled. This is done by racking off the cans, filtering the juice through a mechanical filter, and then sending it to the blending and mixing tanks, whence it goes to the bottling machine. After bottling the juice is pasteurized by heating it to from 165° to 180° F., for periods varying with the size of the bottles. It is then labeled for the market.

Some of the sweetened but undiluted juices have been described as "concentrated" on the commercial labels. This description is entirely unwarranted, as there is no evidence that any of them have been concentrated or evaporated, and they should properly be described as Logan blackberry sirup.

PURPOSE OF THE INVESTIGATION.

The object of the investigation herein reported was to establish methods for the detection of dilution common in commercial products made from the Logan blackberry, and to set analytical standards for such products. Before the inauguration of this work the only analyses of Logan blackberry juice appear to be those by Lewis and Brown,[1] giving merely specific gravity, acidity, and total sugar. Since then, two articles by Daughters,[2] giving analyses of the berries, the exhausted marc, and several samples of the juice, have appeared.

PREPARATION OF THE ANALYTICAL SAMPLES.

In the work conducted during the season of 1916 berries grown in Washington and Oregon were examined; during 1917 the California berries were analyzed. In 1916 the juice of fresh berries from various places, bought on the open market in Seattle, was expressed in the Seattle laboratory of the Bureau of Chemistry, filtered through cotton plugs, and immediately analyzed. These samples are represented by the numbers 76 to 87, inclusive.

The samples analyzed in the San Francisco laboratory in 1916 were of two classes—the pure expressed juices and the commercial products. The samples represented by numbers 101, 102, 112, and 114 were pressed in the presence of a Government inspector, and are, therefore, known to be pure juices; Nos. 107, 108, 111, 116, 119, and 120, although not pressed in the presence of an inspector, are believed to be

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[1] Lewis, C. I., and Brown, F. R., Oregon Agr. Expt. Sta. Bul. 117.

[2] Daughters, M. R., J. Ind. Eng. Chem. (1917), *9*: 1043; (1918) *10*: 30.

pure juices. The samples analyzed in the San Francisco laboratory in 1917 were prepared as follows:

The Logan blackberries, bought in various California wholesale markets, were pressed as soon as they were received at the laboratory, the expressed juice filtered through cotton plugs, and pasteurized in glass bottles by being heated to about 80° C. and held at that temperature for an hour. The juices kept very well and at the time of analysis showed no signs of fermentation.

METHODS OF ANALYSIS.

SOLIDS.

Ten cubic centimeters of juice or diluted sample was evaporated with about 10 grams of sand, on a water bath, to apparent dryness, and then dried in vacuum for from 10 to 14 hours at 70° C., at about 70 millimeters pressure. This gave approximately 1 gram of dried material to be weighed. For comparison, the total solids by the indirect method, calculated from the specific gravity of the juices, using the wine extract tables,[1] are given. In the case of the samples analyzed in the Seattle laboratory, the solids were determined by the indirect method, from the specific gravity, using the tables for the extract in wine.[1] The solids also were determined by direct drying at the temperature of boiling water, but the figures thus obtained varied so much from the figures obtained by the other methods that they are not included in the tables.

NONSUGAR SOLIDS.

The nonsugar solids were calculated as the difference between the total solids in vacuum and the total sugars. The nonsugar solids of the samples analyzed in Seattle were obtained by subtracting the total sugars from the total solids determined by the indirect method.

SUGARS.

The sugars were determined on suitable dilutions of the sample before and after inversion, by copper reduction methods, using Munson and Walker's tables.[2]

ASH.

Twenty-five cubic centimeters of juice, or 25 grams of sweetened product, was ashed directly in platinum. In 1916, the ash was separated into water-soluble and water-insoluble ash, and the respective amounts of each and their alkalinites determined. As this seemed to supply little information, no such separation was made in 1917.

[1] U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 218. [2] Idem, 234.

TOTAL P_2O_5 IN ASH.

This determination was made by the optional volumetric method.[1]

TOTAL ACIDITY.

Ten cubic centimeters of juice was diluted with 50 cubic centimeters of boiled distilled water, and titrated with N/10 alkali, using neutral litmus paper outside the flask as an indicator. The mixture of dry phenolphthalein and sodium sulphate[2] was not satisfactory as an outside indicator, because of the deep color of the samples.

The total acidity of the samples analyzed in Seattle was determined by using azolitmin as an indicator, and the volatile acidity was taken as the difference between the total and fixed acidity.

ADDED SUGAR.

Because of the presence of large amounts of added sugar in the commercial beverages and sirups, weight dilutions of these materials were made, and the analyses carried out on the dilute solutions. For sirups, the most convenient dilutions were from 50 to 100 grams, made up to 500 cubic centimeters.

ORGANIC ACIDS.

The organic acids in a number of samples were determined by the following method: After a preliminary precipitation of the pectins, etc., by alcohol, in a 25-cubic-centimeter portion of the juice, the filtered solution was neutralized with a strong barium hydroxid solution, and an excess of barium acetate added. Coagulation of the barium salts was effected by heating the material on a water bath for from 1 to 2 hours. The barium salts were filtered off, and washed with 95 per cent alcohol.

For the determination of *citric acid*, the barium salts were decomposed with a slight excess of 1:4 sulphuric acid, and the Künz method[3] applied. The values for citric acid thus obtained are practically the same as those for the total acidity by titration, calculated to citric acid.

For *malic* and *tartaric acids* separate portions of the barium salts, prepared as described, were decomposed by heating the material with an excess of sodium sulphate. A test for malic acid was made by the polariscope method.[3] No evidence of the presence of this acid was found.

For *tartaric acid* the barium salts, prepared as already described, were decomposed with sodium sulphate, the solution concentrated to

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 4. [2] Jour. A. O. A. C. (1915) *1*, 3: 485.
[3] Jour. A. O. A. C. (1916) *2*, 2: 182.

50 cubic centimeters, and the method for total tartaric acid in wines [1] applied. No tartaric acid was detected.

Formic acid was tested for in several samples by Fincke's method.[2] Three samples tested gave from 3 to 4 milligrams of formic acid per 100 cubic centimeters.

Benzoic and *salicylic acids*, for which tests were made in the ether extract of the juices, were found to be absent.

RESULTS OF ANALYSES.

Table 1 gives the analyses of the pure Logan blackberry juices in terms of percentage by weight, and Table 2 gives them as grams per 100 cubic centimeters. The juices are classified into those of the season of 1916, which were obtained from Oregon and Washington, and those of the season of 1917, obtained from California only. The Washington and California juices were expressed from the fresh fruit in the laboratory, while the Oregon juices were obtained directly from the factories. Table 3 shows the results of the analyses of commercial beverages and sirup as they appear on the market, and Table 4 shows the approximate composition of these products as determined from Table 3. For convenience of comparison the analyses of the commercial beverages and sirup, as well as of the expressed juices, are given in terms of percentage. Because of the addition of sugar to the commercial products, a comparison on the basis of grams per 100 cubic centimeters would be difficult. The data on the pure juices most valuable for the interpretation of analyses have, therefore, been restated in terms of percentage by weight.

[1] U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 86.

[2] Jour. A. O. A. C. (1916) *2*, 1: 94.

TABLE 1.—*Analyses of pure Logan blackberry juices.*

SEASON OF 1916.

Sample No.	Source.	Specific gravity, 15.6°/15.6° C.	Solids.		Nonsugar solids.		Reducing sugar, before inversion.	Sucrose by copper.	Total ash.	Alkalinity of ash.	Total acid as citric.	P_2O_5, total.
			Indirect.[1]	In vacuo.	Direct.	Indirect.						
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Per cent.*	*Mgm. per 100 grams.*
	Washington:											
76	White River	1.046	11.42	....	....	5.74	5.68	....	0.375	57.0	2.28	28.2
77	Kent	1.042	10.45	....	....	5.41	5.04	....	.367	54.5	2.11	25.1
78	Keyport	1.042	10.45	....	....	5.37	5.08	....	.330	49.5	2.25	23.8
79	Kingston	1.045	11.18	....	....	5.99	5.19	....	.360	55.9	2.33	20.4
80	Thomas	1.0495	12.24	....	....	5.41	6.76	0.07	.328	48.4	2.12	23.0
81	Kennydale	1.0485	12.00	....	....	4.86	7.14	....	.357	48.5	1.71	18.5
82	Poulsbo	1.040	9.98	....	....	4.89	5.04	.05	.341	48.8	2.10	22.6
83	Kingston	1.0445	11.05	....	....	5.05	6.00	....	.357	49.4	1.91	17.5
84	Kennydale	1.0455	11.30	....	....	5.23	5.96	.11	.386	55.9	2.19	14.2
85	White River	1.0440	10.92	....	....	4.82	5.98	.12	.324	49.4	1.94	13.4
86	South Park	1.0460	11.42	....	....	4.79	6.52	.11	.245	39.8	1.92	15.7
87	Kent	1.0355	8.90	....	....	4.36	4.34	.20	.327	45.6	1.60	20.3
	Oregon:											
101	Salem	1.0427	10.62	9.53	2.80	3.89	6.71	.02	.341	51.8	1.76	18.0
102	Do	1.0449	11.15	9.91	3.34	4.58	6.54	.03	.428	63.2	1.92	25.2
112	Do	1.0490	12.12	10.97	3.31	4.46	7.59	.07	.434	58.7	1.79	22.9
114	Sheridan	1.0467	11.58	10.67	2.98	3.89	7.58	.11	.434	56.0	1.42	23.9
111	Eugene	1.0410	10.22	9.24	3.60	4.58	5.30	.34	.378	58.4	2.12	28.4
116	Newberg	1.0478	11.84	10.90	3.20	4.14	7.64	.06	.393	59.6	1.67	33.1
119	Cornelius	1.0470	11.65	10.99	3.26	3.92	7.68	.05	.391	55.2	1.84	28.9
108	Albany	1.0381	9.52	8.79	3.45	4.18	5.26	.08	.397	60.9	1.72	32.2
120	Cornelius (early pressing)	1.0444	11.02	10.21	3.92	4.73	6.29	.00	.428	60.3	2.27	32.1
107	Salem (5 months in tin)	1.0380	9.50	9.27	3.88	4.11	5.34	.05	.339	55.5	2.00	20.4
	Maximum	1.0495	12.24	10.99	3.92	5.99	7.68	.34	.434	63.2	2.33	33.1
	Minimum	1.0355	8.90	9.24	2.80	3.89	4.34	.02	.245	45.6	1.42	13.4
	Average	1.0454	10.93	10.05	3.37	4.75	6.12	.10	.366	54.7	1.96	22.6
103	Second pressing of No. 102	1.0235	5.95	5.26	2.36	3.05	2.86	.04	.320	42.5	1.29	28.3
117	Second pressing of No. 116	1.0238	6.02	5.69	2.40	2.40	3.25	.04	.264	36.9	.88	26.2

[1] From Table VI, U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 221.

TABLE 1.—*Analyses of pure Logan blackberry juices*—Continued.

SEASON OF 1917.

Sample No.	Source.	Specific gravity, 15.6°/15.6° C.	Solids.		Nonsugar solids.		Reducing sugar, before inversion.	Sucrose by copper.	Total ash.	Alkalinity of ash.	Total acid as citric.	P_2O_5, total.
			Indirect.	In vacuo.	Direct.	Indirect.						
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Per cent.*	*Mgm. per 100 grams.*
	California:											
1734	Sebastopol	1.0488	12.08	11.12	3.73	4.69	7.39	.00	.459	64.2	1.82	26.7
3889	Watsonville	1.0454	11.28	10.22	3.06	4.08	7.11	.09	.446	60.8	1.58	30.6
3892	San Carlos	1.0412	10.28	9.18	3.13	4.23	6.00	.05	.626	61.2	1.50	34.1
3893	San Jose	1.0438	10.88	9.77	3.65	4.75	6.08	.05	.560	72.9	1.93	35.2
3895	Lawrence	1.0484	11.98	10.61	3.43	4.80	7.09	.09	.434	71.3	1.85	36.0
3896	Sebastopol	1.0431	11.72	9.81	3.74	5.65	6.05	.02	.460	68.8	1.96	20.6
3898	Watsonville	1.0407	10.16	9.21	3.53	4.48	5.61	.07	.467	61.5	1.88	33.1
4656	Gardena	1.0384	9.60	8.72	3.54	4.43	5.11	.06	.480	62.4	1.96	31.5
4657	Puento	1.0396	9.88	9.07	3.39	4.12	5.68	.10	.507	70.4	1.06	40.3
	Maximum	1.0488	12.08	11.12	3.74	5.65	7.39	.10	.626	72.9	1.96	40.3
	Minimum	1.0384	9.60	8.72	3.06	4.08	5.11	.02	.434	60.8	1.06	20.6
	Average	1.0433	10.87	9.75	3.47	4.58	6.23	.06	.493	65.9	1.73	32.0

TABLE 2.—*Analyses of pure Logan blackberry juices.*

SEASON OF 1916.

Sample No.	Source.	Specific gravity, 15.6°/15.6° C.	Solids. Indirect.[1]	Solids. In vacuo.	Nonsugar solids. Direct.	Nonsugar solids. Indirect.	Reducing sugar before inversion.	Sucrose by copper.	Total ash.	Alkalinity of ash.	Alkalinity number of ash.[2]	Total acid as citric.	P_2O_5 in ash.	Citric acid.[3]
			Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Cc N/10 acid per 100 grams*	*Cc N acid per gram.*	*Grams per 100 cc.*	*Mgm. per 100 cc.*	*Grams per 100 cc.*
	Washington:													
76	White River	1.046	11.91	....	....	5.97	5.94	....	0.392	59.6	15.2	2.38	29.5	....
77	Kent	1.042	10.87	....	....	5.62	5.25	....	.382	56.8	14.9	2.20	26.2	....
78	Keyport	1.042	10.87	....	....	5.58	5.29	....	.344	51.6	15.0	2.35	24.8	....
79	Kingston	1.045	10.65	....	....	6.25	5.40	....	.376	58.4	15.5	2.43	21.3	....
80	Thomas	1.0495	12.82	....	....	5.66	7.09	0.07	.344	50.8	14.8	2.23	24.1	....
81	Kennydale	1.0485	12.56	....	....	5.07	7.49	....	.374	50.8	13.6	1.79	19.4	....
82	Poulsbo	1.040	10.35	....	....	5.06	5.24	.05	.355	50.8	14.3	2.18	23.5	....
83	Kingston	1.0445	11.52	....	....	5.25	6.27	....	.373	51.6	13.8	2.00	18.3	....
84	Kennydale	1.0455	11.78	....	....	5.43	6.23	.12	.404	58.4	14.4	2.29	14.9	....
85	White River	1.0440	11.39	....	....	5.03	6.24	.12	.338	51.6	15.3	2.03	14.0	....
86	South Park	1.0460	11.91	....	....	4.98	6.82	.11	.256	41.6	16.3	2.01	16.4	....
87	Kent	1.0355	9.18	....	....	4.49	4.49	.20	.339	47.2	13.9	1.66	21.0	....
	Oregon:													
101	Salem	1.0427	11.27	9.94	2.92	4.25	7.00	.02	.355	54.0	15.2	1.84	18.8	1.72
102	Do	1.0449	11.62	10.36	3.50	4.76	6.83	.03	.447	66.0	14.7	2.01	26.3	2.08
112	Do	1.0490	12.69	11.51	3.47	4.66	7.96	.07	.455	61.6	13.5	1.88	24.0	....
114	Sheridan	1.0467	12.09	11.17	3.13	4.05	7.93	.11	.454	59.4	13.0	1.49	25.0	....
111	Eugene	1.0410	10.61	9.62	3.75	4.74	5.52	.35	.393	60.8	15.5	2.21	29.6	....
116	Newberg	1.0478	12.38	11.42	3.36	4.32	8.00	.06	.412	62.4	15.1	1.75	34.7	1.81
119	Cornelius	1.0470	12.17	11.51	3.42	4.08	8.04	.05	.409	57.8	14.2	1.93	30.3	....
108	Albany	1.0381	9.86	9.13	3.59	4.32	5.46	.08	.412	63.2	15.3	1.79	33.4	....
120	Cornelius (early pressing)	1.0444	11.49	10.66	4.09	4.92	6.57	.00	.447	63.0	14.1	2.37	33.5	....
[4] 107	Salem (5 months in tin)	1.0404	10.45	9.62	4.03	4.86	5.54	.05	.352	57.6	16.3	2.08	21.2	....
	Maximum	1.0495	12.82	11.51	4.09	6.25	8.04	.35	.455	66.0	16.3	2.43	34.7	....
	Minimum	1.0355	9.18	9.13	2.92	4.08	4.49	.00	.256	41.6	13.0	1.66	14.0	....
	Average	1.0440	11.36	10.49	3.53	4.97	6.39	.08	.382	56.1	14.4	2.04	24.1	....
[5] 103	Second pressing of No. 102	1.0235	6.07	5.38	2.40	3.10	2.93	.04	.328	43.5	13.2	1.32	29.0	1.13
117	Second pressing of No. 116	1.0238	6.15	5.83	2.46	2.78	3.33	.04	.270	37.8	13.9	.90	26.8	.81

[1] From Table V, U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 218.
[2] Buttenberg, Zts. Nahr. Genussm. (1905) *9*: 142.
[3] Künz method.
[4] This sample was held in tin 5 months (4.1 milligrams tin per 100 cc).
[5] This sample contained 0.264 gram malic acid per 100 cc. Apparently other fruit had been added.

TABLE 2.—*Analyses of pure Logan blackberry juices*—Continued.

SEASON OF 1917.

Sample No.	Source.	Specific gravity, 15.6°/15.6° C.	Solids.		Nonsugar solids.		Reducing sugar before inversion.	Sucrose by copper.	Total ash.	Alkalinity of ash.	Alkalinity number of ash.	Total acid as citric.	P_2O_5 in ash.	Citric acid.
			Indirect.	In vacuo.	Direct.	Indirect.								
			Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Cc N/10 acid per 100 grams*	*Cc N acid per gram.*	*Grams per 100 cc.*	*Mgm. per 100 cc.*	*Grams per 100 cc.*
	California.													
1734	Sebastopol	1.0488	12.64	11.66	3.91	4.89	7.75	.00	.481	67.3	14.0	1.91	28.0	....
3889	Watsonville	1.0454	11.75	10.72	3.20	4.24	7.43	.09	.466	63.5	13.6	1.65	32.0	....
3892	San Carlos	1.0412	10.66	9.56	3.26	4.36	6.25	.05	.652	63.7	9.8	1.56	35.5	....
3893	San Jose	1.0438	11.34	10.20	3.81	4.95	6.34	.05	.584	76.1	13.0	2.01	36.7	....
3895	Lawrence	1.0484	12.53	11.12	3.60	5.01	7.43	.09	.455	74.7	16.4	1.94	37.7	....
3896	Sebastopol	1.0431	11.15	10.23	3.90	4.82	6.31	.02	.480	71.8	14.9	2.04	21.5	....
3898	Watsonville	1.0407	10.53	9.58	3.67	4.62	5.84	.07	.486	64.0	13.2	1.96	34.5	....
4656	Gardena	1.0384	9.93	9.05	3.68	4.56	5.31	.06	.498	64.8	13.0	2.03	32.7	....
4657	Puento	1.0396	10.25	9.43	3.42	4.27	5.90	.11	.527	73.2	13.9	1.50	41.9	....
	Maximum	1.0488	12.64	11.66	3.91	5.01	7.75	.09	.652	76.1	16.4	2.04	41.9	....
	Minimum	1.0384	9.93	9.05	3.20	4.24	5.31	.00	.455	63.5	9.8	1.50	28.0	....
	Average	1.0433	11.19	10.17	3.61	4.63	6.51	.06	.514	68.8	13.5	1.84	33.4	....

TABLE 3.—*Analyses of commercial Loganberry juices and sirups.*

SEASON OF 1916.

Sample No.	Description from labels.	Specific gravity, 15.6°/15.6° C.	Solids.		Non-sugar solids.	Reducing sugar before inversion.	Sucrose, by copper.	Total ash.	Total alkalinity.	Alkalinity number of ash.	Total acid as citric.	Volatile acid as acetic.	P_2O_5, total.
			Indirect.[1]	In vacuo.									
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N acid per gram.*	*Per cent.*	*Per cent.*	*Mgm. per 100 grams.*
104	Loganberry juice with sugar	1.1551	35.20	35.40	3.54	12.28	19.58	0.293	31.0	10.5	1.17	0.02	18.2
105	Loganberry sirup	1.2174	47.20	47.77	1.69	14.46	30.62	.207	30.5	14.7	1.06	.01	13.5
106	Loganberry juice with sugar and water	1.0513	12.68	12.59	.43	5.99	6.17	.103	13.9	13.5	.44	.01	5.9
109	Loganberry juice with sugar	1.2549	53.96	54.07	2.79	33.25	18.03	.194	24.2	12.4	1.31	.03	19.1
110	Loganberry juice, cane sugar and water added	1.0809	19.48	19.27	1.72	8.74	8.82	.151	22.4	14.8	.92	.02	12.6
115	Logan juice, ready to drink	1.0673	16.38	16.14	2.06	5.38	8.70	.176	26.1	14.8	.66	.02	13.1
118	Logan juice, concentrated	1.1297	30.02	30.01	2.89	11.85	15.27	.281	40.0	14.2	1.12	.02	21.9
122	Loganberry juice, sugar added	1,1518	34.54	34.11	2.98	24.60	6.53	.313	44.4	14.2	1.49	.02	24.1
123	Loganberry juice, sirup added	1.0664	16.18	15.95	1.75	9.65	4.54	.171	25.0	14.6	.85	.02	10.2
124	Loganberry juice beverage	1.0709	17.20	16.99	1.71	8.73	6.55	.149	25.0	16.8	.82	.06	11.0
125	Loganberry juice, sugar added	1.1801	40.14	39.74	4.25	35.49	None.	.321	47.0	14.6	1.53	.09	22.0
121	40-60 Loganberry beverage	1.0673	16.38	16.40	1.75	7.71	7.04	.144	20.9	14.5	.68	.02	9.5
1376	Loganberry juice	1.0817	19.65	19.27	2.64	11.29	5.34	.226	33.0	14.6	.93	.04	22.4
1377	Loganberry juice sirup	1.2625	55.30	55.75	4.06	38.94	12.75	.218	33.4	15.3	1.09	.03	17.8
20335-L	Loganberry juice with sugar	1.1486	33.90	33.10	2.83	24.47	5.80	.270	40.8	15.1	1.33	.02	16.2
20337-L	....do.	1.1526	34.70	33.94	3.08	26.81	4.05	.325	48.4	14.9	1.50	.03	22.4
20329-L	Loganberry juice, diluted and sugared	1.0696	16.92	16.80	2.03	12.60	2.17	.201	29.4	14.6	.81	.02	15.0

[1] From Table VI, U. S. Dept. Agr., Bur. Chem. Bul. 107, rev., 221.

TABLE 4.—*Approximate composition of commercial Loganberry products.*

Sample No.	Description from label.	Composition.		
		Parts juice.	Parts sugar.	Parts water.
104	Loganberry juice with sugar	3	1	0
105	Loganberry sirup	3	2	0
106	Loganberry juice, with sugar and water	2	1	5
109	Loganberry juice with sugar	1	1	0
110	Loganberry juice with cane sugar and water added	3	1	2
115	Logan juice, a beverage ready to drink	5	1	4
118	Logan juice concentrated	3	1	0
121	40-60 Loganberry beverage	4	1	5
122	Pure Loganberry juice, sugar added	3	1	0
123	Loganberry juice, sirup added	5	1	4
124	Loganberry juice beverage	5	1	4
125	Loganberry juice, sugar added	2	1	0
1376	Loganberry juice	3	1	2
1377	Concentrated Loganberry juice sirup	1	1	0
20335-L	Loganberry juice with sugar	3	1	0
20337-L	Loganberry juice with sugar	3	1	0
20339-L	Loganberry juice, diluted and sugared beverage	5	1	4

DISCUSSION OF RESULTS OF ANALYSES.

The juices from berries grown in Washington and Oregon differ markedly in composition from those from fruit produced in California. There is also a very large variation in the composition of juices from fruit grown in the various parts of these States. This probably is due to the fact that in the northern section the berries are grown under heavy rainfall, whereas the land in California usually is irrigated. Apparently California juices have a somewhat higher ash content and a lower acid content than the juices from the more northern States. Observations extending over several seasons would, of course, be necessary to confirm this apparent difference.

It would seem impossible to determine exactly the amount of added water present in Logan blackberry juice. Its presence can be detected, however, and the amount roughly approximated. Table 5 gives the tentative limits suggested for the most significant determinations of Logan blackberry products. The nonsugar solids are calculated from the solids in vacuum.

TABLE 5.—*Tentative limits for Logan blackberry juices.*

Source.	Nonsugar solids.		Ash.		Acids, as citric.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Washington and Oregon	3.92	2.80	0.43	0.25	2.33	1.42
California	3.74	3.06	.63	.43	1.96	1.06

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L. O. HOWARD, Chief

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LIFE HISTORY AND HABITS OF THE MEALY PLUM APHIS.

By W. M. Davidson, *Scientific Assistant, Deciduous-Fruit Insect Investigations.*

CONTENTS.

The mealy plum aphis (*Hyalopterus arundinis* Fabricius) has been recognized for many years as an enemy of plums, prunes, and to a lesser extent apricots in California. Since 1913 it has been especially severe in some regions, notably those in which artificial control for the pear thrips (*Taeniothrips pyri* Daniel) was not practiced.

ORIGIN.

The insect is European in origin, having been first described in 1794 by Fabricius. In North America it is widely distributed. According to Lowe (3)[1] it is present in Australia and New Zealand, Van der Goot (2) reports it from Java, while the United States Bureau of Entomology has records of its occurence in Japan. Specimens in the writer's collection taken on Arundo in Peru, by Mr. E. W. Rust, late of the Bureau of Entomology, appear to belong to this species but the lack of winged forms prevents certain determination.

HOSTS AND MIGRATORY HABITS.

In California plums and prunes of the *domestica* type are the favorite hosts, but apricots and Asiatic types of plums and rarely

[1] Figures in parenthesis refer to "Literature cited" on the final page of the bulletin.

almonds are attacked also. In Europe grape, peach, and nectarine are also attacked (Lowe).

From the deciduous-fruit hosts mentioned the mealy plum aphis migrates in early summer to plants of the genera Phragmites, Typha, and Arundo, and in the late fall there is a return migration to the fruit trees. This is the normal process of migration. Occasionally the writer has seen generations of aphids persist on plum until September, a habit that Lowe (3) records as not unusual in New York State.[1] The migratory forms are winged aphids and there are strong indications that they traverse long distances in passing from host to host, as summer colonies have been found in June many miles from the nearest winter hosts. Vast numbers of migrants are produced both in spring and fall, and the production of considerable numbers of summer migrants serves to distribute the species among the summer hosts. In California Phragmites and Typha are the known alternate hosts.

INJURY.

In the early summer months the aphids occur on the foliage, often crowding together in great quantities. (Pl. I.) The lower surface of the leaf is the preferred location, but the petioles and upper surface are frequently infested. The young fruit is less commonly attacked. The infested leaves are generally curled and discolored and glisten with honeydew deposits. (Pl. II.) The ground beneath the tree is often sprinkled with the whitish shed skins dropped by the aphids. The combined effect of myriads of aphids feeding simultaneously on the tree produces fruit of small size and an early drop. In the years 1915 and 1916 an unusual midsummer apical cracking of green prunes developed in California. Morris (4), after making observations in the Santa Clara Valley in 1915, opined that this cracking was due to aphis action. In 1916 the writer made some observations in Contra Costa County. He found that whereas on the whole cracking was more general on trees that previously in the season had been heavily infested with the aphis, it occurred also in other cases on trees which had escaped infestation. He could not conclude otherwise than that the aphis was not more than a contributing, or at least not the sole cause of the apical cracking in the prunes.

[1] Blakey (1), conducting his observations at Redditch, England, found no certain migration from the winter hosts, the aphids remaining the year around on fruit trees. In this connection it is of interest to note that he found the active cycle (from hatching of stem mother to oviposition) to extend in England from the beginning of May to the middle of October, 5.5 months, whereas in California the writer found the cycle to cover a period of 9 months (Mar. 1 to Nov. 30). The longer growing period enjoyed by the trees in California is of course responsible for this condition, and it is possible that the much dryer climate of California is concerned in the summer migration of the species to plants of a semiaquatic nature. The writer has observed that the aphids tend to remain on the fruit trees later into the summer in the more humid than in the more arid localities of California, while the occurrence on May 15 of large colonies on a summer host at Salton Sea (a very arid region) suggested that the aphids were living on this host the year around.

SYNONYMS.

1794. *Aphis arundinis* Fabricius, Ent. Syst., v. 4, p. 212.
1794. *Aphis pruni* Fabricius, Ent. Syst., v. 4, p. 213.
1886. *Aphis phragmiticola* Oestlund, List Aphid. Minn., p. 44.
1911. *Hyadaphis umbellulariae* Davidson, Jour. Econ. Ent., v. 4, p. 559.

BIOLOGY.

THE EGG.

Size 0.55 by 0.27 mm. The newly laid egg is pale green, covered with conspicuous silvery filaments excreted by the oviparous female. It darkens rapidly and after about 5 days is shining black; the threads, however, remain silvery.

LOCATION ON TREES.

The eggs are laid almost invariably in the axils of lateral buds of year-old or 2-year-old wood. Rarely more than three eggs are to be found to a single bud group. Occasionally eggs are placed in small scars or wrinkles in the bark of twigs.

HATCHING.

In 1916 hatching commenced about March 4, and continued for about two weeks. At this time most prune varieties were just starting to leaf, but the Myrobalans were in full leaf; nevertheless hatching was no earlier on the latter trees than on other plums and on apricots.

THE STEM MOTHER.

DESCRIPTION.

Newly hatched.—Pale green; eyes dark red; antennæ and legs pale gray; dorsum of head with a median longitudinal narrow pale green stripe; beak gray. Form oval.

Antennæ one-fourth the length of the body, 5-jointed. Comparative lengths: I, 0.03 mm.; II, 0.035; III, 0.045; IV, 0.05; V, 0.11 (0.060 plus 0.050); beak reaching to third abdominal segment, 0.21 mm. in length; cornicles minute raised pores. Style rounded. Length of body 0.63 mm.; width of body 0.39 mm.

During the first and second instars the color darkens and the dark markings on the head gradually disappear. The characteristic longitudinal stripes of darker green appear during the third and fourth instars. There are 3 of these, 1 mediodorsal and 2 dorsolateral. The tarsi, apices of tibiæ, cornicles, tip of beak, and distal third of the antennæ of the growing nymph become gray.

After the second molt the nymph assumes an elongate shape, and there appears on the sides and at the abdominal sutures a pruinose "meal." This "meal" is much more scanty and less conspicuous in the stem mother than in later forms.

Adult.—Yellowish-green with three longitudinal green stripes on dorsum; eyes dark red; antennæ pale green, distal joint dark gray; cornicles pale, dusky at apex; tarsi dark gray; style pale yellowish green; apex of beak blackish. Form elongate oval, comparatively flat; newly molted individuals carinate.

Antennæ on very short frontal tubercles, barely one-third the length of the body, 5-jointed. Comparative lengths: I, 0.075 mm.; II, 0.06; III, 0.30; IV, 0.14; V, 0.22 (0.08 plus 0.14). Beak, length 0.26 mm., reaching to second coxæ; cornicles, 0.045 mm.; style, 0.17 mm. Cornicles wartlike, style ensiform. Prothorax and all abdominal segments bearing small, pale, lateral tubercles. Body bearing a sparse, inconspicuous clothing of granular "meal," most abundant at the sutures. Length of body (style included), 2.39 mm.; width of body, 1.06 mm.

HABITS AND LENGTH OF NYMPHAL LIFE.

After hatching, the young aphids seek out buds, often massing on those most advanced, and contrive to penetrate to the inner portions. On unopened buds they feed on the tender apical portions and numbers of them die in such situations. Newly-hatched aphids move awkwardly on rough spiny leaf surfaces and frequently fail to make headway. This was observed especially in connection with Myrobalan plum leaves, and perhaps explains the fact that the stem mothers on this tree have a high percentage of mortality in their early stages.

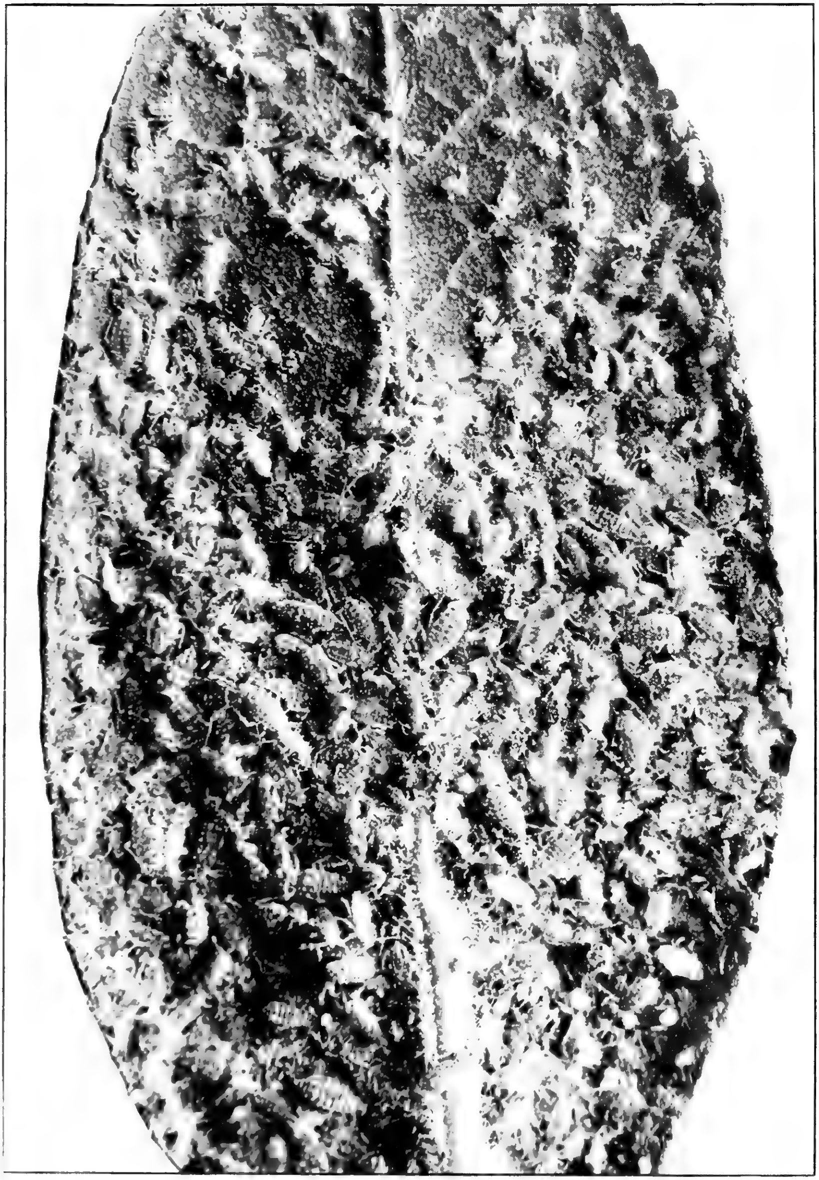
After the blossoms shoot out the aphids feed on the petioles or on the outside of the sepals. In the leaf bud they feed generally on the under (outer) surface of the unfolding foliage and less abundantly on the reverse side. A favored point is that at the junction of sepal and petiole on the flower stalks.

The first stem mothers matured on the plums at time of full bloom (March 19, in 1916), their growth being the more rapid on forward trees. On March 25 it was estimated that on the most advanced trees 85 per cent of the aphids were mature, while on the most backward only 20 per cent were full grown. At this time the mature stem mothers were on the underside of the leaves; none were remaining on the fruit stalks. On March 28 virtually all stem mothers on forward trees were mature; on most backward trees 50 per cent were still immature. By April 5 no more immature stem mothers were found.

Five stem mothers raised on potted Myrobalan seedlings developed in from 13 to 17 days. This time is perhaps less than in the average orchard, since the quality of food available for the newly-hatched aphid is often poor, while the seedlings were well in leaf at the time the experimental eggs hatched. It should be stated that the temperature in 1916 during the first part of the development of the stem mother was higher than usual for that time of year.

REPRODUCTION.

The stem mothers deposit on an average about 4 young a day during a period of from 3 to 5 weeks. The rate of fecundity rises rapidly at first, maintains an even zenith for some three weeks, and then rapidly declines. Stem mothers may live for as long as three weeks after they have deposited their complement of young.



THE MEALY PLUM APHIS (HYALOPTERUS ARUNDINIS).

Colony of aphids on lower surface of leaf. Enlarged.

THE MEALY PLUM APHIS.

Infested plum foliage.

THE SPRING FORMS.

Six wingless generations, in the maximum-generation series, were bred from April to June during 1916. An unusually hot wave occurred June 6, and killed all of the individuals of the seventh and eighth generations in the cages. It has been determined, however, that wingless generations may persist on the winter hosts through the summer as late as September, but apparently they can not produce true sexes. In the maximum series all second-generation individuals were wingless, in the third generation 1 out of 29 was winged, none of the fourth or fifth generations were winged, while the majority of the sixth and seventh generations were wingless. All the individuals in this series were bred on Myrobalan plum.

SPRING WINGLESS FORMS.

DESCRIPTION.

Newly hatched.—Pale yellowish-green; eyes dark red; rims of cornicles dusky. Appendages hyaline greenish-white. Form elongate oval.

Antennæ 5-jointed, half as long as body. Comparative measurements as follows: I, 0.03 mm.; II, 0.025; III, 0.11; IV, 0.06; V, 0.175 (0.05 plus 0.125). Beak reaching third coxæ, 0.22 mm. long; cornicles wartlike, 0.025 mm. long. Style rounded. Length of body, 0.50 mm.; width of body, 0.22 mm.

In the first instar the general color darkens, but it is never as dark as that of the stem mother; the tarsi, last antennal joint, and tip of beak become dark grayish-black. After the first molt a conspicuous "meal" is secreted in four longitudinal rows of circular areas on the body dorsum. This "meal" is more abundant on the first and fifth abdominal segments than elsewhere. The three longitudinal green stripes described in the stem mother appear less distinct in later generations. After the second molt the body is elongate oval. The aphids have a carinated appearance following each molt.

Adult.—Light green; eyes dark red to black; antennæ pale hyaline green, apex gray; legs hyaline greenish-white, tarsi and tibial apices gray; cornicles somewhat dusky in apical half; cauda light greenish-white. Beak pale, tip blackish. "Meal" as in larva, increasing with age of insect. Form elongate oval.

Antennæ on frontal tubercles, 6-jointed, two-thirds as long as body; comparative measurements as follows: I, 0.085 mm.; II, 0.075; III, 0.39; IV, 0.24; V, 0.225; VI, 0.445 (0.105 plus 0.340). In later generations filament of VI is longer in proportion than in earlier. Beak reaching second coxæ, 0.30 mm. long. Cornicles imbricated rather inconspicuously, constricted near base, somewhat enlarged in middle, mouth not flaring; length, 0.115 mm. Cauda ensiform, 0.17 mm. long. Body length, 2.2 to 2.8 mm.; width, 1.2 mm. Small, pale, blunt lateral tubercles occur on the prothorax and on each abdominal segment. Body armed with very few hairs.

DURATION OF NYMPHAL STAGES.

Records of the development of the wingless forms were made both on caged trees and in the orchard. Myrobalan and Agen (*French*) prunes were used for hosts. The development was similar on both hosts, the aphids being retarded on weaker trees. The instars occupied, on the average, equal periods of time, except that the fourth was slightly shorter than any one of the others.

Forty-five individuals of the second generation were observed during the period March 27–May 4, the majority developing during the period March 30–April 22. The average growing period was 12.6 days, the maximum 18, and the minimum 10.

Between April 11 and May 30, 34 third-generation wingless individuals developed in an average of 11.8 days, the maximum and minimum periods being, respectively, 18 and 9 days.

Individual records of generations 4 to 7 were made chiefly from the maximum-generation series and might be grouped best in tabular form as follows:

TABLE I.—*Development of spring wingless generations of the mealy plum aphis. Walnut Creek, Cal., 1916.*

Generation.	Dates included.	Number of individuals.	Developmental period.		
			Average.	Maximum.	Minimum.
			Days.	*Days.*	*Days.*
IV....	Apr. 23–May 16	10	9.9	14	9
V.....	May 3–May 18	27	11.1	14	10
VI....	May 14–May 27	30	12.7	16	11
VII...	May 26–June 3	10	[1] 10	11	9

[1] June 7, five fourth-instar wingless individuals died because of an excessive heat wave. Had these matured, the average developmental period would have been slightly lengthened.

MAXIMUM AND MINIMUM GENERATIONS.

A maximum-generation series of first-born aphids (wingless) is shown in the table following:

TABLE II.—*Development of maximum-generation series of the mealy plum aphis. Walnut Creek, Cal., 1916.*

Generation of individual.	Date of birth.	Date of fourth molt.	Developmental period.
			Days.
I.......	Mar. 11	Mar. 28	17
II......	Mar. 30	Apr. 11	12
III.....	Apr. 11	Apr. 23	13
IV.....	Apr. 23	May 3	10
V......	May 3	May 14	11
VI.....	May 14	May 26	12
VII....	May 27	June 6	9

Thus in the space of 11½ weeks seven complete generations occurred. Had it been possible to have continued the series until winter, certainly 10 more generations would have been produced. The adults usually deposit young within a very few hours after shedding the final skin.

A minimum-generation series of last-born aphids is indicated below:

TABLE III.—*Development of minimum-generation series of the mealy plum aphis. Walnut Creek, Cal., 1916.*

Generation of individual.	Date of birth.	Date of fourth molt.	Developmental period.
			Days.
I		Mar. 31	
II	Apr. 21	May 3	12
III	May 29	June 11	13
IV	July 1	July 12	11

These four generations were completed in about four months, or over a month longer than the seven generations of the first-born series.

The period of reproduction as indicated in the foregoing table varied from 20 to 26 days.

REPRODUCTION.

Observations were made on the reproduction of individuals of wingless generations 2 to 5 inclusive. Adults of the second generation, for a total reproductive period of from 4 to 5 weeks, averaged about 4 young daily, producing the first three weeks a daily average of 6 young. The later generations were less prolific, fourth and fifth generation individuals not averaging above $2\frac{1}{4}$ young per day. Ten young were deposited within 24 hours on several occasions, but on no occasion was this number exceeded. The rise and decline in fecundity was in the main similar to that found in the case of the stem mother.

HABITS OF SPRING GENERATIONS.

The aphids of the second generation, when newly born, dispose themselves in groups, close by the parent, on the underside of the leaf. After the first molt many remove to other leaves and this is the beginning of the migration from leaf to leaf and branch to branch. Second-generation larvæ and adults prefer to suck the rib tissues of the leaf. Owing to the rapidity of reproduction and consequent crowding, the aphids of later generations have little choice of location and feed at any point on the lower surface of the leaves or on petioles. If the lower surface of a leaf is entirely occupied many larvæ will be found feeding on the upper surface, in some cases apparently in preference to seeking other less crowded leaves.

In 1916 infested prune leaves began to curl at the beginning of April, such leaves having one or more colonies of adult stem mothers and first-instar young. As April progressed the leaf-curl became more and more pronounced and the colonies increased rapidly. About the middle of the month the most heavily infested leaves began to have a yellowish appearance in the form of blotched areas at the points where the aphids were most abundantly settled. On April 21 a few leaves were found to have their under surfaces quite covered with feeding aphids, and at the end of the month such leaves were abundant, while twigs and limbs were covered with a sticky "honeydew," and here and there young fruits were coated with this substance. During May and June this condition was greatly aggravated in the orchards examined.

The spring winged form first appeared April 21, and throughout May and June increased in numbers, and after the middle of May there was a corresponding decrease in the numbers of wingless adults produced. By July 1 the mature wingless individuals had diminished greatly in quantity and thereafter their numbers dwindled so that by the middle of August none were to be found. In no instance in 1916 was an infestation prolonged beyond this date, but in 1914 in the same locality a small but vigorous infestation occurred throughout September, later becoming annihilated by natural enemies.

In the rearing cages it was found that the transfer of newly born young was very frequently attended by the loss of the insect, and in most cases the adult was transferred when it was desired to make observations on a new plant. Several transfers of larvæ and adult wingless individuals from plum to apricot failed, while others resulted successfully. Infested apricot leaves did not curl as badly as those of prune and plum.

THE SPRING MIGRANT.

Description.

In the first three instars the nymphs of the migrants do not differ from those of the wingless spring form, except that the third-instar individuals are somewhat narrower.

Pupa.—Light green; eyes dark red; tarsi and apex of beak dark gray. On the body ground color is superimposed a narrow dorsomedian stripe of darker green. Thorax broadened to twice the width of the prothorax. Wing pads yellowish white. Body with pruinose covering as in wingless nymph.

Adult.—Light green; eyes red; antennæ light gray, basal portion of third joint hyaline yellow; head, thoracic lobes, and sternum dark grayish black; scutellum yellowish brown; prothorax, sides of thorax, and wing insertions greenish yellow; wings hyaline, stigma and veins gray; legs pale greenish yellow, apices of tibiæ and the tarsi dusky gray; abdomen and style pale green or greenish yellow; cornicles pale at base, dusky at apex. Beak pale, extreme tip dusky.

Form elongate, the abdomen with parallel sides.

The dorsum and sides are covered with white pruinose "meal," on the abdomen the "meal" occurring in transverse bars.

Antennæ four-fifths as long as body, on frontal tubercles. Comparative measurements as follows: I, 0.08 mm.; II, 0.06; III, 0.405; IV, 0.26; V, 0.21; VI, 0.48 (0.10 plus 0.38). Beak reaching a little beyond anterior border of mesosternum, 0.26 mm. long. Wings 2.5 mm. long. Cornicles faintly imbricated, shorter than in wingless female, barely twice as long as broad at base, slightly constricted near base, in length 0.08 mm. Style ensiform, 0.15 mm. long. Length of body, 1.61 to 2 mm.; width, 0.66 mm.

Lateral tubercles as in wingless form; first antennal joint somewhat gibbous.

Sensoria.—On III, 23 to 30; on IV, 4 to 10; on V, 1 to 2; on VI, usual apical group. Sensoria of unequal size, not at all arranged in longitudinal rows, but rather in spirals.

Duration of Nymphal Stages.

Eight winged spring migrants developed in an average of 14½ days, the developmental period ranging from 13 to 18 days. The winged form therefore develops more slowly than the wingless, due to the increased duration of the fourth instar.

Reproduction.

The migrants commenced to reproduce on the cat-tail rush (Typha) a few days after they settled. In many cases migrants were found to settle, remain for several days, and finally die without reproducing and only a small percentage of those settling reproduced. Most of them remained a few days and then departed. Spring migrants in only one instance out of 76 deposited young on caged plums. In this instance the three young born refused to feed on the plum (Myrobalan). In this connection it might be said that all attempts to induce wingless forms of earlier generations to settle on Typha failed. Migrants placed in small dishes and provided with plum and cat-tail foliage in no instance deposited young and in extremely few instances did migrants placed on cat-tail deposit young. Unfortunately it was not possible to obtain Phragmites for similar tests.

The migrants may remain on the winter host foliage for several days before taking flight, especially if the weather be cool and cloudy.

Field observations indicated that the migrants produced young at the rate of about five every two days at first, and later at a slower rate. On Typha it appeared that the maximum number of young per migrant rarely exceeded 20 and, discounting all migrants which failed to deposit, averaged not much over five. This must have been abnormal, as examination of individuals disclosed the presence of many more embryos than were extruded. It is possible that Typha does not prove an invigorating food for the migrant and this point is perhaps elucidated below in the paragraphs on migrations.

Migrations.

Phragmites and Arundo have long been known as alternate hosts of the mealy plum aphis; in fact the species has been described as new from both of these hosts. In California enormous infestations have been observed on the former in swampy regions, sometimes removed many miles from any winter hosts. On the other hand, Typha grows in abundance close to prune orchards and yet, considering the enormous production of spring migrants throughout May, June, and July, the later infestations on near-by Typha are in the aggregate exceedingly small. The writer has seen clumps of *Typha latifolia*, growing not 30 feet from prune trees on each of which thousands of winged forms were being developed, receive only a few dozen migrants and perhaps have not over 6 out of 100 blades colonized by their progeny. It is true that when once established a colony on Typha increases rapidly, but it is also evident that the migrant fails to do justice to her reproductive capabilities on this plant.

That the migrants fly long distances to seek their alternate hosts, especially Phragmites, is the conviction of the writer.

The spring migrants settle on Typha near the apex of a strongly-growing blade and station themselves parallel to its long axis. The wingless forms later take up this same position. After the migrants have extruded a few young the whitish meal is excreted in greater abundance. On Phragmites the colonies are similarly disposed. On three occasions the writer observed heavy summer infestations on the reed *Phragmites communis* L. On July 5, 1917, along the banks of the San Joaquin River about 15 miles west of Stockton, Cal., this plant was heavily attacked. Among the colonies occurred a few pupæ and winged forms of a winged summer form. *Typha latifolia* growing among the infested reeds was not attacked. On August 13, 1917, at Benicia, Cal., clumps of reeds growing in swampy ground near San Francisco Bay bore heavy infestations of the aphis and the summer winged form was abundant. Plants of Typha growing among the clumps of Phragmites were sparingly infested. On May 15, 1918, heavy infestations were observed on *Phragmites communis* growing on the west shore of the Salton Sea, in southern California.

These observations indicate that Phragmites is the preferred summer host plant.

The summer winged aphids serve to distribute the species among the reeds. They do not differ in appearance or structure from the spring migrants produced on the winter hosts.

Fall migrants appeared both in 1915 and 1916 on Typha about October 15, and continued until the end of November. Males appeared the last week of October and throughout November. The small yellowish pupæ of the latter are easily distinguishable on the cat-tails from the green pupæ of the fall migrant. Mature fall migrants remained on the summer host for a day or two before departing.

Although migrations from Typha were traced with apparent certainty in the fall of 1915, in the following year so few fall migrants were produced on local Typha under observation that they were out of all proportion to the great numbers of winged forms which began to appear in the prune orchards near Walnut Creek toward the end of October, and it was certain that the great majority of migrants were coming from a considerable distance.

THE SUMMER WINGLESS FORMS.

DESCRIPTION.

Newly hatched.—Similar to that of spring wingless form, but more yellowish. Form elongate.

Adult.—In color similar to those of spring wingless, but smaller in size and narrower in shape.

Antennæ about two-thirds body length. Comparative measurements as follows: I, 0.08 mm.; II, 0.045; III, 0.26; IV, 0.16; V, 0.155; VI, 0.40 (0.08 plus 0.32). Beak reaching second coxæ, 0.26 mm. long. Cornicles more cylindrical than in spring wingless form, inconspicuously imbricated, 0.07 mm. long. Style 0.135 mm. long, shaped as in spring wingless form. Length of body, 1.6 to 2 mm.; width of body, 0.65 mm.

Measurements from specimens of what appears to be *H. arundinis* collected in April on Arundo in Peru by Mr. E. W. Rust were noticeably greater, but similar in proportions.

The lateral tubercles are inconspicuous.

DURATION OF STAGES.

Eighteen first-generation (progeny of migrant) individuals in the period May 29–August 20 matured on Typha in an average of 14.6 days, the period of growth ranging from 12 to 18 days. Between June 17 and July 30, 15 aphids of the second and third summer generations developed in an average of 15.8 days, with a range of from 9 to 18 days, while 17 fourth-generation individuals developing between July 26 and August 27 averaged 12.2 days, with a range of from 9 to 16 days. Aphids maturing in September developed in an average of 14 days. All the individuals recorded above were wingless. There is apparently a maximum of as many as 10 wingless summer generations and a mimimum of 3. Molts occurred about as in the spring wingless forms.

HABITS OF SUMMER WINGLESS FORMS.

Colonies are located on both sides of the blades, chiefly on the outer half, occasionally on the basal half of the leaf. In September, 1915, several colonies of over 200 wingless individuals were observed on single blades of Typha at Walnut Creek, and about the end of this month the aphids reached their maximum abundance. This latter condition was repeated in 1916, although the colonies were never as large as the year previous. As has been noted, the aphids lie parallel to the length of the blade. They move off at slight disturbance and much difficulty was experienced in transferring individuals, owing to their failure to settle on a new plant.

Toward the end of October the blades frequently turn yellow, causing the aphids resident thereon to assume a straw-colored appearance.

The aphids frequently deposit a little circle of "meal" around them on the surface of the blade, a habit similar to that practiced on the same host by a species of white fly. On leaves of Phragmites the aphids congregate in large masses on both surfaces, lying parallel to the long axis of the leaf. The central portion of the leaf is colonized first and as the colony increases in numbers the infested area approaches the margins.

THE FALL FORMS.

There are three fall forms—the fall viviparous migrant, the male, and the sexual oviparous female. The first two fly to the winter hosts, after which the viviparous migrants deposit the sexual oviparous females.

FALL MIGRANT.

Description.

The immature stages do not differ materially from those of the spring migrant.

The adult insect, aside from being slightly smaller and having the antennæ, legs, and style more dusky, is similar to the spring migrant. Form elongate.

Antennæ on somewhat gibbous frontal turbercles, about two-thirds as long as the body. Comparative measurements as follows: I, 0.07 mm.; II, 0.06; III, 0.39; IV, 0.235; V, 0.175; VI, 0.48 (0.10 plus 0.38). Beak reaching a little beyond anterior border of mesosternum, 0.26 mm. in length. Wings 2.6 mm. in length. Cornicles shaped as in spring migrant, 0.075 mm. long. Style ensiform, 0.16 mm. long.

Sensoriation and tubercles as in spring migrants.

Reproduction and Habits.

The migrants normally locate on the underside of the leaves (of the winter host), but those that arrive latest in the season often find the leaves blown off by winds and perforce settle on the twigs. Frequently they feed for several days before producing young. In experimental cages inclosing Agen (*French*) prunes and Myrobalan plums 14 was the highest number of young laid by a single migrant, and the average was about 8 (excluding about 20 per cent of the individuals which died without bearing progeny). The migrants were more prolific on Agen (*French*) prunes than on Myrobalan plums. In the field it appeared that from 12 to 35 young sexual females are produced normally, with an average of about 20, on French prunes.

The young were produced within about 12 days (in the cages mostly within 7 days) and at a rate of from 2 to 3 a day. The migrants, after they had extruded their complement of young, remained settled for as long as two weeks.

MALE AND OVIPAROUS FEMALE.

Male.

DESCRIPTION.

Pupa.—Noticeably smaller than that of the fall migrant, light yellow in color; eyes dark red; tarsi and distal antennal joint dusky gray. Form elongate.

Adult.—Light clay yellow; head, antennæ, prothorax, thoracic lobes, scutellum, legs, cornicles, and style brownish-black; eyes dark red; stigma light greenish-gray; veins of wings brown; abdomen with a dorsomedian longitudinal row (segments 1 to 5 inclusive) of subcircular gray spots, similar lateral spots on segments 1 to 3 inclusive, and with cross bars of similar color on segments 6, 7, and 8; genital plate and organs dark gray; beak pale yellow, tip brownish black. The male is almost devoid of "meal."

Antennæ on gibbous frontal tubercles, three-fourths the length of the body; comparative measurements as follows: I, 0.08 mm.; II, 0.07; III, 0.38; IV, 0.25; V, 0.23; VI, 0.46 (0.09 plus 0.37). Wings 2.3 mm. long. Cornicles vase-shaped, narrowed close to base, faintly imbricated, 0.085 mm. in length. Style conical, 0.10 mm. long. Beak reaching a little beyond anterior mesosternal border, 0.30 mm. long. Length of body, 2.05 mm., width, 0.68 mm.

Circular sensoria are distributed along the antennal joints much as in the spring and fall migrants. They are much more numerous, there being from 38 to 53 on III, 19 to 29 on IV, 9 to 18 on V, and the usual apical group on VI.

Oviparous Female.

DESCRIPTION.

Newly hatched.—Light green, appendages hyaline; eyes red. Form oval.

The immature females are bright green with a very scant covering of "meal."

Adult.—Greenish yellow; eyes dark red; distal half of antennæ, cornicles, and tarsi gray; beak pale yellow, tip brown. The coating of "meal" is not so conspicuous as in the earlier forms, in this respect resembling the stem mother. Form elongate oval, rather flat.

Antennæ not quite half as long as body, comparative measurements as follows: I, 0.06 mm.; II, 0.035; III, 0.145; IV, 0.06; V, 0.085; VI, 0.245 (0.05 plus 0.195). Beak reaching second coxæ, 0.25 mm. long. Cornicles cylindrical, twice as long as wide at base, faintly imbricated, 0.05 mm. long.

Style conical, 0.08 mm. long. Length of body, 1.18 mm.; width, 0.52 mm.

The thickened hind tibiæ bear a large number of small circular sensoria.

Nymphal Stages.

For the male the nymphal stages were not observed closely, this form having been very rare on the cat-tails in 1916. From such observations as took place it appears safe to say that both males and fall migrants develop in about three weeks. The development of oviparous females was observed in 1916 on both Agen (*French*) prunes and

Myrobalan seedlings. Within the period October 20–November 23, 40 oviparous females matured in an average of 19.1 days, the period of development ranging from 16 to 22 days. On Myrobalan plum the development was slightly slower than on Agen (*French*) prunes.

Habits and Oviposition.

The females feed normally on the under surface of the leaves, but occasionally also on tender stalks, especially of sucker growth. The males frequently arrive before the females are mature and settle down beside the immature aphids. Copulation takes place very soon after the female casts her fourth skin, and a male may copulate with more than one female. As the males are much less abundant than the females this practice is probably common and was often noticed in the cages. Toward the middle of November, 1916, large numbers of immature females were blown off the trees by winds and perished. In some orchards this only thinned out the infestation to a small degree, as plenty of mature females had been observed previous to the coming of the high winds, but in others wherein the sexes were not so advanced it destroyed the majority of the aphids. The oviparous females bear only a scant coat of "meal" and may be easily confused in the orchard with those of *Phorodon humuli* Schrank and *Aphis cardui* Linnæus, both of which are contemporaneous with *arundinis*. They are less likely to be confused with the plump reddish-brown oviparous form of *Rhopalosiphum nympheae* Linnæus.

As a rule the female commences oviposition within 24 hours of copulation, but this was delayed in some cases as long as 5, and in one instance 10 days. In cages never more than 2 eggs, and more often only 1, were laid in one day by a single aphid.

Sixteen females laid an average of 4.1 eggs in the period November 9–December 18. In the early part of this period the average was 6, while toward the end it was 3.5. Not over 7 eggs were deposited by one female. There was a marked tendency to deposit the eggs over a long period—as much as three weeks—and the females after depositing an egg or eggs on the stems generally returned to the leaf, remaining there until the time for the deposition of the next egg. The females usually died within a week of depositing their last egg, but in some cases lived longer, and one aphid lived beyond three weeks. It appeared, however, that those that persisted had not rid themselves of all their ova, as they did not have the shrunken appearance of sterile aphids.

NATURAL ENEMIES.

The mealy plum aphis, both on winter and summer hosts, is preyed upon by a large series of natural enemies. As early as March 17, 1916, a few eggs of Syrphidae and Chrysopidae were observed deposited near the growing stem mothers on plums. Throughout April lampyrid beetles (*Podabrus comes* Le Conte, *P. binotatus* Le Conte var., and *Telephorus divisus* Le Conte) appeared locally. During May syrphus-fly larvæ (especially *Catabomba pyrastri* Linnæus) and ladybird adults and larvæ (especially *Hippodamia convergens* Guérin) abounded, as did also a few hemerobiid larvæ. Nevertheless these predators made little apparent headway in reducing infestations.

Observations made in June, 1915, indicated that *Hippodamia convergens* was by far the most beneficial of the ladybirds.

The Typha colonies were preyed on by the larvæ of Syrphus; those on Phragmites by beetles of the Hippodamia group and by Leucopis larvæ; and late in the fall the sexual females were attacked by syrphids and Triphleps.

Internal parasitism in the writer's opinion is of very rare occurrence. Occasionally he has observed parasitized specimens in nature.

CONTROL SUGGESTIONS.

There are two especially vulnerable periods in the annual life cycle of the mealy plum aphis—one in early spring when the stem mothers are growing and the other in late fall when the sexual females are developing on the winter hosts. Unfortunately at these two periods the enemies of the aphis are very scarce, but the aphis itself is more easily destroyed than at other times by artificial substances. Both the stem mothers and the oviparous females have a scant protective covering of "meal" and both live for the most part on exposed surfaces of the plant, whereas the aphids of the spring and summer generations bear a comparatively thick coating of meal and live in great part in curled foliage. Contact insecticides, which have little effect on aphids of the intermediate generations, easily destroy the stem mothers and the egg-laying females.

SUMMARY.

The mealy plum aphis in California is a decided pest of plums, prunes, and, to a lesser degree, apricots. Besides devitalizing the trees it causes small-sized fruits and early drops, and is probably concerned in a measure with apical cracking of prunes.

In 1916 winter eggs hatched between March 4 and 18 and early stem mothers began reproduction about March 20. It appeared that normally from 3 to 5 generations were raised on the winter hosts, but rarely series of wingless generations persisted until the fall. The aphids of the earlier generations were mostly wingless like the stem mothers, and the individuals of the later generations mostly winged, and after the middle of June virtually all the insects produced developed wings.

Migration to the summer hosts, Phragmites and Typha, began the last week in April and continued until August, the great body traveling in early June. On these hosts about 10 generations took place, continuing up to November. The vast majority of aphids to be found during the summer were wingless, but winged parthenoparous individuals were also produced on the summer host plants and these served to distribute the species among these plants. About the middle of October and for six weeks succeeding, winged sexuparous migrants and winged males were produced and these flew to the fruit trees whereon the sexuparae proceeded to deposit sexual females. The sexes were most abundant during the forepart of November, and were to be found as late as the middle of December.

Oviposition took place throughout November and December. the majority of ova having been placed before December 10.

The foregoing data are based on observations made at Walnut Creek, Cal., between August, 1915, and December, 1916.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 775

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. ▼ June 3, 1919

COMMERCIAL PRESERVATION OF EGGS BY COLD STORAGE.[1]

By M. K. JENKINS, *Assistant Bacteriologist.* Prepared under the direction of M. E. PENNINGTON, *Chief, Food Research Laboratory.*

CONTENTS.

SOME ASPECTS OF THE COLD STORAGE BUSINESS.

The preservation of eggs by means of cold renders one of the most important of the perishable foods available at all times. According to Holmes,[2] about 50 per cent of the egg crop is produced during the months of March, April, May, and June, and 86 per cent of the eggs held in storage are stored in March, April, and May. During these cool months the eggs are the freshest and most desirable for storing. According to a statement issued by the Bureau of Markets, April 15, 1918, 478 warehouses, which report holdings of eggs in cold storage, are fairly well distributed over the United States. The March 11, 1918, summary report, issued by the Bureau of Markets, shows that a total of 6,595,850 30-dozen cases, valued at $70,487,212, were stored in 396 houses during the season of 1917–18. These figures, although lower than the actual amounts, due, as mentioned in the reports, to the failure of a few houses to forward state-

[1] The work covered in this bulletin was done in the Bureau of Chemistry. In the future, the marketing phases of the Department's work on poultry and eggs will be conducted by the Bureau of Markets, under a cooperative arrangement with the Bureau of Chemistry.

[2] U. S. Dept. Agr., Statistics Bul. 93.

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ments of their holdings, give a fair approximation of the extent and value of the business.

The deliveries in appreciable quantities of eggs from cold storage begin in August, continue in increasing amounts during the fall and early winter months, and gradually decrease from this period until the first of March, when there are but few, or practically no eggs left in storage in normal seasons. For example, during the season of 1916–17 57.7 per cent of the holdings were left in storage on November 1, 34.2 per cent on December 1, 13.8 per cent on January 1, 2.1 per cent on February 1, and 0.1 per cent on March 1.[1] These statistics agree with those collected by Holmes [2] several years earlier. The increase in consumption of cold storage eggs during the winter corresponds to the marked decline in egg production during that time.

PURPOSE OF THE INVESTIGATION.

Although a number of publications discuss the losses in eggs which follow the routine course of marketing without the intervention of cold storage,[3] comparatively few data, showing the changes and losses in different grades of eggs handled according to commercial usages during various holding periods in cold storage, are available. This investigation was made primarily to determine the efficiency of the preservation of commercial eggs by cold storage. The following phases of the problem were studied:

(1) The relative keeping quality of fresh, heated, sound, dirty, and cracked eggs.

(2) The relation of the month of storage to preservation.

(3) Efficiency of the commercial grading of eggs for cold storage.

(4) Analysis of bad eggs developing in commercially packed eggs during storage.

(5) Relation of care in initial grading to the development of bad eggs during storage.

(6) Rate of evaporation of moisture from eggs.

(7) Rate of absorption of moisture by case and fillers.

(8) Physical and chemical changes in eggs during storage.

(9) Absorption of foreign flavors during storage.

GENERAL PLAN OF INVESTIGATION.

The eggs used in these observations were produced in the Corn Belt States of the Middle West, with the exception of a few lots which came from Kentucky. They were shipped East in refrigerator cars, and were from three to seven days en route. As soon

[1] Report of the Bureau of Markets issued Apr. 1, 1917.

[2] U. S. Dept. Agr., Statistics Bul. 93.

[3] U. S. Dept. Agr. Buls. 51, 224, 664; U. S. Dept. Agr., Bur. Chem. Circs. 83, 104; U. S. Dept. Agr., Yearbook (1910) Article 552, and Yearbook (1914) Article 647.

as received they were transferred to a commission house equipped with chill rooms, a candling and breaking room, all of which were refrigerated. Here the observations were made before the eggs were stored, as well as on removal from storage at various intervals during the storage period. The examination of the different classes of eggs to determine the relative deterioration consisted in determining the quality of the eggs in the shell by candling and out of the shell by appearance, odor, and chemical analysis. It was necessary to grade the eggs after they were opened because there are certain classes of bad eggs that can not be recognized and others which are frequently missed by grading in the shell.[1] The method of separating the edible and inedible eggs by candling[2] and breaking[3] was the same as that followed commercially in up-to-date candling and breaking rooms. The inedible eggs detected by candling correspond to those found by the dealers in grading eggs for market, and the bad eggs detected by breaking represent those that would be found when the eggs were opened by the consumer. Samples for laboratory examination were taken from the liquid product obtained on mixing the eggs graded as edible. Observations were made on 9 lots which were received and stored in New York City, and on 12 lots delivered to and stored in Philadelphia. The eggs were stored at a temperature of from 30° to 33° F. in rooms used commercially for the cold storage of eggs in the shell (Pl. I). During this investigation 841 30-dozen cases of eggs of varying grades were examined before and after storing. The history of the different lots under observation is reported in detail in Table 1.

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[1] U. S. Dept. Agr. Bul. 702. [2] U. S. Dept. Agr. Bul. 565. [3] U. S. Dept. Agr. Bul. 391.

TABLE 1.—*History of samples.*

Experiment No.	Cases examined.	Grade of eggs.	Kind of pack.	Origin of shipment.	Date shipped.	Date received.	Date in storage.	Location of cold storage.
41680	55	April firsts	Commercial	Mattoon, Ill.			Apr. 9, 1914	New York.
41896	36	do	do	Casey, Ill.		Apr. 10, 1915	Apr. 17, 1915	Philadelphia.
41897	12	do	Careful	do		do	do	Do.
41933	27	do	Commercial	Dietrich, Ill.	Apr. 6, 1916	Apr. 10, 1916	Apr. 29, 1916	Do.
41934	9	do	Careful	do	do	do	do	Do.
41716	55	May firsts	Commercial	Mattoon, Ill.			May 9, 1914	New York.
41916	33	do	do	Louisville, Ohio	May 10, 1915	May 13, 1915	May 22, 1915	Philadelphia.
41917	11	do	Careful	do	do	do	do	Do.
41936	48	do	Commercial	Manchester, Iowa	May 13, 1916	May 19, 1916	May 26, 1916	Do.
41937	8	do	Careful	do	do	do	do	Do.
41782	40	June firsts	Commercial	(1)			June 5, 1914	New York.
41918	30	do	do	Anderson, Ind.	June 3, 1915	June 7, 1915	June 18, 1915	Philadelphia.
41920	10	do	Careful	do	do	do	do	Do.
41941	27	do	Commercial	Harrodsburg, Ky.	June 8, 1916	June 15, 1916	June 22, 1916	Do.
41942	9	do	Careful	do	do	do	do	Do.
41787	30	July firsts	Commercial	Illinois			July 6, 1914	New York.
41922	27	do	do	New Madison, Ohio	June 26, 1915	June 30, 1915	July 27, 1915	Philadelphia.
41927	9	do	Careful	do	do	do	do	Do.
41945	27	do	Commercial	(2)			July 17, 1916	Do.
41946	9	do	Careful	(2)			do	Do.
41679	55	April dirty eggs	Commercial	Mattoon, Ill.			Apr. 9, 1914	New York.
41935	9	do	Careful				Apr. 29, 1916	Philadelphia.
41686	55	May dirty eggs	Commercial	Mattoon, Ill.			May 6, 1914	New York.
41778	35	June dirty eggs	do	Chicago, Ill.			June 5, 1914	Do.
41943	30	do	do	Abilene, Kans.		June 1, 1916	June 22, 1916	Philadelphia.
41944	9	do	Careful	do		do	do	Do.
41805	30	July dirty eggs	Commercial	(1)			July 13, 1914	New York.
41919	30	June seconds	do	Harrodsburg, Ky.	June 8, 1915	June 14, 1915	June 25, 1915	Philadelphia.
41921	10	do	Careful	do	do	do	do	Do.
41788	30	July seconds	Commercial	Illinois			July 6, 1914	New York.
41923	27	do	do	Kansas City, Mo.	June 28, 1915	July 2, 1915	July 30, 1915	Philadelphia.
41928	9	do	Careful	do	do	do	do	Do.

[1] Purchased on New York market.

[2] Purchased on Philadelphia market.

RESULTS OF THE INVESTIGATION.

EFFECT OF CONDITION OF SHELL UPON PRESERVATION.

The losses in commercial fresh eggs with clean, sound shells were found to be negligible during a storage period of 11 months. In the experiment reported in Table 2 and figure 1, the bad eggs detected by candling and breaking did not amount to more than five eggs per case at any time during the storage period. The principal types of bad eggs found were green whites, crusted yolks, moldy eggs, mixed rots, and white rots (Table 3). The first two types mentioned are characteristic of washed eggs after storing. Unfortunately it is not possible to detect all washed eggs by inspection of the shell before storing.

If the shell of a fresh egg is dirty its liability to spoilage during holding in cold storage is markedly increased. A typical lot stored in April showed on monthly withdrawals from storage from September to March, inclusive, from 12 to 30 bad eggs per case by candling and from 10.5 to 29 additional by breaking (Table 2 and fig. 1). Among commercial dirty eggs are found eggs soiled with feces, mud, and blood, as well as stained eggs showing evidence of having been washed or having come in contact with the wet, muddy feet of hens or wet nests. Bacteria and molds can penetrate wet shells, even though unbroken, and cause the egg to rot. Moldy eggs, green whites, crusted yolks, mixed rots, white rots, and black rots are the principal varieties of bad eggs among dirty refrigerator eggs (Table 3).

It is generally known that eggs with damaged shells will not keep in storage. This is strikingly shown in Table 2 and figure 1. The most common form of deterioration of the cracked egg is through molding, which, in stocks stored in spring, becomes pronounced in September and October, and increases throughout the storage period (Table 4). The bad eggs developing in cracked eggs stored in April and May varied, as found by candling and breaking, from 44 per case in September to 144 per case in March. If the shells were dirty in addition to being cracked, the losses were greater, amounting in eggs stored in April and held until December to as high as 211 to the case as found by candling (Table 2 and fig. 1). These observations were made on damaged eggs present in first-grade commercial packages through oversight or carelessness during the initial sorting of the eggs for storage. The losses found would have been higher had the observations been made on cases containing only cracked eggs, for the mold growing on one egg readily spreads to other broken eggs (Pl. II).

These studies emphasize the importance of selecting only eggs with clean, sound shells for storing.

TABLE 2.—*Effect of condition of shell upon preservation of fresh eggs.*

Month of withdrawal.	Clean, sound shells.			Dirty, sound shells.			Clean, cracked shells.			Dirty, cracked shells.	
	Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case by candling.
		Candling.	Breaking.		Candling.	Breaking.		Candling.	Breaking.		
April	....	....	....	360	0	11	59	0	12	86	0
May	1,026	0	0.5	....	....	....	....	....	....	....	....
June	....	....	....	....	....	....	....	....	....	50	0
July	....	....	....	....	....	....	....	....	....	80	22.5
August	....	....	....	359	9	16	49	22	7.5	104	36
September	710	0	2.5	355	16	15	81	26.5	17.5	158	71.5
October	704	1	1.5	354	12	22.5	58	87	18.5	65	160
November	695	0.5	2	353	21	13.5	73	108	10	114	109
December	709	0.5	1	357	15	21	85	84	21	82	211
January	694	0	2.5	358	18	29	60	132	12	....	....
February	715	1	2	355	30	10.5	82	92.5	21	91	224
March	717	2.5	2.5	358	24	17	45	136	8	....	....

TABLE 3.—*Varieties of bad eggs developing during storage in eggs with sound shells sorted from commercial refrigerators.*[1]

FOUND BY CANDLING.

Kind.	April firsts.		May firsts.		June firsts.		July firsts.		April dirty eggs.		May dirty eggs.		June dirty eggs.		June seconds.		July seconds.	
	No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
Mixed rots	50	25.38	57	25.22	154	44.90	388	52.65	19	7.20	66	11.32	163	40.95	130	32.99	125	40.45
White rots	20	10.15	33	14.60	42	12.24	125	16.96	24	9.09	57	9.78	46	11.56	70	17.76	30	9.71
Black rots	13	6.60	29	12.83	19	5.54	38	5.16	34	12.88	182	31.21	22	5.53	30	7.61	14	4.53
Moldy eggs	88	44.67	72	31.86	93	27.11	138	18.72	140	53.03	177	30.36	129	32.41	122	30.96	110	35.59
Crusted yolks	25	12.69	34	15.04	34	9.91	47	6.37	45	17.04	101	17.32	38	9.55	42	10.66	30	9.71
Bloody whites	1	0.50	1	0.44	1	0.29	1	0.13	2	0.76	....	....	....	....	....	....	....	....
Total	197	....	226	....	343	....	737	....	264	....	583	....	398	....	394	....	309	....

FOUND BY BREAKING.

Green whites	41	53.25	61	42.66	88	31.73	83	30.97	20	33.33	43	23.37	100	51.55	74	23.12	65	28.51
Bad-odor eggs	4	5.20	15	10.47	18	6.50	15	5.60	12	20.00	34	18.48	12	6.19	57	17.81	12	5.26
Mixed rots	14	18.18	49	34.27	133	48.01	143	53.36	7	11.66	48	26.09	61	31.44	167	52.19	124	54.39
White rots	1	1.29	1	0.70	2	0.72	......	......	7	11.66	7	3.80	1	0.51	6	1.88	......	......
Moldy eggs	2	2.60	4	2.80	21	7.58	3	1.11	......	......	3	1.63	......	......	8	2.50	6	2.63
Crusted yolks	15	19.48	12	8.40	15	5.42	23	8.58	14	23.33	49	26.63	20	10.31	8	2.50	21	9.21
Bloody whites	......	......	1	0.70	......	......	1	0.37	......	......	......	......	......	......	......	......	......	......
Total	77	......	143	......	277	......	268	......	60	......	184	......	194	......	320	......	228	......

[1] Data from cases of eggs withdrawn from storage from November to March.

TABLE 4.—*Varieties of bad eggs developing during storage in eggs with cracked shells sorted from commercial refrigerators.*[1]

FOUND BY CANDLING.

Kind.	April firsts.		May firsts.		June firsts.		July firsts.		April dirty eggs.		May dirty eggs.		June dirty eggs.		June seconds.		July seconds.	
	No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
Mixed rots	22	8.30	41	14.54	21	11.35	52	13.27	3	1.44	16	5.18	55	17.19	33	17.64	30	13.64
White rots	7	2.64	12	4.26	9	4.86	27	6.89	9	4.30	22	7.12	24	7.50	16	8.56	24	10.91
Black rots	1	0.38	10	3.54	3	1.62	10	2.55	7	3.35	34	11.00	7	2.19	4	2.14	4	1.82
Moldy eggs	231	87.17	216	76.60	150	81.08	298	76.01	183	87.56	217	70.22	221	69.06	130	69.52	157	71.36
Crusted yolks	4	1.51	3	1.06	2	1.08	5	1.28	7	3.35	20	6.47	13	4.06	4	2.14	5	2.27
Total	265	......	282	......	185	......	392	......	209	......	309	......	320	......	187	......	220	......

FOUND BY BREAKING.

Green whites	17	47.22	7	29.17	5	26.31	13	27.08	......	......	......	......	13	48.15	8	36.36	32	49.23
Bad-odor eggs	3	8.33	2	8.33	2	10.53	5	10.42	......	......	......	......	5	18.52	4	18.18	18	27.69
Mixed rots	7	19.44	14	58.34	9	47.37	22	45.83	......	......	......	......	6	22.22	5	22.73	11	16.92
White rots	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1	1.54
Moldy eggs	7	19.44	......	......	2	10.53	5	10.42	......	......	......	......	2	7.41	2	9.09	......	......
Crusted yolks	2	5.56	1	4.16	1	5.26	3	6.25	......	......	......	......	1	3.70	3	13.64	3	4.61
Total	36	......	24	......	19	......	48	......	......	......	......	......	27	......	22	......	65	......

[1]Data from cases of eggs withdrawn from storage from November until March

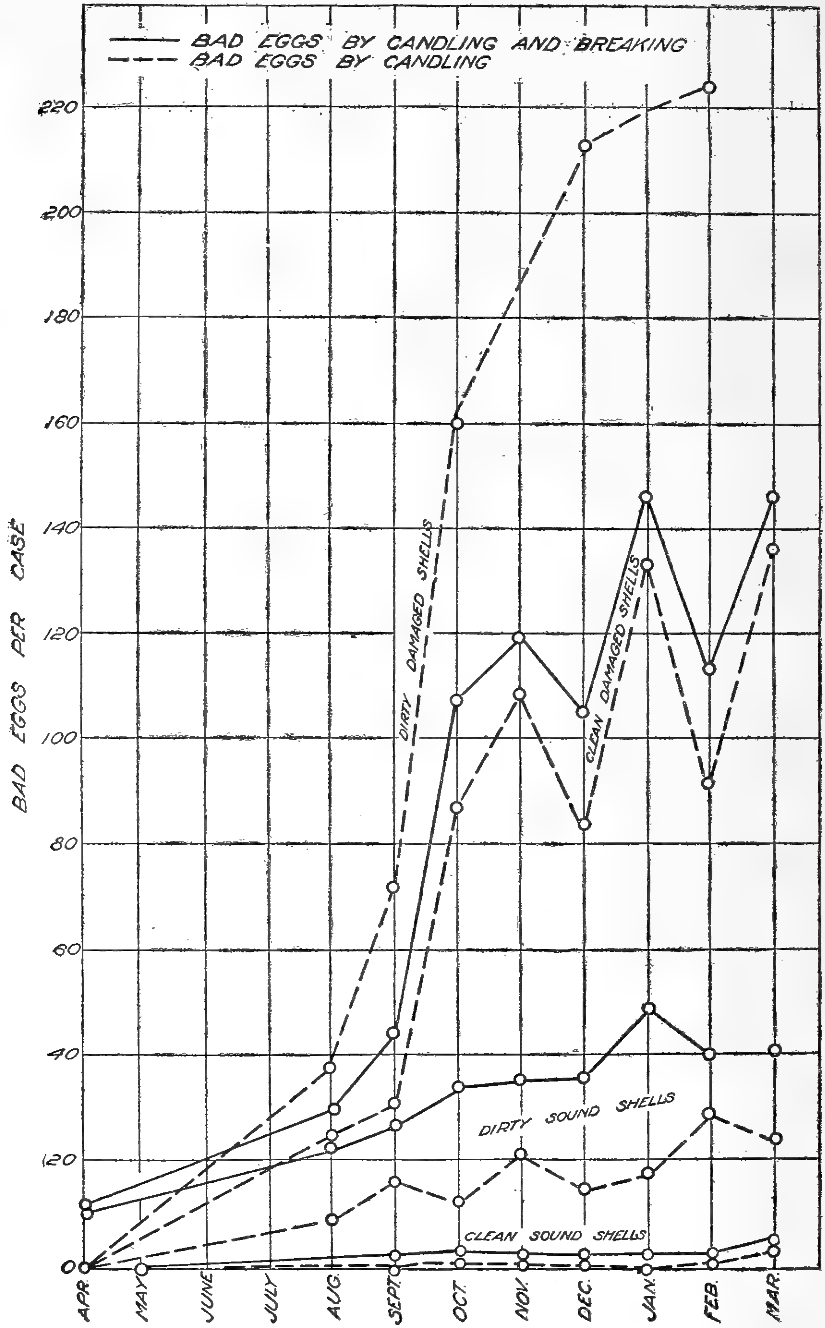
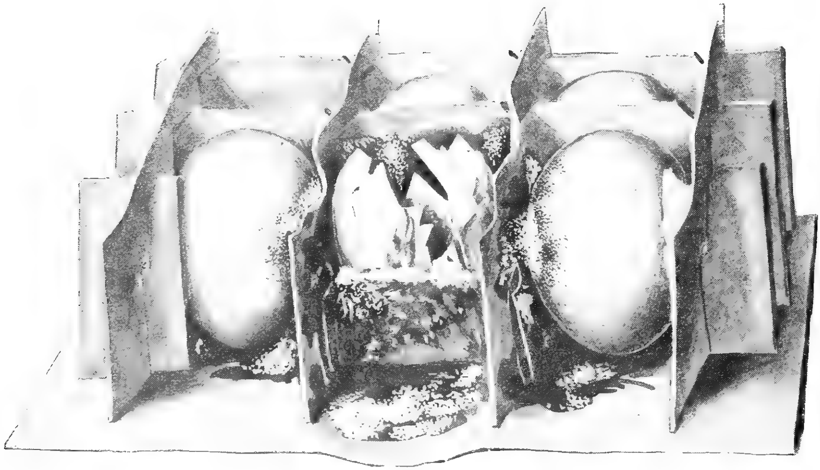


FIG. 1.—Effect of condition of shell upon preservation of fresh eggs.

COLD-STORAGE ROOM, SHOWING BRINE COILS AND STACKS OF STORAGE-PACKED EGGS. CAPACITY, 4,000 CASES, OR 1,440,000 EGGS.



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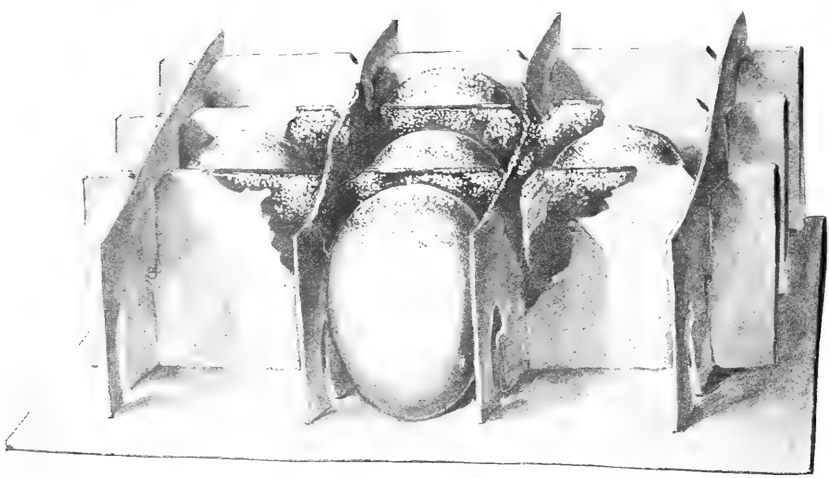

Lower layer.

CONTAMINATION OF NEIGHBORING EGGS BY A MOLDING LEAKER.

RELATION OF QUALITY TO PRESERVATION.

The initial quality of the eggs influences to a large extent their preservation by cold storage. Stale, weak, and hatch-spot eggs, which are only too plentiful in eggs marketed in the summer, lose heavily after a few months holding in cold storage. In the experiment cited in Table 5 and figure 2, the stale and heated eggs stored in July developed comparatively few bad eggs up to September, but from then until the end of March the loss was from 13.5 to 24 eggs per case by candling, with 9.5 to 19 additional by breaking. The number of bad eggs developing may be higher or lower than that found in this experiment, depending upon the degree of deterioration before the eggs entered storage. The most frequent types of bad eggs present in heated stock after storing are those with slightly stuck or broken-down yolks in various stages of addling. These eggs in the early stages are a form of mixed rot and are classed as such in Table 3.

TABLE 5.—*Relation of quality of clean eggs to preservation.*

Month of withdrawal.	Fresh eggs with clean, sound shells.			Stale and heated eggs with clean shells.			Stale and heated eggs with damaged shells.		
	Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.	
		Candling.	Breaking.		Candling.	Breaking.		Candling.	Breaking.
April	1,026	0	0.5						
May									
June									
July				977	0	0	90	0	4
August				949	8	4	104	58	3.5
September	710	0	2.5	938	6	9	106	64	20.5
October	704	1	1.5	949	2.5	4.5	111	83	32
November	695	0.5	2	901	13.5	9.5	109	135.5	33
December	709	0.5	1	954	14.5	10.5	94	175	11.5
January	694	0	2.5	960	14	14	100	147.5	18
February	715	1	2	926	24	12.5	129	232.5	19
March	717	2.5	2.5	946	23	19	96	251	15

It does not follow, however, that because many of the eggs marketed in the summer months are shrunken and heated and do not keep well in storage, the eggs as laid by the hen in the summer are not initially as good in quality as those laid in the spring. Fresh hennery eggs laid in April and July, delivered to storage within approximately 48 hours after being laid, showed a negligible loss in bad eggs, even after a long period of storage (Table 6). The bad eggs present were those showing a slight breaking down of the yolk. No eggs with green whites or crusted yolks were found. Their absence was to be expected, because the natural condition of the shell had not been disturbed through soiling, washing, or contact with damp surroundings. The good results in this report show the improvement yet to be attained in the commercial marketing of summer eggs.

TABLE 6.—*Relative keeping quality of freshly laid April and July hennery eggs.*

April hennery eggs.			July hennery eggs.		
Months in storage.	Number observed.	Bad eggs.	Months in storage.	Number observed.	Bad eggs.
7.2	351	2	6.5	275	1
11	274	2	8.5	267	2
....	....	....	10.8	241	0

After holding from four to eight months stale and heated cracked eggs stored in July showed a total of 168.5 to 266 bad eggs per case (Table 5 and fig. 2). The higher loss in these eggs, in comparison with the clean, cracked fresh eggs stored in the spring, may no doubt be explained by the development of larger numbers of molds and bacteria during the warm weather before storing.

In short, these studies show that, for successful preservation, eggs to be stored for several months should have clean, sound shells, and be fresh in quality.

COMMERCIAL GRADING FOR STORAGE.

Most of the grading of eggs for storage is done in the producing sections, although some ungraded current receipts reach the markets in the consuming centers, particularly from shippers located in the undeveloped poultry and egg sections of the country. It is generally recognized by the industry that only the best eggs should be used for storing, and that more care should be taken in the packing of eggs for storing than for direct marketing. New cases and new medium fillers (3 pounds 3 ounces per case) ordinarily are used. A very small proportion of the eggs are candled before storing, except in the summer when the production is light and the percentage stored small. The usual procedure is to sort the current receipts into various grades by clicking and inspecting the shells. From the case of current receipts the sorters take in each hand three eggs, which, by an inward movement of the index finger, they click together (Plate III). A clear ring indicates whole shells; a deadened sound signifies the presence of cracked eggs. The latter are sorted into cases by themselves, as are also the small and dirty eggs. These eggs are marketed for immediate consumption, or are broken and frozen in cans to be used by bakers as needed. Sometimes a grade called "trade eggs," sold principally in southern markets, is made from the clean, small eggs. The large eggs with clean, whole shells are used in the storage-packed eggs. Usually two grades, firsts and extra firsts, are prepared. The former must weigh at least 42 pounds to the case, and the latter 44 pounds. The making of four grades from current receipts is shown in Plate IV.

The sorting is done by either men or women, who are frequently inexperienced. Usually the work is directed by a foreman more or less skilled in egg handling and grading.

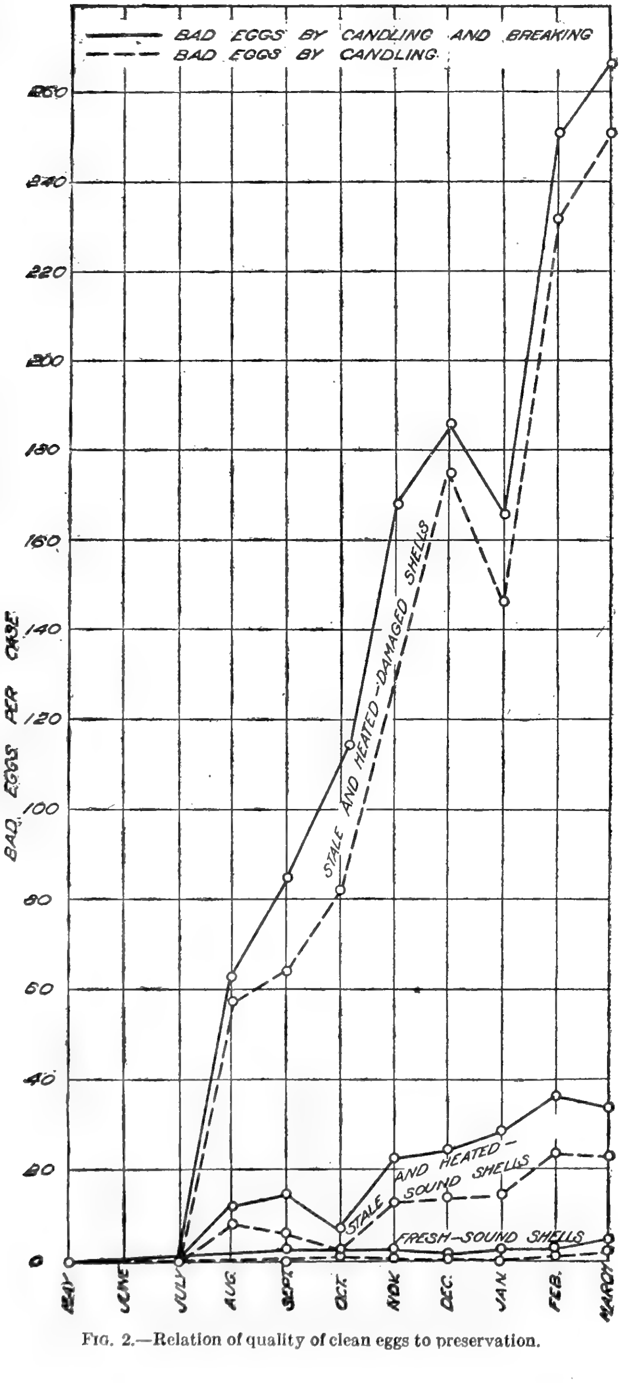

FIG. 2.—Relation of quality of clean eggs to preservation.

RELATION OF MONTH OF STORAGE TO NUMBER OF BAD EGGS IN COLD STORAGE FIRSTS AND SECONDS.

"Market firsts," commercially packed for storage in April, May, June, and July, were studied for three consecutive seasons. It may be seen from Table 7 and figure 3 that the April and May commercially packed eggs showed a low number of bad eggs more uniformly during the course of the storage period than did the June and July commercial stocks. This may be accounted for by the fact that most of the spring eggs on the market are fresh, are not shrunken, and have not been exposed to high temperatures before storing. Some of the commercial summer firsts, for example, Experiments 41782, 41941, and 41787, contained no more bad eggs after storing than did the commercial spring firsts. On the other hand, Experiments 41918, 41922, and 41945 showed heavy losses, even after a comparatively short period of storage. Indeed, it would not pay to carry such low-quality eggs in storage longer than the fall months. In commercial practice very few eggs are stored in summer, and practically all are withdrawn by November or December. In fact, in the summer when the general supply is poor in quality, dealers frequently draw from the spring stock in storage to fill orders requiring eggs of good quality.

On withdrawal from storage between November and March, commercial spring and high-grade summer firsts showed usually from 12 to 18 bad eggs per case by candling, with from 2 to 6 additional by breaking. On the other hand, summer seconds and low-grade commercial summer firsts, when withdrawn from storage between November and March, ordinarily contained from 18 to 42 bad eggs per case, as determined by candling, and from 6 to 12 more as found by breaking (Tables 7 and 8 and fig. 3).

Undergrade eggs, consisting of those which are dirty, small, shrunken, and heated, usually are marketed directly in the shell or used in the preparation of frozen and dried products. These grades of eggs are very seldom stored, except for short intervals, as the industry realizes that they do not keep well in storage for long periods. It is frequently convenient for the management of egg-breaking plants to buy large quantities of seconds in the spring when eggs are plentiful and cheap, to store for one or two months, and to open when the supply of these eggs on the market is short and when otherwise the breaking room would be practically idle. This practice is warranted only for very short intervals. There may be no appreciable increase in bad eggs during a storage period of four or five months, but the general quality is much lower because of increased staleness and higher bacterial content.[1] Because deterioration has already begun, summer seconds should not be stored, even for short periods; they should be sold for immediate consumption or promptly broken and frozen. In short, for successful preservation in storage in the shell, eggs, like other perishable products, must initially be in prime condition.

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[1] Unpublished results.

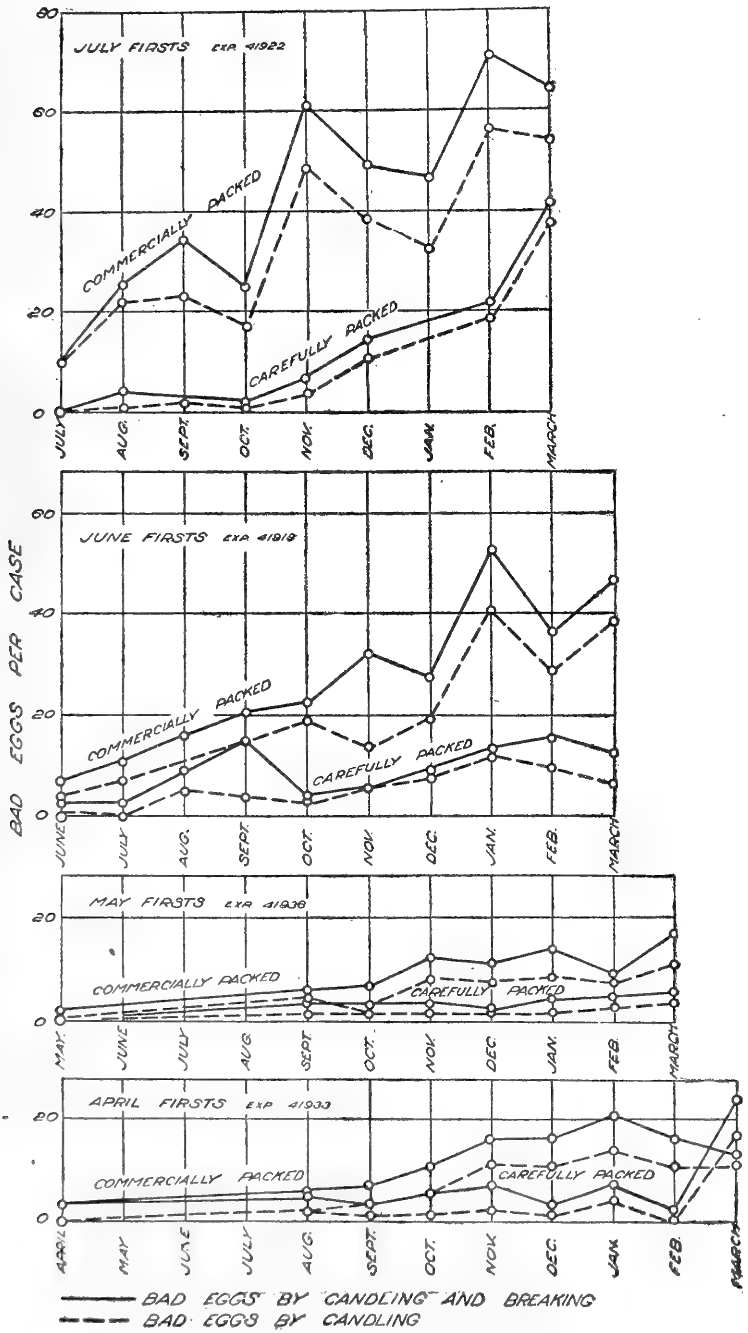


FIG. 3.—Increase in bad eggs per case in refrigerator firsts during storage.

TABLE 7.—*Increase in bad eggs per case in refrigerator firsts during storage.*

Month of withdrawal.	April firsts.				May firsts.				June firsts.					July firsts.				
	Experiment 41680 (1914).	Experiment 41896 (1915).	Experiment 41933 (1916).		Experiment 41716 (1914).	Experiment 41916 (1915).	Experiment 41936 (1916).		Experiment 41782 (1914).	Experiment 41918 (1915).		Experiment 41941 (1916).		Experiment 41787 (1914).	Experiment 41922 (1915).		Experiment 41945 (1916).	
	Candling.	Candling.	Candling.	Breaking.	Candling.	Candling.	Candling.	Breaking.	Candling.	Candling.	Breaking.	Candling.	Breaking.	Candling.	Candling.	Breaking.	Candling.	Breaking.
COMMERCIALLY PACKED:[1]																		
April	0	0.5	0.5	4.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May	0	2.5	...	...	0.5	2	0.5	1.5	...	...	...	...	...	...	...	...	...	...
June	0.5	2.5	...	...	2	2	...	...	4	4	3.5	1.5	1	...	...	...	...	...
July	0.5	9	...	...	3	2.5	...	...	4	7.5	3	...	...	0	10	0.5	3.5	2.5
August	1	7.5	2.5	13.5	5	10	...	...	4.5	9.5	6.5	1.5	2.5	1	22	3.5	10.5	9.5
September	4	9.5	3	11.5	4	10	4	2	6	12.5	8	2	2.5	2	23.5	10.5	12.5	4.5
October	2	10.5	5.5	5	4	24	3	3.5	8	19	4.5	5	4	2	17.5	7.5	24.5	5.5
November	12.5	10.5	11.5	5	6.5	13.5	8	4	6	14	18.5	8	6	2	48.5	13	28.5	8
December	11	16.5	11.5	5	12	19.5	7	4.5	7.5	19.5	8.5	2.5	8.5	5	38.5	11	24.5	17
January	15.5	15	14	6.5	6	25	8.5	5.5	7.5	41	12	13.5	12	...	33	14.5	20.5	14
February	21	13.5	10.5	5.5	13	22.5	7	2	...	29.5	9	14	5.5	...	56.5	15	49.5	15.5
March	...	36.5	10.5	2.5	33	21.5	11	6	...	39.5	8	9.5	4.5	...	55	10.5	45.5	4.5
CAREFULLY PACKED:[2]																		
April	...	0	0	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May	...	1	...	...	...	0	0	0.5	...	...	...	...	...	...	...	...	...	...
June	...	1	...	...	...	0	...	...	...	0	2.5	0	1	...	...	...	...	...
July	...	0	...	...	...	0	...	...	...	0	3	...	...	...	0	0	0	2.5
August	...	3	2	1	...	1	...	...	...	5	4.5	1	2	...	1	3	2	9
September	...	1	1	1	...	1	1	2.5	...	4	11	0	5	...	2	...	22	17
October	...	2	1	5	...	3	1.5	1.5	...	3	1	2	2	...	1	1	14	7
November	...	2	2	5	...	3	1.5	2	...	6	0	1	3	...	4	3	13	4
December	...	3	1	2	...	2	1	1	...	8	1	2	3	...	11	4	14	12
January	...	2	4	3	...	2	1.5	2.5	...	12	...	3	12	...	...	...	18	5
February	...	8	0	2	...	15	2.5	2	...	10	6	8	1	...	19	3	43	9
March	...	7	17	7	...	2	3	2.5	...	7	6	11	2	...	38	4	26	5

[1] Five cases examined monthly in 1914 and three monthly in 1915 and 1916.

[2] One case examined monthly.

TABLE 8.—*Increase in bad eggs per case in refrigerator seconds during storage.*

Month of withdrawal.	April dirty eggs.	May dirty eggs.	June dirty eggs.	June seconds.		June dirty eggs.		July seconds.	July dirty eggs.	July seconds.	
	Experiment 41679 (1914).	Experiment 41686 (1914).	Experiment 41778 (1914).	Experiment 41919 (1915).		Experiment 41943 (1916).		Experiment 41788 (1914).	Experiment 41805 (1914).	Experiment 41923 (1915).	
	Candling.	Candling.	Candling.	Candling.	Breaking.	Candling.	Breaking.	Candling.	Candling.	Candling.	Breaking.
COMMERCIALLY PACKED:[1]											
April	3.5										
May	3	5									
June	3	10	12	9.5	11	8.5	3				
July	3.5	12	16	10.5	9.5	17		0	0	21.5	3.5
August	6	11	23.5	12	8	17	19	7	18	48.5	18.5
September	9.5	35	29	27.5	17	42	14	4.5	19	22.5	9.5
October	11	20	22.5	28.5	9.5	25.5	16.5	8	23	26.5	13.5
November	14.5	26.5	32	26	16.5	22.5	10.5	15.5	35	44	19
December	20	24	41	38.5	14	32.5	13	11	38	58.5	7.5
January	30	32.5		37.5	13.5	59	19			56.5	14.5
February	30	28		56.5	28.5	68.5	13.5			52	17.5
March		67		54.5	20.5	74.5	7.5			52.5	20.5
CAREFULLY PACKED:[2]											
April											
May											
June				0	11	0	3				
July				2	9					0	20
August				11	7	4	13			3	
September				5	16	10	15			4	16
October				9	11	11	16			2	11
November						11	8			29	11
December				12	7	4	4			11	7
January				25		11				14	
February						18	4			16	37
March				49	8	26	13			13	8

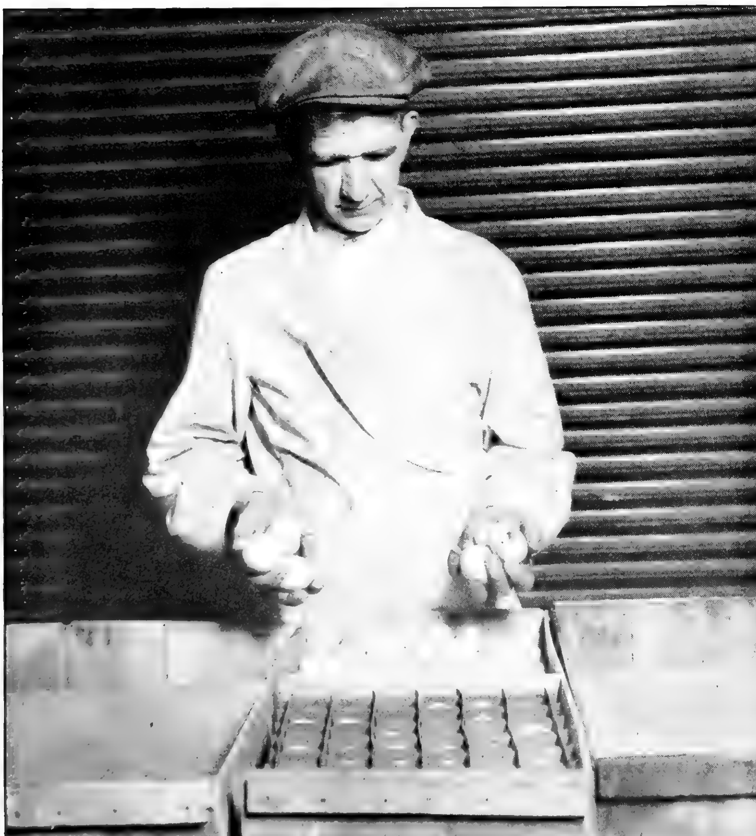
[1] Five cases examined monthly in 1914 and three monthly in 1915.

[2] One case examined monthly.

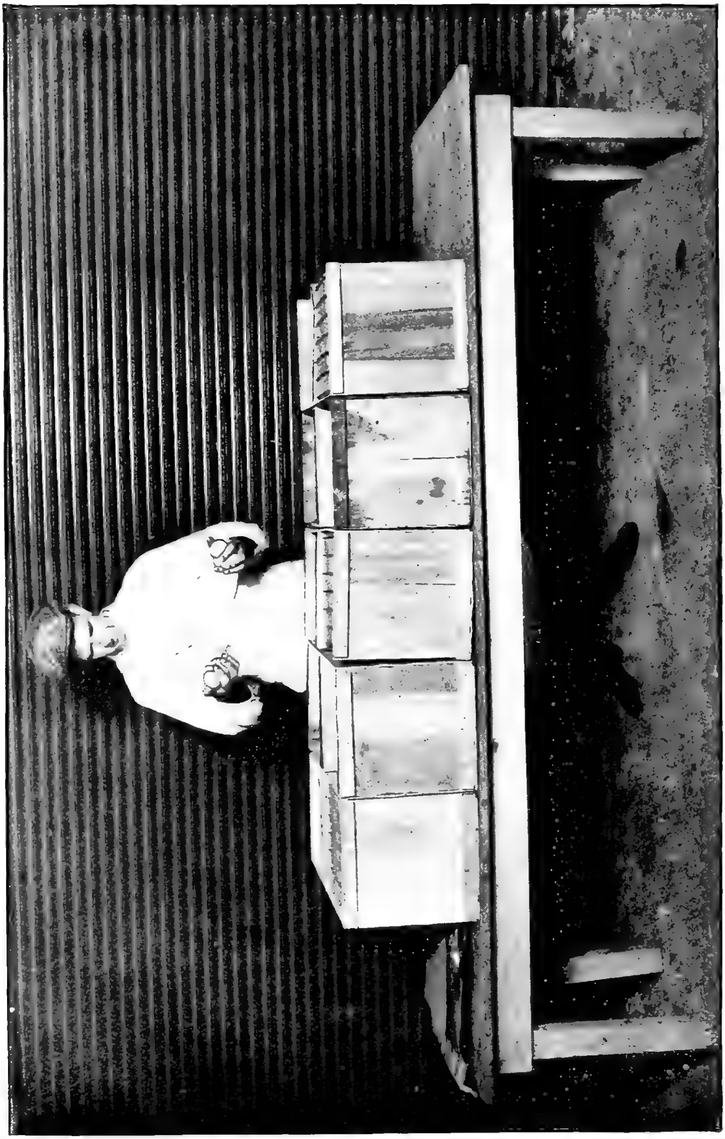
CONDITION OF COMMERCIAL PACKAGES AS STORED.

Most warehouses require an examination of the cases of eggs for mechanical damage before permitting them to be taken to the cold-storage rooms, the thoroughness of the examination depending upon the strictness of the management. The officials of some warehouses demand that representative portions of carload lots be inspected, while others ask that each case be examined. In some cold-storage plants the examinations are made by the employees; in others, by the patrons. In the latter instance some firms exercise more care in inspection than the rulings of the warehouse require. In the warehouse where the eggs used in these investigations were stored, each patron examines his eggs and usually every case is opened. The top layers of each case are examined without being removed (Pl. V, fig. 1), or they are lifted from the case and both the upper and lower sides examined (Pl. V, fig. 2 and Pl. VI, fig. 1). When evidences of broken eggs are found in the top fillers (Pl. VI, fig. 2) each layer is inspected, and all leaking eggs discovered are replaced by eggs with whole shells in dry fillers. If no breakage is found in the top layers the remaining layers are undisturbed.

The cases of eggs under observation were inspected according to the system shown in Plate V, figure 2, and Plate VI, figure 2. These cases, then, represented the condition of commercial packages on entering storage. The eggs were next candled to determine quality and to ascertain the number of dirty, cracked, leaking, and bad eggs included with the good, clean eggs. Representative samples were also broken to further discover the quality and to find the number of bad eggs not recognized by candling, and samples of the liquid edible product were prepared for chemical analysis (Table 9, "Eggs as stored", and Tables 12 and 13).



GRADING EGGS FOR COLD STORAGE BY INSPECTING AND CLICKING THE SHELLS.



GRADING CURRENT RECEIPTS INTO STORAGE-PACKED EXTRA FIRSTS, STORAGE-PACKED FIRSTS, TRADE EGGS, AND CRACKED AND DIRTY EGGS.

FIG. 1.—TOP FILLER EXAMINED WITHOUT REMOVING EGGS UNLESS DAMAGE IS FOUND.

FIG. 2.—REMOVING TOP LAYERS AND INSPECTING UPPER AND LOWER SIDES.

INSPECTING STORAGE-PACKED EGGS. IF DAMAGE IS FOUND IN TOP FILLERS ALL THE LAYERS ARE REMOVED AND SOUND EGGS SUBSTITUTED FOR THE BROKEN EGGS.

FIG. 1.—EACH WORKER WITHDRAWS A LAYER AND HOLDS THE BOTTOM IN POSITION FOR THE OTHER WORKER TO INSPECT.

FIG. 2.—LAYER OF EGGS SHOWING WET SPOTS ON FLAT, DUE TO DAMAGED EGGS.

INSPECTING CASES OF STORAGE-PACKED EGGS. IF DAMAGE IS FOUND IN TOP FILLERS ALL LAYERS ARE REMOVED AND SOUND EGGS SUBSTITUTED FOR THOSE THAT ARE BROKEN.

TABLE 9.—*Relation of care in initial sorting to bad eggs in refrigerator eggs.*

[Data given as eggs per case from eggs withdrawn from storage from November to March, inclusive.]

Experiment No.	Grade.	Cases.	Method of packing.	Eggs as stored. By candling. Good eggs. Clean.	Good eggs. Dirty.	Good eggs. Cracked.	Good eggs. Leaking.	Bad eggs.	Haul damage.[1] Cracked.	Haul damage. Leaking.	Bad eggs after storing. By candling. Clean.	By candling. Dirty.	By candling. Cracked.	By candling. Leaking.	By candling. Contaminated.	By candling. Total.	By breaking. Whole.	By breaking. Damaged.	By breaking. Total.	Grand total bad eggs.
41896[2]	April firsts	33	Commercial[3]	333.5	5	19	2	0.5	5.5	0.5	4	0.5	9	2	2	17.5	......	1.5	......	......
41897[2]	do	11	Careful[3]	360	0	0	0	0	8	1	3	0	1	0	0	4	......	......	......	......
41933	do	24	Commercial	312.5	27	19.5	0.5	0.5	2	0.5	2	0.5	6	1	1	10.5	4	1	5	16
41934	do	8	Careful	360	0	0	0	0	2	0	4.5	0	0.5	0	0	5	4	0	4	9
41916	May firsts	30	Commercial	338.5	1	17	1.5	2	3	0.5	7	0	7.5	1.5	2	18	......	1	......	......
41917	do	10	Careful	360	0	0	0	0	2.5	0.5	4.5	0	0.5	0	0	5	......	......	......	......
41936[4]	do	42	Commercial	327.5	16	15	0.5	0.5	3	0.5	2.5	0.5	4	0.5	0	7.5	4	0.5	4.5	12.5
41937	do	18	Careful	360	0	0	0	0	2.5	0	1.5	0	0	0	0	1.5	2	0	2	3.5
41918	June firsts	27	Commercial	336.5	0.5	16.5	2.5	4	3	0.5	9	0	8	2	4	23	10.5	1	11.5	38.5
41920	do	19	Careful	360	0	0	0	0	4	0.5	8	0	0.5	0	0	8.5	3	0	3	11.5
41941	do	23	Commercial	314	30	14.5	0	1.5	3	0	4.5	1	2	0	0	7.5	6.5	0.5	7	16
41942	do	8	Careful	360	0	0	0	0	2	0	4.5	0	0.5	0	0	5	4	0	4	9
41922	July firsts	24	Commercial	313.5	4.5	29	3	10	3	0.5	15	0.5	16	2.5	1.5	35.5	10.5	2	12.5	58
41927	do	8	Careful	360	0	0	0	0	3.5	0	17	0	1	0	0	18	3.5	0	3.5	21.5
41945	do	23	Commercial	296.5	39	20	1	3.5	3.5	0.5	17	2.5	7	0.5	0.5	27.5	10.5	1	11.5	42.5
41946	do	8	Careful	360	0	0	0	0	3.5	0	22.5	0	0	0	0	22.5	7	0	7	29.5
41919	June seconds	27	Commercial	293	35.5	20	2	9.5	2.5	0	13.5	5.5	10.5	2	1.5	33	17	1.5	18.5	61
41920	do	7	Careful	360	0	0	0	0	3	0	27	0	2	0	0	29	16	0	16	45
41943	do	23	Commercial	44	272	34	1.5	8.5	5	0	1	19.5	19.5	2	1	43	11	2	13	64.5
41944	do	8	Careful	0	360	0	0	0	3.5	0	14	0	0	0	0	14	7	0	7	21
41923[4]	July seconds	24	Commercial	282	25.5	29	1.5	21.5	3.5	0.5	15	0	13	1.5	0	29.5	13.5	4.5	18	69
41927	do	8	Careful	360	0	0	0	0	3.5	0	16.5	0	0	0	0	16.5	9	0	9	25.5

[1] From commission house to warehouse and return.
[2] Poor fillers.
[3] Three to five commercially packed cases and one carefully packed case examined monthly.
[4] One-half egg per case short.

The number of bad eggs found by candling among commercial spring firsts before storing averaged from 0.5 to 2 eggs per case, as compared with 1.5 to 10 eggs per case in the summer packed firsts. As would be expected, the initial number of bad eggs in the summer seconds was higher, averaging from 8.5 to 21.5 per case in the different lots (Table 9). The bad eggs found by candling could not have been recognized by sorting, that is, by visual inspection and clicking of shells; therefore, their presence did not reflect upon the accuracy of the initial sorting, but upon the inadequacy of the system as compared with candling. The additional bad eggs found by breaking, consisting mostly of green whites, averaged from 0.5 to 4.5 eggs per case in the spring and summer supply. The condition of these eggs, not recognizable by candling, would not be discovered in the routine marketing until opened by the consumer.

The number of cracked eggs averaged from 14.5 to 29 per case in the storage packed firsts, and from 20 to 34 per case in the summer seconds. The leakers averaged from none to 3 per case in the different lots studied, showing that the absence of damage in the top layers, as determined by commercial inspection, does not always indicate that there is none in the lower layers. The findings here corroborate the more extensive investigations made by Pennington, McAleer, and Greenlee.[1]

Some lots of storage packed firsts contained but few dirty eggs; others showed an average of 30 eggs per case. The presence of dirty eggs in commercial packages may be attributed directly to oversight or carelessness in the initial sorting of the eggs for storage.

ANALYSIS OF BAD EGGS IN COMMERCIAL FIRSTS AND SECONDS AFTER STORING.

Studies were made to determine the relative number of bad eggs developing in storage from whole, cracked, and leaking eggs present in the commercial storage stocks. These observations were based on spring and summer eggs withdrawn at monthly intervals from November until March, inclusive. Three cases of each lot were examined monthly, but, for simplicity, the results for the entire period are averaged. It was observed that most of the bad eggs developing in storage packed eggs were evident by November.

As might be expected, a large portion of the cracked eggs originally present in the commercial packages spoiled during storage (Table 9, "Bad eggs after storing," and figs. 4 and 5). Out of the average of from 15 to 19.5 cracked eggs per case present when the commercial spring firsts entered storage, from 4 to 9 bad eggs per case developed, as detected by candling, and from 0.5 to 1.5 additional per case as found by breaking. The losses were still higher in the summer packed firsts. For example, Experiment 41945 when stored contained an

[1] U. S. Dept. Agr. Bul. 664.

average of 20 cracked eggs per case, of which 8 were found to be inedible after storing. Practically all of the leaking eggs spoiled by molding.

Damaged eggs, particularly leaking eggs, in becoming moldy may contaminate neighboring eggs and cause them to spoil. When the contents of a broken egg leak out and soak into a strawboard filler, the filler usually becomes moldy, and causes eggs coming in contact with it to mold. This contamination may extend to eggs in adjoining

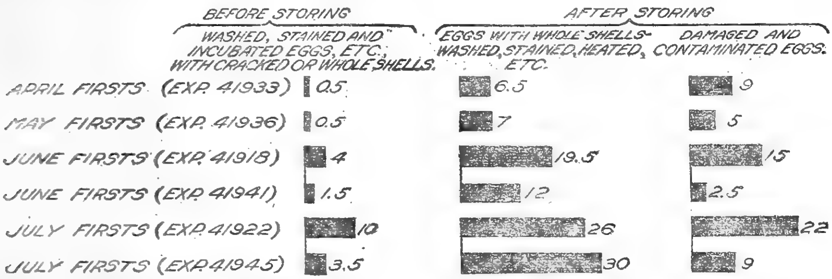


FIG. 4.—Analysis of bad eggs in refrigeration firsts, commercially packed (data given as bad eggs per case from Table 9.)

pockets or through flats to the eggs beneath. Plate II illustrates an aggravated case of the spoilage which may result from the presence of only one badly broken egg in the case. In the different lots of eggs studied, an average of from 1 to 4 eggs with sound shells per case was spoiled by leaking eggs.

Dirty eggs constituted but few of the bad eggs present in the commercially packed firsts. As found by candling, the bad eggs with dirty shells averaged from none to 2.5 eggs per case in the different lots examined.

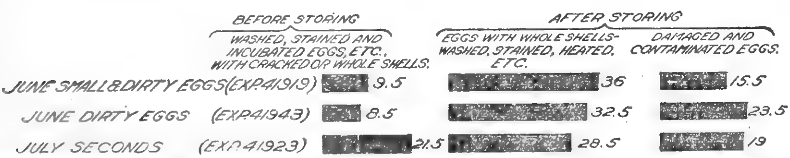


FIG. 5.—Analysis of bad eggs in refrigerator seconds, commercially packed (data given as bad eggs per case from Table 9.)

The clean eggs with sound shells constituted the majority of the eggs in the commercial cold storage firsts. In the spring stocks these eggs furnished an average of from 2 to 7 bad eggs per case, as found by candling, and an average of 4 extra, by breaking. In the summer stocks they contributed an average of 4.5 to 17 bad eggs per case by candling, and 6.5 to 10.5 additional by breaking. The inedible eggs in the clean summer seconds with sound shells, as found by candling and opening, were practically the same in number as the poorer grade of summer firsts. A large proportion of the bad eggs in the spring firsts with whole shells may be attributed to the presence of eggs which at some time previous to storage had had wet shells, because of washing the eggs or for some other reason. If the dirt is left on the shells the eggs can be graded accordingly, but if washed it is not always possible to differentiate between them, with the result that washed eggs are frequently graded as firsts. Washed eggs do not keep as well as dirty eggs. Attempts, therefore, to improve the appearance of dirty eggs by washing is a practice which can not be too strongly condemned. In eggs stored from summer production there is an additional loss due to the physical breaking down of the egg contents as a result of exposure to warm temperatures before storing.

These studies show that the following factors are responsible for the development of a large percentage of bad eggs in commercial spring firsts during storage: (1) Inaccuracies in the system of sorting eggs for storage; (2) the inadequacy of that system in determining quality and detecting bad eggs; and (3) to a lesser extent, damage during the railroad haul. The bad eggs developing during storage in the summer stocks are due to these factors, combined with a lower initial quality.

CAREFULLY PREPARED PACKAGES.

In order to determine the relation between care in initial grading and the number of bad eggs developing during storage, packages containing as far as possible only good eggs with clean whole shells were prepared from each lot of commercially packed eggs studied during the last two seasons of the investigation. To determine quality and to eliminate bad eggs, the eggs were selected by candling instead of by simply inspecting and clicking the shells.

Candling is a more accurate method for the detection of cracked eggs than is the clicking of shells, as ordinarily practiced. Enough carefully graded packages were prepared so that one case could be withdrawn monthly from storage with each three cases of corresponding commercially packed eggs. Following such a procedure, the carefully packed eggs, excluding Experiment 41897, contained an average of three cracked eggs per case after carting from the commission house to the cold storage warehouse and return. Of this number from one to two of the cracked eggs may be accounted for by handling error in putting up the eggs for storage, and the balance by damage during cartage. The number of cracked eggs in Experiment 41897 was unusually high, largely because of the use of a very poor grade of filler, so that more damage than usual was incurred during cartage.

Table 9 and figures 6 and 7 show that the number of inedible eggs present after storing was reduced in the carefully packed, as compared with the commercial cases. In the April and May refrigerator firsts there was an average of 13.5 inedible eggs per case found by candling in the commercially packed eggs, as compared with 4 in those carefully packed. These figures are the averages of the results of monthly observations made from November to March. Figuring the value of eggs when stored in the spring of 1917 as 35.6[1] cents per dozen, and charging 3 cents a dozen to cover insurance, interest, and carrying cost, there was an average money loss in bad eggs in the commercially packed eggs of 43.5 cents, as compared with 13 cents per case in those

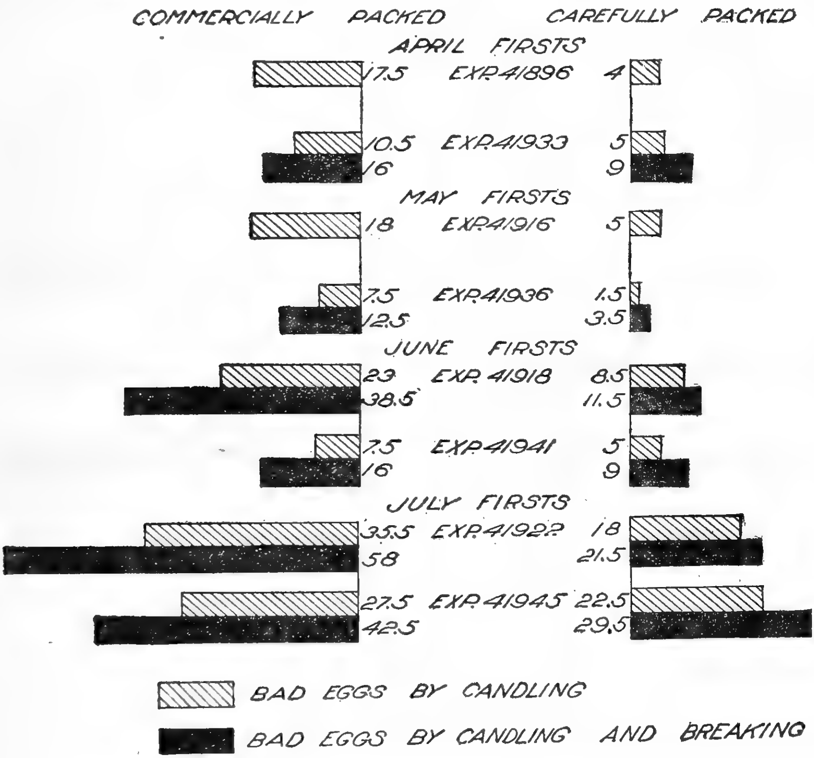


FIG. 6.—Relation of care in initial sorting to number of bad eggs in refrigerator firsts (data given as bad eggs per case from Table 9).

carefully packed. An average of 11 cracked eggs, which were still good by candling, was found in the case of the commercially packed eggs. These, however, on account of their impaired shells, would bring one-third less on the markets than their companion eggs with good shells, making a further additional loss of 12 cents per case. The total loss, then, in the commercial stocks averages 55.5 cents per case, as compared with 13 cents in the carefully packed eggs. It costs about 5 cents more per case to grade by candling than by sorting. Even

[1] U. S. Dept. Agr., Bureau of Markets Report of Mar. 11, 1918.

with this added expense there was a saving of 37.5 cents per case in favor of the carefully packed eggs which amounts to $140 per carload of 400 cases in spring stocks stored until after November.

In the summer commercial firsts and seconds careful packing did much to reduce the number of bad eggs developing during storage, but it did not offset the losses due to the lower initial quality of the entering material (Table 9 and fig. 7).

It is believed with a little attention given to the checking of the accuracy of the sorting of eggs for storage, the number of cracked and dirty eggs missed could be greatly lessened without materially reducing the amount of work accomplished. In addition, since the detection of cracked eggs depends upon hearing distinctly the sound emitted on tapping the eggs together, noises in the work room should be eliminated as far as possible. Far greater efficiency, however,

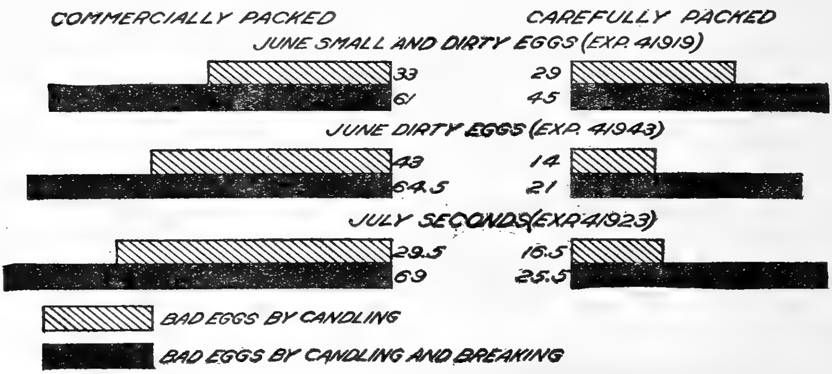


FIG. 7.—Relation of care in initial sorting to number of bad eggs in refrigerator seconds (data given as bad eggs per case from Table 9).

would be obtained by candling all eggs entering storage. Realizing the importance of having a uniformly graded product, some of the more progressive western houses make a practice of candling all eggs stored, at the same time enforcing a checking system [1] to see that the work is accurately done. This is a big step forward, for by candling the cracked eggs can be more accurately eliminated, and low quality and bad eggs may be detected and discarded. Under such a system the graders become so skilled that their work is as accurate as that of the carefully packed stocks of this investigation.

Such eggs, being practically free from mold after several months in storage, are an advertisement to the firm selling them, and in practice it has been found that their more uniform quality has secured for them special outlets with higher prices. According to the present system of marketing, storage packed eggs may pass through several hands before they are finally consumed, with the

[1] U. S. Dept. Agr. Bul. 702.

result that the original shipper seldom sees the condition of his goods when they are withdrawn from storage. For example, the packer in the producing section may sell to a commission man in the East, who in turn may sell to another dealer. Upon withdrawal from storage the eggs may go into another buyer's hands before they are finally graded for the retail market. In addition to buying according to shrinkage before the candle and weight, dealers in storage packed eggs should demand that the cases be practically free from cracked eggs. This factor has received too little attention in the past, taking into consideration the fact that the average of 19 cracked eggs per case as the eggs leave the shipper's hand frequently furnishes half of the bad eggs developing during storage. In the final analysis, the original packer must bear the burden of expense of the stale, dirty, cracked, leaking, and bad eggs included in the storage grade, for, in order to play safe, buyers must pay a lower price for the whole package than they would if sure of receiving cases containing only large, clean, fresh eggs with whole shells. If there is no direct market for the cracked, dirty, shrunken, and leaking eggs in the shell, their initial quality can be conserved by breaking and freezing in cans. Ordinarily there is a good market for frozen egg products of high quality.

SHRINKAGE OF EGGS AND ABSORPTION OF MOISTURE BY CASE AND FILLERS.

The changes in weight of eggs, case, and fillers were studied in three different storage rooms. All the weighings were made in the room where the eggs were held, because it was found that the cases and fillers frequently gained in weight if removed to a higher temperature. A sensitive scale was used. First the gross weight was found; then the eggs were transferred to a second case, and the fillers and the case weighed. The net weight of the eggs was determined by difference. After weighing, the eggs were returned to the original cases and fillers, so that the periodical weighings during the storage period were made on the same cases, fillers, and eggs.

There was an almost regular decrease in the net weight of the eggs during the course of the storage period, amounting to an average of 4.48 ounces per case per month for eggs stored in Room 1, and 3.46 ounces per month for eggs stored in Rooms 2 and 3. In Room 1 the decrease in the gross weight of a case of eggs weighing initially 56.84 pounds gross and 45.80 pounds net was 25.29 ounces and 38.20 ounces, respectively, during a storage period of 9.2 months. In Room 2 a case of eggs weighing 57.33 pounds gross and 45.01 pounds net at the beginning of the season lost 12.73 ounces gross and 26.14 ounces net after 9 months in storage. These typical results show, then, that attempts to determine shrinkage of eggs by finding changes in weight of the total package alone, a procedure frequently followed commercially, give misleading figures (Table 10 and fig. 8).

TABLE 10.—*Shrinkage of eggs and rate of absorption of moisture by case and fillers (case lots).*

COLD STORAGE ROOM 1.

Initial weight and time in storage.	Shrinkage (loss in weight).												Absorption of moisture (gain in weight).											
	Total package.						Eggs.						Fillers and flats.						Case.					
	Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.	
Initial weight (pounds).	56.84		55.37		54.50		45.80		43.53		43.09		3.78		3.68		3.61		7.27		8.16		7.74	
	Oz.	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*
1 month, 5 days	3.00	0.33	4.09	0.46	1.76	0.20	7.37	1.00	5.89	0.85	5.22	0.76	2.40	3.97	1.87	3.17	1.76	3.01	2.00	1.70	−0.07	−0.05	1.69	1.36
2 months, 3 days	5.19	0.57	8.40	0.93	7.94	0.91	10.01	1.36	9.81	1.40	11.14	1.61	2.61	4.32	1.59	2.70	1.83	3.13	2.22	1.91	0.18	0.13	1.38	1.11
3 months, 6 days	9 88	1.09	10.93	1.23	12.35	1.42	16.26	2.21	13.05	1.87	15.66	2.27	3.14	5.19	2.01	3.41	1.94	3.31	3.17	2.73	0.11	0.08	1.38	1.11
4 months, 8 days	14.14	1.56	16.59	1.87	15.17	1.74	21.34	2.91	19.08	2.70	20.42	2.96	3.74	6.18	2.29	3.89	2.58	4.40	3.46	2.97	0.21	0.16	2.68	2.16
5 months, 6 days	14.71	1.62	18.10	2.04	18.59	2.13	24.55	3.35	21.98	3.15	23.84	3.46	6.21	10.26	2.82	4.79	2.58	4.40	3.63	3.12	1.05	0.81	2.68	2.16
6 months, 13 days	17.35	1.91	24.12	2.72	20.46	2.35	28.15	3.84	27.76	3.98	27.48	3.98	6.53	10.79	2.82	4.79	3.32	5.66	4.27	3.67	0.81	0.62	3.70	2.99
7 months, 13 days	19.40	2.13	25.15	2.84	23.91	2.74	31.36	4.28	30.55	4.38	31.04	4.50	7.27	12.01	3.35	5.67	3.53	6.02	4.69	4.03	2.04	1.57	3.95	3.19
8 months, 8 days	21.76	2.39	26.28	2.96	25.93	2.97	34.53	4.71	32.73	4.70	33.72	4.88	7.44	12.31	3.88	6.59	3.60	6.14	5.33	4.58	2.58	1.98	4.20	3.39
9 months, 7 days	25.29	2.78	28.29	3.19	28.64	3.28	38.20	5.21	35.52	5.10	37.35	5.42	7.44	12.31	4.13	7.01	3.99	6.81	5.47	4.70	3.10	2.39	4.73	3.81
9 months, 25 days	28.29	3.11	31.39	3.54	31.04	3.56	41.23	5.62	38.38	5.58	38.87	5.64	7.44	12.31	4.06	6.89	3.81	6.51	5.47	4.70	2.93	2.25	4.02	3.24
Average monthly loss	......	......	......	......	......	......	4.70	0.64	4.27	0.61	4.46	0.65	......	......	......	......	......	......	......	......	......	......	......	......

COLD STORAGE ROOM 2.

Initial weight and time in storage.	Total package, Case 1.		Total package, Case 2.		Total package, Case 3.		Eggs, Case 1.		Eggs, Case 2.		Eggs, Case 3.		Fillers and flats, Case 1.		Fillers and flats, Case 2.		Fillers and flats, Case 3.		Case, Case 1.		Case, Case 2.		Case, Case 3.	
Initial weight (pounds).	58.29		56.04		57.33		45.37		44.37		45.01		3.70		3.71		3.71		9.22		7.98		7.98	
	Oz.	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*
23 days	+1.58	+0.17	+4.23	+0.47	+0.50	+0.04	4.40	0.61	2.29	0.32	5.22	0.73	2.93	4.94	2.75	4.75	2.36	3.97	3.07	2.07	3.49	2.73	2.86	2.07
1 month, 21 days	+0.88	+0.10	+0.35	+0.04	+0.84	+0.09	7.55	1.04	8.08	1.14	7.44	1.03	4.23	7.15	3.77	6.36	3.63	6.11	4.20	2.84	4.37	3.42	4.16	3.01
2 months, 24 days	+0.53	+0.06	0.02	0.02	1.20	0.13	10.19	1.40	11.39	1.61	11.75	1.63	5.36	8.91	4.87	8.20	4.62	7.77	5.01	3.39	6.07	4.75	5.43	3.93
3 months, 25 days	0.35	0.04	3.17	0.35	3.21	0.35	12.52	1.77	14.57	2.06	14.43	2.00	5.75	9.72	4.87	8.20	4.83	8.07	6.42	4.35	6.24	4.89	5.89	4.26
5 months, 3 days	1.80	0.19	3.52	0.39	4.44	0.48	14.50	1.99	16.26	2.30	17.21	2.39	6.03	10.20	5.47	9.21	5.64	9.50	6.67	4.51	6.98	5.46	6.63	4.79
6 months	3.52	0.38	5.47	0.60	4.97	0.54	16.83	2.32	19.51	2.76	18.48	2.57	6.28	10.61	5.89	9.74	5.82	9.79	7.02	4.75	7.69	6.02	7.02	5.07
7 months, 6 days	5.64	0.61	7.02	0.78	7.94	0.87	17.53	2.41	20.71	2.93	20.53	2.85	4.69	7.93	5.75	9.69	5.82	9.79	7.20	4.88	7.55	5.90	6.49	4.69
8 months, 6 days	7.94	0.85	10.40	1.16	11.25	1.22	22.05	3.03	23.77	3.36	25.00	3.47	6.53	11.03	5.93	9.98	6.10	10.26	7.58	5.14	7.69	6.02	6.35	4.59
9 months, 1 day	7.76	0.83	16.40	1.29	12.73	1.35	22.92	3.16	26.17	3.70	26.14	3.63	6.81	11.50	6.46	10.87	6.17	10.37	7.30	4.95	7.80	6.11	6.70	4.84
9 months, 29 days	12.52	1.34	14.46	1.61	16.72	1.82	25.08	3.45	29.03	4.10	29.88	4.15	6.24	10.55	3.56	11.05	5.93	9.97	6.60	4.47	7.73	6.03	6.70	4.84
10 months, 17 days	14.64	1.57	19.15	2.13	20.60	2.24	27.69	3.81	32.10	4.53	32.59	4.53	6.53	11.03	5.93	9.98	5.47	9.20	6.53	4.42	6.74	5.21	6.00	4.33
Average monthly loss	......	......	......	......	......	......	2.98	0.41	3.37	0.48	3.37	0.47	......	......	......	......	......	......	......	......	......	......	......	......

COLD STORAGE ROOM 3.

Initial weight (pounds)	57.56		57.63				45.73		45.77															
	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.	Oz.	P.ct.
3 months, 29 days	10.00	1.08	13.93	1.51			15.52	2.12	16.33	2.23														
5 months, 16 days	16.01	1.74	17.57	1.91			22.29	3.04	21.98	3.00														
6 months, 21 days	17.04	1.85	19.65	2.13			24.48	3.34	24.80	3.39														
7 months, 13 days			19.65	2.13					26.95	3.68														
8 months, 17 days			20.32	2.20					29.78	4.07														
9 months, 17 days			19.75	2.14					31.53	4.30														
10 months, 15 days			19.01	2.06					32.94	4.50														
Average monthly loss							3.92	0.54	3.64	0.50														

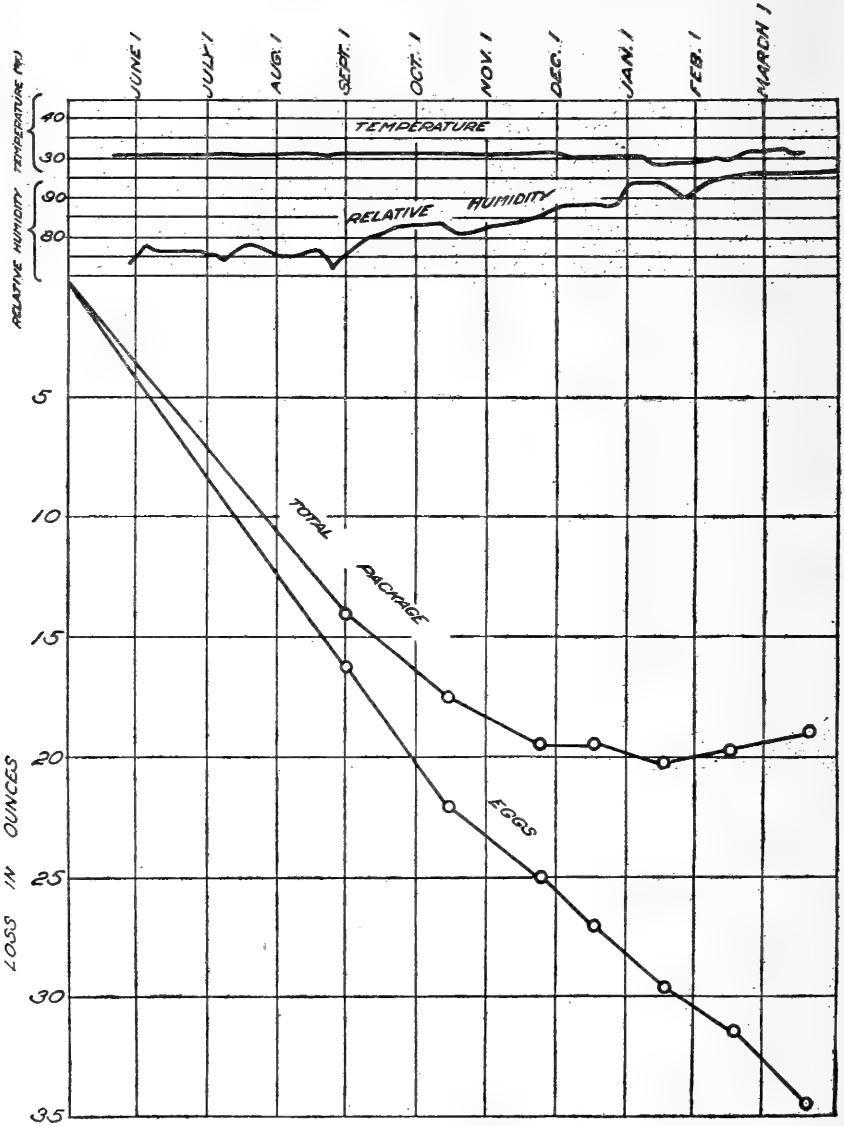


FIG. 8.—Temperature, relative humidity, and amount of shrinkage of eggs in a case of 30-dozen capacity in Cold Storage Room 3 (data from Tables 10 and 11).

The amount of moisture absorbed by the fillers and case varied in different rooms and for different cases in the same room during the storage period. Probably most of the moisture absorbed is from the water evaporating from the eggs. Cases exposed to drafts from the outside, as through the opening of doors, would condense moisture from the incoming air, but under ordinary conditions the moisture coming from this source would be small in quantity compared with that derived from the eggs. Most of the moisture was taken up by the case and fillers during the first four or five months, and from this time on the weights usually showed a slight gain or remained practically stationary. In Room 1 fillers having an initial weight of 3.61 and 3.68 pounds gained 3.99 and 4.13 ounces, respectively, after 9.2 months in storage; and in Room 2 of two sets of fillers, each weighing 3.7 pounds at the beginning, one gained 6.17 and the other 6.81 ounces in 9 months. In Room 1 cases weighing 7.74 and 8.16 pounds at the outset absorbed 4.73 and 3.10 ounces, respectively, of moisture in 9.2 months; and in Room 2 of two cases each weighing 7.98 pounds, one gained 6.70 ounces and the other 7.80 ounces of moisture during practically the same period of time (Table 10 and fig. 8).

The temperature of the three rooms in which these observations were made was quite uniform throughout the storage period. For example, in Room 3 the fluctuations in temperature were rarely more than 30° to 33° F., except during the severe winter, when the thermometer dropped to 28° F. and occasionally to 26° F. for a few hours. During most of the season the average temperature was 31° F. (Table 11 and fig. 8).

TABLE 11.—*Average relative humidity and average temperature of Cold Storage Room 3.*

Week ending.	Average relative humidity.	Average temperature.	Week ending.	Average relative humidity.	Average temperature.
1917.	*Per cent.*	° *F.*	1917.	*Per cent.*	° *F.*
May 28	74	31	Nov. 5	83	31
June 4	78	31	Nov. 12	84	31
June 11	76	31	Nov. 19	85	31
June 18	76	31	Nov. 26	87	31
June 25	76	31	Dec. 2	88	31
July 2	75	31	Dec. 9	88	31
July 8	74	31	Dec. 17	88	30
July 16	78	31	Dec. 24	88	30
July 23	78	31	Dec. 31	89	30
July 30	76	31	1918.		
Aug. 5	75	31	Jan. 7	89	30
Aug. 17	77	31	Jan. 14	89	28
Aug. 23	72	31	Jan. 21	87.5	29
Aug. 27	73	30	Jan. 28	80	29
Sept. 4	77	31	Feb. 4	89	30
Sept. 10	80	31	Feb. 11	90	29
Sept. 17	82	31	Feb. 18	90	31
Sept. 24	83	31	Feb. 25	91	32
Oct. 1	83	31	Mar. 4	91	32
Oct. 8	84	31	Mar. 11	91	31
Oct. 16	82	31	Mar. 18	91	31
Oct. 22	81	31	Mar. 25	91	....
Oct. 29	82	31	Apr. 1	91	....

Table 11 and figure 8 give the average percentage relative humidities[1] by weeks in Room 3. The humidity from the beginning of the season up to September varied from 72 to 77 per cent, and from that time until the end of the season gradually increased to a maximum of 91 per cent. The cause of the rise in relative humidity in this room may be attributed to several factors: (1) Beginning with September the doors were opened frequently on account of the removal of eggs from cold storage, thus allowing an inrush of air frequently laden with moisture; (2) during the early fall months the cases and fillers had become saturated with moisture for the temperatures at which they were held, so that they did not continue to assist materially in the removal of moisture from the air; (3) by this time the brine pipes had become heavily frosted because of the condensation of moisture from the air, which rendered them less efficient both as absorbers of heat and as condensers of moisture; (4) after the warm weather of the summer had passed, less brine was circulated through the pipes, thereby reducing their efficiency as condensation agents; (5) with the advance of the season the number of cases decreased, so that there was more air in the room to carry moisture and less surface exposed for condensation and absorption. In this room, as well as in the other two rooms in which observations were made on the shrinkage of eggs, calcium chlorid was used as a drying agent. All three rooms were chilled by brine pipes on the walls.

PHYSICAL AND CHEMICAL CHANGES IN EGGS DURING STORAGE.

During the commercial holding of eggs in cold storage the air space increases in size because of the evaporation of moisture; the white becomes thinner and eventually loses its opalescence. After six or seven months the white usually develops a yellow tinge, which deepens with the length of the storage period. The clouded appearance of the white is especially noticeable when eggs are separated in large quantities, as is done in a commercial egg-breaking room. The slightly yellow color does not destroy the beating quality of the white nor the porcelain white color of the resulting froth. The yolk membrane weakens slowly, but, if the eggs are fresh on storing, most of them can be separated, even after storage for 11 months. The separation, however, is usually not as easy as in the earlier part of

[1] The determinations of relative humidities were made according to a sulphuric acid vapor pressure method by N. Hendrickson and H. C. Woodward, which, in brief, was as follows: Two gram samples of sulphuric acid of concentrations varying from 15 to 35 per cent were allowed to come to equilibrium in the storage rooms in low, wide-mouth weighing bottles. The bottles were then covered, allowed to come to room temperature, and then weighed. The percentage of the sulphuric acid in equilibrium was calculated from the original concentration. The vapor pressure corresponding to the concentration of the sulphuric acid in equilibrium divided by the vapor pressure of saturated water vapor at 32° F. equals the percentage of the relative humidity of the air of the cold-storage room. The usual method of determining the relative humidity by a sling pschychrometer was not used, as it is not accurate at 32° F. and below, because of the freezing of the water on the wet bulb.

the storage period. If the physical condition of the egg is weakened through being stale, or heated, or both, separation is difficult after being held in storage for only a few months.

Accompanying the evaporation of moisture from the egg, Greenlee [1] found that there was a transfer of moisture from the white to the yolk by osmosis. For example, samples of whites and yolks, showing 87.42 per cent and 49.15 per cent moisture, respectively, after holding in storage for 41 days, contained 85.35 per cent and 50.60 per cent, respectively, at the end of 266 days in storage.

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[1] U. S. Dept. Agr., Bur. Chem. Cir. 83.

TABLE 12.—*Increase in ammoniacal nitrogen in refrigerator firsts during storage.*

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	April firsts.						May firsts.					
	Experiment 41896.			Experiment 41933.			Experiment 41916.			Experiment 41936.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			*Per cent.*			*Per cent.*			*Per cent.*
April	Initial	48	0.0018	Initial	1,026	0.0019						
May	1 month 4 days	48	.0020				Initial	60	0.0021	Initial	1,047	0.0020
June	2 months 2 days	60	.0024				27 days	60	.0025			
July	3 months 8 days	60	.0022				2 months 3 days	60	.0023			
August	4 months 3 days	72	.0025	3 months 18 days	1,025	0.0023	2 months 28 days	72	.0028			
September	5 months 6 days	72	.0024	4 months 23 days	997	.0025	4 months 1 day	72	.0028	3 months 28 days	1,023	0.0025
October	6 months 5 days	72	.0027	5 months 21 days	1,019	.0026	5 months	72	.0026	4 months 26 days	1,015	.0024
November	7 months 4 days	72	.0028	6 months 17 days	995		5 months 29 days	72	.0033	5 months 22 days	1,014	.0028
December	8 months 2 days	72	.0030	7 months 25 days	981	0.0025	6 months 27 days	72	.0029	7 months	995	.0026
January	9 months 8 days	994	.0028	8 months 27 days	1,000	.0030	8 months 2 days	72	.0034	7 months 28 days	1,002	.0028
February	10 months 4 days	986	.0030	9 months 19 days	987	.0031	9 months 1 day	972	.0032	8 months 25 days	997	.0030
March	11 months 1 day	910	.0030	10 months 26 days	1,021	.0031	9 months 26 days	992	.0035	10 months 1 day	995	.0030

EGGS WITH CRACKED SHELLS.

Month of withdrawal.	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
April	Initial	64	0.0012	Initial		0.0018						
May							Initial	96	0.0014	Initial	30	0.0018
June	2 months 3 days	66	0.0012				29 days	58	.0011			
July	3 months 9 days	82	.0030				2 months 4 days	62	.0029			
August	4 months 4 days	82	.0027	3 months 18 days	48	0.0025	2 months 29 days	59	.0029			
September	5 months 7 days	40	.0026	4 months 24 days	75	.0023	4 months 2 days	61	.0028	3 months 29 days	44	.0025
October	6 months 6 days	46	.0026	5 months 21 days	44	.0028	5 months 1 day	52	.0030	4 months 26 days	59	.0025
November	7 months 5 days	71	.0026	6 months 19 days	51	.0025	6 months	39	.0034	5 months 24 days	44	.0029
December	8 months 3 days	62	.0030	7 months 25 days	65	.0031	6 months 28 days	51	.0030	7 months	57	.0025
January	9 months 8 days	41	.0028	8 months 29 days	38	.0038	8 months 3 days	33	.0031	8 months 1 day	46	.0028
February	10 months 5 days	54	.0031	9 months 22 days	61	.0032	9 months	41	.0035	8 months 27 days	56	.0032
March	11 months 2 days	61	.0040	10 months 26 days	27	.0030	9 months 27 days	24		10 months 1 day	42	.0029

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	June firsts.						July firsts.					
	Experiment 41918.			Experiment 41941.			Experiment 41922.			Experiment 41945.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			*Per cent.*			*Per cent.*			*Per cent.*
April												
May												
June	Initial	1,008	0.0026	Initial	1,024	0.0020						
July	1 month 4 days	977	.0027				Initial	903	0.0020	Initial	1,011	0.0022
August	2 months	1,000	.0024	1 month 27 days	1,034	0.0020	29 days	927	.0028	1 month 4 days	961	.0023
September	3 months 7 days	1,004	.0021	3 months 3 days	972	.0022	2 months 4 days	922	.0026	2 months 9 days	976	.0026
October	4 months 2 days	978	.0028	4 months	1,012	.0023	3 months	942	.0038	3 months 7 days	939	.0027
November	5 months 1 day	989	.0032	4 months 27 days	1,014	.0026	3 months 29 days	867	.0028	4 months 4 days	936	.0028
December	5 months 29 days	994	.0032	6 months 8 days	1,025	.0027	4 months 27 days	916	.0034	5 months 15 days	927	.0026
January	7 months 4 days	917	.0030	7 months 6 days	958	.0027	6 months 2 days	922	.0030	6 months 13 days	968	.0028
February	8 months 3 days	963	.0035	7 months 29 days	1,011	.0028	7 months 1 day	864	.0037	7 months 8 days	905	.0035
March	8 months 29 days	944	.0040	9 months 25 days	1,025	.0030	7 months 28 days	886	.0037	8 months 12 days	914	.0031

EGGS WITH CRACKED SHELLS.

April												
May												
June	Initial	48	0.0010	Initial	50	0.0018						
July	1 month 4 days	80	.0022				Initial	117	0.0014	Initial	87	0.0021
August	2 months	52	.0028	1 month 27 days	42	0.0020	28 days	87	.0029	1 month 4 days	87	.0024
September	3 months 4 days	39	.0028	3 months 3 days	102	.0026	2 months 2 days	87	.0024	2 months 10 days	67	.0024
October	4 months 2 days	45	.0029	4 months	53	.0026				3 months 7 days	68	.0028
November	5 months 1 day	49	.0030	4 months 28 days	41	.0028	3 months 28 days	68	0.0024	4 months 5 days	58	.0027
December	5 months 29 days	27	.0030	6 months 8 days	47	.0025	4 months 27 days	48	.0031	5 months 15 days	30	.0028
January	7 months 4 days	40	.0029	7 months 5 days	30	.0028	6 months 1 day	59	.0027			
February	8 months 5 days	29	.0037	8 months 1 day	27	.0030	7 months 2 days	46	.0032	7 months 18 days	27	.0041
March	8 months 28 days	18	.0040	9 months 5 days	27	.0031	7 months 28 days	28	.0045	8 months 12 days	28	.0034

TABLE 13.—*Increase in ammoniacal nitrogen in refrigerator seconds during storage.*

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	June seconds.			June dirty eggs.			July seconds.		
	Experiment 41919.			Experiment 41943.			Experiment 41923.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			*Per cent.*			*Per cent.*
June	Initial	948	0.0011	Initial	958	0.0022			
July	29 days	992	.0026				Initial	900	0.0025
August	1 month 26 days	989	.0022	1 month 27 days	898	.0021	21 days	848	.0023
September	3 months 2 days	951	.0024	3 months 2 days	994	.0025	1 month 26 days	936	.0032
October	3 months 27 days	926	.0024	4 months	928	.0025	2 months 22 days	897	.0032
November	4 months 27 days	951	.0026	4 months 26 days	933	.0030	3 months 21 days	866	.0033
December	5 months 25 days	913	.0028	6 months 8 days	910	.0027	4 months 18 days	855	.0034
January	6 months 29 days	934	.0026	7 months 6 days	838	.0032	5 months 24 days	864	.0038
February	7 months 29 days	862	.0027	8 months	818	.0031	6 months 24 days	865	.0035
March	8 months 25 days	894	.0035	9 months 5 days	808	.0034	7 months 20 days	870	.0039

EGGS WITH CRACKED SHELLS.

Month of withdrawal.	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
June	Initial	75	0.0016	Initial	133	0.0022			
July	29 days	56	.0025				Initial	117	0.0018
August	1 month 26 days	54	.0026	1 month 27 days	131	.0021	21 days	87	.0030
September	2 months 29 days	46	.0029	3 months 3 days	54	.0023	1 month 25 days	76	.0032
October	3 months 27 days	61	.0030	4 months	75	.0026	2 months 22 days	104	
November	4 months 26 days	51	.0029	4 months 28 days	64	.0025	3 months 20 days	82	.0031
December	5 months 25 days	52	.0028	6 months 8 days	72	.0032	4 months 19 days	49	.0030
January	6 months 29 days	33	.0029	7 months 5 days	65	.0030	5 months 23 days	47	.0040
February	8 months	47	.0029	8 months	56	.0032	6 months 24 days	59	.0039
March	8 months 24 days	23	.0039	9 months 5 days	48	.0033			

The amount of ammoniacal nitrogen [1] in samples of April and May storage eggs graded as edible by candling and breaking was found to be initially from 0.0012 to 0.0021 per cent on the wet basis, and to increase gradually during storage to about 0.0030 per cent in November or December, that is, the seventh or eighth month in storage, and to remain nearly stationary or even to rise slightly until the end of March, the close of the storage period (Tables 12 and 13). Summer eggs entering storage with the same degree of freshness as the spring eggs showed practically the same increase during the same period of holding. In samples having a high initial percentage of ammonia, for example, Experiment 41923 in Table 13, the slowing down in the production of ammonia seemed to occur sooner than in the case of the better quality eggs. This may, perhaps, be explained by the chemical change which took place before the eggs were stored. The amount of ammoniacal nitrogen in the summer firsts and seconds was less consistent during the different months of storage than in the spring eggs. This may be explained by variations in quality between different cases in the same lot, a condition of frequent occurrence in summer shipments. There was very little difference in ammoniacal nitrogen in samples prepared from cracked eggs and those from eggs with whole shells sorted from the same lot. The evidence seems to show that even though the loss in unmarketable eggs varies with different classes, such as clean, dirty, and cracked eggs, if the eggs initially have the same interior quality, those that do keep show practically the same degree of preservation, judged by physical appearance and the amount of ammoniacal nitrogen present.

Pennington, Hendrickson, and collaborators [2] found that during a storage period of six months there was no change in the dextrose in eggs, provided they were not infected with bacteria. In unpublished studies by these investigators, it was found that even up to 10 months storage the dextrose content remained constant.

ABSORPTION OF FOREIGN FLAVORS DURING STORAGE.

It has been found that under commercial conditions a characteristic unpleasant flavor, commonly termed the "cold storage taste," develops in eggs which have been held in cold storage for several months. It is especially noticeable when the eggs are soft boiled or poached. The flavor is not as marked in the white as in the yolk which contains a large percentage of fat. It is known that fats have an affinity for odors and flavors. The facts indicate that the "cold storage taste" is due to the absorption of surrounding odors. When closed the storage room itself has some odor, as have also the

[1] The determinations of ammoniacal nitrogen in these samples were made by G. C. Swan, according to the methods described in the Journal of Industrial and Engineering Chemistry, Vol. 10, No. 8, p. 614, August, 1918, "Determination of Loosely Bound Nitrogen as Ammonia in Eggs," by N. Hendrickson and G. C. Swan. A forthcoming publication will give the bacterial findings, also determinations of ammoniacal nitrogen in large numbers of individual eggs during various holding periods in cold storage.

[2] Jour. Biol. Chem. (1915) Vol. 20, p. xxi, Proceedings of the American Society of Biological Chemists.

cases and excelsior, but the strawboard fillers and flats possess an odor more nearly resembling that found in storage eggs. The fillers and flats become slightly damp in storage, due to the absorption of moisture evaporating from the eggs and the air of the room, and acquire a stronger odor than when dry. Experiments which will be described in connection with another investigation show that when eggs are protected from air by immersion in a preserving liquid and held in cold storage, the typical "cold storage taste" does not develop. This shows almost conclusively that the "storage taste" is a foreign flavor absorbed by the eggs.

Dirty and cracked eggs absorb this flavor more quickly and to a greater extent than do eggs with clean shells. Although summer eggs usually do not keep as well in storage as spring eggs, they are preferable in winter from the point of view of flavor, because they have not been held in storage as long as the spring eggs. A "storage" flavor can usually be found in April stock in November, in May eggs in December, in June eggs in January, and in July eggs in February.

SUMMARY.

(1) Practically all the eggs used in these investigations were produced in the Middle West and all were stored in warehouses located in the East.

(2) Freshly laid eggs with clean whole shells that have not been wet show a negligible loss in bad eggs, even after 10 to 11 months in storage.

(3) Imperfections in commercial handling, grading, and marketing previous to storage are mainly responsible for the bad eggs developing in commercial eggs during storage.

(4) The preservation in the shell of undergrade eggs, such as dirty, cracked, leaking, heated, and stale eggs, should not be attempted. If not marketed for prompt consumption, the contents should be removed under proper conditions and frozen. The frozen product will keep for a year or more, whereas there would be a marked deterioration in quality, if the eggs were stored in the shell.

(5) Spring eggs on the market are usually fresher than summer eggs, and for that reason keep better in storage. Most of the eggs stored are produced in the spring.

(6) The commercial selection by inspection and clicking of clean eggs with sound shells from current receipts is inefficient. Commercial packages of spring firsts when ready to be taken to the storage rooms showed an average of 17.5 cracked eggs and 1 leaking egg to the case. Dirty and stained eggs were often included. Owing to the high quality of spring stock, there was usually less than 1 bad egg to the case initially present as found by candling.

(7) Candling is a much more accurate method for the selection of eggs for storage. By this method eggs can be graded according to

quality; cracked eggs can be more accurately detected and eliminated; and bad eggs can be found and rejected. Cases of spring firsts graded by candling did not average more than 3 cracked eggs per case when ready for storage.

(8) Spring eggs prepared for storage by commercial sorting showed after 7 to 11 months' storage an average total loss of 18.5 bad eggs per case, 13.5 of which were detected by candling and 5 by breaking. Corresponding cases of eggs graded for storage by candling showed after a similar period in storage 4 bad eggs per case as found by candling and 3 additional by breaking. The value of the good eggs saved by the careful candling of eggs for storage more than offsets the extra cost of preparation.

(9) Of the average of 18.5 bad eggs per case present in the commercially graded spring packages after long storing, 9 were due to direct spoilage of damaged eggs or to their contamination of neighboring eggs by molding. The deterioration of the balance of the eggs with whole shells was no doubt due to deleterious pre-storage conditions, such as dirty, wet, stained, or washed shells, or heated shell contents. Careful grading of eggs for storage very largely eliminates the loss due to damaged, dirty, or stained shells.

(10) The rate of evaporation of moisture from eggs was remarkably uniform during the storage period, and averaged from 3 to 4 ounces per case per month in the different storage rooms under observation.

(11) The moisture from the eggs is condensed on the brine pipes, and absorbed by the air, case, and fillers. Most of the absorption of moisture by the egg package occurs during the first few months in storage. In these studies the gain in weight of individual cases with the accompanying cushions, fillers, and flats varied from 11.5 to 14 ounces during a storage period of 10.8 months.

(12) In the cold-storage rooms under observation there was a gradual rise in the humidity with the advance of the season.

(13) Eggs that are fresh when stored show after storing an increased air space and often a tinge of yellow in the white. The yolk membrane is slightly weakened, but commercial separation into white and yolk is usually easily accomplished, even after 11 months' storage.

(14) The percentage of ammoniacal nitrogen in eggs increases during storage, the rise being the fastest during the early part of the storage period. The amount of ammoniacal nitrogen in eggs is a good index of chemical deterioration.

(15) During commercial holding in cold storage the eggs develop a characteristic "cold-storage taste," which is usually present after the seventh month and becomes stronger the longer the eggs are stored. The evidence seems to indicate that the flavor is due to the absorption of the odors from the surrounding environment, particularly from the strawboard fillers in which the eggs are packed.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE PRODUCTION AND MARKETING OF EGGS.

Natural and Artificial Incubation of Hens' Eggs. (Farmers' Bulletin 585.)

Community Egg Circle. (Farmers' Bulletin 656.)

Marketing Eggs by Parcel Post. (Farmers' Bulletin 830.)

Bacteriological and Chemical Study of Commercial Eggs in Producing Districts of Central West. (Department Bulletin 51.)

Study of Preparation of Frozen and Dried Eggs in Producing Section. (Department Bulletin 224.)

How to Candle Eggs. (Department Bulletin 565.)

The Installation and Equipment of an Egg Breaking Plant. (Department Bulletin 663.)

The Prevention of Breakage of Eggs in Transit When Shipped in Carlots. (Department Bulletin 664.)

Efficiency of Commercial Egg Candling. (Department Bulletin 702.)

Winter Egg Production. (Secretary's Circular 71.)

Marketing Eggs Through the Creamery. (Farmers' Bulletin 445.)

Shipping Eggs by Parcel Post. (Farmers' Bulletin 594.)

Eggs and Their Value as Food. (Department Bulletin 471.)

Variation in Annual Egg Production. (Bureau of Animal Industry Bulletin 110, pt. 1.)

Seasonal Distribution of Egg Production. (Bureau of Animal Industry Bulletin 110, pt. 2.)

Improvement of Farm Egg. (Bureau of Animal Industry Bulletin 141.)

Care of Farm Egg. (Bureau of Animal Industry Bulletin 160.)

Preliminary Study of Effects of Cold Storage on Eggs, Quails, and Chickens. (Bureau of Chemistry Bulletin 115.)

Bacteriological Study of Shell, Frozen, and Desiccated Eggs, Made Under Laboratory Conditions at Washington, D. C. (Bureau of Chemistry Bulletin 158.)

Deterioration of Eggs as Shown by Changes in Moisture Content. (Bureau of Chemistry Circular 83.)

Practical Suggestions for Preparation of Frozen and Dried Eggs, Statement Based on Investigations Made in the Producing Section During Summer, 1911. (Bureau of Chemistry Circular 98.)

The Handling and Marketing of Eggs. (Yearbook Separate 467.)

The Effect of the Present Method of Handling Eggs on the Industry and the Product. (Yearbook Separate 552.)

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 752

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief
and the Bureau of Animal Industry, J. R. MOHLER, Chief

Washington, D. C. ▼ April 24, 1919

THE UTILIZATION OF IRRIGATED FIELD CROPS FOR HOG PASTURING

By

F. D. FARRELL, formerly Agriculturist in Charge of the Office of Demonstrations on Reclamation Projects

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 753

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. ▼ March 10, 1919

THE USE OF WOOD FOR FUEL

Compiled by the Office of Forest Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 754

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 26, 1919

INHERITANCE OF WAXY ENDOSPERM IN MAIZE

By

J. H. KEMPTON, Assistant in Crop Acclimatization

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 757

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
R. L. ADAMS, Acting Chief

Washington, D. C. ▼ March 25, 1919

FARM PRACTICES IN GRAIN FARMING IN NORTH DAKOTA

By

C. M. HENNIS, Assistant Agriculturist, and
REX E. WILLARD, Agriculturist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 759

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 19, 1919

THE LEAF-SPOT DISEASES OF ALFALFA AND RED CLOVER CAUSED BY THE FUNGI PSEUDOPEZIZA MEDICAGINIS AND PSEUDOPEZIZA TRIFOLII, RESPECTIVELY

By

FRED REUEL JONES, Pathologist, Cotton, Truck, and Forage Crop Disease Investigations

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WASHINGTON
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THIS paper presents one part of a study of a group of alfalfa and clover diseases, which was begun in the Department of Plant Pathology at the University of Wisconsin in 1914. In 1916 the writer became a collaborator in the Office of Cotton, Truck, and Forage Crop Disease Investigations of the Bureau of Plant Industry, and through cooperation between the Bureau and the Wisconsin Agricultural Experiment Station the scope of the work was extended. The work has been done under the immediate direction of Dr. L. R. Jones, to whom grateful acknowledgments are expressed.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 760

OFFICE OF THE SECRETARY

Joint Contribution from the Office of Farm Management
R. L. ADAMS, Acting Chief
and
Bureau of Plant Industry
W. A. TAYLOR, Chief

Washington, D. C. March 14, 1919

FARM PRACTICE IN GROWING SUGAR BEETS IN THREE CALIFORNIA DISTRICTS

By

T. H. SUMMERS, Scientific Assistant, L. A. MOORHOUSE, Agriculturist, and R. S. WASHBURN, Scientific Assistant, Office of Farm Management

and

C. O. TOWNSEND, Pathologist in Charge of Sugar-Plant Investigations, Bureau of Plant Industry

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By

E. G. BOERNER, Grain Supervisor

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JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER April 28, 1919

OAK-LEAF POISONING OF DOMESTIC ANIMALS

By

C. DWIGHT MARSH, Physiologist in Charge of Poisonous Plant Investigations, A. B. CLAWSON, Physiologist, and HADLEIGH MARSH, Veterinary Inspector, Bureau of Animal Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 768

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HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER April 5, 1919

PRODUCTION OF LUMBER, LATH, AND SHINGLES IN 1917

By

FRANKLIN H. SMITH and ALBERT H. PIERSON
Statisticians in Forest Products

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UNITED STATES DEPARTMENT OF AGRICULTURE

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WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER March 20, 1920

THE GENERA OF GRASSES OF THE UNITED STATES

WITH SPECIAL REFERENCE TO THE ECONOMIC SPECIES

By

A. S. HITCHCOCK, Systematic Agrostologist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 775

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. ▼ June 3, 1919

COMMERCIAL PRESERVATION OF EGGS BY COLD STORAGE

By

M. K. JENKINS, Assistant Bacteriologist. Prepared under the direction of M. E. PENNINGTON, Chief, Food Research Laboratory

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