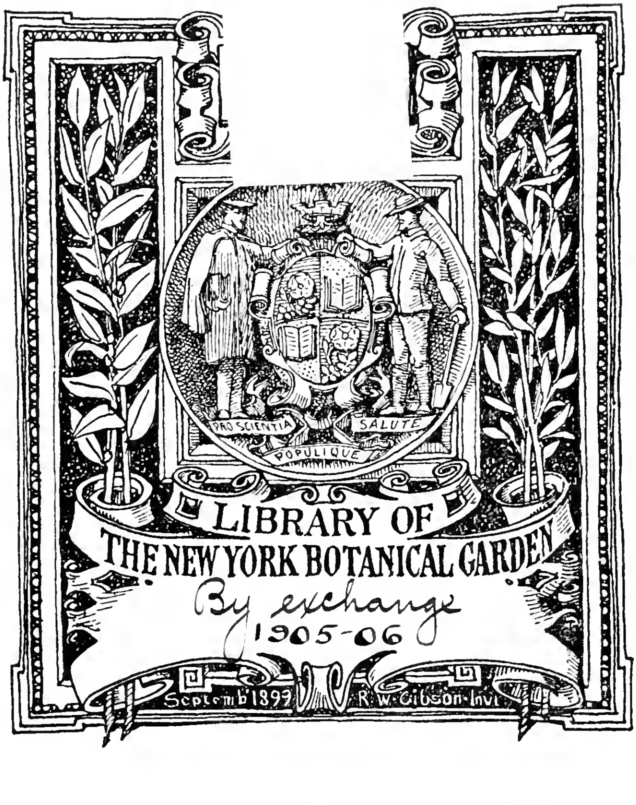

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 78.
B. T. GALLOWAY, *Chief of Bureau.*

IMPROVING THE QUALITY OF WHEAT.

BY

T. L. LYON,
AGRICULTURIST AND ASSOCIATE DIRECTOR OF THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA, AND
COLLABORATOR OF THE BUREAU OF PLANT INDUSTRY.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS,
IN COOPERATION WITH THE
AGRICULTURAL EXPERIMENT STATION OF NEBRASKA.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., April 15, 1905.

SIR: I have the honor to transmit herewith the manuscript of a technical paper entitled "Improving the Quality of Wheat," prepared by Dr. T. L. Lyon, Agriculturist of the Agricultural Experiment Station of Nebraska, who, as a collaborator of this Bureau, is in charge of the cooperative breeding experiments conducted by the Nebraska Agricultural Experiment Station and the Department of Agriculture, and I recommend its publication as Bulletin No. 78 of the series of this Bureau.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

The following technical paper on "Improving the Quality of Wheat," by Dr. T. L. Lyon, of the Agricultural Experiment Station of Nebraska, embodies the results of extended investigations on the application of chemical methods to the selection and improvement of wheat. The investigations were carried on mainly at the Nebraska Agricultural Experiment Station in connection with the cooperative work of that institution and the Plant-Breeding Laboratory of this Office.

In the breeding of wheat more extended data are greatly desired so that more intelligent methods of selection may be devised. The investigations of Doctor Lyon, it is believed, have established methods which will be of great value to wheat breeders and materially facilitate the work in their field.

This paper was originally presented as a thesis to the faculty of Cornell University for the degree of doctor of philosophy. The author wishes to express his appreciation of the guidance of Prof. I. P. Roberts, Prof. G. C. Caldwell, and Prof. Thos. F. Hunt, who constituted the committee having his work in charge, also of the assistance of Prof. L. H. Bailey and Mr. G. N. Lauman, with whom he frequently sought counsel. For the analytical work, extending through a period of seven years and involving several thousand chemical determinations, he is indebted to Prof. S. Avery, Mr. R. S. Hiltner, Prof. R. W. Thatcher, Mr. Y. Nikaido, Miss Rachael Corr, Mr. H. B. Slade, and Mr. G. H. Walker. Mr. Alvin Keyser has kept the records of wheat-breeding plats and Mr. E. G. Montgomery has assisted in keeping other records.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., March 31, 1905.

INTRODUCTORY STATEMENT.

While the art of plant breeding has been practiced for nearly a century, the last decade has witnessed a marvelous awakening of interest in the subject, both from a scientific and practical standpoint. The keen competition in crop production and the resulting cheaper prices, the great and varying demands of modern trade conditions, etc., render it necessary that the modern plant breeder have the most thorough knowledge possible of the plant which he is striving to improve. Not only must we secure varieties and races differing in external characters and yielding more heavily under a certain set of conditions, but we must also examine the chemical constituents of the product and strive to change and improve them in order that they may better fit our purpose.

The great achievements of plant breeding in the past have been mainly in physical characters, requiring only superficial knowledge and gross examination for recognition. Many of the improvements now demanded, however, require the most careful chemical examination of the product and the devising of careful means and methods of selection based on the knowledge thus obtained.

The first and still the most noteworthy achievement of this nature is the increase of the sugar content in the sugar beet. When the work on this subject was first started by Louis Vilmorin, the mother beets, which were supposed to contain the most sugar, were separated by their greater density, this being determined by throwing the beets into a solution of brine of such density that the greater number of them would float. The few heavier ones which were found to sink were retained as mothers and planted to raise seed. Later the methods were improved, and finally the percentage of sugar content in the different individual beets was determined by actual chemical analysis. This careful method of selection has been in operation for more than forty years, and has resulted in greatly increasing the sugar content in the beets, and has rendered their cultivation profitable where otherwise the industry would have failed.

The second most noteworthy case of increasing certain chemical constituents in a plant by careful breeding is that furnished by the investigations of the Illinois Agricultural Experiment Station in increasing the nitrogen, oil, and starch content in corn. These noteworthy experiments carried out by Doctor Hopkins and his assistants have greatly stimulated breeding work of this nature, and have paved the way for further research of a similar kind.

In wheat it is particularly necessary that a thorough knowledge be obtained of the variations in the chemical constituents and their relation to the other characters of the plant, such as yield, size of kernel, size of head, season of maturity, etc. Doctor Lyon's extensive researches will thus be found very valuable in enabling us to understand more clearly these complex relations and in pointing out the main factors to be considered in breeding wheats to increase the gliadin and glutenin content, and still obtain increased yield and better bread-making qualities.

The gross selection of wheat seed heretofore has largely been based on the separation of large and heavy kernels. Doctor Lyon's researches have demonstrated that the smaller and lighter kernels contain the largest percentage of nitrogen, and that while the yield from kernels of this kind at first gives a smaller yield of grain, the total yield per acre of nitrogen is nevertheless greater. By continuous selection of the smaller and lighter kernels for several generations he shows that the grain yield gradually increases and finally approaches or equals the yield derived from the select large and heavy kernels. This gives us a new view of the process of wheat selection necessary to increase the nitrogen yield per acre.

The very numerous chemical analyses made by Doctor Lyon give an indication of the great variation of the percentage of proteid nitrogen present in different plants. In the analyses of samples in 1902 the plants varied from 2.02 per cent to 4 per cent, while in the analyses of the next year a variation from 1.20 per cent to 5.85 per cent was found. The existence of this wide variation affords abundant opportunity for improvement by selection.

Evidence is also given which shows conclusively that the average composition of a spike of wheat may be judged from the analyses of a row of its spikelets. A satisfactory method of conducting selections has thus been devised.

The results also show that early-maturing plants give much the largest average yield, which is a most important point in guiding selection to increase the yield. The percentage of proteid nitrogen is rather less in the early plants, but the total nitrogen per plant is probably greater.

The quality of the gluten largely determines the bread-making value of a variety of wheat, and it is thus important to keep the ratio of the two elements constituting the gluten—the gliadin and glutenin—the same. Doctor Lyon has shown that as the gluten content is increased by selection the ratio of gliadin to glutenin remains about the same, so that the value of the wheat for bread-making purposes is not impaired.

The extensive data presented in this bulletin bearing on important matters relating to the improvement of wheat by breeding will enable wheat breeders to plan and conduct their operations with a degree of certainty which would otherwise not be possible.

HERBERT J. WEBBER,
Physiologist in Charge of Laboratory of Plant Breeding.

WASHINGTON, D. C., *March 30, 1905.*

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IMPROVING THE QUALITY OF WHEAT.

OBJECT OF THE INVESTIGATION.

Efforts to improve the wheat plant have been numerous and have accomplished important results. The work of Fultz, Clawson, Rudy, Wellman, Powers, Hayne, Bolton, Cobb, Green, and Hays in improving by selection, and of Pringle, Blount, Schindel, Saunders, Farrar, Jones, Carleton, and Hays in improving by hybridization, has resulted in giving this country many prolific strains and varieties of wheat, while Garton Brothers, of England, Farrar, of New South Wales, Vilmorin, of France, Rimpau, of Germany, and others have accomplished the same for other portions of the world. Attempts at improvement have, however, been directed primarily toward effecting an increase in the yield rather than in the quality of the crop. While the latter property has not been entirely lost sight of, selection based on quality has never been applied to the individual plant, but only to the progeny of otherwise desirable plants.

Why selection for quality of grain in the individual plant has not gone hand in hand with selection for other desirable properties is perhaps to be explained by the fact that no method for such selection has ever been devised. Mr. W. Farrar, of Queanbeyen, New South Wales, in an address made a short time ago, said:

> Before we can make any considerable progress in improving the quality of the grain of the wheat plant we shall have to devise a method for making a fairly correct quantitative estimate of the constituents * * * of the grain of a single plant and yet have seeds left to propagate from that plant.

In devising a method for increasing the percentage of nitrogen in wheat it becomes desirable to know the causes that produce variation in this constituent of the kernel. Numerous experiments and observations have been made on this subject, the results of which agree in the main in attributing such variation to the following conditions:

(1) Stage of development of the kernel.

(2) Variation in temperature of different regions.

(3) Variation in temperature of different years in the same region.

(4) Variation in the supply and form of soil nitrogen.

(5) Variation in the supply of soil moisture.

All of these factors have been studied, and are recognized as operative. Nothing, however, appears to have been done to show their influence upon the actual amount of nitrogen taken up by the wheat plant and deposited in the kernel. This is really the point of greatest interest; for although it is desirable to secure a wheat of greater nutritive value, it should not be done at the sacrifice of yield of nitrogenous substance.

Admitting that variation in the nitrogen content of wheat is induced by the conditions mentioned, it is essential to the plant breeder to know whether a high or low nitrogen content may be, under similar conditions, a characteristic of an individual plant; whether this quality is transmitted to the offspring; with what constant characteristics it is correlated, and whether a high percentage of nitrogen in a normal, perfectly matured wheat plant is an indication of a large accumulation of nitrogen by that plant.

The data contained in this paper cover the points mentioned, and it is hoped that some definite information has been gained that will lead to a practical solution of the problem of improving by breeding the quality of wheat for bread making.

PART I.

HISTORICAL.

SOME CONDITIONS AFFECTING THE COMPOSITION AND YIELD OF WHEAT.

Experiments to ascertain the effect of different conditions upon the composition and yield of wheat have been conducted mainly along the following lines:

(1) Stage of growth at which the grain is harvested.
(2) Influence of immature seed upon the resulting crop.
(3) Effect of climate.
(4) Effect of soil.
(5) Effect of soil moisture.
(6) Influence of size or weight of seed upon the resulting crop.
(7) Influence of specific gravity of seed upon the resulting crop.

A brief summary of a number of these experiments is herewith given.

COMPOSITION AS AFFECTED BY TIME OF CUTTING.

In 1879,[a] and again in 1892,[b] Dr. R. C. Kedzie conducted very careful experiments to note the chemical changes that occur in the wheat kernel during its formation and ripening. These agree in the main in showing a gradual decrease in the percentage of total nitrogen, albuminoid nitrogen, and non-albuminoid nitrogen from the time the grain set to the time the kernel was ripe. The decrease in all of these constituents was much more rapid during the first than during the last stages of this development. The percentage of ash decreased at the same time.

In 1897 Prof. G. L. Teller[c] carried on some experiments in which he covered the ground already gone over by Doctor Kedzie and also contributed to the knowledge of the subject some very important data concerning the proportion of the various proteids contained in the wheat kernel during the process of development. Teller found that the proportion of total nitrogen in the dry matter steadily decreased from the time the kernel was formed up to about a week before ripening, but that, unlike Doctor Kedzie's results, it gradually increased from that time on. He intimates that this increase before ripening may have been due to defective sampling and hoped to

[a] Report of Michigan Board of Agriculture, 1881–82, pp. 233–239.
[b] Michigan Agricultural Experiment Station Bulletin 101.
[c] Arkansas Agricultural Experiment Station Bulletin 53.

repeat the experiment to remedy this, but he has published nothing further. The amid nitrogen continued to decrease up to the time of ripening, as did also the ash, fats, fiber, dextrins, and pentosans. There was a gradual and marked increase in the proportion of gliadin up to the time of ripening, and a somewhat less and rather irregular decrease in the proportion of glutenin during the same period.

Failyer and Willard[a] report analyses of wheat in the soft-dough stage and when ripe. The ash, crude fiber, fat, and the total and albuminoid nitrogen were higher in the soft-dough wheat, and the nitrogen-free extract and non-albuminoid nitrogen were higher in the ripe wheat.

Dietrich and König[b] quote results from five experimenters—Reiset, Stockhardt, Heinrich, Nowacki, and Handtke. Only in one case (Heinrich) is there a constant decrease in total nitrogen as the grain approaches ripeness. There is much inconstancy in the results, there being in some cases a decrease in nitrogen between the milk stage and full ripeness and sometimes an increase. There is little information to be gained from the results quoted by Dietrich and König.

Körnicke and Werner in their "Handbuch des Getreidebaues"[c] refer to the work of Stockhardt, and also that of Heinrich, to show that during the process of ripening the percentage of nitrogen in the wheat kernel gradually diminishes, as does also the percentage of ash, and that, on the other hand, the percentage of carbohydrates increases during the same period. Heinrich also shows by a statement of the number of grams of these constituents in 2,600 kernels at different stages of development that the absolute amount of nitrogen and ash increases up to the time of ripening, and that consequently the decrease in the percentage of these constituents is due to the rapid increase in the carbohydrates. The results obtained by Heinrich appear as follows when tabulated:

Stage of growth.	Starch.		Protein.		Ash.	
	Percentage in 100 parts of dry matter of kernel.	Grams in 2,600 kernels.	Percentage in 100 parts of dry matter of kernel.	Grams in 2,600 kernels.	Percentage in 100 parts of dry matter of kernel.	Grams in 2,600 kernels.
14 days after bloom	61.44	22.0	14.05	5.0	2.48	0.84
Beginning to ripen	74.17	58.5	12.21	10.0	2.14	1.70
Ripe	75.66	67.0	11.82	10.5	1.97	1.75
Overripe	76.38	70.0	11.67	10.7	1.88	1.79

Nedokutschajew[d] analyzed wheat kernels at different stages of development and found an almost uniform decrease in the percentage

[a] Kansas Agricultural Experiment Station Bulletin 32.

[b] Zusammensetzung u. Verdaulichkeit der Futtermittel, 1, p. 419.

[c] Handbuch des Getreidebaues, Berlin, 1884, 2, pp. 474–476.

[d] Landw. Vers. Stat., 56 (1902), pp. 303–310.

of total nitrogen, a slight but irregular decrease in the percentage of proteid nitrogen in the dry matter, and a constant decrease in the percentage of amid nitrogen. He holds that the amid substances are converted into albumen as the kernels ripen. His figures are as follows:

Date.	Weight of kernel (mg.).	Percentage of—				
		Dry matter.	Total nitrogen.	Proteid nitrogen.	Asparagin nitrogen.	Amid nitrogen.
July 13	9.17	30.14	2.87	1.90	0.29	0.68
July 18	15.80	37.23	2.55	1.94	.20	.41
July 24	30.79	45.18	2.65	2.33	.19	.13
July 29	37.99	38.37	2.46	2.08	.16	.22
August 3	46.39	51.52	2.32	1.98	.13	.21
August 9	45.46	49.83	2.37	2.13	.11	.13

Judging from these results there can be no doubt that the percentage of nitrogen, both total and proteid, decreases as the kernel develops, owing to the more rapid deposition of starch that goes on during the later stages of growth. The larger part of the nitrogen used by the wheat plant appears to be absorbed during the early life of the plant. This is transferred in large amounts to the kernel in the early stages of its development, after which nitrogen accretion by the kernel is comparatively slight. The deposition of starch, on the other hand, continues actively during the entire development of the kernel. It would further appear that the amid nitrogen is converted into proteid compounds as development proceeds.

As showing the stages of growth of the wheat plant at which the greatest absorption of nitrogen occurs, some experiments may be quoted.

Lawes and Gilbert [a] say:

In 1884 we took samples of a growing wheat crop at different stages of its progress, commencing on June 21, and determind the dry matter, ash, and nitrogen in them. Calculation of the results showed that, while during little more than five weeks from June 21 there was comparatively little increase in the amount of nitrogen accumulated over a given area, more than half the total carbon of the crop was accumulated during that period.

Snyder's analyses [b] show that of the total amount of nitrogen taken up by the wheat plant, 85.97 per cent is removed from the soil within fifty days after coming up, 88.6 per cent by time of heading out, and 95.4 per cent by the time the kernels are in the milk.

Adorjan [c] finds that assimilation of plant food from the soil is not proportional to the formation of dry matter in the plant, but that it proceeds more rapidly in the early stages of growth. During early growth nitrogen is the principal requirement. The nitrogen stored

[a] On the Composition of the Ash of Wheat Grain and Wheat Straw, London, 1884.

[b] Minnesota Experiment Station Bulletin 29, pp. 152–160.

[c] Abstract, Experiment Station Record, 14, p. 436, from Jour. Landw., 50 (1902), pp. 193–230.

up at that time is, he says, used later for the development of the grain.

It is too well known to require substantiation by experimental evidence that the yield of grain per acre and the weight of the individual kernel increase as the grain approaches ripeness. It is therefore quite evident that immaturity, although resulting in a higher percentage of nitrogen in the wheat kernel, would curtail the production of nitrogen by the crop, and, furthermore, that the production of proteids would be still further lessened by reason of the greater proportion of amid substances present in the grain at that time.

INFLUENCE OF IMMATURE SEED UPON YIELD.

Georgeson[a] selected kernels from wheat plants that were fully ripe, and from plants cut while the grain was in the milk. He seeded these at the same rate on 2 one-tenth acre plots of land. The immature seed yielded at the rate of 19.75 bushels per acre of grain and 0.8 ton of straw, while the mature seed produced 22 bushels of grain and 1.04 tons of straw per acre. Georgeson says that in a similar experiment the previous year the difference in favor of the mature seed was still more pronounced.

Although the evidence is limited, it may safely be considered that the use of immature seed will result in a smaller yield of wheat than if fully ripe seed be used.

INFLUENCE OF CLIMATE UPON COMPOSITION AND YIELD.

Lawes and Gilbert[b] state that "high maturation in the wheat crop as indicated by the proportion of dressed corn in total corn, proportion of corn in total product (grain and straw), and heavy weight of grain per bushel, is, other things being equal, generally associated with a high percentage of dry substance and a low percentage of both mineral and nitrogenous constituents." This is based upon the wheat crops at Rothamsted for the years 1845 to 1854, inclusive.

More recent publications[c] by these investigators reaffirm their belief that the composition of the wheat kernel depends more largely upon the conditions that affect its degree of development than upon any other factor. They found almost invariably that a season that favored a long and continuous growth of the plant after heading, resulting in a large yield of grain, a high weight per bushel, and a plump kernel, produced a kernel of low nitrogen content.

[a] Abstract, Experiment Station Record, 4, p. 407, from Kansas Experiment Station Bulletin 33, p. 50.

[b] On Some Points in the Composition of Wheat Grain, London, 1857.

[c] Our Climate and Our Wheat Crops, London, 1880, and On the Composition of the Ash of Wheat Grain and Wheat Straw, London, 1884.

Körnicke and Werner[a] cite an experiment in which winter wheat grown in Poppelsdorf for several years was sent to and grown in the moist climate of Great Britain, in Germany, and in the continental climate of Russia (steppes). The results were as follows:

Locality.	Number of experiments.	Weight (in grams) of—		Percentage of—	
		100 plants.	Kernels from 100 plants.	Grain.	Straw.
Great Britain	37	600	227	37.8	62.3
Germany	18	500	204	40.8	59.2
Southern Russia	19	365	160	44.0	56.0

These investigators conclude from the results that in a moist climate relatively more straw and less grain are produced than in a dry, warm climate. The thickness of the straw and the weight of the kernels from 100 heads are greater, while the percentage by weight of kernels to straw is much less in a moist climate. They also quote Haberlandt as saying that a continental climate produces a small, hard wheat kernel, rich in gluten and of especially heavy weight.

Dehérain and Dupont[b] report some interesting observations as to the effect of climate on the composition of wheat. They state that the harvest of 1888 at Grignon was late and the process of ripening slow. There was a heavy yield of grain having a gluten content of 12.60 per cent and a starch content of 77.2 per cent. The following season was dry and hot, with a rapid ripening of the grain, resulting in a smaller crop. The gluten content of the grain was 15.3 per cent and the starch content 61.9 per cent. They removed the heads from a number of plants. The next day the stems were harvested, as were also an equal number of entire plants. The stems without heads showed that carbohydrates equal to 5.94 per cent of the dry matter had been formed. The stems on which the heads remained one day longer contained 1.63 per cent carbohydrates. They argue from this that the upper portion of the stem, provided it is still green, performs the functions of the leaves in other plants and thus elaborates the starch that fills out the kernel in its later development.

A report from the Ploti Experiment Station[c] states that the conditions that favored an increase in yield caused a reduction in the relative proportion of nitrogen in the grain. Excessive humidity favored the process of assimilation of carbohydrates, while drought hastened maturation and produced a grain relatively rich in proteids.

[a] Handbuch des Getreidebaues, Berlin, 1884, pp. 69, 70.

[b] Ann. Agron., 1902, p. 522.

[c] Abstract, Experiment Station Record, 14, p. 340, from Sept. Rap An. Sta. Expt. Agron. Ploty, 1901, pp. xiv–180.

Wiley[a] sent wheat of the same origin to California, Kentucky, Maryland, and Missouri. The original grain and the product from each State were analyzed. The results of one year's test were reported. Regarding the effect of climate, he says:

There appears to be a marked relation between the content of protein matter and starch and the length of the growing season. The shorter the period of growth and the cooler the climate the larger the content of protein and the smaller the content of starch, and vice versa.

Shindler,[b] in his book upon this subject, says (p. 75):

With the length of the growing period, especially with the length of the interval between bloom and ripeness, varies not only the size of the kernel, but also the relative amount of carbohydrates and protein it contains.

Again, on page 76, Shindler says:

All this shows that the protein constituent of the kernel depends in the first place upon the length of the growing period and next upon the richness of the soil.

Melikov[c] made analyses of different varieties of wheat of the crops of the years 1885–1899 grown in southern Russia. The protein varied in different years from 14 to 21.2 per cent. Melikov concludes that the nitrogen content is highest in dry years and lowest in years of larger rainfall, in which years the yield of wheat per acre is also greater.

Gurney and Morris,[d] in one of their reports, say:

This increased gluten [over previous years] is probably largely due to differences in the seasons, the weather being hot and dry while the grain was ripening, since it is characteristic not of these wheats alone but of most of the grain grown in the colony.

The conclusion to be inevitably derived from these observations is that climate is a potent factor in determining the yield and composition of the wheat crop, and, further, that its effect is produced by lengthening or shortening the growing season, particularly that portion of it during which the kernel is developing. A moderately cool season, with a liberal supply of moisture, has the effect of prolonging the period during which the kernel is developing, thus favoring its filling out with starch, the deposition of which is much greater at that time than is that of nitrogenous material. With this goes an increase in volume weight and an increased yield of grain per acre. On the other hand, a hot, dry season shortens the period of kernel development, curtails the deposition of starch, leaving the per-

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[a] Yearbook U. S. Department of Agriculture, 1901, pp. 299–308.

[b] Der Weizen in seinem Beziehungen zum Klima und das Gesetz der Korrelation, Berlin, 1893.

[c] Abstract, Experiment Station Record, 13 p. 451, from Zhur. Opuitn. Agron., 1 (1900), pp. 256–267.

[d] Agricultural Gazette of New South Wales, 12, pt. 2, pp. 1403–1424.

centage of nitrogen relatively higher, and gives a grain of lighter weight per bushel and smaller yield per acre.

The fact that one variety of wheat is adapted to a hot, dry climate and another to a cool, moist one does not mean that the former undergoes as complete maturation as the latter, even though the grain is not shriveled. This is shown by the fact that a variety of wheat well adapted to a hot, dry climate will, when planted in a cool, moist one, immediately grow plumper and the kernel weight will increase, as was the case in the experiment of taking Minnesota wheats to Maine.

INFLUENCE OF SOIL UPON COMPOSITION AND YIELD.

In considering the effect of the soil upon the wheat crop there will naturally be included experiments designed to show the effect of fertilizers upon the crops. It is, in fact, upon experiments with fertilizers that we must depend for most of our information on this subject.

Experiments to ascertain the effect of fertilizers upon the composition of the wheat kernel were conducted by Lawes and Gilbert for a period of years extending from 1845 to 1854.[a] Plots of land in which wheat was grown continually were treated annually as follows: Unmanured, manured with ammoniacal fertilizer alone, and manured with ammoniacal fertilizer and proportionate amounts of mineral salts. In composition calculated to dry matter, the wheat on the plots receiving ammoniacal fertilizer alone contained quite uniformly a slightly larger amount of nitrogen than either of the other two. The averages for the ten years were as follows:

Kind of fertilizer, if any.	Percentage of— Nitrogen in dry matter.	Percentage of— Ash in dry matter.	Weight of grain per bushel (pounds).	Percentage of good kernels.	Yield per acre (pounds).
Unmanured	2.13	2.07	58.51	90.6	1,045
Ammonium salts	2.26	1.85	58.9	90.3	1,668
Minerals and ammonium salts	2.22	1.96	60.2	92.8	1,969

There was practically no difference in the nitrogen content of the straw. From these experiments the authors quoted conclude that there is no evidence that the nitrogen content of the wheat kernel can be increased at pleasure by the use of nitrogenous manures.

Ritthausen and Pott[b] report an experiment in which plots of land were manured (1) with superphosphate alone, (2) with nitrate alone, (3) with a mixture of superphosphate and nitrate, and (4) were left

[a] On Some Points in the Composition of Wheat Grain, London, 1857.
[b] Landw. Vers. Stat., 16 (1873), pp. 384–399.

unmanured. There were three plots of each. The following is a tabulated statement of their results:

Kind of fertilizer, if any.	Weight of 52 c. c. of kernels (grams).	Yield of grain on plot (kilos).	Percentage of nitrogen in dry matter.
Unfertilized	1,306	....	2.60
Superphosphate	1,339	2.72	3.49
Nitrate	1,413	2.30	3.43
Superphosphate and nitrate	1,451	2.03	3.62

It will be noticed that the effect of the nitrate fertilizer was to decrease the yield of grain, but to increase the size of the kernel and its content of nitrogen.

Wolff,[a] as early as 1856, in summing up the experiments of Hermbstadt, Muller, and John with barley, and of Lawes and Gilbert with wheat, says:

In the presence of a sufficient amount of phosphoric acid and alkali the effect of manuring with an easily soluble nitrogen compound is an improvement in the grain both in quantity and quality [meaning plumper kernels]. The kernels decrease in percentage of nitrogen, but become plumper, become absolutely and relatively richer in starch, and have a better appearance and a higher commercial value. But when the nitrogenous food in the soil exceeds a certain relation to the temperature and rainfall the quality of the grain becomes poorer [harder], it becomes lighter and smaller, takes on a darker color, and generally becomes richer in percentage of nitrogen in the air-dry substance.

Von Gohren[b] also reports results of experiments in fertilizing wheat. All experiments were apparently made in the same year. He grew the crop on six different plots of land, five of which were manured and each with a different fertilizer. In the crop he distinguished between large kernels and small kernels to show the quality of the product. Determinations of proteids and starch were made, and these were calculated to the yield of each constituent on each plot.

The following table shows the yield of each of the characters determined, and compares those raised on the unmanured plot with those on the manured ones by taking the former as one and reducing the others to the corresponding figure:

Yield and percentage.	Unfertilized.	Ashes.	Oil cake.	Bat guano.	Oil cake and ashes.	Peruvian guano.
Yield of grain	1.000	1.011	1.071	1.143	1.215	1.286
Yield of large kernels	1.000	.146	1.928	2.552	2.226	2.786
Yield of small kernels	1.000	.953	.704	.538	.781	.642
Yield of proteids	1.000	.999	.915	.936	1.070	1.114
Yield of starch	1.000	1.009	1.081	1.174	1.264	1.303
Percentage of proteids	14.42	14.25	12.70	11.81	12.70	13.22
Percentage of starch	62.67	62.56	63.25	64.41	65.24	63.55

The results show an increased yield from the use of fertilizers, the production increasing with the application of complete manures.

[a] Die naturgesetzlichen Grundlagen des Ackerbaues, Leipzig, 1856, p. 774.
[b] Landw. Vers. Stat., 6 (1864), pp. 15–19.

The yield of grain of good quality increases in the same way, and the yield of grain of poor quality decreases proportionately. It must be remembered that by good quality of grain in these early writings is meant plump kernels and not necessarily what would be considered wheat of good milling quality at the present day. The production of proteids per acre decreased with the use of the incomplete fertilizers, ashes and oil cake, and even with the bat guano. It increased, however, with the use of oil cake and ashes combined and of Peruvian guano. The percentage of proteids was greatest in the unfertilized grain and the percentage of starch least, with the exception of one fertilized plot.

The very evident effect of the fertilizers in this case was to produce a more completely matured kernel. It will be noticed that the plots producing grain of highest starch content were those having the greatest proportion of plump kernels.

Again, in 1884, Lawes and Gilbert[a] report results obtained from manured and unmanured soils. These experiments cover a period of sixteen years and are divided into two periods of eight years each. In one of these periods the seasons were favorable for wheat, in the other unfavorable.

Character.	Favorable seasons.			Unfavorable seasons.		
	Barnyard manure.	Unmanured.	Ammonium salts alone.	Barnyard manure.	Unmanured.	Ammonium salts alone.
Weight of grain per bushel (pounds)	62.6	60.5	60.4	57.1	54.3	53.7
Percentage of grain to straw	62.5	67.4	66.2	54.5	51.1	46.7
Grain per acre (pounds)	2,342.0	1,156.0	1,967.0	1,967.0	823.0	1,147.0
Straw per acre (pounds)	6,089.0	2,872.0	4,774.0	5,574.0	2,433.0	3,601.0
Percentage of nitrogen in dry matter	1.73	1.84	2.09	1.96	1.98	2.25
Percentage of ash in dry matter	1.98	1.96	1.74	2.06	2.08	1.91
Nitrogen per bushel (pounds)	1.083	1.113	1.262	1.125	1.075	1.208

It is evident from this statement that the largest crops and best developed kernels were obtained from the soils treated with barnyard manure, and that these kernels contained the lowest percentage of nitrogen. The crops on unmanured soil stood next in these respects, except in yield. Those on the soil receiving ammonium salts produced the most poorly developed kernels and those of highest nitrogen content, but gave larger yields than the unmanured soil.

In the unmanured soil there was a very evident lack of plant food, as indicated by the light crops. The effect upon the kernel was to curtail its development, leaving it of light weight and with a relatively high nitrogen content.

[a] On the Composition of the Ash of Wheat Grain and Wheat Straw, London, 1884.

Hermbstadt obtained some curious results, as quoted by D. G. F. MacDonald,[a] as follows:

He sowed equal quantities of wheat upon the same ground and manured them with equal weights of the different manures set forth below. From 100 parts of each sample of grain produced he obtained starch and gluten in the following proportions:

Kind of fertilizer, if any.	Gluten.	Starch.	Produce.
Unfertilized	9.2	66.7	Threefold.
Potato peels	9.6	65.94	Fivefold.
Cow dung	12.0	62.3	Sevenfold.
Pigeon dung	12.2	63.2	Ninefold.
Horse dung	13.7	61.64	Tenfold.
Goat dung	32.9	42.4	Twelvefold.
Sheep dung	32.9	42.8	Do.
Dried night soil	33.14	41.44	Fourteenfold.
Dried ox blood	34.24	41.43	Do.
Dried human urine	31.1	39.3	Twelvefold.

These results are not to be considered seriously, representing as they do an impossible condition.

Prof. H. A. Huston[b] treated 0.01-acre plots of land each with nitrate of soda, dried blood, sulphate of ammonia, rotted stable manure, and muck, respectively, either in the autumn or spring, or in both seasons. In 1891 all the plots treated with nitrogenous compounds showed marked increase in the percentage of nitrogen in the grain. In 1892 the results were by no means so uniform and would not justify the conclusion that nitrogenous fertilizers increased the nitrogen content of the wheat.

Vignon and Conturier[c] tested the effect of phosphate fertilizer alone upon the nitrogen content of the grain of two varieties of wheat. On Plot 1 they used 75 kilograms of phosphoric acid per hectare; on Plot 2, 150 kilograms, and on Plot 3, 225 kilograms.

Variety.	Percentage of nitrogen in grain.		
	Plot 1.	Plot 2.	Plot 3.
Goldendrop	1.83	1.61	1.54
Riéte	2.07	1.98	1.82

There was a very evident decrease in the nitrogen content of the crop as the quantity of fertilizer was increased.

It was concluded from experiments conducted at the Ploti Experiment Station[d] that, with favorable meteorological conditions, manure increased the total amount of nitrogen taken up by wheat, but,

[a] Practical Hints on Farming, London, 1868.

[b] Indiana Experiment Station Bulletins 41 and 45.

[c] Compt. Rend., 132 (1901), p. 791.

[d] Abstract, Experiment Station Record, 14, p. 340, from Sept. Rap. An. Sta. Expt. Agron. Ploty, 1901, pp. xiv–180.

although it thus increased the total production of nitrogen, it decreased the relative proportion of nitrogenous substance.

Bogdau[a] conducted investigations the results of which indicated that with an increase in the soluble salt content of 22 alkali soils the nitrogen and ash contents of the wheat kernels increased, but the absolute weight of the kernels diminished. These soluble salts are rich in nitrates.

Experiments were conducted by Whitson, Wells, and Vivian[b] in which plants were grown in pots the soils of which were in some cases fertilized with nitrates and in others with leachings of single and of double strengths from fertile soils. Field experiments were conducted on manured and unmanured plots. All of the analyses, except in the case of oats, were of the whole plant. Of the ripe oat kernels those from the unfertilized soil contained 2.57 per cent of nitrogen, while the average of those from the fertilized soil was 2.78 per cent.

Guthrie[c] conducted experiments with fertilizers for wheat during two years, in which he kept a record of the yield and gluten content of the grain. The following is a statement of the results:

Kind of fertilizer, if any.	Experiments in 1901— At Wagga.		Experiments in 1901— At Bathurst.		Experiments in 1902, at Wagga.	
	Yield per acre (bushels).	Percentage of gluten.	Yield per acre (bushels).	Percentage of gluten.	Yield per acre (bushels).	Percentage of gluten.
None	7.7	11.99	13	11.80	17.6	9.8
Ammonium sulphate	8.7	10.43	16	11.21	17.6	8.7
Superphosphate	13.3	12.06	13.5	12.01	22.6	11.4
Potassium sulphate	13.0	12.02	13.0	11.29	19.2	10.0
Ammonium sulphate, superphosphate, potassium sulphate	10.0	11.70	13.7	12.05	20.3	12.0

In this experiment there was in each case a higher percentage of gluten in the wheat raised on the fertilized soil than in that from the soil fertilized with ammonium sulphate, and in the latter less than in the grain fertilized with other material.

The most striking feature of these results is their apparent lack of uniformity. In some cases the use of nitrogenous fertilizers was accompanied by an increase in the nitrogen content of the grain and in other cases no increase appeared; in some cases phosphoric acid fertilizers apparently increased the nitrogen content and in others they did not have this effect.

Climatic influences have doubtless operated largely in these results, but they are not considered by any of the experimenters except Wolff.

[a] Abstract, Experiment Station Record, 13, p. 329, from Report of Department of Agriculture, St. Petersburg, 1900.

[b] Wisconsin Experiment Station Report, 19 (1902), pp. 192–209.

[c] Agricultural Gazette of New South Wales, 13 (1902), No. 6, p. 664; and No. 7, p. 728.

It is evident that in all experiments with depleted soils the plants on the plots receiving complete fertilizers would take up larger amounts of plant food, including nitrogen, than would plants on unmanured soils. Any conditions that would prevent the normal ripening of the crop on both soils would therefore leave a higher percentage of nitrogen in the plants upon the unmanured soil. On the other hand, under conditions which would permit of a complete maturation of the crop there might be no difference in the composition of the grain from the manured and unmanured soils. It is evident, however, that the production of both nitrogen and starch in pounds per acre would be greater on the manured soils.

Another condition that may affect the results is the arrested development of kernels on unmanured soils that are seriously depleted of plant food. Such depletion may interfere with complete maturation of the crop while the crop on the manured soil will mature fully. In consequence the grain on the unmanured soil will contain a higher percentage of nitrogen but a smaller yield per acre. The use of a nitrogenous manure alone on exhausted soils may likewise result in a grain of higher nitrogen content.

Expressed in a more general way, this means that wheat of the same variety grown under the same climatic conditions will have approximately the same percentage of nitrogen if allowed to mature fully, but any permanent interruption in the process of maturation will result in a higher percentage of nitrogen, and in the latter case the percentage of nitrogen will depend upon the stage at which development was interrupted, and also upon the amount of nitrogen accumulated by the plant, that being greater on soils manured with nitrogenous fertilizers alone than on exhausted soils, and greater on soils receiving complete manures than on exhausted soils receiving only nitrogenous fertilizers, provided the stage at which development ceased be the same in both cases. It thus happens that wheat growing on the soil allowing it to absorb the largest amount of nitrogen will, other things being equal, have a higher nitrogen content if the development of the kernel be permanently checked, although if it were allowed to mature fully it would not have a greater percentage of nitrogen than that grown on the soil affording less nitrogen.

Reviewing the experiments, we find that in Lawes and Gilbert's first experiment the percentage of nitrogen in the unmanured soil was less than on the soil receiving only nitrogenous fertilizer, and that the weight of grain per bushel and the percentage of good kernels on the two plots were practically the same. It would not appear, therefore, that the wheat on the plot receiving the nitrogenous fertilizer was less well matured than that on the unmanured plot. In this case there appears to be a slight increase in the percentage of nitrogen, due entirely to the use of nitrogenous fertilizers. Comparing the grain on the plot receiving only nitrogenous fertilizer with that receiving the complete fertilizer it will be seen that the former has a higher percentage of nitrogen, but this is evidently due to the poorly developed kernels which weigh less per bushel than the grain on the completely fertilized plot.

Von Gohren's results show plainly that the kernels on the manured land developed better than on the unmanured, and with this better development there was an increase in the percentage of starch and a decrease in the nitrogen.

In Lawes and Gilbert's second experiment the percentage of nitrogen in the wheat on the soil manured with ammonium salts was less than that in the wheat on the unmanured soil, but the weight of grain per bushel shows that the higher nitrogen content was due, in part at least, to incomplete maturation. The higher percentage of nitrogen in the wheat on the soil receiving only nitrogenous manures as compared with that receiving complete manures can be traced to the same condition of the grain.

INFLUENCE OF SOIL MOISTURE UPON COMPOSITION AND YIELD.

Experiments were conducted by D. Prianishinkov[a] in which wheat was raised with different degrees of moisture, but in the same soil and under the same conditions of light and temperature. With a larger amount of moisture in the soil there was a lower nitrogen content in the grain. It was also stated that the duration of the period of vegetation was somewhat shorter when the moisture supply was greater.

Traphagen[b] reports marked changes in the composition of wheat grown with and without irrigation at the Montana Experiment Station. A wheat grown under irrigation on the station farm was planted the following year on land not irrigated. Presumably the land was of similar character. The two crops of grain were analyzed and the percentages stated below were found.

Crop.	Moisture.	Crude protein.	Ether extract.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Irrigated wheat	7.87	8.81	1.93	76.99	2.60	1.80
Unirrigated wheat	7.65	14.41	2.23	71.33	2.65	1.70

No records of yields or of weights of kernels are given, but it is fair to suppose that the unirrigated wheat possessed the light, shrunken kernel which is characteristic of wheat raised without sufficient moisture.

[a] Abstract, Experiment Station Record, 13, p. 631, from Zhur. Opuitn. Agron., 1 (1900), No. 1, pp. 13-20.

[b] Montana Experiment Station Report (1902), pp. 59-60.

Irrigation experiments were conducted by Widtsoe[a] in which wheat of the same variety was raised on plots of land each one of which received a different quantity of water. A record was kept of the yield and composition of the grain on each plot.

Plot.	Water applied (inches).	Yield per acre (bushels).	Percentage of—		Yield (in pounds) per acre of—	
			Protein in grain.	Ash in grain.	Nitrogen.	Ash.
317	4.63	4.50	24.8	2.50	10.7	6.75
319	5.14	3.83	23.2	3.07	8.5	7.05
320	8.73	10.33	19.9	2.54	19.7	15.74
318	8.89	11.33	19.4	2.93	21.1	19.72
321	10.30	14.66	18.4	2.34	25.9	20.24
325	12.09	11.16	21.3	3.25	22.8	21.44
322	12.18	11.66	23.1	2.88	25.8	20.30
326	12.80	13.00	17.1	2.52	21.3	21.50
327	17.50	15.33	17.2	2.57	25.3	23.64
328	21.11	17.33	15.9	2.34	26.4	24.33
329	30.00	26.66	14.0	4.14	35.8	66.20
330	40.00	14.50	17.1	2.52	23.8	21.92

The results show that with an increase in the water used for irrigation up to 30 inches there were in general an increase in the yield of grain and a decrease in the nitrogen content. No volume weights or other means of judging of the development of the kernels on the different plots are given, but there is no reason to suppose that the grain on the plots receiving small quantities of water was not poorly developed. The column added showing the yield of nitrogen in pounds per acre indicates a lack of nutriment in the grain on these plots.[b]

High nitrogen content arising from a small supply of soil moisture is sometimes due to a restricted development of the kernel. There is nothing in these results to indicate a greater absorption of nitrogen by the crop on soil having less moisture, but results of this nature are cited elsewhere in this bulletin.

INFLUENCE OF SIZE OR WEIGHT OF THE SEED-WHEAT KERNEL UPON THE CROP YIELD.

Sanborn[c] reports experiments to ascertain the effect of separating seed wheat into kernels of different grades to ascertain the effect upon the yield. He divided the kernels into large, medium, small, ordinary (grain as it came from the thrasher), and shriveled, and continued the experiments for four years. Apparently the large kernels were separated from the crop grown from large seed the previous year, and

[a] Utah Experiment Station Bulletin 80.

[b] Nitrogen has been calculated from proteids by dividing by 6.25.

[c] Utah Experiment Station Report, 1893, p. 168.

so with the other classes of kernels. He tabulates his results as follows:

Kind of seed.	Yield of grain on plots (in pounds).				Average for 4 years.
	1890.	1891.	1892.	1893.	Bushels per acre.
Large	88.5	72.5	111	63.0	18.72
Medium		70.0	87	67.0	16.60
Small	94.0	105.0	64	74.0	18.72
Ordinary	84.0	95.0	87	29.5	16.42
Shriveled		43.0	78	31.0	11.25

The relation between yields of the crops representing different sized kernels is so irregular from year to year that suspicion is aroused regarding the accuracy of the results, due to lack of uniformity in soil. Sanborn's conclusion is that very little, if any, advantage is to be gained by separating seed wheat and planting the large kernels.

At the Indiana Experiment Station, Latta[a] conducted experiments in which wheat was separated by means of a fanning mill into heavy and light kernels, but impurities and chaffy seed were fanned out of each lot of wheat. The experiments were continued three years, but the separations were made each year from seed that had not been so separated the year before. The average gain from the large seed for three years was 2.5 bushels per acre.

Georgeson,[b] at the Kansas station, seeded plots of land with (1) light seed weighing 56 pounds per bushel, (2) common seed weighing 62.5 pounds, (3) heavy seed weighing 63 pounds, and (4) selected seed, obtained by picking the largest and finest heads in the field just before the crop was cut, weighing 61.5 pounds per bushel. Seed was separated each year from wheat not grown from previously selected seed. The average results for three years were as follows:

Grade of seed.	Yield of grain per acre (bushels).	Grade of seed.	Yield of grain per acre (bushels).
Light	25.19	Heavy	27.07
Common	26.57	Select (average for 2 years)	25.82

Desprez[c] reports experiments extending through three years in which large kernels were selected from a crop grown from large seed

[a] Indiana Experiment Station Bulletin 36, pp. 110–128.

[b] Kansas Experiment Station Bulletin 40, pp. 51–62.

[c] Abstract, Experiment Station Record, 7, p. 679, from Jour. Agr. Prat., 59 (1895), 2, pp. 694–698.

for several years and small seed from a crop grown from small seed for several years. Five varieties of wheat were used. The average results for three years were a difference of 1,067 to 1,828 kilograms of grain per hectare in favor of the large seed, but the difference was in general greater the first year than later. The use of large seed gave a crop with kernels larger than those grown from small seed.

Middleton[a] reports the yields obtained from large wheat kernels to be almost double those obtained from small seed kernels.

Bolley,[b] as the results of experiments continuing for four years in which plump kernels of large size and plump kernels of small size were selected for seed, concludes that "perfect grains of large size and greatest weight produce better plants than perfect grains of small size and light weight, even when the grains come from the same head."

At the Ontario Agricultural College, Zavitz[c] selected large plump seed, small plump seed, and shrunken seed of both spring and winter wheat. Experiments were continued for eight years with spring wheat and five years with winter wheat, the selections each year being from a crop grown from previously unselected seed. His results are as follows:

Kind of seed.	Yield per acre (in bushels).	
	Spring wheat.	Winter wheat.
Large, plump	21.7	42.4
Small, plump	18.0	34.8
Shrunken	16.7	33.7

Dehérain and Dupont[d] report that the yields from small and large kernels of a number of varieties of wheat were in all cases in favor of the large kernels, but a large difference in yield was obtained only when there was a marked difference in the weight of the kernels.

Soule and Vanatter[e] conducted experiments for three years in which large and small kernels were separated by means of sieves. In addition a plot of unselected seed was planted. The large seed was, each year after the first, selected from the crop grown from large seed the previous year. The same was true of the small seed. These investigators say:

[a] Abstract, Experiment Station Record, 12, p. 441, from Univ. Coll. of Wales Rept., 1899, pp. 68–70.

[b] North Dakota Experiment Station Report, 1901, p. 30.

[c] Ontario Agricultural College and Experiment Farm Report, 1901, p. 84.

[d] Abstract, Experiment Station Record, 15, p. 672, from Compt. Rend., 135 (1902), p. 654.

[e] Tennessee Experiment Station Bulletin, vol. 16, No. 4, p. 77.

The average difference in yield at the end of three years between large grains (607 per ounce), commercial sample (689 per ounce), and small grains (882 per ounce), with Mediterranean wheat, was 2.06 bushels in favor of large grains as compared with the commercial sample, and 5.18 bushels in favor of large grains over small grains. The difference in yield between the large grains and the commercial sample chiefly occurred the first year; but it is possible, though hardly probable, that the difference was partly due to variation in the soil. The experiment has been carried on in different parts of the field for the last two years, and the difference in yield is now only 0.32 bushel per acre in favor of the large grains.

Cobb[a] reports tests of various grades of wheat kernels with respect to size, and concludes that large kernels give better yields of grain. The seed of one year was not the product of the corresponding grade of the previous one.

Grenfell[b] selected plump and shriveled kernels from the same bulk of grain. Of these 150 kernels were sown in each row, with rows of plump and shriveled kernels alternating. The germination in both rows appeared much alike, but the plants in the rows sown from plump grain soon began to gain on the others and kept ahead for the remainder of the season. The tillering was better in the plump-grain plants. Grenfell tabulates his results thus:

Variety.	Kind.	Percentage of plants that grew.	Number of heads.	Tillering power.	Average yield per acre (bushels).
Steinwedel	Plump	96.0	179	1.24	10.9
Do	Shriveled	89.3	174	1.29	9.9
Purple Straw	do	89.3	153	1.14	6.1
Do	Plump	90.0	200	1.49	10
Do	Shriveled	76.0	110	1.16	6.9
Do	Plump	92.0	161	1.23	8.4
Do	Shriveled	98.0	155	1.34	7.2
Plump-kernel averages		92.7	180	1.32	9.8
Shriveled-kernel averages		88.5	155	1.23	7.5

As bearing upon this subject some experiments conducted by Rünker[c] are of interest. He weighed each of the kernels of a large number of heads of wheat of the Spalding Prolific and Martin Amber varieties, and found that the heaviest kernels occur in the lower half of the spike. With spikes of different lengths and weights, the weight of the average kernel increases with the size of the spike.

Weights of individual kernels from the same spikes show that there is a great range in this respect. One spike, of which Rünker gives the weights of all the kernels, and which is given as representative of the average, shows kernels varying in weight from 36 to 71 milligrams.

[a] Agricultural Gazette of New South Wales, 14 (1903), No. 2, pp. 145–169.

[b] Agricultural Gazette of New South Wales, 12 (1901), No. 9, pp. 1053–1062.

[c] Jour. f. Landw., 38 (1890), p. 309.

It is therefore quite evident that a sample of wheat taken from spikes of different sizes when separated into lots of light and heavy kernels would have both the larger spikes and smaller spikes represented in each lot of kernels, but doubtless the proportion of kernels from large heads would be greater in the lot of heavy kernels.

It would appear from these results that the evidence was overwhelmingly in favor of large or heavy wheat kernels for seed. Most of the experimenters selected seed of different kinds each year without reference to previous selection. If large seed or small seed represent plants of different characteristics and if these properties are hereditary, the results of selection of large or small seeds for several years may be quite different from what they would be the first year. It is only those experiments in which selection of the same kind of seed has been continued for several generations that may be relied upon to indicate the value of continuous selection of large kernels for seed.

Such experiments have been conducted by Sanborn, by Desprez, and by Soule and Vanatter. The work of Desprez indicates that the size of the kernel is a hereditary quality. That being the case, it is evident that the small seed of the first separation may be composed partly of seed that is small on account of immaturity and partly of seed that is small by inheritance, but which is perfectly normal. When such seed is planted the immature seed will be largely eliminated in the crop, but the naturally small seed will have reproduced itself and will compose most of the crop. When the seed is again separated a much smaller percentage of small seed will be immature, and in consequence a larger number of kernels will produce plants. It would appear from Desprez's experiments, however, that those plants producing small kernels are not so prolific as those producing large kernels.

Sanborn's results make a very good showing for the small kernels, but, as before stated, the extreme irregularity would lead to the belief that the soil on the plots lacked uniformity, or that some other errors had influenced the results. To offset this the tests cover a period of four years, which should help to rectify mistakes, and in consequence the good showing made by the small kernels is entitled to some consideration.

Soule and Vanatter's results fulfill exactly the conditions of the hypothesis that the small seed would the first year contain a much larger proportion of immature kernels than it would in subsequent years, and hence yield more poorly the first year. Their results with heavy kernels as compared with ordinary seed offer little encouragement to the continuous selection of large kernels.

The fact before referred to that both large and small kernels are found on the same head of wheat is perhaps an argument against the superior value of large seed. If the plant and not the seed is the unit of reproduction, small seed from a plant whose kernels averaged large size may be better than large seed from a plant whose kernels averaged small size.

On the other hand, there can be no doubt that the majority of the kernels in the lot of heavy kernels would be from plants having large spikes, and vice versa. This would give the kernels in the heavy lot some advantage. Again, the advantage that the large kernel is supposed to possess for seed may not be in producing a large kernel in the resulting crop, but in giving the plant a better start in life, or producing a more vigorous plant.

RELATION OF SIZE OF KERNEL TO NITROGEN CONTENT.

Richardson[a] has made a large number of analyses of wheats from different parts of the United States. The weight of 100 kernels was also determined in each sample. There can not be said to be any constant relation between the nitrogen content and the kernel weight, but in the main the large kernels have a lower percentage of nitrogen than the small kernels, and inversely.

Pagnoul[b] reports that in a test of eleven varieties of wheat there was in the main a decrease in the percentage of nitrogen in the crop as compared with the seed when there was an increase in the weight of 1,000 kernels in the crop as compared with the seed.

The same investigator[c] again states that in an examination of seventy varieties of wheat there was no constant relation between the size of the kernels and their nitrogen content, but that in general the varieties with small kernels were the varieties richest in nitrogen.

Marek[d] separated wheat of the same variety into lots of large and of small kernels. He found on analysis that the large kernels contained 12.52 per cent protein and the small kernels 13.55 per cent protein.

Woods and Merrill[e] made analyses of a number of wheats grown in Minnesota and of the same varieties grown in Maine. The wheats uniformly developed a larger kernel when grown in Maine. Grouping five varieties raised in Minnesota and five raised in Maine, it will be seen that with this increase in the size of the kernel there was a

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[a] U. S. Department of Agriculture, Division of Chemistry, Bulletins 1 and 3.

[b] Abstract in Centrlb. f. Agr. Chem., 1893, p. 616, from Ann. Agron., 1892, p. 486.

[c] Abstract in Centrlb. f. Agr. Chem., 1888, p. 767, from Ann. Agron., 14, pp. 262–272.

[d] Abstract in Centrlb. f. Agr. Chem., 1876, from Landw. Zeitung f. Westfalen u. Lippe, 1875, p. 362.

[e] Maine Experiment Station Bulletin 97.

decrease in the nitrogen content. The analyses, reduced to a water-free basis, are as follows:

Where grown.	Weight of 100 kernels (grams).	Percentage of protein.
Minnesota	2.239	16.22
Maine	3.109	15.43

In a review of the experiments concerning the relation of weight to composition of cereals, Gwallig[a] says that the results obtained by Marek, Wollny, Märcker, Hoffmeister, and Nothwang divide barley and rye into one group, and wheat and oats into another, as regards this relation. With barley and rye, the largest, heaviest kernels are the richest in protein. With wheat and oats, the smallest, lightest kernels have the highest protein content.

Gwallig says further that with an increased protein content there is a decrease in nitrogen-free extract. The fat and ash do not stand in a definite relation to the kernel weight, but the small, light kernels have a higher percentage of crude fiber, which circumstance is accounted for by the larger surface possessed by the smaller kernels.

Snyder[b] has divided small kernels into two classes—those which are small because shrunken and those which are small although well filled. He finds that as between small kernels of the first class and large, well-filled kernels, the former contain a higher percentage of nitrogen, but as between the small, well-filled and the large, well-filled kernels, the latter contain the higher percentage of nitrogen. In testing this he used large and small kernels of the same variety in each case, and the wheats represented a large portion of the wheat-growing area of the United States. As regards the relation of large, perfect, and small, perfect kernels there were twenty-four out of twenty-seven cases in which the large kernels contained a greater percentage of nitrogen.

Johannsen and Weis,[c] in experiments with five varieties of wheat, find that as a general rule the percentage of nitrogen is increased with increasing grain weight, but that there are many exceptions to the rule.

Cobb[d] states that small wheat kernels contain a larger proportion of gluten than do large ones, but he does not submit any analyses to substantiate his statement.

[a] Abstract in Centrlb. f. Agr. Chem., 24 (1895), p. 388, from Landw. Jahrbücher, 23 (1894), p. 835.

[b] Minnesota Experiment Station Bulletin 85.

[c] Abstract, Experiment Station Record, 12, p. 327, from Tidsskr. Landbr. Planteavl., 5 (1899), pp. 91–100.

[d] Agricultural Gazette of New South Wales, 5 (1894), No. 4, pp. 239–250.

Körnicke and Werner[a] quote the experiments of Reiset to show that shriveled kernels have a higher nitrogen content than plump ones. With different varieties of wheat he found the following:

Variety.	Kind	Percentage of nitrogen in dry matter
Spalding	Shriveled	2.48
Do	Plump	2.33
Victoria	Shriveled	2.44
Do	Plump	2.08
Albert	Shriveled	2.59
Do	Plump	2.35

Carleton[b] records the weight of 100 kernels and the percentage of "albuminoids" in sixty-one samples of wheat from various parts of the world. Dividing these into classes according to the weight of 100 kernels we have the following:

Weight of 100 kernels (grams).	Average weight of kernels (grams).	Percentage of albuminoids	Number of samples
2 to 3	2.66	14.58	6
3 to 4	3.67	12.31	25
over 4	4.57	11.62	30

Reviewing these experiments there would seem to be no doubt that shrunken kernels contain a higher percentage of nitrogen than do well-filled ones, but as between large and small kernels, both of which are well filled, there is not a great deal of information. Snyder's experiments are the only ones that cover this ground, but they are extensive and very uniform, and may be considered as deciding the question in favor of a higher nitrogen content for the large kernels, so far as small, plump kernels and large, plump kernels are concerned. But, as small and light kernels are usually not plump, taking the crop as a whole and dividing it equally into large and small or heavy and light kernels, the evidence would be in favor of the small or light kernels for high nitrogen content. As between wheats from different regions and of different varieties, those having small kernels are generally of higher nitrogen content.

INFLUENCE OF THE SPECIFIC GRAVITY OF THE SEED KERNEL UPON YIELD.

Sanborn[c] separated seed wheat with a sieve into large, medium, small, and shriveled kernels. The large seed was separated by means

[a] Handbuch des Getreidebaues, 1, pp. 520–521, Berlin, 1884.

[b] U. S. Department of Agriculture, Division of Vegetable Physiology and Pathology, Bulletin 24.

[c] Abstract, Experiment Station Record, 5, p. 58, from Utah Experiment Station Report, 1892, pp. 133–135.

of a brine solution into two nearly equal parts. The seed thus separated was planted on separate plots. The experiment was continued three years. The heavy seed yielded 10.8 bushels and the light 16.3 bushels per acre. Unselected seed yielded 16.4 bushels per acre.

Seed wheat of four varieties was separated by Church[a] by means of solutions of calcium chlorid having specific gravities of 1.247, 1.293, and 1.31. The seed was first treated with a solution of mercuric chlorid to remove adherent air. Each lot of seed was planted separately. From the results the following conclusions are drawn:

(1) The seed wheat of the greatest density produced the densest seed.

(2) The seed wheat of the greatest density yielded the largest amount of dressed grain.

(3) The seed of medium density generally gave the largest number of ears, but the ears were poorer than those from the densest seed.

(4) Seed of medium density generally produced the largest number of fruiting plants.

(5) The seed wheat that sank in water, but floated in a solution having the density 1.247, was of very low value, yielding on an average only 34.4 pounds of dressed grain for every 100 yielded by the densest seed.

Haberlandt,[b] as the result of experiments with several cereals, has shown that the comparative weight of kernels is transmitted to the grain resulting from this seed. This was the case with wheat, rye, barley, and oats. The results with wheat were as follows:

Number of pounds.	Weight of kernels.		
	Light.	Medium.	Heavy.
	Grams.	*Grams.*	*Grams.*
1,000 seed kernels	29.5	31.2	33.0
1,000 crop kernels	34.3	35.5	36.3

Wollny[c] objects to the results of the experiments by F. Haberlandt, Church, Trommer, Hellriegel, and Ph. Dietrich with various cereals, in which almost without exception the kernels of high specific gravity produced the best yields, because no distinction was made between absolute weight and specific gravity in the kernels. He claims that the value of the seed lies in the kernels of absolutely heavy weight rather than in the kernels of high specific gravity. He concludes that the specific gravity of the seed exerts no influence on the yield of the crop.

[a] Science with Practice.

[b] Jahresb. Agr. Chem., 1866–67, p. 298.

[c] Abstract in Centrlb. f. Agr. Chem., 1887, p. 169, from Forschungen a. d. Gebiete Agrikulturphysik, 9 (1886), pp. 207–216.

In the light of the experiments that have been conducted with seed wheat of high and low specific gravities, it would appear that, in general, seed of very low specific gravity does not yield well, and it is evident that such seed must be deficient in mineral matter and is probably not normal in other respects. There would not appear, however, to be any marked difference in the productive capacity of kernels of medium specific gravity and kernels of great specific gravity.

RELATION OF SPECIFIC GRAVITY OF KERNEL TO NITROGEN CONTENT.

Marek[a] found that with an increase in the specific gravity of the kernel there was a decrease in nitrogen content.

Pagnoul,[b] in testing seventy varieties of wheat, found that the nitrogen content rose with the specific gravity, but not regularly, and that a definite relation could not be traced.

Wollny[c] took kernels of horny structure and kernels of mealy structure. He says it is generally recognized that the hard, horny kernels have a higher specific gravity, and that it is commonly attributed to their higher content of proteids. He contends that as starch has a higher specific gravity than protein the mealy kernels must really have a higher specific gravity than the horny ones.

Körnicke and Werner[d] state the specific gravities of the various chemical constituents of the wheat kernel as follows: Starch, 1.53; sugar, 1.60; cellulose, 1.53; fats, 0.91 to 0.96; gluten, 1.297; ash, 2.50; water, 1.00; air, 0.001293. They state also (p. 121) that the specific gravity of the kernel does not stand in any relation to the volume weight, for the factor which results from weighing a certain volume mass is influenced by the air spaces between the kernels, and these depend upon the form and size as well as the surface and accidental structure of the kernel. They also contend that there is no relation between the volume weight and the content of proteid material.

Schindler[e] shows that by tabulating a large number of varieties of wheat from different parts of the world, and representing different varieties, there is no relation between the weight of 1,000 kernels and the volume weight of 100 c. c. By separating these into varieties, even when grown in different localities, kernels of the same variety did show a definite and constant relation. The volume weight increased with an increase in the weight of 1,000 kernels.

[a] Abstract in Centrlb. f. Agr. Chem., 1876, p. 46, from Landw. Zeitung f. Westfalen u. Lippe, 1875, p. 362.

[b] Abstract in Centrlb. f. Agr. Chem., 1888, p. 767, from Ann. Agron., 14, pp. 262–272.

[c] Abstract in Centrlb. f. Agr. Chem., 1887, p. 169, from Forschungen a. d. Gebiete Agrikulturphysik, 9 (1886), pp. 207–216.

[d] Handbuch des Getreidebaues, 2, p. 120, Berlin, 1884.

[e] Jour. Landw., 45 (1897), p. 61.

There has long been a desire manifested by workers in this field to establish some definite relation between the specific gravity of the wheat kernel and its composition, or at least its nitrogen content. Very contradictory results have been obtained by several experimenters, and little progress has been made.

It is true that the various chemical constituents that go to compose the wheat kernel have different specific gravities, and as those of the carbohydrates are all less than those of the proteids it might be argued that a wheat having a large proportion of proteid material would have a low specific gravity. However, the specific gravity of the ash is so much greater than that of any other constituent and the ash in wheats from different soils and climates varies so much that these factors completely prevent the establishment of a definite relation. The size and number of the vacuoles also influence the specific gravity.

In general, it may be said that as between kernels of the same variety grown in the same season and upon the same soil, the specific gravity is inversely proportional to the nitrogen content.

CONDITIONS AFFECTING THE PRODUCTION OF NITROGEN IN THE GRAIN.

So far as the writer has been able to ascertain there is no literature bearing directly upon the conditions affecting the production of nitrogen in the grain of wheat.

Regarding high nitrogen in the wheat crop as arising merely from failure on the part of the kernel to develop fully, it would seem that a high percentage of nitrogen would inevitably be accompanied by a small production of nitrogen per acre. This, however, does not always appear to be the case.

Taking, for instance, the yields of wheat obtained by Lawes and Gilbert[a] for a period of twenty years, which they divide into two periods of good and of poor crops, each covering ten years, we have the following figures:

Seasons.	Average yield of grain per acre (pounds).	Weight per bushel (pounds).	Yield of nitrogen per acre (pounds).
Good crop seasons	1,833	60.2	28.0
Poor crop seasons	1,740	57.1	29.8

It will be noticed that the largest production of nitrogen per acre was in those years in which the weight per bushel and the yield per acre were least.

Of course this is not always the case, but that it should occur at all is an indication that the conditions that make for high nitrogen

[a] On the Composition of the Ash of Wheat Grain and Wheat Straw, London, 1884.

content in the grain also conduce to a large accumulation of nitrogen by the crop, or perhaps it would be more accurate to say that the conditions which favor a large accumulation of nitrogen by the crop often result in giving it a high nitrogen content.

Reference has already been made to the observations of Dehérain and Dupont[a] on the wheat crops of 1888 and 1889 at Grignon. The figures for the yields of grain, the percentages of starch and gluten, and the production per acre of these constituents for the two years are as follows:

Year.	Yield of grain per hectare (kilos).	Percentage of— Gluten.	Percentage of— Starch.	Gluten per hectare (kilos).	Starch per hectare (kilos).
1888	3,445	12.6	77.2	434	2,659
1889	2,922	15.3	61.9	447	1,808

From this it will be seen that for the year in which the yield of grain was less per acre the production of gluten per acre was greater. Apparently the conditions were favorable for a large accumulation of nitrogen by the plant in 1889, but were unfavorable to the production of starch. If the latter had not been the case, the crop of 1889 would have been larger than the crop of 1888.

A number of instances of this kind have occurred among the wheat crops at the Nebraska Experiment Station. In fact, it may be said that, in general, large yields of grain have there been accompanied by a low percentage of nitrogen per acre as compared with the same properties in small yields of grain. The following table will show this:

Production of nitrogen per acre in wheat raised at the Nebraska Experiment Station.

Variety.	Year.	Yield of grain per acre (pounds).	Percentage of proteid nitrogen.	Proteid nitrogen per acre (pounds).	Date of ripening.
Turkish Red	1900	1,980	3.02	52.73	June 27
Do	1901	2,370	2.00	43.04	June 24
Do	1902	1,800	2.86	51.48	June 23
Do	1903	1,864	2.40	44.74	July 9
Yaroslav	1900	1,320	3.01	34.58	July 2
Do	1901	1,794	2.18	36.08	July 1
Do	1903	[a]962	2.54	24.43	July 14
Weissenburg	1902	1,605	3.16	46.32	June 24
Do	1903	1,891	2.10	39.71	July 10
Pester Boden	1902	1,475	2.92	43.10	June 24
Do	1903	1,830	2.16	39.53	July 10
Average		1,717	....	41.43	

[a] Yield decreased by lodging of grain.

A word in regard to the character of the seasons that produced these crops may help to an understanding of their differences.

[a] Ann. Agron., 28 (1902), p. 522.

The season of 1900 was rather dry and hot from the time growth started in the spring until harvest. There was no time when there was an abundant supply of moisture, but occasional rains wet the soil for a few days at a time. The temperatures during the day were high and the air was dry. In 1901 the spring was quite moist and cool until June, when it became extremely hot and dry. A few days before harvest the temperatures ranged above 100° F. daily, with no rainfall. The season of 1902 was the direct opposite of that of 1901, except that the change came earlier. It was extremely dry and hot until the middle of May, when abundant rains came, and the temperatures were considerably below normal until harvest. The season of 1903 was wet and cool throughout.

In general, it may be said that in those seasons, like 1900 and 1902, in which the temperatures were high and moisture scarce during all or the early part of the growing season, the grain had a high percentage of nitrogen, and there was a large production of nitrogen per acre. In years of low temperatures and abundant moisture, as in 1903, or even when such conditions obtained late in the season, as in 1901, there were a low percentage of nitrogen in the grain and a small production of nitrogen per acre.

High temperatures and scant moisture during early growth would, therefore, seem to favor the accumulation of nitrogen by the wheat plant.

It may also be noted that these are the conditions favorable to the process of nitrification and to the accumulation of nitrates near the surface of the soil.

Comparing the wheat crops grown at Rothamsted for a period of twenty years, the yields and nitrogen production of which have just been stated, with the averages for the Nebraska-grown wheats contained in the last table, it will be seen that the yields of grain were larger at Rothamsted, but that the production of nitrogen per acre was considerably greater in Nebraska.[a]

Station.	Yield (in pounds) per acre of—	
	Grain.	Nitrogen.
Rothamsted station	1,786	28.9
Nebraska station	1,717	41.4

The maximum production of nitrogen per acre at Rothamsted during the twenty years was 38.1 pounds, while at Nebraska it was 52.7 pounds.

There can be little doubt as to whether this difference was due in greater measure to soil fertility or to climate. Nowhere is better

[a] The yield of nitrogen at Rothamsted is calculated from total organic nitrogen, while at the Nebraska Station it is from proteid nitrogen.

tillage given or are crops more scientifically provided with food than at Rothamsted. It is true that of the ten plots of land on which these wheats were raised one received no manure and three were not sufficiently manured. In order to make the comparison more favorable to the English environment, the five plots completely manured and producing the largest yields may be taken. The yield of nitrogen per acre was 36.4 pounds for the years 1852–1861 and 34.6 pounds for 1862–1871. Even with the best manuring the yields of nitrogen fall very much short of those in Nebraska.

In Nebraska no commercial fertilizers had ever been used on the land on which the wheats were grown, but farm manure had been applied. The soil was a heavy one, well adapted to wheat growing, and had been well tilled. It had been well manured for corn in a rotation of corn, oats, and wheat. The varieties, with the exception of Turkish Red, had just been introduced from Europe and had not fully adapted themselves to the new environment. The average nitrogen production for the only acclimated variety, Turkish Red, was 48 pounds per acre. It would seem, therefore, that a climate affording high temperatures, dry air, and a moderately dry soil is favorable to the accumulation of a large amount of nitrogen by the wheat plant, provided there is a large supply of nitrogen in the soil. The heat and scant soil moisture are doubtless instrumental in making available the nitrogen of the humus, and the bright sunshine and dry, hot air stimulate growth and increase transpiration.

It has just been said that hot, dry weather in the early growing season contributes to a large nitrogen accumulation by the wheat plant. The same conditions cut short the growing period of the plant and prevent the large accumulation of starch that takes place in the kernel of wheat raised in a cool or moist region. It thus happens that such wheats are high in nitrogen and low in starch.

The properties of the wheat kernel characteristic of a continental climate and rich soil are probably due to rapid nitrification and highly stimulated growth causing a large accumulation of nitrogen by the crop, and to incomplete maturation, caused either by heat, or frost, or lack of moisture, resulting in high nitrogen.

It would be interesting to know what relation the production of nitrogen per acre bears to the production of mineral matter, but the necessary figures are not at hand.

The wheat kernel produced in a continental climate is not usually plump as compared with the kernel produced in an insular or coastal one. The yield of grain per acre is also usually less. That this is due to incomplete maturation is shown by the fact that winter varieties of wheat that make their growth early in the season always yield better than spring varieties. The latter, on the other hand, have a higher percentage of nitrogen, but usually not so large a nitrogen production. Their disadvantage lies in the fact that their roots are not sufficiently developed to absorb a large quantity of nitrogenous matter at the time most favorable for its accumulation. As a maximum nitrogen accumulation is the chief desideratum, spring wheats are not desirable where winter ones can be grown.

This does not mean that a variety of wheat which has been grown, for instance, in England will show all the qualities of an inland wheat when first grown in Kansas or Nebraska. Such a wheat will undergo modifications that will give it some of these qualities, such, for instance, as less well-filled kernels, and less weight per bushel. On the other hand, the Turkish Red wheat, when raised in a cool, moist climate, becomes later maturing, and the kernel becomes plumper, more starchy, and softer. It is between varieties adapted each to its peculiar climate, and raised there for years, that these distinctions are most marked, but the fact that a modification of any variety begins at once when transferred from one climate to another shows that such qualities as those mentioned are influenced by the climate.

It must be quite apparent, although it has not often been remarked, that the ordinary selection of seed wheat to increase the yield has resulted in producing a grain of lower nitrogen content.

This has been noticed by Girard and Lindet[a] and by Biffen,[b] and incidentally by Balland,[c] who, in commenting on the decrease in the nitrogen content of wheat in northern France and the increased yields, attributes the former to a deficiency of nitrogen in the fertilizers used, and states that the gluten in the wheat of that region in 1848 ranged from 10.23 to 13.02 per cent, while fifty years later it ranged from 8.96 to 10.62 per cent. In the same time the average yield increased from 14 to 17.5 hectoliters per hectare. In the light of the results of experiments to ascertain the effect of nitrogenous fertilizers upon the composition of wheat, it can not be supposed that this decrease in nitrogen content can be due primarily to lack of nitrogen. It would seem more likely that the increased yield was largely due to the deposition of starch in the grain, and that consequently the percentage of gluten was smaller.

Has the improvement in the yield of wheat been accompanied by a greater yield of nitrogen per acre? It is evident that the increase in the grain and that in the nitrogen are not proportional, but it is

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[a] Le Froment et sa Monture, Paris, 1903.

[b] Nature (London), 69 (1903), No. 1778, pp. 92, 93.

[c] Abstract in Centrlb. f. Agr. Chem., 1897, p. 785, from Compt. Rend., 124 (1897), p. 158.

desirable to know whether there has been any increase in nitrogen per acre. Returning to the figures given by Balland it will be seen that the wheat of 1848 produced on an average 163 kilos per hectare, while that of fifty years later produced 171 kilos, an increase of about 5 per cent in gluten per hectare, with an increase of 25 per cent in yield. These figures can not, of course, be taken as strictly accurate, as they are based merely on what M. Balland refers to as the range of nitrogen content.

Some data on this subject are available in the published records of wheat improvement at the Minnesota Experiment Station.[a] Yields and gluten content of improved varieties and of the original variety from which the improved strains have been developed by selection are given. The figures cover the same seasons for all varieties, and the averages of six trials are reported for each, as follows:

Variety	Yield per acre (bushels).	Percentage of dry gluten.	Gluten per acre (pounds).	Nitrogen per acre (pounds).
Minnesota No. 149, produced from Power's Fife	25.6	13.5	207.4	36.4
Power's Fife, unmodified by selection	23.6	14.0	198.2	34.8
Minnesota No. 169, produced from Hayne's Blue Stem	28.5	12.5	213.7	37.5
Hayne's Blue Stem, unmodified by selection	24.6	13.4	198.8	34.7

In each case the new variety yielded more grain per acre, possessed a lower gluten content, and produced more nitrogen per acre in the grain. It should be explained that determinations of gluten and baking tests were made of strains of wheat produced by the selection of individual plants, and that the quantity and quality of the gluten in these strains were considered in deciding which strain was to be perpetuated. For that reason the gluten content of the improved wheat is doubtless greater than it would have been if no attention had been paid to those qualities. Incidentally it may be stated that the quality of the gluten in these new varieties of wheat originated by Professor Hays is much better than that in the original varieties. The difference between selection for gluten carried on in this way and selection for gluten applied to the individual plant is that the latter must increase many times the opportunity for developing a strain of desirable gluten content.

Returning to the nitrogen production per acre, it is apparent that it is slightly greater in the improved wheats, or at least is not less than in the original varieties. This is encouraging, as it indicates the possibility of increasing the production of gluten per acre.

[a] Minnesota Experiment Station Bulletin 63.

Gluten is the valuable constituent of wheat. The wheat growing of the future may be looked upon as a gluten-producing industry. The problem is to secure the highest possible quantity and quality of gluten per acre. If this can be done by sacrificing starch production, it will be economical. Starch can be more cheaply produced in other crops and, if necessary, added to the flour of wheat.

It may be argued that this is not to the interest of the farmer. But it is clearly to the interest of mankind and any step toward its accomplishment must in the end redound to the advantage of the farmer.

PART II.

EXPERIMENTAL.

SOME PROPERTIES OF THE WHEAT KERNEL.

If a number of wheat kernels of the same variety and raised under similar conditions are separated into approximately equal parts with regard to their specific gravity, the kernels of low specific gravity will be found to contain a higher percentage of both total and proteid nitrogen than the kernels having a high specific gravity.

A number of samples of wheat grown in different years and representing different varieties were separated into approximately equal parts by throwing the kernels into a solution of calcium chlorid having such a density that about half the kernels would float and the other half sink. The specific gravity of the solution in which each sample was separated is given in Table 1 and the signs < and > are used to represent "less than" and "greater than," respectively. Thus "<1.29" means that the kernels have a specific gravity of less than 1.29, while ">1.29" indicates that the kernels have a specific gravity greater than 1.29.

TABLE 1.—*Analyses of kernels of high and of low specific gravity.*

Serial number.	Specific gravity.	Percentage of— Total nitrogen.	Proteid nitrogen.[a]	Nonproteid nitrogen.	Name of variety and year of growth.
1	<1.290	3.51	2.49	1.02	Hickman, grown in 1895.
2	>1.290	3.27	2.39	.88	
30	<1.286	2.51	1.88	.63	Turkish Red, grown in 1897.
31	>1.286	2.51	1.94	.57	
38	<1.250	2.80	2.26	.54	Spring wheat, Marvel, grown in 1897.
39	>1.250	2.78	2.15	.63	
40	<1.265	2.95	2.13	.82	Spring wheat, Velvet Chaff grown in 1897.
41	1.265	2.66	2.01	.65	
59	<1.264	3.30	2.41	.89	Turkish Red, grown in 1898.
60	>1.264	3.06	2.29	.77	

[a] Proteid nitrogen in this paper = nitrogen by Stutzer's method. Proteids = proteid nitrogen × 5.7.

With the exception of serial Nos. 30 and 31 the kernels of low specific gravity have in each case a higher percentage of both total and proteid nitrogen than have the kernels of high specific gravity. It will also be noticed that the percentage of nonproteid nitrogen is greater in the kernels of low specific gravity.

Samples of wheat were also divided into light and heavy portions by means of a machine which operates by directing upward a current of air, the velocity of which can be regulated. Into this current the grain is directed. The result is that the heavy kernels and the large kernels fall, and the light kernels and small kernels are driven out. The separation thus accomplished is somewhat different from that effected by a solution, the difference being that the latter separates the kernels entirely according to their specific gravities while with the air blast a large kernel of a certain specific gravity might descend with the heavy kernels, when if it were smaller, although of the same specific gravity, it would be blown out.

The number of light kernels that descend on account of their large size is relatively small, owing to the fact that large kernels are, as a rule, of higher specific gravity than small ones. The following test was made to determine the relation between the size of wheat kernels and their specific gravity. An average lot of wheat was nearly equally divided by means of two sieves into three portions representing medium, small, and large kernels. Each of these portions was then thrown upon solutions of the same specific gravity, and the proportion by weight that floated, or light seed, and the proportion that sank, or heavy seed, were determined.

TABLE 2.—*Proportion of light and of heavy seed.*

Kind of seed.	Heavy seed (grams).	Light seed (grams).	Ratio.	
			Heavy.	Light.
Small	8.72	11.28	1	1.29
Medium	9.62	10.78	1	1.12
Large	11.96	8.04	1	.67

The weight of light kernels among the small was nearly twice that of light kernels among the large seeds.

Analyses of samples of wheat separated by this machine into light and heavy kernels gave about the same results as the samples separated by solutions of certain specific gravities.

TABLE 3.—*Analyses of large, heavy kernels and of small, light kernels.*

Serial number.	Relative weight.	Percentage of— Total nitrogen.	Proteid nitrogen.	Nonproteid nitrogen.	Name of variety and year of growth.
9	Light	2.99	2.21	0.78	Spring wheat, Marvel, grown in 1896.
10	Heavy	2.76	2.04	.72	
57	Light	2.77	2.11	.66	Currell, grown in 1898.
58	Heavy	2.70	2.04	.66	
65	Light	2.91	2.29	.62	Spring wheat, grown in 1898.
66	Heavy	2.65	2.04	.61	
80	Light	2.45	2.00	.45	Big Frame, grown in 1899.
81	Heavy	2.19	1.96	.23	
383	Light	3.12	3.10	.02	Turkish Red, grown in 1900.
384	Heavy	3.02	2.93	.09	
385	Light	3.13	2.82	.31	Big Frame, grown in 1900.
386	Heavy	2.95	2.65	.30	
602	Light	3.30	3.06	.21	Big Frame, grown in 1901.
603	Heavy	2.46	2.24	.22	
613	Light	2.35	2.13	.22	Turkish Red, grown in 1901.
612	Heavy	2.11	1.94	.17	

It thus becomes very apparent that the percentage of nitrogen is relatively greater in the light wheat selected in the manner described.

It is well known that immature wheat is of lighter weight than mature wheat and that it contains a greater percentage of nonproteid nitrogen. In a field of wheat there are always certain plants that mature early, others that mature late, and some that never reach a normal state of maturity. The last condition is very likely to occur in a region of limited rainfall and intense summer heat. The conditions most favorable for the filling out of the grain are shown to be an abundance of soil moisture and a fair degree of warmth. The more nearly the conditions are the reverse of this the more shriveled the kernel and the lighter the weight. In the same variety and in the same field there are kernels that are small and shriveled because of immaturity, disease, or lack of nutriment. All of these classes would appear among the "light" kernels separated in this way.

In order to approach the question from another standpoint, a number of spikes of wheat of the Turkish Red variety were selected in the field, care being taken that all were fully ripe, and that they were composed of healthy, well-formed kernels. These spikes were sampled by removing one row of spikelets from each spike and the kernels so removed were tested for moisture, proteid nitrogen, specific gravity, and weight of kernel, and from the last two the relative volume was calculated. It will be shown later that a sample taken in this way permits of an accurate estimation of the average composition of the kernels on the spike.

The number of grams of proteid nitrogen in the row of spikelets on each spike was calculated from the data mentioned, and the average weight of the kernels on the row of spikelets was determined from their total weight and number, thus permitting of the estimation of the number of grams of proteid nitrogen in the average kernel on each spike.

In Table 4 the spikes having a proteid nitrogen content of from 2 to 2.5 per cent are arranged in one group, and on the same line with each spike are placed the number of kernels on one row of spikelets, weight of these kernels, weight of average kernel, relative volume of average kernel, specific gravity of kernel, grams of proteid nitrogen in one row of spikelets, and grams of proteid nitrogen in average kernel. Spikes having a proteid nitrogen content of from 2.5 to 3 per cent are similarly arranged, and so with all spikes up to 4 per cent. The average for each group is shown in the table.

There are, in all, 257 spikes, of which 18 have from 2 to 2.5 per cent proteid nitrogen, 82 from 2.5 to 3 per cent, 107 from 3 to 3.5 per cent, and 49 from 3.5 to 4 per cent.

TABLE 4.—*Analyses of spikes of wheat, arranged according to nitrogen content of kernels. Crop of 1902.*

2 TO 2.5 PER CENT PROTEID NITROGEN.

Record number.	Number of kernels on row of spikelets	Weight (in grams) of— Kernels.	Weight (in grams) of— Average kernel.	Volume of average kernel.	Specific gravity of kernels	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Kernels.	Proteid nitrogen (gram) in— Average kernel.
183	17	0.4772	0.0280			2.06	0.00983	0.000577
188	16	.4425	.0276			2.37	.01049	.000654
193	14	.3721	.0266			2.41	.00897	.000642
205	15	.4824	.0321	0.0241	1.3323	2.41	.01548	.000774
291	18	.5221	.0290	.0209	1.3850	2.23	.01616	.000647
304	21	.5336	.0254	.0189	1.3424	2.24	.01195	.000569
318	22	.6708	.0304	.0220	1.3853	2.02	.01354	.000614
347	15	.4549	.0303	.0216	1.4031	2.44	.01110	.000739
357	15	.4063	.0270	.0192	1.4074	2.36	.00959	.000637
358	21	.6689	.0318	.0235	1.3544	2.33	.01559	.000742
380	14	.4336	.0309	.0225	1.3735	2.35	.01019	.000726
396	19	.4787	.0251	.0183	1.3680	2.28	.01091	.000572
402	17	.4594	.0258	.0188	1.3718	2.33	.01070	.000601
406	21	.5878	.0279	.0200	1.3915	2.44	.01434	.000681
415	13	.2771	.0213			2.44	.00676	.000520
440	17	.4566	.0268			2.36	.01078	.000632
444	16	.4110	.0256			2.38	.00978	.000609
445	16	.4318	.0269			2.37	.01023	.000638
Average	17	.4759	.0266	.0209	1.374	2.323	.01141	.000643

2.5 TO 3 PER CENT PROTEID NITROGEN.

181	19	0.4482	0.0235			2.66	0.01192	0.000625
182	17	.4299	.0252			2.76	.01187	.000696
185	19	.5041	.0265			2.71	.01366	.000718
187	15	.3945	.0263			2.99	.01180	.000786
189	18	.4871	.0270			2.64	.01286	.000713
196	17	.4995	.0293			2.71	.01354	.000794
197	20	.5683	.0284			2.85	.01620	.000809
199	17	.4589	.0269			2.99	.01372	.000804
207	15	.4584	.0305	0.0230	1.3248	2.73	.01709	.000833
210	14	.3955	.0282	.0288	1.2363	2.95	.01167	.000832
211	17	.5211	.0306	.0228	1.3416	2.90	.01511	.000887
212	15	.4298	.0286	.0211	1.3537	2.97	.01277	.000849
217	18	.6299	.0349	.0259	1.3461	2.86	.01802	.000998
218	18	.5130	.0285	.0214	1.3303	2.58	.01324	.000735
219	19	.3862	.0203	.0157	1.2950	2.71	.01047	.000550
222	19	.4611	.0242	.0182	1.3331	2.93	.01351	.000709
227	19	.5581	.0293	.0214	1.3704	2.71	.01624	.000794
229	17	.4849	.0285	.0206	1.3856	2.96	.01387	.000844
230	15	.4867	.0324	.0234	1.3815	2.54	.01236	.000823
238	17	.5166	.0303	.0220	1.3794	2.70	.01395	.000818
239	17	.3910	.0230	.01649	1.3941	2.60	.01017	.000598
241	18	.4230	.0235	.0178	1.3196	2.76	.01168	.000649
242	18	.4562	.0253	.0184	1.3753	2.96	.01350	.000749
252	19	.4898	.02578	.0186	1.3875	2.55	.01249	.000655
277	14	.3792	.0270	.0203	1.3286	2.86	.01085	.000772
288	17	.4956	.0291	.0217	1.3428	2.82	.01398	.000821
289	19	.5042	.0265	.0187	1.4155	2.53	.01276	.000670
293	17	.4858	.0285	.0206	1.3835	2.64	.01283	.000752
294	19	.4173	.0219	.0159	1.3813	2.56	.01068	.000561
302	22	.5569	.0253	.0190	1.3312	2.68	.01437	.000678
306	19	.4922	.0258	.0185	1.3996	2.51	.01235	.000650
308	15	.4951	.0330	.0237	1.392	2.85	.01411	.000941
315	16	.4994	.0312	.0224	1.3916	2.75	.01373	.000858
319	17	.4644	.0273	.0203	1.3447	2.86	.01328	.000781
320	18	.5668	.0314	.0229	1.3710	2.98	.01689	.000938
322	16	.5107	.0219	.0236	1.352	2.55	.01302	.000813
329	12	.3903	.0325	.0234	1.3911	2.88	.01241	.000936
330	17	.3431	.0201	.0161	1.2498	2.62	.00899	.000527
332	16	.4817	.0302	.0218	1.3879	2.58	.01251	.000779
334	18	.5399	.0299	.0215	1.3922	2.62	.01415	.000783
335	18	.6474	.0359	.0258	1.3928	2.82	.01826	.001012
337	15	.4497	.0299	.0215	1.3877	2.89	.01345	.000864
340	20	.4155	.0207	.0153	1.3550	2.74	.01138	.000567
341	15	.5058	.0337	.0243	1.3890	2.97	.01502	.001001
342	14	.4486	.0320	.0228	1.4037	2.60	.01166	.000832
343	13	.4112	.0316	.0224	1.4107	2.50	.01028	.000791
344	16	.4004	.0250	.0184	1.3611	2.93	.01173	.000733
345	18	.5122	.0301	.0216	1.3919	2.56	.01388	.000771
346	19	.6393	.0336	.0212	1.3913	2.55	.01630	.000857
348	18	.6328	.0351	.0262	1.3415	2.88	.01822	.001010

TABLE 4.—*Analyses of spikes of wheat, arranged according to nitrogen content of kernels. Crop of 1902*—Continued.

2.5 TO 3 PER CENT PROTEID NITROGEN—Continued.

Record number.	Number of kernels on row of spikelets	Weight (in grams) of—		Volume of average kernel	Specific gravity of kernels.	Percentage of proteid nitrogen in kernels	Proteid nitrogen (gram) in	
		Kernels.	Average kernel.				Kernels.	Average kernel.
349........	17	0.4573	0.0269	0.0195	1.3822	2.66	0.01216	0.000716
350........	16	.4437	.0277	.0199	1.3891	2.64	.01171	.000731
354........	21	.6386	.0304	.0217	1.4002	2.73	.01743	.000830
355........	16	.5008	.0313	.0223	1.4022	2.84	.01422	.000889
356........	19	.5304	.0279	.0200	1.390	2.91	.01543	.000812
359........	15	.3882	.0259	.0186	1.3915	2.97	.01153	.000769
360........	24	.6375	.0265	.0191	1.3810	2.89	.01842	.000766
361........	14	.3297	.0235	.0170	1.3819	2.94	.00969	.000691
364........	18	.4724	.0262	.0191	1.3729	2.92	.01379	.000765
371........	18	.5695	.0316	.0227	1.3906	2.99	.01703	.000915
373........	18	.5861	.0325	.0235	1.3838	2.87	.01682	.000933
376........	12	.2677	.0223	.0162	1.3747	2.60	.00696	.000580
378........	14	.4099	.0292	.0212	1.3761	2.75	.01127	.000803
383........	12	.3416	.0284	.0206	1.3771	2.96	.01011	.000841
386........	16	.4921	.0307	.0223	1.3741	2.52	.01240	.000774
387........	19	.5177	.0272	.0198	1.3758	2.73	.01413	.000743
389........	21	.5830	.0277	.0204	1.3569	2.96	.01726	.000820
392........	16	.3547	.0221	.0171	1.2917	2.91	.01043	.000650
393........	15	.3494	.0232	.0165	1.4070	2.70	.00943	.000626
394........	16	.3897	.0243	.0180	1.3508	2.77	.01079	.000673
395........	17	.4805	.0282	.0206	1.3693	2.98	.01432	.000840
419........	14	.3448	.0246	....	....	2.86	.00986	.000704
421........	15	.3097	.0206	....	....	2.53	.00784	.000521
424........	18	.4991	.0277	....	....	2.62	.01308	.000726
428........	17	.4635	.0272	....	....	2.60	.01205	.000707
430........	18	.5714	.0317	....	....	2.82	.01611	.000894
434........	16	.4624	.0289	....	....	2.86	.01322	.000827
436........	22	.6138	.0279	....	....	2.88	.01768	.000834
438........	23	.6997	.0304	....	....	2.67	.01868	.000812
439........	18	.5600	.0311	....	....	2.98	.01669	.000927
441........	19	.5327	.0280	....	....	2.93	.01561	.000820
443........	13	.4131	.0317	....	....	2.51	.01037	.000796
Average...	17.07	.4791	.0279	.0207	1.3680	2.76	.01332	.000776

3 TO 3.5 PER CENT PROTEID NITROGEN.

173........	20	0.5913	0.0295	....	....	3.08	0.01821	0.000909
175........	21	.5773	.0274	....	....	3.16	.01997	.000948
176........	20	.5804	.0290	....	....	3.10	.01799	.000899
190........	18	.4673	.0259	....	....	3.25	.01519	.000842
191........	17	.4279	.0251	....	....	3.25	.01091	.000816
192........	17	.4126	.0242	....	....	3.12	.01287	.000755
194........	13	.3218	.0247	....	....	3.43	.01104	.000847
195........	19	.4924	.0259	....	....	3.33	.01640	.000862
198........	18	.4683	.0260	....	....	3.18	.01489	.000827
200........	18	.5764	.0320	....	....	3.24	.01868	.001040
202........	14	.3824	.0273	0.0200	1.3615	3.13	.01197	.000854
203........	16	.5251	.0328	.0241	1.3614	3.07	.01612	.001007
206........	17	.3392	.0199	.0157	1.2709	3.44	.01166	.000685
208........	19	.4939	.0259	.0192	1.3494	3.21	.01585	.000831
213........	15	.4116	.0274	.0204	1.3415	3.31	.01362	.000907
214........	16	.4371	.0273	.0208	1.3082	3.09	.01351	.000844
216........	15	.3122	.0208	.0165	1.2588	3.33	.01040	.000693
220........	17	.5040	.0296	.0222	1.3350	3.20	.01613	.000947
223........	17	.4795	.0282	.0201	1.3970	3.31	.01587	.000933
226........	21	.5380	.0256	.0170	1.4951	3.11	.01673	.000796
228........	14	.4143	.0295	.0211	1.3945	3.40	.01409	.001003
231........	18	.5888	.0327	.0242	1.3514	3.11	.01831	.001017
232........	13	.3825	.0294	.0221	1.3280	3.11	.01190	.000914
233........	17	.5331	.0313	.0231	1.3558	3.32	.01663	.001039
234........	16	.5201	.0325	.0243	1.3363	3.23	.01680	.001050
236........	25	.7451	.0298	.0220	1.3504	3.19	.02377	.000951
243........	24	.6349	.0264	.0196	1.3487	3.47	.02203	.000916
244........	19	.5839	.0307	.0214	1.4305	3.30	.01927	.001013
249........	16	.4415	.0275	.0199	1.3850	3.21	.01117	.000883
250........	15	.4514	.0300	.0213	1.4100	3.12	.01408	.000936
251........	22	.6190	.0281	.0203	1.3823	3.46	.02112	.000972
255........	18	.5948	.0330	.0233	1.4146	3.03	.01802	.001000
256........	21	.5277	.0251	.0184	1.3629	3.31	.01747	.000852
258........	17	.4703	.0276	.0211	1.3065	3.38	.01590	.000933

TABLE 4.—*Analyses of spikes of wheat, arranged according to nitrogen content of kernels. Crop of 1902*—Continued.

3 TO 3.5 PER CENT PROTEID NITROGEN—Continued.

Record number	Number of kernels on row of spikelets	Weight (in grams) of		Volume of average kernel	Specific gravity of kernels.	Percentage of proteid nitrogen in kernels	Proteid nitrogen (gram) in—	
		Kernels.	Average kernel				Kernels	Average kernel
262	18	0.4604	0.0255	0.0193	1.3216	3.20	0.01473	0.000816
263	18	.5040	.0280	.0197	1.4206	3.24	.01633	.000907
264	18	.4138	.0229	.0169	1.3541	3.37	.01395	.000772
265	18	.4429	.0246	.0189	1.3005	3.30	.01462	.000812
266	19	.5010	.0263	.0187	1.4090	3.11	.01558	.000818
269	17	.4531	.0266	.0209	1.2748	3.21	.01454	.000854
270	20	.5183	.0259	.0191	1.3541	3.37	.01747	.000873
271	14	.3275	.0233	.0177	1.3143	3.39	.01110	.000790
272	15	.3858	.0257	.0190	1.3561	3.14	.01212	.000807
273	18	.4559	.0253	.0178	1.4228	3.39	.01546	.000858
275	18	.4862	.0270	.0197	1.3711	3.33	.01619	.000899
276	15	.3973	.0264	.0191	1.3815	3.15	.01251	.000832
278	15	.4715	.0314	.0226	1.3903	3.12	.01471	.000980
281	21	.6938	.0330	.0241	1.3693	3.26	.02262	.001076
282	18	.4973	.0276	.0200	1.3795	3.02	.01502	.000834
295	19	.5205	.0273	.0201	1.3608	3.06	.01593	.000835
300	19	.4994	.0262	.0188	1.3945	3.07	.01533	.000894
301	16	.5492	.0343	.0249	1.3787	3.09	.01697	.001060
305	13	.3452	.0265	.0197	1.3432	3.07	.01060	.000814
307	20	.4122	.0206	.0140	1.4727	3.19	.01315	.000657
310	18	.4867	.0270	.0198	1.3681	3.16	.01538	.000853
312	15	.4324	.0288	.0210	1.3718	3.49	.01509	.001005
314	15	.4122	.0274	.0201	1.3657	3.16	.01303	.000866
316	17	.4157	.0244	.0178	1.3733	3.36	.01397	.000820
317	17	.4412	.0259	.0193	1.3424	3.43	.01513	.000888
321	18	.5484	.0304	.0207	1.4600	3.43	.01881	.001043
323	17	.4075	.0239	.0177	1.3487	3.43	.01398	.000820
324	17	.4230	.0248	.9180	1.3740	3.19	.01349	.000791
325	17	.5110	.0300	.0220	1.3658	3.46	.01768	.001038
327	16	.4039	.0252	.0191	1.3225	3.45	.01393	.000869
333	16	.4610	.0288	.0206	1.3956	3.26	.01503	.000939
336	13	.3637	.0279	.0198	1.4102	3.36	.01222	.000937
339	16	.3803	.0237	.0171	1.3828	3.33	.01266	.000789
351	15	.3843	.0256	.0186	1.3812	3.32	.01276	.000851
352	15	.4497	.0299	.0217	1.3879	3.05	.01372	.000914
353	16	.4726	.0295	.0211	1.3988	3.11	.01470	.000917
362	19	.5258	.0276	.0201	1.3701	3.03	.01593	.000836
366	17	.4211	.0247	.0185	1.3350	3.17	.01336	.000783
367	20	.5351	.0267	.0197	1.3555	3.37	.01803	.000900
368	19	.3877	.0204	.0151	1.3497	3.06	.01186	.000624
369	19	.5560	.0292	.0214	1.3621	3.34	.01857	.000975
370	17	.4200	.0247	.0180	1.3735	3.09	.01298	.000763
372	17	.4811	.0283	.0206	1.3714	3.31	.01593	.000937
374	17	.5249	.0308	.0218	1.4112	3.15	.01653	.000970
375	18	.5147	.0285	.0203	1.4018	3.41	.01755	.000975
377	14	.3173	.0226	.0174	1.3013	3.47	.01101	.000784
379	18	.5271	.0292	.0213	1.3703	3.09	.01629	.000902
381	13	.3506	.0269	.0199	1.3544	3.45	.01210	.000928
382	19	.5057	.0266	.0194	1.3728	3.23	.01633	.000859
388	19	.5799	.0305	.0221	1.3773	3.05	.01769	.000930
390	19	.4764	.0250	.0181	1.3806	3.22	.01534	.000805
391	18	.4474	.0248	.0182	1.3628	3.26	.01459	.000808
399	12	.3058	.0254	.0188	1.3510	3.10	.00948	.000787
400	20	.5720	.0286	.0206	1.3837	3.35	.01916	.000958
401	16	.3996	.0249	.0183	1.3575	3.37	.01347	.000839
403	17	.5000	.0294	.0211	1.3927	3.04	.01520	.000894
404	18	.4286	.0238	.0180	1.3221	3.30	.01414	.000785
410	20	.5368	.0268	....	....	3.27	.01755	.000780
411	14	.3479	.0248	....	....	3.15	.01096	.000781
414	19	.5044	.0265	....	....	3.14	.01584	.000832
416	15	.4269	.0284	....	....	3.24	.01383	.000920
418	21	.4995	.0237	....	....	3.05	.01523	.000723
423	18	.4845	.0269	....	....	3.14	.01521	.000845
425	16	.4801	.0300	....	....	3.30	.01584	.000990
426	18	.5166	.0287	....	....	3.09	.01596	.000887
427	19	.5433	.0285	....	....	3.06	.01662	.000872
429	20	.4704	.0235	....	....	3.04	.01430	.000714
431	18	.4119	.0228	....	....	3.20	.01318	.000732
432	21	.6306	.0300	....	....	3.00	.01892	.000900
433	20	.5206	.0260	....	....	3.12	.01624	.000811
437	16	.4336	.0271	....	....	3.13	.01357	.000848
442	17	.3889	.0228	....	....	3.23	.01256	.000736
Average	17.4	.4724	.0270	.0199	1.3666	3.23	.01520	.000874

TABLE 4.—*Analyses of spikes of wheat, arranged according to nitrogen content of kernels. Crop of 1902*—Continued.

3.5 TO 4 PER CENT PROTEID NITROGEN.

Record number.	Number of kernels on row of spikelets.	Weight (in grams) of Kernels.	Weight (in grams) of Average kernel.	Volume of average kernel	Specific gravity of kernels.	Percentage of proteid nitrogen in kernels	Proteid nitrogen (gram) in Kernels	Proteid nitrogen (gram) in Average kernel.
174	18	0.4025	0.0223	....	....	3.76	0.01513	0.000838
177	19	.4073	.0214	....	....	3.57	.01454	.000764
179	19	.4972	.0261	....	....	3.85	.01914	.001005
180	17	.5262	.0309	....	....	3.58	.01884	.001110
184	20	.5512	.0275	....	....	3.78	.02084	.001040
186	21	.5414	.0257	....	....	3.97	.02149	.001020
204	15	.4015	.0267	0.0198	1.3460	3.90	.01566	.001043
209	17	.3588	.0211	.0164	1.2828	3.82	.01371	.000806
215	12	.3318	.0276	.0205	1.3493	3.79	.01258	.001046
221	17	.4891	.0287	.0220	1.3039	3.65	.01785	.001048
225	19	.4976	.0261	.0193	1.3507	3.55	.01766	.000927
235	18	.4555	.0253	.0192	1.3164	3.65	.01663	.000923
240	16	.3984	.0249	.0177	1.4025	3.53	.01406	.000879
245	15	.3971	.0264	.0200	1.3230	3.64	.01445	.000961
246	18	.4562	.0253	.0194	1.3058	3.75	.01711	.000949
247	18	.4937	.0274	.0202	1.3564	3.50	.01728	.000959
248	17	.4617	.0271	.0193	1.4095	3.65	.01685	.000991
253	21	.5960	.0283	.0203	1.3917	3.63	.02163	.001327
259	19	.4932	.0259	.0193	1.3400	3.81	.01894	.000995
261	17	.5195	.0305	.0229	1.3333	3.50	.01818	.001068
274	15	.3347	.0223	.0168	1.3300	3.57	.01195	.000796
279	16	.4304	.0269	.0200	1.3444	3.79	.01631	.001020
280	16	.4305	.0269	.0198	1.3600	3.70	.01593	.000995
283	17	.4974	.0292	.0210	1.3911	3.86	.01920	.001127
284	14	.3723	.0265	.0189	1.4050	3.72	.01385	.000986
285	18	.5769	.0320	.0233	1.3745	3.87	.02233	.001238
286	17	.4140	.0243	.0178	1.3650	3.56	.01474	.000865
287	16	.4740	.0296	.0223	1.3270	3.87	.01835	.001146
290	16	.3955	.0247	.0177	1.3921	4.00	.01582	.000988
296	17	.5037	.0296	.0214	1.3832	3.94	.01985	.001166
299	17	.4553	.0267	.0195	1.3715	3.68	.01676	.000983
309	18	.4753	.0264	.0239	1.1051	3.75	.01782	.000990
313	17	.4798	.0282	.0202	1.3971	3.52	.01689	.000993
328	20	.5795	.0289	.0215	1.3466	3.61	.02092	.001043
363	17	.3795	.0223	.0165	1.3499	3.50	.01328	.000781
365	16	.3469	.0216	.0169	1.2787	3.50	.01214	.000756
384	14	.4012	.0286	.0212	1.3499	3.56	.01428	.001020
385	15	.4162	.0277	.0203	1.3670	3.79	.01578	.001050
405	18	.4940	.0274	.0203	1.3508	3.76	.01857	.001030
407	20	.4707	.0235	.0171	1.3700	3.79	.01784	.000891
408	19	.4462	.0234	....	....	3.61	.01624	.000852
409	17	.4329	.0254	....	....	3.59	.01554	.000912
412	16	.3390	.0211	....	....	3.63	.01231	.000766
413	17	.4393	.0258	....	....	3.77	.01656	.000973
417	19	.4530	.0238	....	....	3.80	.01721	.000904
420	17	.4156	.0244	....	....	3.73	.01550	.000910
422	23	.5395	.0234	....	....	3.53	.01904	.000826
435	20	.4310	.0215	....	....	3.53	.01521	.000759
446	17	.4425	.0260	....	....	3.75	.01659	.000975
Average	17.3	.4517	.0257	.01987	1.3194	3.70	.01672	.000952

Table 5 shows at a glance the averages for each of the classes of spikes just tabulated, and permits of a comparison of the average figures for each class.[a]

[a] The determinations of specific gravity were made by the following method, devised by Prof. S. Avery: A light basket of wire gauze was suspended by a hair from the hook that supported one of the pan hangers of the balance. The basket was allowed to hang in a beaker of benzol supported by a shelf above the pan. By using a counterpoise the balance was now brought to the zero point. The balance was kept at zero by the occasional adjustment of a rider on the left arm of the beam. The wheat was weighed on the pan of the balance, then transferred to the basket and weighed in benzol, and the temperature of the latter carefully noted. The specific gravity was calculated from the well-known formula:

$$\frac{\text{Wt. in air} \times \text{sp. gr. in benzol at } T^{\circ}}{\text{Wt. in air} - \text{wt. in benzol}} = \text{Sp. gr.}$$

TABLE 5.—*Summary of analyses of spikes of wheat, arranged according to nitrogen content of kernels. Crop of 1902.*

Range of percentage of proteid nitrogen.	Percentage of proteid nitrogen in kernels.	Number of—		Weight (in grams) of—		Volume of average kernel.	Specific gravity.	Proteid nitrogen (gram) in—	
		Analyses.	Kernels on row of spikelets.	Kernels.	Average kernel.			Kernels.	Average kernel.
2 to 2.5	2.32	18	17	0.4759	0.0266	0.0209	1.374	0.01141	0.000643
2.5 to 3	2.76	82	17.1	.4791	.0279	.0207	1.368	.01332	.000776
3 to 3.5	3.23	107	17.4	.4724	.0270	.0199	1.367	.01520	.000874
3.5 to 4	3.70	19	17.3	.4715	.0257	.0199	1.349	.01672	.000982

From this table it will be seen that with an increase in the percentage of proteid nitrogen the number of kernels on a row of spikelets remains about constant; that in general there were a decrease in the weight of the kernels on a row of spikelets and a slight decrease in the weight of the average kernel; and that the volume of the average kernel decreased, as did the specific gravity.

It may safely be stated that a high percentage of proteid nitrogen was in these spikes associated with a kernel of low specific gravity, light weight, and small relative volume, and, as the spikes were selected for their ripeness and healthy appearance, this relation can not be attributed to immaturity or disease.

The table last referred to shows a decrease in the weight of the kernels on the spike as the percentage of proteid nitrogen increases; but it also shows that in spite of the decrease in the weight of the kernels there is an increase in the actual amount of proteid nitrogen they contain, and that the same is true of the average kernel.

Table 6 gives a summary of the same analyses, arranged according to the specific gravities of the kernels. All spikes whose kernels had a specific gravity below 1.30 are grouped in one class, those having a specific gravity of 1.30 to 1.33 in another class, and so on until finally all spikes having a specific gravity of more than 1.42 form the last class.

TABLE 6.—*Summary of analyses of spikes of wheat, arranged according to specific gravities of kernels. Crop of 1902.*

Range of specific gravity.	Specific gravity of kernels.	Number of—		Weight of kernels (gram).	Percentage of proteid nitrogen in kernels.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
		Analyses.	Kernels.				Kernels.	Average kernel.
Below 1.30	1.255	8	16.7	0.3887	3.29	0.02331	0.01280	0.0007662
1.30 to 1.33	1.315	17	16.5	.4315	3.35	.02617	.01446	.0008762
1.33 to 1.36	1.347	50	17.3	.4008	2.91	.02366	.01508	.0008756
1.36 to 1.39	1.375	71	17.2	.4794	3.06	.02786	.01462	.0008559
1.39 to 1.42	1.399	40	16.7	.4848	3.03	.02899	.01459	.0008729
1.42 and over	1.463	8	19.1	.5287	3.07	.02773	.01605	.0008371

This table shows no constant relation between the specific gravity and the number of kernels on the spike. With an increase in the specific gravity there is an increase in the weight of the kernels on the spike, and with some exceptions an increase in the weight of the average kernel. As the specific gravity increases, the percentage of proteid nitrogen decreases, which agrees with the previous table. The grams of proteid nitrogen in the kernels on the spikes and in the average kernel increase with the specific gravity.

Table 7 shows the summary of the same analyses, arranged according to the weight of the average kernel. Spikes whose kernels have an average weight of less than 0.024 gram form the first class, and each succeeding class increases by 0.002 gram.

TABLE 7.—*Summary of analyses of spikes of wheat, arranged according to weight of average kernel. Crop of 1902.*

Range of weight of average kernel (gram).	Weight of average kernel (gram).	Number of—		Weight of kernels (gram).	Specific gravity of kernels.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in—	
		Analyses.	Kernels.				Average kernel.	Kernels.
Below 0.024	0.02214	27	16.9	0.3812	1.341	3.197	0.0007184	0.01215
0.024 to 0.026	.02528	38	17.5	.4425	1.361	3.28	.0008294	.01438
0.026 to 0.028	.02705	18	17.0	.4609	1.360	3.22	.0008711	.01475
0.028 to 0.030	.02896	40	17.0	.4916	1.372	3.11	.0009090	.01546
0.030 to 0.032	.03089	26	17.0	.5274	1.388	2.86	.0008787	.01506
0.032 and over	.03324	19	16.8	.5588	1.373	2.88	.0009594	.01617

There seems to be no relation between the weight of the average kernel and the number of kernels on the spike. The weight of all the kernels on the spike naturally increases with the weight of the average kernel. The specific gravity of the kernels increases with the weight of the average kernel. The percentage of proteid nitrogen decreases with an increase in the weight of the average kernel, in which respect it agrees with the two previous tables. The grams of proteid nitrogen in the average kernel and the total proteid nitrogen in the spike increase with the weight of the average kernel.

Samples from each of the spikes of wheat from which these data were derived were planted, together with samples from other spikes, all of which have been analyzed, aggregating 800 in all. Each kernel was planted separately at a distance of 6 inches each way from every other kernel. The kernels from each spike were marked by a stake bearing the record number of the spike.

During the winter a considerable number of plants were killed, so that the stand was irregular in the spring. In some cases all of the plants resulting from a spike of the previous year were killed, and in other cases only a portion of such plants. The result was a somewhat uneven stand, which doubtless gave certain plants an advantage over others in growth and yield.

When the crop was ripe in 1903 each plant was harvested separately, and all of those resulting from spikes which the previous year had shown a proteid nitrogen content of more than 4 per cent or less than 2 per cent were analyzed, as were also a certain number resulting from spikes of intermediate values.

The good kernels on each plant were counted and weighed, thus giving a record of the yield of each plant. From these data the average weight of the kernels per plant was calculated. The specific gravity was not determined and consequently the average volume of the kernels on each plant was not calculated, as was done the previous year.

In Table 8 the plants harvested in 1903 are arranged in classes of 1 to 2 per cent proteid nitrogen, 2 to 2.5 per cent, 2.5 to 3 per cent, 3 to 3.5 per cent, 3.5 to 4 per cent, 4 to 4.5 per cent, and over 4.5 per cent. The number and weight of the kernels on each plant are stated, as is also the average weight of each kernel. The number of grams of proteid nitrogen in all the kernels of the plant is shown, and also the number of grams of proteid nitrogen in the average kernel on each plant. Table 9 shows the average for each class.

These results, so far as they cover the same ground as those of the previous year, have the same significance. They show a quite uniform although slight decrease in the weight of the average kernel accompanying an increase in the percentage of proteid nitrogen, and a very marked increase in the number of grams of proteid nitrogen in the average kernel. Especially marked is the increase in the amount of proteid nitrogen in the average kernel, amounting to 28 per cent of the weight of the kernel for every 1 per cent increase in the content of proteid nitrogen.

One column of this table, not contained in that compiled from results of the previous year, shows the number of grams of proteid nitrogen contained in all of the kernels on the plant; or, in other words, the proteid nitrogen production of the plant. This appears, on the whole, to increase with the percentage of proteid nitrogen, although the results are not sufficiently consistent to permit of an unqualified statement to that effect. The uneven stand of the plants, before referred to, doubtless accounts for these inconsistent results.

Two other columns contain data not obtained in 1902. The first of these shows the number of kernels per plant, which apparently decreases slightly as the percentage of proteid nitrogen increases, but this can not be stated unqualifiedly. The next column shows the weight of kernels per plant, or the yield per plant, which likewise seems to decrease slightly with an increase in the percentage of proteid nitrogen.

TABLE 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903.*

1 TO 2 PER CENT PROTEID NITROGEN.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
32206	1.81	507	10.4036	0.02052	0.18831	0.0003714
32605	1.20	225	5.2268	.02323	.06272	.0002788
33407	1.62	305	7.0889	.02271	.11223	.0003679
33408	1.39	77	1.1132	.01446	.01547	.0002009
33905	1.61	508	11.1476	.02194	.17948	.0003533
42206	1.46	25	.3161	.01264	.00462	.0001846
45606	1.91	220	4.0358	.01834	.07708	.0003504
45805	1.84	124	1.5298	.01234	.02815	.0002700
48407	1.50	718	11.2890	.01572	.16933	.0002358
51005	1.34	862	15.5935	.01804	.20881	.0002422
55307	1.89	342	5.6864	.01663	.10747	.0003142
57308	1.69	577	9.8378	.01705	.16626	.0002881
57405	1.98	41	.8328	.02031	.01649	.0004022
57607	1.73	736	16.4433	.02234	.24847	.0003865
58806	1.88	95	1.9469	.02049	.03660	.0003853
60605	1.87	35	.5952	.01701	.01113	.0003180
63505	1.90	208	4.0230	.01934	.07644	.0003674
69806	1.66	558	12.0136	.02153	.19943	.0003574
72606	1.89	543	9.3629	.01724	.18538	.0003414
74305	1.98	216	4.4222	.02047	.08756	.0004054
80305	1.81	729	15.7835	.02165	.28569	.0003919
81705	1.98	465	9.7922	.02106	.19388	.0004170
81710	1.92	396	9.1411	.02308	.17550	.0004432
92407	1.66	53	.8983	.01695	.01491	.0002814
94205	1.65	64	1.2117	.01893	.01999	.0003124
94605	1.95	56	.7319	.01307	.01427	.0002549
94908	1.96	125	2.3678	.01894	.04641	.0003713
95510	1.81	159	2.8356	.01783	.05132	.0003228
Average	1.749	320.3	6.23823	.01871	.10655	.00032914

2 TO 2.5 PER CENT PROTEID NITROGEN

17405	2.13	738	15.6996	0.02127	0.33441	0.0004531
17408	2.18	497	9.2038	.01852	.20065	.0004037
18805	2.02	137	2.1462	.01567	.04335	.0003164
21212	2.16	84	1.7216	.02050	.03718	.0004427
21705	2.45	58	1.5420	.02659	.03778	.0006514
21707	2.19	582	12.3685	.02125	.27086	.0001654
21708	2.33	390	9.2850	.02381	.21634	.0005547
21709	2.47	361	7.7296	.02141	.19092	.0005289
21912	2.31	510	9.7236	.01907	.22461	.0004404
27205	2.41	891	16.4061	.01841	.39539	.0004437
27206	2.36	777	19.1854	.02469	.45276	.0005827
27306	2.47	684	13.3011	.01945	.32853	.0004803
27505	2.12	539	12.0399	.02183	.21942	.0004627
33107	2.35	318	6.1026	.01919	.14341	.0004510
33405	2.03	421	8.1268	.01930	.16498	.0003919
33605	2.39	301	7.0596	.02345	.16872	.0005605
33606	2.21	382	8.1890	.02144	.18098	.0004738
34208	2.13	156	2.9886	.01916	.06366	.0004081
37706	2.34	56	1.2069	.02155	.02824	.0005053
37906	2.44	19	.2063	.01086	.00503	.0002649
39205	2.11	1,031	21.5399	.02089	.45435	.0004407
39606	2.37	346	4.6383	.01341	.10967	.0003177
44607	2.44	101	1.8246	.01806	.04452	.0004408
48106	2.38	608	11.6655	.01919	.27765	.0004567
48409	2.02	314	6.4302	.02048	.12989	.0004137
55305	2.48	167	2.5160	.01507	.06240	.0003736
55306	2.18	214	4.1323	.01931	.09008	.0004210
55608	2.31	837	22.5848	.02699	.52194	.0006236
55908	2.42	562	12.2210	.02175	.29575	.0005262
55909	2.30	302	9.2120	.03050	.21187	.0007016
56206	2.42	509	9.3093	.01829	.22529	.0004426
56207	2.34	462	10.9073	.02361	.25522	.0005524
57307	2.43	261	4.7117	.01801	.11445	.0004387
57508	2.21	380	12.0728	.03177	.26680	.0007021
58905	2.43	170	2.3031	.01355	.05596	.0003292
59605	2.12	382	7.1828	.01880	.15228	.0003986
59606	2.16	567	9.7084	.01712	.20970	.0003698
63107	2.43	417	9.3120	.02233	.22628	.0005426

Table 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903*—Continued.

2 TO 2.5 PER CENT PROTEID NITROGEN—Continued.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
63506	2.44	153	2.3986	.01568	0.05853	0.0003825
65306	2.41	544	9.8298	.01807	.23690	.0004355
65307	2.28	373	7.0051	.01878	.15971	.0004282
65308	2.09	583	11.7066	.02008	.24468	.0004197
69505	2.29	225	4.7116	.01847	.10790	.0004231
71905	2.47	1,260	28.2136	.02239	.69688	.0005531
72705	2.13	372	9.1522	.02191	.19936	.0004668
72708	2.27	398	9.0386	.02270	.20518	.0005154
72905	2.48	167	2.6462	.01585	.06563	.0003930
73306	2.45	414	8.5373	.02062	.20918	.0005052
73307	2.39	25	.5572	.02229	.01332	.0005327
74606	2.30	464	9.6451	.02079	.22184	.0004781
76205	2.35	498	8.4407	.01695	.19836	.0003983
81707	2.34	786	18.3614	.02336	.42965	.0005466
81708	2.41	287	7.3993	.02578	.17833	.0006213
81709	2.28	757	16.4692	.02175	.37548	.0004960
84405	2.48	428	8.7448	.02043	.21687	.0005067
84905	2.32	37	.7130	.01927	.01654	.0004471
88608	2.47	74	1.5355	.02075	.03793	.0005125
88609	2.42	470	9.8719	.02100	.23890	.0005082
92409	2.30	315	5.7131	.01814	.13140	.0004171
94209	2.49	190	3.6006	.01895	.08965	.0004719
94406	2.47	549	10.5556	.01923	.26073	.0004749
94407	2.07	419	6.7664	.01615	.14007	.0003343
94905	2.35	286	4.4423	.01553	.10439	.0003650
95509	2.48	138	2.9475	.02136	.07310	.0005297
95707	2.47	52	.7577	.01457	.01872	.0003599
Average	2.319	396.8	8.2502	.020113	.190316	.0004660

2.5 TO 3 PER CENT PROTEID NITROGEN.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
17409	2.75	802	14.8957	0.01857	0.40964	0.0005108
17410	2.88	744	16.9987	.02285	.48957	.0006580
20706	2.78	163	3.3138	.02033	.09212	.0005652
20707	2.77	444	9.9070	.02282	.27443	.0006181
20708	2.58	122	2.4690	.02024	.06399	.0005221
20710	2.83	867	17.1115	.01974	.48428	.0005586
21207	2.96	118	2.3066	.01955	.06804	.0005766
21305	2.67	312	6.2514	.02004	.16691	.0005350
21306	2.90	226	4.1516	.01837	.12039	.0005327
21710	2.59	59	.8478	.01437	.02196	.0003722
21711	2.71	873	17.1820	.01968	.46563	.0005334
21805	2.69	1,232	20.9290	.01699	.56299	.0004569
21806	2.71	599	14.2450	.02378	.38604	.0006444
21807	2.73	377	9.4172	.02498	.25709	.0006664
21808	2.57	1,156	19.7446	.01708	.50744	.0004389
21809	2.73	418	8.0214	.01919	.21898	.0005238
21810	2.69	52	1.0304	.01982	.02772	.0005330
21905	2.64	791	14.3111	.01809	.37781	.0004777
22205	2.81	283	2.6965	.00953	.07577	.0002677
22207	2.77	169	3.2787	.01940	.09082	.0005374
25205	2.71	522	10.7836	.02066	.28560	.0005599
25206	2.76	205	4.6754	.02281	.12904	.0006295
26106	2.63	90	2.0737	.02304	.05454	.0006060
26805	2.81	220	4.9456	.02248	.13897	.0006317
26806	2.60	152	2.7255	.01793	.07086	.0004662
26807	2.80	721	17.2324	.02390	.48250	.0006692
26905	2.76	326	6.4102	.01966	.17692	.0005427
26906	2.71	228	4.2376	.01859	.11484	.0005037
26907	2.61	102	1.8276	.01792	.04995	.0004677
26908	2.96	192	3.9797	.02073	.11780	.0006135
26909	2.80	180	2.9999	.01667	.08400	.0004667
27005	2.63	866	16.4120	.01895	.43164	.0004984
27207	2.92	166	3.3266	.02004	.09712	.0005850
27305	2.58	267	5.5666	.02085	.14362	.0005379
27307	2.53	167	3.0850	.01847	.07805	.0004674
27506	2.70	444	10.0005	.02252	.27003	.0006082
27508	2.64	251	5.5324	.02287	.14608	.0006037
27509	2.90	243	5.3615	.02206	.15549	.0006399
28805	2.91	87	2.1851	.02512	.06359	.0007309
32606	2.88	94	2.0162	.02145	.05807	.0006177

Table 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903*—Continued.

2.5 TO 3 PER CENT PROTEID NITROGEN—Continued.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
33105	2.91	132	2.5601	0.01939	0.07450	0.0005644
33106	2.94	18	.3089	.01716	.00908	.0005045
33406	2.87	283	4.6045	.01627	.13215	.0004670
33906	2.81	119	2.2862	.01921	.06424	.0005399
34205	2.73	464	9.1498	.01972	.24979	.0005383
34207	2.84	611	13.5556	.02219	.38505	.0006273
37305	2.96	309	6.1394	.01987	.18173	.0005881
37705	2.64	461	8.0905	.01972	.23998	.0005327
37707	2.94	193	3.3004	.01710	.09670	.0005010
37905	2.53	37	.9452	.02555	.02391	.0006463
38005	2.84	139	2.5134	.01808	.07138	.0005135
38506	2.89	85	1.6799	.01975	.04855	.0005712
38606	2.63	401	8.4605	.02110	.22251	.0005549
38608	2.82	158	3.0228	.01913	.08522	.0005394
38609	2.74	293	6.7665	.02309	.18540	.0006475
38706	2.59	365	7.2545	.01988	.18789	.0005148
39405	2.88	447	9.3541	.02093	.21399	.0006027
39506	2.93	67	1.9218	.02869	.05631	.0008401
40505	2.82	170	4.1546	.02444	.11716	.0006892
43405	2.92	124	2.8000	.02258	.08176	.0006594
44505	2.94	340	5.9990	.01764	.17637	.0005187
44605	2.86	55	1.1271	.02049	.03223	.0005861
44606	2.90	124	2.5235	.02035	.07318	.0005902
45605	2.82	61	.7081	.01161	.01997	.0003273
46106	2.54	82	1.6103	.01964	.04090	.0004988
46107	2.54	478	8.3935	.01756	.21319	.0004460
48305	2.87	473	12.0278	.02543	.34524	.0007299
48408	2.81	27	.3485	.01291	.00979	.0003627
48507	2.64	70	1.6036	.02296	.04233	.0006062
48508	2.76	603	11.2008	.01858	.30986	.0005127
48806	2.70	547	9.8346	.01798	.26553	.0004877
50706	2.80	35	.4701	.01343	.01316	.0003761
55008	2.60	944	17.4226	.01846	.45299	.0004799
55206	2.56	578	11.3592	.01965	.29079	.0005031
55308	2.54	397	9.5078	.02395	.24150	.0006225
55506	2.80	866	17.8506	.02062	.49995	.0005773
55507	2.63	504	9.8228	.01949	.25834	.0005126
55605	2.64	500	10.9180	.02184	.28823	.0005765
55606	2.58	503	11.0930	.02205	.28580	.0005690
55607	2.69	138	2.3931	.01734	.06437	.0004665
55905	2.67	331	5.7948	.01751	.15470	.0004674
55906	2.81	499	7.9968	.01603	.22171	.0004503
55907	2.59	749	19.3966	.02590	.50238	.0006707
56105	2.73	336	5.7431	.01709	.15679	.0004667
56106	2.57	644	12.0161	.01866	.30881	.0004795
56107	2.96	872	14.4556	.01658	.42790	.0004907
56205	2.51	333	6.5232	.01959	.16373	.0004917
56208	2.61	563	13.5720	.02356	.34616	.0006149
56209	2.59	950	15.8086	.01664	.40945	.0004310
57005	2.71	88	1.5364	.01746	.04164	.0004731
57006	2.76	701	10.1836	.01453	.28107	.0004010
57007	2.65	168	3.3176	.01975	.08792	.0005233
57105	2.76	407	3.7263	.00916	.10285	.0002527
57306	2.86	434	7.9772	.01838	.22815	.0005257
57406	2.75	135	2.4923	.01846	.06854	.0005077
57407	2.62	762	14.9992	.01968	.39297	.0005157
57408	2.61	596	12.2004	.02047	.31842	.0005343
57506	2.80	180	2.7616	.01534	.07733	.0004296
57507	2.85	359	6.9861	.01946	.19905	.0005545
57509	2.54	611	10.6261	.01739	.26990	.0004417
57606	2.74	132	3.0790	.02333	.08436	.0006391
57608	2.64	438	8.6189	.01968	.22756	.0005195
57805	2.87	270	4.8988	.01814	.14060	.0005207
58206	2.67	148	1.3961	.00943	.03728	.0002519
58505	2.95	273	7.4516	.02730	.21982	.0008052
58805	2.74	1,158	23.1471	.01999	.63422	.0005464
63106	2.79	165	3.3006	.02001	.09208	.0005581
66005	2.63	370	7.6690	.02073	.20170	.0005451
69506	2.50	663	13.5696	.02047	.33923	.0005117
69705	2.50	244	3.7810	.01550	.09453	.0003874
72406	2.95	430	8.2929	.01929	.24464	.0005689
73308	2.92	624	14.2986	.02291	.41752	.0006539
74506	2.73	23	.4096	.01781	.01118	.0004862
74508	2.60	57	.8172	.01434	.02125	.0003728
74605	2.60	399	7.1181	.01781	.18507	.0004638

TABLE 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903*—Continued.

2.5 TO 3 PER CENT PROTEID NITROGEN—Continued

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
74607	2.56	491	8.3406	0.01699	0.21352	0.0004349
81405	2.62	240	4.5737	.01862	.11710	.0004879
81505	2.94	146	2.8327	.01940	.08328	.0005704
81706	2.71	722	15.3928	.02132	.41715	.0005778
85205	2.60	214	3.4766	.01625	.09039	.0004224
85206	2.66	376	4.9315	.01312	.13118	.0003332
86105	2.56	203	3.0282	.01495	.07964	.0003923
86106	2.63	436	7.6241	.01749	.20052	.0004599
88605	2.80	69	1.6362	.02731	.04581	.0007640
88606	2.53	481	9.9456	.02068	.25162	.0005231
88607	2.61	234	5.1584	.02205	.13463	.0005754
88905	2.83	293	5.3069	.01811	.15019	.0005126
88906	2.65	546	9.9034	.01814	.26245	.0004807
91906	2.81	200	3.5486	.01774	.09972	.0004986
92205	2.74	345	5.2616	.01525	.14417	.0004179
92206	2.67	46	1.1074	.02407	.02957	.0006428
92207	2.55	209	3.6926	.01767	.09416	.0004505
92208	2.72	353	6.6206	.01876	.18008	.0005102
92305	2.93	160	2.3859	.01491	.06991	.0004369
92408	2.97	207	3.7820	.01827	.11233	.0005426
92507	2.58	505	9.6779	.01916	.24969	.0004944
94206	2.78	402	7.5006	.01866	.20851	.0005187
94207	2.86	718	13.7057	.01909	.39199	.0005460
94907	2.91	626	12.1918	.01948	.35844	.0005726
95505	2.81	37	.3146	.00850	.00884	.0002389
95506	2.74	597	11.0548	.01852	.30291	.0005074
95507	2.59	571	12.1592	.02030	.31492	.0005515
95508	2.56	740	14.4617	.01954	.37023	.0005003
95705	2.54	636	10.3426	.01626	.26270	.0004131
95706	2.73	267	5.1629	.01934	.14095	.0005279
Average	2.731	370.36	7.1755	.019354	.194423	.00052706

3 TO 3.5 PER CENT PROTEID NITROGEN.

17305	3.03	183	3.6302	0.01984	0.10999	0.0006010
17306	3.09	243	3.9968	.01645	.12350	.0005082
17307	3.46	138	3.1451	.02280	.10883	.0007886
17308	3.25	61	1.2275	.02012	.03994	.0006540
17406	3.29	124	2.0907	.01685	.06878	.0005547
18906	3.48	65	.9229	.01420	.03212	.0004941
20705	3.09	109	1.8517	.01698	.05722	.0005249
20709	3.05	258	5.3229	.02063	.16235	.0006292
20805	3.32	697	14.6942	.02157	.48784	.0006999
21205	3.16	123	2.3642	.01922	.07471	.0006074
21208	3.24	287	5.1594	.01798	.16712	.0005824
21211	3.15	10	.2806	.02806	.00884	.0008839
21307	3.04	143	2.5691	.01796	.07810	.0005461
21308	3.45	354	5.8080	.01641	.20038	.0005660
21906	3.18	408	10.4800	.02563	.33403	.0008168
21907	3.35	158	2.9248	.01851	.09798	.0006201
21913	3.01	492	10.1925	.02072	.30680	.0006235
22206	3.22	146	2.5712	.01720	.08086	.0005538
22208	3.18	118	1.9090	.01619	.06071	.0005144
22210	3.17	298	6.0173	.02019	.19075	.0006401
22211	3.17	561	11.5675	.02062	.36671	.0006537
26105	3.02	131	1.8242	.01393	.05508	.0003662
26808	3.09	222	3.8811	.01748	.11992	.0005402
27507	3.08	75	1.3746	.01833	.04234	.0005646
28206	3.07	219	4.3698	.01996	.13415	.0006126
28806	3.02	685	14.4630	.02111	.43679	.0006376
32207	3.48	69	1.2573	.01822	.04375	.0006341
33305	3.41	150	3.1346	.02090	.10689	.0007126
33607	3.22	136	2.8903	.02125	.09307	.0006843
34606	3.12	280	6.1962	.02213	.19332	.0006904
39507	3.02	111	1.8862	.01699	.05696	.0005132
40305	3.11	179	3.6003	.02011	.11197	.0006255
40405	3.17	46	.6316	.01373	.02002	.0004352
42405	3.07	66	1.4892	.02251	.04572	.0006927
42905	3.17	67	1.2499	.01866	.03650	.0005447
46105	3.00	260	4.6146	.01775	.13843	.0005324
48306	3.29	157	2.6571	.01692	.08742	.0005568

Table 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903*—Continued.

3 TO 3.5 PER CENT PROTEID NITROGEN—Continued.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
48405........	3.31	76	0.9701	0.01276	0.03211	0.0004225
48506........	3.20	556	9.4585	.01701	.30267	.0005444
48705........	3.13	264	4.3615	.01652	.13652	.0005171
48706........	3.00	379	6.1986	.01635	.18596	.0004906
49505........	3.24	67	1.2716	.01898	.04120	.0006149
50905........	3.30	221	2.3982	.01085	.07914	.0003581
55005........	3.05	393	7.9684	.02028	.24304	.0006185
55006........	3.16	451	7.1852	.01593	.22705	.0005034
55205........	3.10	40	.6893	.01723	.02137	.0005342
55508........	3.11	216	3.7407	.01732	.11636	.0005386
57305........	3.19	501	8.5777	.01666	.29188	.0005326
57905........	3.18	221	2.4731	.01118	.07859	.0003556
58207........	3.09	307	4.2207	.01375	.13042	.0004248
58705........	3.01	235	2.5436	.01082	.07656	.0003256
62805........	3.25	111	1.3451	.01212	.04272	.0003938
63105........	3.24	90	1.5452	.01717	.05007	.0005563
72405........	3.36	213	8.4415	.03963	.28363	.0013316
72707........	3.49	225	4.5806	.02036	.15986	.0007105
72806........	3.01	110	2.0970	.01906	.06312	.0005738
74507........	3.02	493	9.2130	.01869	.27823	.0005644
81406........	3.31	72	1.2391	.01721	.04101	.0005697
84906........	3.43	382	7.5438	.01975	.25873	.0006773
91305........	3.21	138	3.0940	.02242	.09932	.0007197
91905........	3.36	198	3.4436	.01739	.11570	.0005844
92405........	3.10	214	3.4356	.01605	.10650	.0004977
92406........	3.11	380	8.2366	.02168	.25616	.0006741
92505........	3.00	156	2.6615	.01706	.07985	.0005118
94208........	3.10	322	3.7828	.01175	.11727	.0003642
94906........	3.41	685	12.3862	.01808	.42236	.0006166
Average	3.184	235.5	4.38558	.018366	.139656	.00058156

3.5 TO 4 PER CENT PROTEID NITROGEN.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant.	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
17506........	3.52	93	2.2881	0.02460	0.08044	0.0008660
17507........	3.80	43	.7220	.01795	.02933	.0006822
18905........	3.81	103	1.4864	.01443	.05663	.0005498
21209........	3.61	89	1.4484	.01627	.05228	.0005875
21811........	3.75	567	11.9114	.02101	.44666	.0007877
21908........	3.82	173	3.5574	.02056	.13589	.0007855
22209........	3.84	31	.4336	.01399	.01665	.0005371
26107........	3.92	144	2.0390	.01416	.07993	.0005551
32608........	3.78	55	1.0183	.01851	.03849	.0006998
34206........	3.73	81	1.5940	.01968	.05916	.0007340
36905........	3.88	267	5.0200	.01880	.19478	.0007295
38505........	3.61	563	12.1088	.02252	.43713	.0007764
42205........	3.63	94	1.8494	.01967	.06713	.0007142
45005........	3.58	235	3.2340	.01376	.11575	.0004927
48505........	3.66	137	1.9154	.01398	.07010	.0005117
49905........	3.62	23	.6760	.02939	.02436	.0010640
50705........	3.54	30	.5958	.01986	.02109	.0007032
50906........	3.57	114	1.7280	.01516	.06169	.0005411
66006........	3.54	366	6.0090	.01642	.21272	.0005812
66008........	3.59	174	3.1555	.01814	.11328	.0006510
72706........	3.86	591	14.6802	.02484	.56666	.0009588
94909........	3.60	218	3.6977	.01696	.13312	.0006106
Average	3.69	190.5	3.68947	.018666	.13698	.00068723

TABLE 8.—*Analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903*—Continued.

4 TO 4.5 PER CENT PROTEID NITROGEN.

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
21812	4.26	983	14.8139	0.01507	0.63107	0.0006420
21813	4.04	216	4.0258	.01877	.16377	.0007582
21909	4.43	525	12.1819	.02317	.53889	.0010265
27308	4.15	254	4.5123	.01777	.18726	.0007373
34405	4.33	207	4.1281	.01994	.17875	.0008635
43505	4.13	93	1.4464	.01555	.05974	.0006423
45705	4.18	44	.7532	.01712	.03148	.0007155
55007	4.21	118	2.1571	.01828	.09082	.0007696
69305	4.42	103	2.0430	.01984	.09030	.0008767
76206	4.45	447	5.4111	.01217	.24213	.0005417
92506	4.39	229	3.8709	.01690	.16993	.0007421
Average	4.27	292.6	5.03397	.017689	.21674	.00075594

MORE THAN 4.5 PER CENT PROTEID NITROGEN

Record number.	Percentage of proteid nitrogen in kernels.	Number of kernels per plant	Weight (in grams) of— Kernels per plant.	Weight (in grams) of— Average kernel.	Total proteid nitrogen in all kernels (gram).	Proteid nitrogen in average kernel (gram).
17505	4.70	29	0.3885	0.01340	0.01826	0.0006296
21206	5.23	149	2.8564	.01917	.14939	.0010026
21210	5.03	237	3.9143	.01578	.19689	.0007934
21706	4.71	807	19.3318	.02390	.91052	.0011283
21911	5.48	383	8.4593	.02209	.46356	.0012103
38605	5.85	61	1.2124	.01988	.07093	.0011627
38607	4.55	19	.3037	.01598	.01382	.0007273
40205	4.69	194	3.6302	.01871	.17026	.0008776
48406	4.87	249	3.2964	.01324	.16053	.0006447
65305	4.92	78	1.8018	.02310	.08865	.0011365
69805	5.82	110	2.4420	.02220	.14213	.0012921
72605	4.65	65	1.1166	.01718	.05192	.0007988
72607	5.59	188	3.4442	.01832	.19253	.0010241
92306	4.93	347	6.0091	.01732	.29625	.0008539
Average	5.07	208.28	4.15727	.01859	.208974	.0009487

TABLE 9.—*Summary of analyses of plants, arranged according to percentage of proteid nitrogen. Crop of 1903.*

Range of percentage of proteid nitrogen.	Percentage of proteid nitrogen in kernels.	Number of—		Weight (in grams) of—		Proteid nitrogen (in grams) in—	
		Analyses.	Kernels.	Kernels.	Average kernel.	All kernels.	Average kernel.
1 to 2	1.749	28	320.3	6.2382	0.01871	0.10655	0.0003291
2 to 2.5	2.32	65	396	8.2502	.02011	.19032	.0004660
2.5 to 3	2.73	145	370	7.1755	.01935	.19442	.0005271
3 to 3.5	3.18	66	235	4.3856	.01837	.13966	.0005816
3.5 to 4	3.69	22	190	3.6895	.01867	.13698	.0006872
4 to 4.5	4.27	11	292	5.0340	.01769	.21674	.0007559
4.5 and over	5.07	14	208	4.1573	.01859	.20897	.0009487

Table 10 shows the analyses of the crop of 1903 arranged on the basis of weight of average kernel. Determinations of gliadin and glutenin were made in these analyses and the sums of these are inserted in this table.[a] All plants having an average kernel weight

[a] Determinations of gliadin and glutenin were made by methods practically the same as those described by Prof. Harry Snyder in Bulletin No. 63 of the Minnesota Experiment Station, except that smaller quantities were used.

of less than 0.010 gram form the first class and each succeeding class increases by 0.002 gram. Table 11 is a summary of these analyses.

Table 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903.*

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
WEIGHT OF AVERAGE KERNEL, 0.000 TO 0.010 GRAM.									
22205	0.00953	283	2.6965	2.81	0.0002677	0.07577	1.97	0.0001877	0.05312
57105	.00916	407	3.7263	2.76	.0002527	.10285			
58206	.00943	148	1.3961	2.67	.0002519	.03728			
95505	.00850	37	.3146	2.81	.0002389	.00884			
Average	.00915	219	2.0334	2.76	.0002528	.05618	1.97	.0001877	.05312
WEIGHT OF AVERAGE KERNEL, 0.010 TO 0.012 GRAM.									
37906	0.01086	19	0.2063	2.44	0.0002649	0.00503			
45605	.01161	61	.7081	2.82	.0003273	.01997			
50905	.01085	221	2.3982	3.30	.0003581	.07914			
57905	.01118	221	2.4731	3.18	.0003556	.07859	2.92	0.0003264	0.07221
58705	.01082	235	2.5436	3.01	.0003258	.07656	2.47	.0002673	.06283
94208	.01175	322	3.7828	3.10	.0003642	.11727			
Average	.01118	179	2.0187	2.98	.0003326	.06276	2.69	.0002968	.06752
WEIGHT OF AVERAGE KERNEL, 0.012 TO 0.014 GRAM.									
17505	0.01340	29	0.3885	4.70	0.0006296	0.01826			
22209	.01399	31	.4336	3.84	.0005371	.01665			
26105	.01393	131	1.8242	3.02	.0003662	.05508			
39606	.01341	346	4.6383	2.37	.0003177	.10967			
40405	.01373	46	.6316	3.17	.0004352	.02002			
42206	.01264	25	.3161	1.46	.0001846	.00462			
45005	.01376	235	3.2340	3.58	.0001927	.11575	1.36	0.0001871	0.04398
45805	.01234	124	1.5298	1.84	.0002700	.02815			
48405	.01276	76	.9701	3.31	.0004225	.03211			
48406	.01324	249	3.2964	4.87	.0006447	.16053	2.25	.0002979	.08168
48408	.01291	27	.3485	2.81	.0003627	.00979			
48505	.01398	137	1.9154	3.66	.0005117	.07010	1.76	.0002460	.03371
50706	.01343	35	.4701	2.80	.0003761	.01316			
58207	.01375	307	4.2207	3.09	.0004248	.13042	2.49	.0003424	.10510
58905	.01355	170	2.3031	2.43	.0003292	.05596			
62805	.01212	111	1.3451	3.25	.0003938	.04272			
76206	.01217	447	5.4411	4.45	.0005417	.24213	2.03	.0002471	.11046
85206	.01312	376	4.9315	2.66	.0003332	.13118			
94605	.01307	56	.7319	1.95	.0002549	.01427			
Average	.01323	155.7	2.0510	3.12	.0004120	.06687	1.98	.0002641	.07499
WEIGHT OF AVERAGE KERNEL, 0.014 TO 0.016 GRAM.									
18805	0.01567	137	2.1462	2.02	0.0003164	0.04335			
18905	.01443	103	1.4864	3.81	.0005498	.05663	1.54	0.0003218	0.03315
18906	.01420	65	.9229	3.48	.0004941	.03212			
21210	.01577	237	3.9143	5.03	.0007934	.19689	1.34	.0002113	.05245
21710	.01437	59	.8478	2.59	.0003722	.02196			
21812	.01507	983	14.8139	4.26	.0006420	.63107	2.02	.0003044	.29934
26107	.01416	144	2.0390	3.92	.0005551	.07993	1.35	.0001912	.02753
33408	.01446	77	1.1132	1.39	.0002009	.01547			
38607	.01598	19	.3037	4.55	.0007273	.01382			
43505	.01555	93	1.4464	4.13	.0005423	.05974			
48407	.01572	718	11.2890	1.50	.0002358	.16933			
50906	.01516	114	1.7280	3.57	.0005411	.06169			
55006	.01593	451	7.1852	3.16	.0005034	.22705	1.75	.0002788	.12574
55305	.01507	167	2.5160	2.48	.0003736	.06240	1.97	.0002969	.04957
57006	.01453	701	10.1836	2.76	.0004010	.28107			

TABLE 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903*—Continued.

WEIGHT OF AVERAGE KERNEL, 0.014 TO 0.016 GRAM—Continued.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
57506.....	0.01534	180	2.7616	2.80	0.0004296	0.07733	2.34	0.0003590	0.06462
63506.....	.01568	153	2.3986	2.44	.0003825	.05853	....	....	....
69705.....	.01550	244	3.7810	2.50	.0003874	.09453	....	....	....
72905.....	.01585	167	2.6462	2.48	.0003930	.06563	....	....	....
74508.....	.01434	57	.8172	2.60	.0003728	.02125	....	....	....
86105.....	.01495	203	3.0282	2.56	.0003923	.07964	....	....	....
92205.....	.01525	345	5.2616	2.74	.0004179	.14417	....	....	....
92305.....	.01491	160	2.3859	2.93	.0004369	.06991	....	....	....
92905.....	.01534	176	2.7000	3.50	.0005369	.09450	....	....	....
92906.....	.01592	181	2.8816	2.99	.0004760	.08616	....	....	....
94905.....	.01553	286	4.4423	2.35	.0003650	.10439	....	....	....
95707.....	.01457	52	.7577	2.17	.0003599	.01872	....	....	....
Average.	.01516	232	3.5480	3.00	.0004555	.10619	1.76	.0002805	.09320

WEIGHT OF AVERAGE KERNEL, 0.016 TO 0.018 GRAM.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
17306.....	0.01645	243	3.9968	3.09	0.0005082	0.12350	....	....	....
17406.....	.01686	124	2.0907	3.29	.0005547	.06878	....	....	....
17507.....	.01795	43	.7720	3.80	.0006822	.02934	....	....	....
20705.....	.01698	109	1.8517	3.09	.0005249	.05722	....	....	....
21208.....	.01798	287	5.1594	3.24	.0005824	.16712	2.15	0.0003866	0.11093
21209.....	.01627	89	1.4484	3.61	.0005875	.05228	....	....	....
21307.....	.01796	143	2.5691	3.04	.0005461	.07810	....	....	....
21308.....	.01641	354	5.8080	3.45	.0005660	.20038	....	....	....
21805.....	.01699	1,232	20.9290	2.69	.0004569	.56299	....	....	....
21808.....	.01708	1,156	19.7446	2.57	.0004389	.50744	1.96	.0003348	.38700
22206.....	.01720	146	2.5712	3.22	.0005538	.08086	2.11	.0003629	.05425
22208.....	.01619	118	1.9090	3.18	.0005144	.06071	2.14	.0003465	.04084
26806.....	.01793	152	2.7255	2.60	.0004662	.07086	....	....	....
26808.....	.01748	222	3.8811	3.09	.0005402	.11992	2.28	.0003985	.08849
26907.....	.01792	102	1.8276	2.61	.0004677	.04995	....	....	....
26909.....	.01667	180	2.9999	2.80	.0004667	.08400	1.88	.0003134	.05640
27308.....	.01777	254	4.5123	4.15	.0007373	.18726	....	....	....
33106.....	.01716	18	.3089	2.94	.0005045	.00908	....	....	....
33406.....	.01627	283	4.6045	2.87	.0004670	.13215	....	....	....
37707.....	.01710	193	3.3004	2.93	.0005010	.09670	2.10	.0003591	.06931
39507.....	.01699	111	1.8862	3.02	.0005132	.05696	....	....	....
44505.....	.01764	340	5.9990	2.94	.0005187	.17637	....	....	....
45705.....	.01712	44	.7532	4.18	.0007155	.03148	....	....	....
46105.....	.01775	260	4.6146	3.00	.0005324	.13843	....	....	....
46107.....	.01756	478	8.3935	2.54	.0004460	.21319	2.08	.0003652	.17458
48306.....	.01692	157	2.6571	3.29	.0005568	.08742	2.13	.0003604	.05660
48506.....	.01701	556	9.4585	3.20	.0005444	.30267	2.17	.0003691	.20525
48705.....	.01652	264	4.3615	3.13	.0005171	.13652	1.56	.0002577	.06804
48706.....	.01635	379	6.1986	3.00	.0004906	.18596	....	....	....
48806.....	.01798	547	9.8346	2.70	.0004877	.26553	....	....	....
55205.....	.01723	40	.6893	3.10	.0005342	.02137	....	....	....
55307.....	.01663	342	5.6864	1.89	.0003142	.10747	1.56	.0002594	.08871
55508.....	.01732	216	3.7407	3.11	.0005386	.11636	1.96	.0003395	.07332
55607.....	.01734	138	2.3931	2.69	.0004665	.06437	....	....	....
55905.....	.01751	331	5.7948	2.67	.0004674	.15470	1.75	.0003064	.10141
55906.....	.01603	499	7.9968	2.81	.0004503	.22471	1.47	.0002356	.11755
56105.....	.01709	336	5.7431	2.73	.0004667	.15679	2.12	.0003622	.12175
56107.....	.01658	872	14.4556	2.96	.0004907	.42790	2.23	.0003697	.32236
56209.....	.01664	950	15.8086	2.59	.0004310	.40945	2.21	.0003677	.34937
57005.....	.01746	88	1.5364	2.71	.0004731	.04164	2.09	.0003649	.03211
57305.....	.01666	501	8.5777	3.19	.0005826	.29188	....	....	....
57308.....	.01705	577	9.8378	1.69	.0002881	.16626	....	....	....
57509.....	.01739	611	10.6261	2.54	.0004417	.26990	....	....	....
59606.....	.01712	567	9.7084	2.16	.0003698	.20970	....	....	....
60605.....	.01701	35	.5952	1.87	.0003180	.01113	....	....	....
63105.....	.01717	90	1.5452	3.24	.0005563	.05007	....	....	....
66006.....	.01642	366	6.0090	3.54	.0005812	.21272	1.38	.0002266	.08292

TABLE 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903*—Continued.

WEIGHT OF AVERAGE KERNEL, 0.016 TO 0.018 GRAM—Continued.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
72605.....	0.01718	65	1.1166	4.65	0.0007988	0.05192			
72606.....	.01724	543	9.3629	1.89	.0003414	.18538			
74506.....	.01781	23	.4096	2.73	.0004862	.01118			
74605.....	.01784	399	7.1181	2.60	.0004638	.18507			
74607.....	.01699	491	8.3406	2.56	.0004349	.21352			
76205.....	.01695	498	8.4407	2.35	.0003983	.19836			
81406.....	.01721	72	1.2391	3.31	.0005697	.04101			
85205.....	.01625	214	3.4766	2.60	.0004224	.09039			
86106.....	.01749	436	7.6241	2.63	.0004599	.20052			
91905.....	.01739	198	3.4436	3.36	.0005844	.11570			
91906.....	.01774	200	3.5486	2.81	.0004986	.09972			
92207.....	.01767	209	3.6926	2.55	.0004505	.09416			
92306.....	.01732	347	6.0091	4.93	.0008539	.29625	4.06	0.0007032	0.24597
92405.....	.01605	214	3.4356	3.10	.0004977	.10650			
92407.....	.01695	53	.8983	1.66	.0002814	.01491			
92505.....	.01706	156	2.6615	3.00	.0005118	.07985			
92506.....	.01690	229	3.8709	4.39	.0007421	.16993			
92908.....	.01732	187	3.2388	2.32	.0004018	.07514			
94407.....	.01615	419	6.7664	2.07	.0003343	.14007			
94909.....	.01696	218	3.6977	3.60	.0006106	.13312			
95510.....	.01783	159	2.8356	1.81	.0003228	.05132			
95705.....	.01626	636	10.3426	2.54	.0004131	.26270			
Average.	.01709	305.9	5.2055	2.93	.0005020	.14618	2.07	.0003519	.13548

WEIGHT OF AVERAGE KERNEL, 0.018 TO 0.020 GRAM.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
17305.....	0.01984	183	3.6302	3.03	0.0006010	0.10999			
17408.....	.01852	497	9.2038	2.18	.0004037	.20065			
17409.....	.01857	802	14.8957	2.75	.0005108	.40964			
20710.....	.01974	867	17.4115	2.83	.0005586	.48428	2.00	0.0003948	0.34222
21205.....	.01922	123	2.3642	3.16	.0006074	.07471			
21206.....	.01917	149	2.8564	5.23	.0010026	.14939			
21207.....	.01955	118	2.3066	2.96	.0005766	.06804			
21306.....	.01837	226	4.1516	2.90	.0005327	.12039			
21711.....	.01968	873	17.1820	2.71	.0005334	.46563			
21809.....	.01919	418	8.0214	2.73	.0005238	.21898	2.18	.0004183	.17487
21810.....	.01982	52	1.0304	2.69	.0005330	.02772			
21813.....	.01877	216	4.0258	4.04	.0007582	.16377	2.14	.0004017	.08615
21905.....	.01809	791	14.3111	2.64	.0004777	.37781	2.18	.0003944	.31198
21907.....	.01851	158	2.9248	3.35	.0006201	.09798	2.15	.0003980	.06288
21912.....	.01907	510	9.7236	2.31	.0004404	.22461			
22207.....	.01940	169	3.2787	2.77	.0005374	.09082	1.82	.0003531	.05967
26905.....	.01966	326	6.4102	2.76	.0005427	.17692	2.09	.0004109	.13398
26906.....	.01859	228	4.2376	2.71	.0005037	.11484	1.82	.0003383	.07712
27005.....	.01895	866	16.4120	2.63	.0004981	.43164	1.90	.0003600	.31182
27205.....	.01841	891	16.4061	2.11	.0004437	.39539	1.70	.0003130	.27890
27306.....	.01945	684	13.3011	2.47	.0004803	.32853			
27307.....	.01847	167	3.0850	2.53	.0004674	.07805			
27507.....	.01833	75	1.3746	3.08	.0005646	.04234			
28206.....	.01996	219	4.3698	3.07	.0006126	.13415	2.42	.0004830	.10575
32207.....	.01822	69	1.2573	3.48	.0006341	.04375			
32608.....	.01851	55	1.0183	3.78	.0006998	.03849			
33105.....	.01939	132	2.5601	2.91	.0005644	.07450	3.50	.0006787	.07450
33107.....	.01919	318	6.1026	2.35	.0004510	.14341	1.92	.0004163	.12643
33405.....	.01930	421	8.1268	2.03	.0003919	.16498			
33906.....	.01921	119	2.2862	2.81	.0005399	.06424			
34205.....	.01972	464	9.1498	2.73	.0005383	.24979			
34206.....	.01968	81	1.5940	3.73	.0007340	.05946			
34208.....	.01916	156	2.9886	2.13	.0004081	.06366			
34405.....	.01994	207	4.1281	4.33	.0008635	.17875	2.44	.0004865	.10073
36905.....	.01880	267	5.0200	3.88	.0007295	.19478			
37305.....	.01987	309	6.1394	2.96	.0005881	.18173	2.29	.0004550	.14060
37705.....	.01972	461	8.0905	2.64	.0005327	.23998	1.26	.0002485	.10194
38005.....	.01808	139	2.5134	2.84	.0005135	.07138	1.23	.0002224	.03091
38506.....	.01975	85	1.6799	2.89	.0005712	.04855			
38605.....	.01987	61	1.2124	5.85	.0011627	.07093			
38608.....	.01913	158	3.0228	2.82	.0005394	.08522	1.73	.0003309	.05229
38706.....	.01988	365	7.2545	2.59	.0005148	.18789			
40205.....	.01871	194	3.6302	4.69	.0008776	.17026	3.07	.0005744	.11145

TABLE 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903*—Continued.

WEIGHT OF AVERAGE KERNEL, 0.018 TO 0.020 GRAM—Continued.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in—		Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in—	
					Average kernel.	Kernels on plant.		Average kernel.	Kernels on plant.
42205	0.01967	94	1.8494	3.63	0.0007142	0.06713	2.73	0.0005370	0.05049
42905	.01866	67	1.2499	3.17	.0005447	.03650			
44607	.01806	101	1.8246	2.44	.0004408	.04452			
45606	.01831	220	4.0358	1.91	.0003504	.07708			
46106	.01964	82	1.6103	2.54	.0004988	.04090			
48106	.01919	608	11.6655	2.38	.0004567	.27765	1.80	.0003454	.20997
48508	.01858	603	11.2008	2.76	.0005127	.30986			
49505	.01898	67	1.2716	3.24	.0006149	.04120			
50705	.01986	30	.5958	3.54	.0007032	.02109			
51005	.01804	862	15.5835	1.34	.0002422	.20881			
55007	.01828	118	2.1571	4.21	.0007696	.09082	2.21	.0004040	.04767
55008	.01846	944	17.4226	2.60	.0004799	.45299	1.58	.0002917	.27528
55206	.01965	578	11.3592	2.56	.0005031	.29079	1.87	.0003675	.21241
55306	.01931	214	4.1323	2.18	.0004210	.09008			
55507	.01949	504	9.8228	2.63	.0005126	.25834	2.07	.0004034	.20333
56106	.01866	644	12.0161	2.57	.0004795	.30881	2.09	.0003900	.25114
56205	.01959	333	6.5232	2.51	.0004917	.16373	1.85	.0003624	.12068
56206	.01829	509	9.3093	2.42	.0004426	.22529	1.95	.0003566	.18153
57007	.01975	168	3.3176	2.65	.0005233	.08792			
57306	.01838	434	7.9772	2.86	.0005257	.22815			
57307	.01801	261	4.7117	2.43	.0004387	.11445			
57406	.01846	135	2.4923	2.75	.0005077	.06854	2.13	.0003932	.05309
57407	.01968	762	14.9992	2.62	.0005157	.39297	1.86	.0003660	.27898
57507	.01946	359	6.9861	2.85	.0005545	.19905	1.55	.0003016	.10828
57608	.01968	438	8.6189	2.64	.0005195	.22756			
57805	.01811	270	4.8988	2.87	.0005207	.14060	2.68	.0004861	.13126
58805	.01999	1,158	23.1471	2.74	.0005464	.63422	2.11	.0004218	.48859
59[illegible]05	.01880	382	7.1828	2.12	.0003986	.15228			
63505	.01934	208	4.0230	1.90	.0003674	.07644			
65306	.01807	541	9.8298	2.41	.0004282	.23690	1.68	.0003036	.16514
65307	.01878	373	7.0051	2.28	.0004355	.15971	1.81	.0003399	.12680
66008	.01814	171	3.1555	3.59	.0006510	.11328			
69305	.01984	103	2.0430	4.42	.0008767	.09030			
69505	.01847	255	4.7116	2.29	.0004231	.10790			
72406	.01929	430	8.2929	2.95	.0005689	.24464			
72607	.01832	188	3.4442	5.59	.0010241	.19253	2.51	.0004598	.08645
72806	.01906	110	2.0970	3.01	.0005738	.06312			
74507	.01869	493	9.2130	3.02	.0005644	.27823			
81405	.01862	240	4.5737	2.62	.0004879	.11710			
81505	.01940	146	2.8327	2.91	.0005704	.08328	2.65	.0005141	.07507
84905	.01927	37	.7130	2.32	.0004471	.01654			
84906	.01975	382	7.5438	3.43	.0006773	.25873			
88905	.01811	293	5.3069	2.83	.0005126	.15019			
88906	.01814	546	9.9034	2.65	.0004807	.26245			
92208	.01876	353	6.6206	2.72	.0005102	.18008			
92408	.01827	207	3.7820	2.97	.0005426	.11233			
92409	.01814	315	5.7131	2.30	.0004171	.13140			
92507	.01916	505	9.6779	2.58	.0004944	.24969			
92909	.01916	529	10.1363	2.70	.0005173	.27367			
94205	.01893	64	1.2117	1.65	.0003124	.01999			
94206	.01866	402	7.5006	2.78	.0005187	.20851			
94207	.01909	718	13.7057	2.86	.0005460	.39199			
94209	.01895	190	3.6006	2.49	.0004719	.08965			
94406	.01923	549	10.5556	2.47	.0004749	.26073			
94906	.01808	685	12.3862	3.41	.0006166	.42236			
94907	.01948	626	12.1918	2.94	.0005726	.35844			
94908	.01894	125	2.3678	1.96	.0003713	.04641			
95506	.01852	597	11.0548	2.74	.0005074	.30291			
95508	.01951	740	14.4617	2.56	.0005003	.37023			
95706	.01934	267	5.1629	2.73	.0005279	.14095			
Average	.01901	349.6	6.6327	2.88	.0005476	.18039	2.08	.0003979	.15541

WEIGHT OF AVERAGE KERNEL, 0.020 TO 0.022 GRAM.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel.	Proteid nitrogen in kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in kernels on plant.
17308	0.02012	61	1.2275	3.25	0.0006540	0.03994			
17405	.02127	738	15.6996	2.13	.0004531	.33441			
20706	.02033	163	3.3138	2.78	.0005652	.09212	2.05	0.0004168	0.06793
20708	.02024	122	2.4690	2.58	.0005221	.06399			
20709	.02063	258	5.3229	3.05	.0006292	.16235	2.31	.0004766	.12296
20815	.02157	697	14.6942	3.32	.0006999	.48784	2.26	.0004875	.33208

Table 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903*—Continued.

WEIGHT OF AVERAGE KERNEL, 0.020 TO 0.022 GRAM—Continued.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
21212.....	0.02049	84	1.7216	2.16	0.0004427	0.03718	....	....	....
21305.....	.02004	312	6.2514	2.67	.0005350	.16691	1.97	0.0003948	0.12315
21707.....	.02125	582	12.3685	2.19	.0004654	.27086	....	....	....
21709.....	.02141	361	7.7296	2.47	.0005289	.19092	....	....	....
21811.....	.02101	567	11.9114	3.75	.0007877	.44666	2.16	.0004538	.25728
21908.....	.02056	173	3.5574	3.82	.0007855	.13589	1.88	.0003955	.06688
21913.....	.02072	492	10.1925	3.01	.0006235	.30680	....	....	....
22210.....	.02019	298	6.0173	3.17	.0006401	.19075	1.55	.0003129	.09327
22211.....	.02062	561	11.5675	3.17	.0006537	.36671	1.69	.0003485	.19548
25205.....	.02066	522	10.7836	2.71	.0005599	.28560	....	....	....
26908.....	.02073	192	3.9797	2.96	.0006135	.11780	2.16	.0004478	.08596
27207.....	.02004	166	3.3266	2.92	.0005850	.09712	1.95	.0003908	.06487
27305.....	.02085	267	5.5666	2.58	.0005379	.14362	1.73	.0003607	.09630
27505.....	.02183	539	12.0399	2.12	.0004627	.24942	1.65	.0003602	.19866
28806.....	.02111	685	14.4630	3.02	.0006376	.43679	1.86	.0003926	.26901
32206.....	.02052	507	10.4036	1.81	.0003714	.18831	....	....	....
32605.....	.02145	94	2.0162	2.88	.0006177	.05807	....	....	....
33305.....	.02090	150	3.1346	3.41	.0007126	.10689	2.41	.0005037	.07554
33606.....	.02144	382	8.1890	2.21	.0004738	.18098	....	....	....
33607.....	.02125	136	2.8903	3.22	.0006843	.09307	2.45	.0005206	.07081
33905.....	.02194	508	11.1476	1.61	.0003533	.17948	....	....	....
37705.....	.02155	56	1.2069	2.34	.0005053	.02824	....	....	....
38606.....	.02110	401	8.4605	2.63	.0005549	.22251	1.39	.0002933	.11760
39205.....	.02089	1,031	21.5399	2.11	.0004407	.45435	1.84	.0003844	.39635
39405.....	.02093	447	9.3541	2.88	.0006027	.21399	1.44	.0003014	.13470
40305.....	.02011	179	3.6003	3.11	.0006255	.11197	....	....	....
44605.....	.02049	55	1.1271	2.86	.0005861	.03223	....	....	....
44606.....	.02035	124	2.5235	2.90	.0005902	.07318	1.29	.0002625	.03255
48409.....	.02048	314	6.4302	2.02	.0004137	.12989	1.50	.0003072	.09645
55005.....	.02028	393	7.9684	3.05	.0006185	.24303	1.99	.0004036	.15857
55506.....	.02062	866	17.8506	2.80	.0005773	.4995	2.20	.0004536	.39272
55605.....	.02184	500	10.9180	2.64	.0005765	.28823	1.96	.0004281	.21400
55908.....	.02175	562	12.2210	2.42	.0005262	.29575	1.96	.0004263	.23953
57405.....	.02031	41	.8328	1.98	.0004022	.01649	....	....	....
57408.....	.02047	596	12.2004	2.61	.0005343	.31842	1.64	.0003357	.20008
58806.....	.02049	95	1.9479	1.88	.0003853	.03660	....	....	....
63106.....	.02001	165	3.3006	2.79	.0005581	.09208	2.20	.0004402	.072[illegible]
65308.....	.02008	583	11.7066	2.09	.0004197	.24468	1.95	.0003916	.22828
66005.....	.02073	370	7.6690	2.63	.0005451	.20170	2.18	.0004519	.16711
69506.....	.02047	663	13.5696	2.50	.0005117	.33923	....	....	....
69806.....	.02153	558	12.0136	1.66	.0003574	.19943	....	....	....
72705.....	.02191	372	9.1522	2.13	.0004668	.19936	....	....	....
72707.....	.02036	225	4.5806	3.49	.0007105	.15986	....	....	....
73306.....	.02062	414	8.5373	2.45	.0005052	.20918	....	....	....
74305.....	.02047	216	4.4222	1.98	.0004051	.08756	....	....	....
74606.....	.02079	464	9.6451	2.30	.0004781	.22184	2.05	.0004262	.19772
80305.....	.02165	729	15.7835	1.81	.0003919	.28569	1.77	.0003832	.27937
81705.....	.02106	465	9.7922	1.98	.0004170	.19388	1.96	.0004128	.19193
81706.....	.02132	722	15.3928	2.71	.0005778	.41715	2.03	.0004328	.31248
81709.....	.02175	757	16.4692	2.28	.0004960	.37548	....	....	....
84405.....	.02043	428	8.7448	2.48	.0005067	.21687	....	....	....
88606.....	.02068	481	9.9456	2.53	.0005231	.25162	....	....	....
88608.....	.02075	74	1.5355	2.47	.0005125	.03793	....	....	....
88609.....	.02100	470	9.8719	2.42	.0005082	.23890	....	....	....
92405.....	.02168	380	8.2366	3.11	.0006741	.25616	....	....	....
92907.....	.02040	219	4.4673	2.56	.0005220	.11436	....	....	....
95507.....	.02029	571	12.1592	2.59	.0005515	.31492	....	....	....
95509.....	.02136	138	2.9475	2.48	.0005297	.07310	....	....	....
Average.	.02085	386.6	8.1267	2.60	.0005422	.20510	1.92	.0003999	.17351

WEIGHT OF AVERAGE KERNEL, 0.022 TO 0.024 GRAM.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in— Average kernel.	Proteid nitrogen (gram) in— Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in— Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in— Kernels on plant.
17307.....	0.02279	138	3.1451	3.46	0.0007886	0.10883	....	....	....
17410.....	.02285	744	16.9987	2.88	.0006580	.48957	....	....	....
20707.....	.02282	444	9.9070	2.77	.0006181	.27443	1.85	0.0004222	0.18328
21706.....	.02390	807	19.3318	4.71	.0011283	.91052	....	....	....
21708.....	.02381	390	9.2850	2.33	.0005547	.21631	....	....	....
21806.....	.02378	599	14.2450	2.71	.0006444	.38604	....	....	....
21909.....	.02317	525	12.1819	4.43	.0010265	.53889	1.98	.0005677	.29846
21911.....	.02209	383	8.4593	5.48	.0012103	.46356	....	....	....

TABLE 10.—*Analyses of plants, arranged according to weight of average kernel. Crop of 1903*—Continued.

WEIGHT OF AVERAGE KERNEL, 0.022 TO 0.024 GRAM—Continued

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in Average kernel.	Proteid nitrogen (gram) in Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in Kernels on plant.
[illegible]	0.02281	205	4.6754	2.76	0.0006295	0.12901	....	....	....
26106	.02304	90	2.0737	2.63	.0006060	.05454	....	....	....
26805	.02248	220	4.9456	2.81	.0006317	.13897	....	....	....
26807	.02390	721	17.2324	2.80	.0006692	.48250	....	....	....
27506	.02252	144	10.0005	2.70	.0006082	.27003	1.98	0.0004459	0.19800
27508	.02287	251	5.5324	2.64	.0006037	.14608	2.32	.0005306	.12835
27509	.02206	243	5.3615	2.90	.0006399	.15549	1.09	.0002405	.05844
32605	.02323	225	5.2268	1.20	.0002788	.06272	....	....	....
33407	.02271	305	7.0889	1.62	.0003679	.11223	....	....	....
33605	.02345	301	7.0596	2.39	.0005605	.16872	1.92	.0004502	.13554
34207	.02219	611	13.5556	2.84	.0006273	.38505	....	....	....
34606	.02213	280	6.1962	3.12	.0006904	.19332	....	....	....
38505	.02252	563	12.1088	3.61	.0007764	.43713	1.77	.0003986	.21432
38609	.02309	293	6.7665	2.71	.0006475	.18540	1.34	.0003094	.09067
42405	.02251	66	1.4892	3.07	.0006927	.04572	....	....	....
43405	.02258	124	2.8000	2.92	.0006594	.08176	1.18	.0002664	.03304
48507	.02296	70	1.6036	2.64	.0006062	.04233	....	....	....
55308	.02395	397	9.5078	2.54	.0006225	.24150	....	....	....
55606	.02205	503	11.0930	2.58	.0005690	.28580	1.49	.0002609	.16529
56207	.02361	462	10.9073	2.34	.0005524	.25522	1.83	.0004321	.19960
56208	.02356	563	13.5720	2.61	.0006149	.34616	1.95	.0004591	.26405
57606	.02333	132	3.0790	2.74	.0006391	.08436	....	....	....
57607	.02234	736	16.4433	1.73	.0003865	.24847	....	....	....
63107	.02233	417	9.3120	2.43	.0005426	.22628	....	....	....
65305	.02310	78	1.8018	4.92	.0011365	.088[illegible]5	....	....	....
69805	.02220	110	2.4420	5.82	.0012921	.14213	1.94	.0004307	.04738
71905	.02239	1,2[illegible]0	28.2136	2.47	.0005531	.69688	....	....	....
72708	.02270	398	9.0386	2.27	.0005154	.20518	....	....	....
73307	.02229	25	.5572	2.39	.0005327	.01332	....	....	....
73308	.02291	624	14.2986	2.92	.0006539	.41752	....	....	....
81707	.02336	786	18.3614	2.34	.0005466	.42965	....	....	....
81710	.02308	396	9.1411	1.92	.0004432	.17550	....	....	....
88607	.02205	234	5.1584	2.61	.0005754	.13463	....	....	....
91305	.02242	138	3.0940	3.21	.0007197	.09932	....	....	....
Average	.02285	388.1	8.8879	2.90	.0006624	.25166	1.74	.0004011	.15515

WEIGHT OF AVERAGE KERNEL, 0.024 TO 0.026 GRAM.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in Average kernel.	Proteid nitrogen (gram) in Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in Kernels on plant.
17505	0.02460	93	2.2881	3.52	0.0008660	0.08044	2.23	0.0005486	0.05102
21807	.02498	377	9.4172	2.73	.0006664	.25709	2.11	.0005271	.19870
21906	.02563	408	10.4800	3.18	.0008168	.33403	2.10	.0005382	.22008
2720[illegible]	.02469	777	19.1854	2.36	.0005827	.45276	1.46	.0003605	.28010
28805	.02512	87	2.1851	2.91	.0007309	.06359	1.55	.0003894	.03387
37905	.02555	37	.9452	2.53	.0006463	.02391	....	....	....
40505	.02444	170	4.1546	2.82	.0006892	.11716	2.19	.0005352	.09099
48305	.02543	473	12.0278	2.87	.0007299	.34524	1.77	.0004501	.21289
55907	.02590	749	19.3966	2.59	.0006707	.50238	1.61	.0004170	.31229
72706	.02484	591	14.6802	3.86	.0009588	.56666	....	....	....
81708	.02578	287	7.3993	2.41	.0006213	.17833	1.64	.0004228	.12135
92206	.02407	46	1.1071	2.67	.0005428	.02957	....	....	....
94105	.02543	22	.5595	2.67	.0006790	.01494	....	....	....
Average	.02511	316.7	7.9866	2.86	.0007154	.22816	1.85	.0004654	.10903

WEIGHT OF AVERAGE KERNEL, 0.026 GRAM AND OVER.

Record number.	Weight of average kernel (gram).	Number of kernels on plant.	Weight of kernels on plant (grams).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in Average kernel.	Proteid nitrogen (gram) in Kernels on plant.	Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in Average kernel.	Gliadin-plus-glutenin nitrogen (gram) in Kernels on plant.
21211	0.02806	10	0.2806	3.15	0.0008839	0.00884	....	....	....
21705	.02659	58	1.5420	2.45	.0006514	.03778	....	....	....
39506	.02869	67	1.9218	2.93	.0008404	.05631	2.06	0.0005915	0.05959
49905	.02939	23	.6760	3.62	.0010640	.02436	....	....	....
55608	.02699	837	22.5848	2.31	.0006236	.52194	....	....	....
55909	.03050	302	9.2120	2.30	.0007016	.21187	1.66	.0005063	.15292
57508	.03177	380	12.0728	2.21	.0007021	.26680	2.05	.0006513	.24750
58505	.02730	273	7.4516	2.95	.0008052	.21982	....	....	....
72105	.03963	213	8.4415	3.36	.0013316	.28363	....	....	....
Average	.02988	240.3	7.2425	2.81	.0008449	.18126	1.92	.0005829	.14667

TABLE 11.—*Summary of analyses of plants, arranged according to weight of average kernel. Crop of 1903.*

Range of weights of average kernel (gram).	Number of analyses.	Weight of average kernel (gram).	Number of kernels	Weight of kernels (grams).	Percentage of proteid nitrogen in kernels	Proteid nitrogen (gram) in—		Percentage of gliadin-plus-glutenin nitrogen in kernels.	Gliadin-plus-glutenin nitrogen (gram) in	
						Average kernel	Kernels		Average kernel	Kernels
0.000 to 0 010....	4	0.00915	219	2.0334	2.76	0.0002528	0.05618	1.97	0.0001877	0.05312
0.010 to 0 012....	6	.01118	179	2.0187	2.98	.0003326	.06276	2.69	.0002968	.06752
0.012 to 0 014....	19	.01323	155.7	2.0510	3.12	.0004120	.06687	1.98	.0002641	.07499
0.014 to 0 016....	27	.01516	232	3.5480	3.00	.0004555	.10619	1.76	.0002805	.09320
0.016 to 0 018....	69	.01709	305.9	5.2055	2.93	.0005020	.14618	2.07	.0003519	.13548
0 018 to 0 020....	103	.01901	349.6	6.6327	2.88	.0005476	.18039	2.08	.0003979	.15541
0 020 to 0 022....	64	.02085	386.6	8.1257	2.60	.0005422	.20510	1.92	.0003999	.17351
0.022 to 0 024....	42	.02285	388.1	8.8879	2.90	.0006624	.25166	1.74	.0004011	.15515
0.024 to 0 026 ...	13	.02511	316.7	7.9866	2.86	.0007154	.22816	1.85	.0004654	.16903
0.026 and over..	9	.02988	210.3	7.2425	2.81	.0008449	.18126	1.92	.0005829	.14667

With an increase in the weight of the kernel, as shown by this table, there is an irregular increase in the number of kernels on the plant up to a point somewhat beyond the kernel of average weight, after which there is a decrease. The weight of the kernels on the plant seems to follow the same rule. The percentage of proteid nitrogen in the kernels decreases, in general, with the weight of the average kernel, while the number of grams of proteid nitrogen in the average kernel increases steadily. The grams of proteid nitrogen in all the kernels on the plant increase up to the same point as do the number of kernels on the plant, and then decrease.

Table 12 shows the summary of the analyses of the crop of 1903, arranged according to the grams of proteid nitrogen in the average kernel. All plants having less than 0.0003 gram of proteid nitrogen form the first class, and the following classes increase with each 0.0001 gram of proteid nitrogen.

It is difficult to trace any relation between the grams of proteid nitrogen in the average kernel and the number of kernels on the plant, or the weight of the kernels on the plant. The weight of the average kernel increases directly with the grams of proteid nitrogen in the kernel. The percentage of proteid nitrogen increases regularly with an increase in the grams of proteid nitrogen in the average kernel. The grams of proteid nitrogen in all the kernels on the plant show no definite relation to the grams of proteid nitrogen in the average kernel.

It becomes evident from these results that selection of large, heavy kernels for seed would result in discarding the immature and unsound kernels, but that there would also be discarded many sound kernels, which, although small and of low specific gravity, would contain a high percentage of proteids.

Another effect of such selection, as indicated by the foregoing results, would be to increase the yield of grain from each plant when grown under the conditions that obtained in these experiments. What the effect would be upon the yield under ordinary field conditions these experiments do not indicate.

On the other hand, selection based upon percentage of proteid nitrogen alone would not result in securing plants of greatest yield when raised under these conditions. It would, moreover, not result in obtaining plants producing the greatest amount of proteid nitrogen, nor even of kernels containing the largest quantity of proteid nitrogen.

TABLE 12.—*Summary of analyses of plants, arranged according to grams of proteid nitrogen in average kernel. Crop of 1903.*

Range of proteid nitrogen in average kernel (gram).	Proteid nitrogen in average kernel (gram).	Number of analyses.	Number of kernels on plant.	Weight (in grams) of—		Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels on plant (gram).
				Kernels on plant.	Average kernel.		
Below 0.00030	0.0002509	14	257.9	3.9190	0.01364	1.96	0.06531
0.00030 to 0.00040	.0003602	42	266.7	4.6742	.01628	2.31	.09644
0.00040 to 0.00050	.0004537	80	409.2	7.5309	.01811	2.54	.18644
0.00050 to 0.00060	.0005406	116	341.5	6.7159	.01908	2.86	.18440
0.00060 to 0.00070	.0006409	59	310.3	6.7257	.02137	3.07	.19805
0.00070 to 0.00080	.0007430	24	204.9	4.5158	.02110	3.66	.15318
0.00080 to 0.00090	.0008538	9	189.1	4.2480	.02334	3.79	.15944
0.00090 to 0.00100	.0009588	1	591.0	14.6802	.02484	3.86	.56666
0.00100 and over	.0011578	11	244.9	6.6082	.02875	4.62	.27980

It will be shown later that the determination of gliadin-plus-glutenin nitrogen is a safer guide to the bread-making value of wheat than is a determination of proteid nitrogen, but whether selection should be based upon the percentage of nitrogen or the total production of nitrogen by the plant, or upon the amount contained in the average kernel, is a question that can not be solved except by trial under field conditions.

Some results of experiments with light and with heavy seed conducted on large field plots for several years may throw some light on this subject, and are given herewith.

YIELD OF NITROGEN PER ACRE.

It is important to know whether the absolute amount of nitrogen per acre of grain raised is greater in light or in heavy wheat.

If the absolute amount of nitrogen per acre is less in light than in heavy wheat the supposition would be justifiable that the kernels were immature or had been prematurely checked in their development. On the other hand, if the amount of nitrogen per acre is greater in the light wheat it would be reasonable to suppose that, as both had been raised under the same conditions, the light wheat had, in part at least, come from plants that possessed greater ability to acquire and elaborate nitrogenous material.

To afford information on this point analyses were made of crops grown from light and from heavy seed. Records of the yields of the plots were kept in each case so that the actual amount of proteid nitrogen contained in an acre of each kind of wheat can be calculated. The number of grams of proteid nitrogen in 1,000 kernels of each seed and crop sample is also stated. The first samples separated, Nos. 78 and 79 of the Turkish Red variety and 80 and 81 of the Big Frame variety, were taken from seed that had never before been treated in this way. When planted they produced the crops indicated in Table 13 by 78b, 79b, 80b, and 81b, respectively. Each of these crops was then separated into two portions, of which the light portion of the light wheat was retained for analyzing and planting, and the heavy portion of the heavy wheat likewise retained. Thus No. 383 is the light portion of No. 78b, and No. 384 is the heavy portion of No. 79b.

The accuracy of the records of relative yields of light and heavy seed harvested in 1902 being open to suspicion, samples of the same seed were sown again in the autumn of 1902 and harvested in 1903. The results from this test are stated at the bottom of the table under the heading "Check experiment."

These experiments are to be understood as duplicating those of 1902, which, as regards the relative yield of light and heavy wheat, should be accurate, although tried in 1903. The difference between this check experiment and the regular one of 1903 is that in the check experiment the seed of the crop of 1901 was used, while in the regular experiment in 1903 the seed of the crop of 1902 was used.

TABLE 13.—*Crops grown from light and from heavy seed for four years.*

SEED

Farm number.	Variety.	Percentage of— Total nitrogen	Percentage of— Proteid nitrogen.	Percentage of— Non-proteid nitrogen	Weight of 1,000 kernels (grams).	Proteid nitrogen in 1,000 kernels (gram).	Relative weight
78	Turkish Red				17.24		Light.
79	.....do				30.63		Heavy.
80	Big Frame	2.45	2.00	0.45	15.57	0.3120	Light
81	.....do	2.20	1.96	.24	28.56	.5606	Heavy.
383	Turkish Red	3.12	3.10	.02	27.11	.8401	Light.
384	.....do	3.02	2.93	.09	28.17	.8350	Heavy.
385	Big Frame	3.13	2.82	.31	27.11	.7642	Light
386	.....do	2.95	2.65	.30	28.09	.7446	Heavy
	Turkish Red						Light
	.....do						Heavy.
	Big Frame						Light
	.....do						Heavy
957	Turkish Red	3.33	2.87	.46			Light
956	.....do	3.06	2.86	.20			Heavy
952	Big Frame	2.88	2.63	.25			Light
953	.....do						Heavy.
	CHECK EXPERIMENT.						
	Turkish Red						Light
	.....do						Heavy.
	Big Frame						Light
	.....do						Heavy

TABLE 13.—*Crops grown from light and from heavy seed for four years*—Continued.

CROP

Farm number of seed.	Variety.	Yield per acre (bushels).	Weight per bushel (pounds).	Percentage of— Total nitrogen	Percentage of— Proteid nitrogen	Percentage of— Nonproteid nitrogen.	Proteid nitrogen per acre (pounds).	Weight of 1,000 kernels (grams).	Proteid nitrogen in 1,000 kernels (gram).	Year grown.	Farm number of crop.
78	Turkish Red	23.0	......	3.20	3.09	0.11	45.54	......	......	1900	78b
79	....do	29.5	......	3.08	2.94	.14	52.04	25.10	0.7379	1900	79b
80	Big Frame	20.5	......	3.13	3.06	.07	37.63	......	......	1900	80b
81	....do	25.1	......	2.81	2.59	.22	39.01	24.84	.6423	1900	81b
383	Turkish Red	26.7	60.5	2.35	2.13	.22	34.12	26.19	.5581	1901	612
384	....do	29.3	61.5	2.11	1.94	.17	34.11	27.04	.5238	1901	613
385	Big Frame	21.2	58.0	3.30	3.06	.24	38.92	23.89	.7409	1901	602
386	....do	27.7	60.5	2.46	2.24	.22	37.22	28.82	.6451	1901	603
	Turkish Red	19.7	57.0	2.15	2.14	.01	25.29	......	......	1902	621
	....do	18.0	58.0	1.98	1.87	.11	20.20	......	......	1902	614
	Big Frame	Lost	......	3.54	3.32	.22	......	19.56	.6494	1902	604
	....do	Lost	......	2.44	2.21	.23	......	26.41	.5837	1902	611
957	Turkish Red	25.6	......	......	3.51	......	53.91	22.12	.7764	1903	1240
956	....do	21.3	......	......	2.18	......	27.86	23.13	.5042	1903	1239
952	Big Frame	25.8	......	......	2.14	......	33.13	19.82	.4241	1903	1248
953	....do	20.8	......	......	1.98	......	24.71	23.26	.4605	1903	1249
	CHECK EXPERIMENT.										
	Turkish Red	30.9	......	......	1.95	......	36.34	......	......	1903	1245
	....do	31.8	......	......	1.64	......	31.29	......	......	1903	1243
	Big Frame	23.9	......	......	1.79	......	25.67	......	......	1903	1252
	....do	24.2	......	......	1.62	......	23.52	......	......	1903	1254

Comparing the analyses of the light and heavy seed in this table with those in the preceding tables, it will be noticed that the total and proteid nitrogen are both uniformly higher in the light seed. The nonproteid nitrogen is not so uniform as in the previous analyses, but the general tendency is the same.

In the crop the high total and proteid nitrogen of the light seed is uniformly transmitted. There is no uniformity in the nonproteid nitrogen. As was to be expected, the heavy seed produced in the first two years the largest yields per acre. The quality of light or heavy weight as indicated in the resulting crop by weight of grain per bushel gave some indication of being transmitted. In 1900 there was an absence of data on the subject, but in 1901 the heavy seed in each case produced grain having a greater weight per bushel than did the light seed.

Turning to the column showing the absolute amount of proteid nitrogen produced per acre, it is very apparent that the heavy seed produced in 1900 considerably larger amounts of proteid nitrogen per acre than did the light seed, but in 1901 the difference was very slightly in favor of the light wheat, which advantage continued with the light wheat during the remaining years.

It would seem from these results that the quality of lightness, with its correlated qualities of high total and proteid nitrogen, is hereditary. The question then arises, Why should the light wheat accumulate more nitrogen per acre than the heavy wheat after the first generation?

A possible explanation for this is that the light seed from the first generation contained kernels whose lightness was due in some cases to immaturity, and in other cases to the individual peculiarity of the plant on which they grew. The latter class transmitted this peculiarity in the crop, while the former became less conspicuous with each generation, on account of the lesser vitality and productiveness of the immature seed.

A peculiar feature of these results is found in the fact that the yield of grain from the light seed approaches each succeeding year more nearly in quantity to that obtained from the heavy seed until, in 1903, it becomes greater. These two qualities of seed were raised on plots side by side, and every precaution was taken to obtain an accurate estimate of the yield of each. While it is probable that the results for 1903 are misleading, it is certainly significant that so little difference in yield exists after three years' selection in this way. Instead of the difference between the light and heavy seed becoming greater each year it is without doubt becoming less.

In considering the relative yields of the light and heavy wheat, it must be borne in mind that the seeding was done with a drill set to deliver 1½ bushels per acre of ordinary seed wheat. The result would be to deposit a larger number of kernels of light seed per acre than of heavy seed. In a season like that of 1903, when the rainfall was large and the weather moderately cool until harvest, there might be an advantage resulting from the thicker seeding, which may account for the greater yield from the light seed in that year.

It is possible that the same cause may have operated in other years to increase the yields from the light seed, but it is not likely that it produced a very marked effect, because the seeding was a large one for Nebraska, and, the wheat being sown in the early fall, there was abundant opportunity for it to stool, and thus equalize the stand. It has never been observed that there was any difference between the plots in this respect.

Taking, together, the results of 1902, which show a decrease in the weight of the kernels on a single head as the content of proteid nitrogen increases, the results of 1903, which show a slight decrease in the weight of the kernels from the plant, accompanying an increase in the percentage of proteid nitrogen, and the yields of the light and heavy seed for the four years beginning with 1900, there would appear to be a slight decrease in yield of grain, accompanying an increase in the percentage of proteid nitrogen. This loss in yield is not sufficient to counteract the increase in nitrogen, and the result is to increase the production of proteids per acre.

Viewed in the light of these various experiments, the selection of large, heavy wheat kernels for seed does not appear to be altogether unobjectionable, as in this case it resulted in a decreased production of proteids per acre, without a compensating increase in the yield of grain, when continued for a number of years. On the other hand, the selection of the small, light seed is hardly to be recommended. In fact, selection based upon kernel size or weight is not a satisfactory method for permanently improving wheat. The individual plant should be taken as the basis for selection, and very large numbers should be handled. The figures in Table 8 show what great opportunity there is for securing not only kernels of high nitrogen content, but also plants giving at the same time an increased yield of grain and abundant production of proteids. If the average nitrogen content and yield of grain by plants be observed in this table, it will be seen that numerous plants may be selected that have not only a nitrogen content above the average, but also a greater yield of grain. While, therefore, it is probable that improvement in yield of grain can not be effected so rapidly where it is combined with improvement in nitrogen content as if the latter were neglected, yet present yields of wheat in Nebraska can be increased at the same time that the production of proteids is augmented.

METHOD FOR SELECTION TO INCREASE THE QUANTITY OF PROTEIDS IN THE KERNEL.

The following tables show the results of analyses of a total of forty-eight spikes of wheat. In the case of each spike one row of spikelets, for instance, row No. 1, was analyzed, and the other row of spikelets, which would then be row No. 2, was analyzed separately. In the case of the set of spikes forming Table 14 the total organic nitrogen was determined in both lots, and in the set comprised by Table 15 the proteid nitrogen was determined. The last column shows the difference between the nitrogen content of the two rows of kernels.

TABLE 14.—*Analyses of twenty-five spikes of wheat, showing their total organic nitrogen.*

Number of spike.	Percentage of total organic nitrogen.			Number of spike.	Percentage of total organic nitrogen.		
	Row 1.	Row 2.	Difference.		Row 1.	Row 2.	Difference.
1	3.14	3.32	0.18	18	2.83	2.79	0.04
2	2.97	3.15	.18	22	2.78	2.76	.02
3	2.89	2.99	.10	23	2.94	3.03	.09
7	2.99	3.21	.22	24	2.98	2.89	.09
8	2.89	2.82	.07	44	3.00	3.08	.08
9	2.82	2.81	.01	45	2.84	2.67	.17
10	2.50	2.76	.26	46	3.03	2.90	.13
11	3.13	3.11	.02	47	2.65	2.79	.14
12	3.11	3.18	.07	48	2.62	2.84	.22
13	2.76	2.80	.04	49	3.02	3.18	.16
14	2.85	2.79	.06	50	3.02	2.80	.22
15	3.26	3.07	.19				
16	2.91	3.07	.13	Average			.12
17	3.45	3.67	.22				

TABLE 15.—*Analyses of twenty-three spikes of wheat, showing their percentage of proteid nitrogen.*

Number of spike.	Percentage of proteid nitrogen.			Number of spike.	Percentage of proteid nitrogen.		
	Row 1.	Row 2.	Difference.		Row 1.	Row 2.	Difference.
4	2.90	3.12	0.22	34	2.86	3.02	0.16
5	2.97	2.86	.11	35	2.33	2.52	.19
20	2.68	2.79	.11	36	2.88	2.85	.03
21	2.54	2.76	.22	37	2.43	2.45	.02
25	2.42	2.53	.11	38	3.15	3.14	.01
26	2.42	2.50	.08	39	3.46	3.34	.12
27	3.01	2.91	.10	40	2.45	2.59	.14
28	2.35	2.71	.36	41	2.73	2.68	.05
29	2.72	2.75	.03	42	3.42	3.61	.19
30	2.49	2.44	.05	43	2.47	2.57	.07
31	2.92	3.09	.17				
32	2.60	2.48	.12	Average	2.77	2.82	.11
33	3.41	3.37	.04				

It will readily be seen that the analyses of the rows agree very closely, the extreme difference being 0.22 per cent, and the average difference being 0.12 per cent, in the total nitrogen. If, therefore, one row of spikelets were to be used for seed and the other were analyzed, it is quite evident that a very accurate estimate of the nitrogen content of the kernels used for seed would be obtained. In the determination of proteid nitrogen there is an extreme difference of 0.36 per cent in one case, but in the main the differences are small. As will be shown later, the variation in the proteid nitrogen content of individual plants is so great that even this maximum difference would cause no confusion when selecting plants for reproduction.

It is very desirable to have for analysis a larger sample than can be obtained from one spike. It has therefore been attempted to ascertain whether a sample consisting of one-half the whole number of spikes on a plant would afford a fair estimate of the composition of the other kernels on the remainder of the spikes. The plants whose spikes were analyzed were grown in hills 5 inches apart each way, with one seed in each hill. Each plant was harvested separately and the spikes from each placed in a separate envelope. The following table gives the results, lot 1 in each case being composed of the kernels from one-half the number of spikes on a plant, and lot 2 of kernels from the remaining spikes.

TABLE 16.—*Analyses of twenty-one plants, showing total nitrogen and proteid nitrogen.*

Number of plant.	Percentage of total nitrogen.			Percentage of proteid nitrogen.		
	Lot 1.	Lot 2.	Difference.	Lot 1.	Lot 2.	Difference.
1	2.65	2.91	0.26	2.51	2.69	0.18
2	3.01	3.02	.01	2.77	2.76	.01
3	3.01	2.83	.24	2.69	2.57	.12
4	2.82	3.10	.28	2.63	2.83	.20
5	3.06	2.97	.09	2.92	2.70	.22
6	2.94	2.56	.38	2.51	2.42	.09
7	2.84	3.03	.19	2.66	2.86	.20
9	3.21	3.05	.16	2.83	2.81	.01
10	2.98	2.87	.11	2.59	2.70	.11
11	2.59	2.66	.07	2.34	2.57	.23
12	2.81	2.62	.19	2.59	2.52	.07
13	3.47	3.62	.15	3.04	3.35	.31
14	2.61	2.54	.07	2.44	2.42	.02
15	2.54	2.46	.08	2.25	2.29	.04
16	2.71	2.87	.16	2.25	2.71	.46
17	2.85	3.01	.16	2.73	2.75	.02
18	2.99	3.13	.14	2.85	2.91	.06
19	2.78	2.77	.01	2.61	2.33	.28
20	2.78	2.80	.02	2.60	2.57	.03
21	2.79	2.71	.08	2.51	2.48	.03
Average			.14			.13

The above table shows a maximum difference of 0.38 per cent in the content of total nitrogen of the two lots of spikes from one plant, and of 0.46 per cent in the content of proteid nitrogen. The average difference is only 0.14 per cent and 0.13 per cent, respectively.

These tables give unmistakable evidences that the average composition of a spike of wheat may be judged from the analysis of a row of its spikelets, and that the average composition of all of the spikes of a wheat plant is shown by an analysis of one-half the number. In practice it is better to take as the sample for analysis one row of spikelets from each spike, and the remaining row of spikelets from each spike for planting.

In order to ascertain what variation occurs between the several spikes on a single wheat plant, analyses were made of each spike from a number of plants. On some plants there were more spikes than on others, but every spike on each plant was analyzed. In the following tabulation of these analyses the percentage of proteid nitrogen is stated.

TABLE 17.—*Analyses of spikes of wheat, showing difference in proteid nitrogen.*

Spike.	Percentage of proteid nitrogen.					
	Plant 23.	Plant 24.	Plant 25.	Plant 26.	Plant 27.	Plant 29.
1	2.33	2.46	2.31	2.73	3.22	2.38
2	2.69	2.73	2.36	3.02	3.24	2.60
3	2.37	2.35	2.47	2.80	3.02	3.03
4	2.36	2.11	2.59	2.60	3.31	3.00
5	2.15	2.19	2.35	2.53	....	2.34
6	2.31	2.21	2.39	2.37	....	2.71
7	2.09	2.53	2.39	2.72	....	2.21
8	2.71	....	2.60	2.37	....	....
9	2.32	....	2.54	2.61	....	2.60
10	2.37	....	2.83	2.45	....	2.30
Maximum	2.69	2.73	2.83	3.02	3.31	3.03
Average	2.37	2.37	2.48	2.62	3.20	2.57
Minimum	2.09	2.11	2.31	2.37	3.02	2.21
Greatest difference	.60	.62	.52	.65	.29	.82

These results show that there may be large differences between the proteid nitrogen content of spikes on the same plant. They do not, however, indicate that the determination of the average composition of the kernels on a plant is not a safe guide for selecting breeding stock. If the plant is the unit in reproduction, whether the plant reproduces itself from one seed or another does not affect its hereditary qualities in very marked degree.

It is evident, from a comparison of the variations that occur in the composition of the spikes from a single plant, and of the kernels on a single spike, that it is impossible to do more than obtain a reasonably close estimate of the composition of the kernels either on a part or on the whole of a plant. It therefore becomes desirable to obtain as closely as possible the average composition of the unit of reproduction. If the plant as a whole, and not any particular part, is this unit, the average composition of all of the kernels on the plant is a much safer guide as a basis for selection than is the average composition of the kernels of any part of it. One row of spikelets from each spike should therefore give the best sample for analysis.

In Table 18 is given a statement of the percentage of proteid nitrogen in the dry matter of the kernels on a row of spikelets of 800 spikes of wheat of the Turkish Red variety. These spikes were taken from a field of wheat, and were selected with reference to length of head, plumpness of kernel, uprightness of straw, freedom from rust, etc. They are therefore not spikes in which high nitrogen content is likely to be due to immaturity or arrested development.[a] Variations in the nitrogen content of different plants may in some degree be due to a larger or smaller supply of available nitrogen, although all were taken from the same field. Variations due to climate are, of course, precluded, as all grew during the same season.

[a] In practice undeveloped kernels are discarded.

TABLE 18.—*Variations in content of proteids.*

Record number.	Percentage of—		Record number.	Percentage of—		Record number.	Percentage of—	
	Proteid nitrogen in water-free material.	Proteids (proteid N. × 5.7).		Proteid nitrogen in water-free material.	Proteids (proteid N. × 5.7).		Proteid nitrogen in water-free material.	Proteids (proteid N. × 5.7).
1	2.25	12.82	78	3.40	19.38	155	1.99	11.37
2	3.04	17.33	79	3.33	18.98	156	3.03	17.20
3	2.45	13.96	80	3.79	21.60	157	2.07	11.87
4	3.14	17.90	81	3.63	20.69	158	2.75	15.64
5	2.86	16.30	82	2.68	15.28	159	2.82	16.07
6	2.83	16.13	83			160	3.06	17.44
7	3.67	20.92	84	2.46	14.02	161	2.54	14.48
8	3.42	19.49	85	2.62	14.93	162	3.33	18.98
9	2.36	13.45	86	2.87	16.49	163	2.73	15.56
10	2.28	13.00	87	2.89	16.86	164	2.47	14.08
11	2.98	16.99	88	2.14	13.91	165	3.22	18.35
12	3.51	20.01	89	3.56	20.29	166	2.80	15.96
13	3.63	20.69	90	3.76	21.43	167		
14	2.48	14.14	91			168	3.59	20.46
15	2.30	13.11	92	3.11	19.14	169	2.52	13.72
16	3.48	19.84	93	2.30	13.11	170	2.72	15.50
17	3.55	20.23	94			171	3.28	18.70
18	3.31	18.87	95			172	2.74	15.62
19	2.30	13.11	96	2.75	15.67	173	3.07	17.54
20	2.52	14.36	97	4.07	23.20	174	3.75	21.43
21	2.93	16.70	98	3.28	18.70	175	3.46	19.74
22	3.25	18.52	99	3.24	18.47	176	3.09	17.67
23			100	2.15	12.25	177	3.56	20.34
24	2.84	16.19	101	3.12	17.78	178		
25	2.73	15.56	102	3.00	17.10	179	3.85	21.95
26	3.55	20.23	103	2.87	16.36	180	3.57	20.38
27	2.33	13.28	104	3.58	20.41	181	2.66	15.18
28	2.65	15.11	105	2.61	14.88	182	2.76	15.74
29	2.82	16.07	106	2.01	11.46	183	2.05	11.73
30	2.70	15.39	107	2.68	15.28	184	3.77	21.53
31	1.84	10.49	108	3.10	17.67	185	2.70	15.43
32	3.10	17.67	109	2.58	14.71	186	3.97	22.63
33	2.86	16.30	110	2.76	15.73	187	2.98	17.03
34	2.16	12.31	111	4.30	24.51	188	2.36	13.48
35	2.58	14.71	112	2.89	16.47	189	2.63	15.03
36	3.22	18.35	113	2.59	14.67	190	3.24	18.52
37	3.49	19.89	114	2.68	15.28	191	3.24	18.52
38	2.76	15.73	115	1.71	9.75	192	3.12	17.80
39	2.96	16.87	116	2.59	14.75	193	2.40	13.72
40	2.86	16.30	117	3.31	18.87	194	3.43	19.58
41	3.50	19.95	118			195	3.33	18.99
42	3.05	17.38	119	2.17	12.37	196	2.71	15.46
43	2.88	16.42	120	2.88	16.42	197	2.85	16.27
44	2.75	15.67	121			198	3.18	18.13
45	2.61	14.88	122	1.33	7.58	199	2.98	17.03
46	2.50	14.25	123	2.54	14.48	200	3.23	18.46
47	3.10	17.67	124	3.20	18.24	201		
48	3.17	18.07	125	2.04	11.63	202	3.12	17.83
49	2.86	16.30	126	2.34	13.34	203	3.07	17.51
50	2.80	15.96	127	2.89	16.47	204	3.90	22.24
51	3.65	20.80	128	2.98	16.99	205	2.41	13.74
52	2.88	16.42	129	2.85	16.24	206	3.44	19.62
53	3.21	18.30	130	2.99	17.04	207	2.73	15.58
54	2.96	16.87	131	3.18	18.13	208	3.20	18.30
55	3.84	21.89	132			209	3.81	21.76
56	3.38	19.27	133			210	2.94	16.79
57	3.11	17.73	134			211	2.89	16.52
58	3.21	18.30	135			212	2.96	16.91
59	3.06	17.44	136			213	3.30	18.86
60	3.02	17.21	137	2.13	12.14	214	3.09	17.62
61	1.78	10.13	138	3.08	17.56	215	3.79	21.63
62	2.67	15.22	139	1.37	7.81	216	3.33	18.99
63	3.39	19.32	140			217	2.86	16.30
64	2.49	14.19	141	2.57	14.65	218	2.58	14.72
65	2.58	11.71	142	2.75	15.67	219	2.71	15.45
66	2.12	12.08	143	3.03	17.27	220	3.19	18.22
67	2.61	15.05	144	3.17	18.07	221	3.98	22.70
68	2.46	11.02	145	2.09	11.91	222	2.93	16.71
69	2.35	13.39	146	2.75	15.67	223	3.30	18.86
70	2.93	16.70	147	2.12	13.79	224	3.65	20.82
71	2.32	13.22	148	2.68	15.28	225	3.54	20.23
72	2.20	12.54	149	2.25	12.82	226	3.11	17.73
73	2.58	14.71	150	2.61	11.88	227	2.71	15.46
74	2.58	14.71	151	1.51	8.61	228	3.39	19.36
75	3.22	18.35	152	1.64	9.35	229	2.96	16.88
76			153	2.93	16.70	230	2.54	14.46
77			154	2.85	16.24	231	3.11	17.73

TABLE 18.—*Variations in content of proteids*—Continued.

Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).
232	3.11	17.73	309	3.74	21.36	386	2.52	15.07
233	3.31	18.92	310	3.15	18.01	387	2.73	15.59
234	3.23	18.43	311	2.99	17.07	388	3.05	17.41
235	3.65	20.82	312	3.48	19.88	389	2.95	16.87
236	3.18	18.17	313	3.52	20.11	390	3.22	18.36
237	4.87	27.79	314	3.16	18.03	391	3.26	18.60
238	2.69	15.38	315	2.75	15.68	392	2.93	16.74
239	2.59	14.77	316	3.35	19.13	393	2.70	15.41
240	3.52	20.12	317	3.42	19.54	394	2.77	15.81
241	2.76	15.75	318	2.01	11.50	395	2.98	16.99
242	2.96	16.89	319	2.86	16.33	396	2.28	13.02
243	3.47	19.78	320	2.98	17.00	397	....	....
244	3.30	18.83	321	3.42	19.54	398	....	....
245	3.64	20.77	322	2.54	14.53	399	3.09	17.65
246	3.75	21.39	323	3.42	19.54	400	3.35	19.12
247	3.50	19.95	324	3.18	18.16	401	3.36	19.20
248	3.64	20.78	325	3.45	19.70	402	2.32	13.26
249	3.21	18.32	326	....	....	403	3.03	17.31
250	3.11	17.76	327	3.44	19.64	404	3.30	18.83
251	3.46	19.73	328	3.60	20.55	405	3.75	21.43
252	2.54	14.52	329	2.87	16.39	406	2.43	13.90
253	3.63	20.71	330	2.61	14.93	407	3.79	21.63
254	....	....	331	....	....	408	3.63	20.74
255	3.02	17.26	332	2.57	14.68	409	3.59	20.47
256	3.31	18.88	333	3.25	18.56	410	3.26	18.63
257	....	....	334	2.61	14.92	411	3.15	17.95
258	3.37	19.24	335	2.81	15.70	412	3.63	20.70
259	3.84	21.89	336	3.35	19.11	413	3.77	21.51
260	1.93	11.03	337	2.88	16.45	414	3.13	17.89
261	3.49	19.92	338	4.95	28.23	415	2.44	13.93
262	3.19	18.21	339	3.33	19.01	416	3.23	18.44
263	3.24	18.48	340	2.73	15.61	417	3.79	21.65
264	3.36	19.20	341	2.97	16.94	418	3.05	17.39
265	3.29	18.80	342	2.60	14.82	419	2.85	16.28
266	3.10	17.70	343	2.50	14.27	420	3.73	21.27
267	3.18	18.18	344	2.93	16.71	421	2.53	14.45
268	4.10	23.39	345	2.55	14.57	422	3.53	20.12
269	3.20	18.29	346	2.55	14.55	423	3.14	17.90
270	3.36	19.19	347	2.44	13.92	424	2.61	14.93
271	3.39	19.34	348	2.87	16.39	425	3.29	18.81
272	3.13	17.88	349	2.65	15.18	426	3.08	17.60
273	3.39	19.78	350	2.63	15.03	427	3.06	17.46
274	3.56	20.34	351	3.31	18.90	428	2.59	14.80
275	3.32	18.96	352	3.04	17.38	429	3.03	17.31
276	3.15	17.95	353	3.10	17.72	430	2.81	16.06
277	2.85	16.26	354	2.72	15.53	431	3.20	18.25
278	3.11	17.77	355	2.83	16.18	432	3.00	17.11
279	3.78	21.60	356	2.91	16.61	433	3.12	17.80
280	3.70	21.10	357	2.36	13.47	434	2.85	16.28
281	3.26	18.60	358	2.33	13.60	435	3.53	20.14
282	3.01	17.19	359	2.97	16.95	436	2.88	16.44
283	3.85	22.00	360	2.88	16.45	437	3.12	17.82
284	3.71	21.20	361	2.94	16.77	438	2.66	15.20
285	3.87	22.07	362	3.03	17.28	439	2.98	16.99
286	3.55	20.26	363	3.49	19.89	440	2.35	13.44
287	3.86	22.04	364	2.91	16.62	441	2.93	16.72
288	2.82	16.09	365	3.49	19.94	442	3.22	17.98
289	2.52	14.40	366	3.16	18.04	443	2.50	14.30
290	4.00	22.81	367	3.37	19.23	444	2.37	13.56
291	2.23	12.73	368	3.06	17.47	445	2.37	13.51
292	4.15	23.68	369	3.33	19.02	446	3.75	21.37
293	2.63	15.04	370	3.09	17.64	447	2.86	16.33
294	2.56	14.60	371	2.98	17.04	448	3.13	16.67
295	3.05	17.41	372	3.30	18.84	449	2.76	15.76
296	3.93	22.44	373	2.86	16.33	450	3.61	20.62
297	1.99	11.35	374	3.15	17.97	451	2.92	16.68
298	....	....	375	3.49	19.89	452	3.17	18.07
299	3.67	20.96	376	2.59	14.76	453	3.15	17.96
300	3.06	17.49	377	3.46	19.76	454	3.14	17.92
301	3.08	17.61	378	2.74	15.65	455	2.62	14.95
302	2.68	15.28	379	3.09	17.64	456	2.71	15.47
303	....	....	380	2.35	13.42	457	3.14	17.92
304	2.23	12.74	381	3.45	19.67	458	3.18	18.20
305	3.07	17.52	382	3.22	18.40	459	2.60	14.84
306	2.50	14.30	383	2.96	16.88	460	3.91	22.29
307	3.19	18.20	384	3.55	20.26	461	....	....
308	2.84	16.22	385	3.79	21.62	462	2.39	13.64

TABLE 18.—*Variations in content of proteids*—Continued.

Record number.	Percentage of— Proteid nitrogen in water-free material	Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material	Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material.	Proteids (proteid N. × 5.7).
463	2.49	11.24	540	3.17	18.12	617	3.12	17.83
464	1.98	11.29	541	3.09	17.66	618	2.67	15.27
465	3.32	18.97	542	3.33	19.01	619	3.59	20.49
466	2.98	17.01	543	3.50	19.96	620	2.68	15.30
467	2.89	16.48	544	1.29	7.37	621	2.24	12.79
468	2.95	16.82	545	2.10	11.98	622	3.19	18.23
469	2.74	15.62	546	2.54	14.49	623	3.52	20.09
470	2.80	15.97	547	2.73	15.59	624	2.67	15.27
471	2.24	12.79	548	3.01	17.21	625	2.68	15.30
472	2.49	14.22	549	2.50	14.30	626	2.69	15.38
473	2.76	15.78	550	2.84	16.20	627	2.88	16.44
474	2.80	15.97	551	2.99	17.08	628	3.68	21.01
475	2.95	16.83	552	2.30	13.11	629	3.47	19.82
476	2.52	14.39	553	3.21	18.35	630	2.48	14.16
477	2.95	16.85	554	2.91	16.59	631	3.39	19.35
478	3.15	18.00	555	3.16	18.06	632	3.22	18.41
479	2.27	12.96	556	3.02	17.26	633	1.64	9.38
480	2.72	15.53	557	3.30	18.86	634	2.10	11.99
481	3.04	17.38	558	3.25	18.58	635	3.42	19.52
482	3.15	17.97	559	2.94	16.78	636	3.08	17.61
483	2.60	14.86	560	3.32	18.93	637	2.77	15.79
484	3.45	19.71	561	3.00	17.13	638	3.54	20.21
485	2.59	14.81	562	1.12	6.40	639	3.15	18.00
486	2.68	15.31	563	2.36	13.49	640	2.82	16.10
487	3.01	17.18	564	3.83	21.84	641	3.37	19.26
488	2.41	13.77	565			642	2.57	14.68
489	3.45	19.70	566	3.49	19.49	643	3.35	19.14
490	2.46	14.02	567	3.08	17.57	644	3.41	19.47
491	2.87	16.40	568	2.17	12.39	645	2.44	13.91
492	2.06	11.78	569	3.03	17.29	646	3.77	21.54
493	3.18	18.16	570	3.20	18.27	647	2.82	16.08
494	2.45	13.97	571	2.52	14.37	648	2.53	14.47
495	2.36	13.45	572	3.12	17.82	649	2.56	14.63
496	2.52	14.38	573	2.52	14.41	650	2.59	14.82
497	2.84	16.21	574	3.25	18.53	651		
498	2.82	16.08	575	3.17	18.10	652	2.83	16.19
499	2.97	16.95	576	2.52	14.40	653	2.50	14.31
500	3.06	17.48	577	3.09	17.61	654	2.59	14.81
501	2.64	15.09	578	2.73	15.60	655	3.21	18.30
502	2.72	15.56	579	3.35	19.10	656	2.56	14.61
503	2.31	13.19	580			657	2.55	14.57
504	3.06	17.48	581	3.79	21.61	658		
505	2.71	15.46	582	2.59	14.77	659	2.92	16.70
506	2.49	14.24	583	3.13	17.86	660	3.26	18.60
507	3.13	17.85	584	3.49	19.91	661	2.55	14.76
508	2.89	16.51	585	3.05	17.40	662	2.50	14.26
509	3.20	18.29	586	3.27	18.65	663	2.82	16.11
510	2.93	16.71	587	2.56	14.60	664	2.80	15.98
511	3.61	20.59	588	2.83	16.17	665	3.33	19.01
512	2.71	15.45	589	2.84	16.20	666	2.35	13.40
513	2.86	16.33	590	2.86	16.31	667	2.31	13.20
514	2.41	13.79	591	3.06	17.44	668	2.50	14.30
515	2.27	12.98	592	3.20	18.29	669	4.36	24.86
516	3.28	18.75	593	2.88	16.47	670	6.33	36.12
517	2.36	13.49	594	3.32	18.93	671	2.32	13.23
518	3.64	20.75	595	3.18	18.17	672	4.82	28.15
519	2.81	16.03	596	3.09	17.66	673	3.39	19.35
520	2.54	14.48	597	3.32	18.93	674	3.24	18.48
521	2.68	15.28	598	2.34	13.39	675	3.41	19.44
522	3.12	17.79	599	3.12	17.81	676	3.11	17.73
523	2.99	17.05	600	2.97	16.97	677	2.51	14.36
524	1.93	11.01	601	2.08	11.91	678	3.09	17.65
525	2.51	14.35	602	3.64	20.77	679	2.48	14.17
526	1.71	9.79	603	2.56	14.62	680	2.30	13.13
527	3.15	17.99	604	2.53	14.45	681	3.36	19.17
528	2.35	13.42	605	2.56	14.60	682	2.49	14.20
529	2.88	16.44	606	3.13	17.85	683	2.70	15.41
530	2.64	15.06	607	3.01	17.20	684	3.59	20.51
531	2.97	16.94	608	3.05	17.41	685	4.04	23.06
532	2.75	15.73	609	2.75	15.72	686	2.79	15.90
533	3.22	18.37	610	3.51	20.05	687	2.83	16.13
534	2.95	16.82	611	3.00	17.15	688	2.65	15.12
535	3.03	17.29	612	3.26	18.62	689	2.68	15.28
536	2.57	14.66	613	3.84	21.92	690	3.38	19.26
537	2.88	16.47	614	2.77	15.79	691	3.04	17.33
538	2.64	15.09	615	2.72	15.52	692	2.81	16.04
539	3.76	21.46	616	3.72	21.22	693	2.35	13.76

TABLE 18.—*Variations in content of proteids*—Continued.

Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).	Record number.	Percentage of— Proteid nitrogen in water-free material.	Percentage of— Proteids (proteid N. × 5.7).
694	2.15	12.29	730	2.09	11.92	766	2.87	16.41
695	2.92	16.69	731	3.18	18.18	767	2.22	12.69
696	....	....	732	2.41	13.78	768	2.45	13.98
697	2.11	12.07	733	2.06	11.77	769	2.37	13.51
698	3.03	17.29	734	2.76	15.73	770	1.37	7.86
699	2.64	15.09	735	2.09	11.96	771	1.62	9.27
700	4.10	23.42	736	2.29	13.09	772	2.00	11.42
701	2.51	14.33	737	1.61	9.20	773	1.73	9.87
702	2.27	12.96	738	2.01	11.44	774	2.32	13.26
703	2.33	13.34	739	2.85	16.26	775	1.88	10.76
704	2.43	13.94	740	1.87	10.71	776	2.28	13.03
705	2.48	14.18	741	1.75	9.99	777	2.80	16.02
706	1.87	10.69	742	3.57	20.36	778	1.98	11.33
707	3.07	17.52	743	2.63	15.02	779	2.35	13.40
708	2.12	12.09	744	1.97	11.23	780	2.85	16.29
709	1.87	10.67	745	2.98	16.99	781	2.79	15.94
710	2.10	12.00	746	1.77	10.10	782	2.64	15.09
711	2.08	11.87	747	2.79	15.95	783	2.81	16.02
712	2.61	14.88	748	1.83	10.44	784	1.92	10.96
713	2.20	12.58	749	2.29	13.06	785	2.25	12.88
714	2.16	12.32	750	2.22	12.66	786	3.29	18.75
715	3.23	18.44	751	3.48	19.85	787	2.95	16.82
716	2.77	15.81	752	3.48	19.87	788	2.13	12.17
717	2.38	13.61	753	1.33	7.53	789	2.20	12.57
718	3.14	17.91	754	3.55	20.29	790	2.86	16.32
719	2.16	12.35	755	2.43	13.90	791	3.02	17.22
720	1.80	10.29	756	2.30	13.15	792	2.16	12.36
721	2.14	12.22	757	2.14	12.24	793	2.32	13.24
722	2.16	12.36	758	1.67	9.54	794	2.82	16.11
723	2.18	12.43	759	2.14	12.25	795	2.48	14.15
724	2.04	11.67	760	3.72	21.21	796	2.45	14.00
725	2.32	13.26	761	2.47	14.12	797	2.20	12.56
726	2.19	12.52	762	2.93	16.72	798	2.95	16.82
727	1.79	10.23	763	2.02	11.56	799	2.18	12.48
728	2.49	14.22	764	2.18	12.47	800	2.02	11.57
729	2.92	16.46	765	2.20	12.57			

It will be noticed that there is a very large range of variation in the proteid nitrogen content of these wheats, running from 1.12 to 4.95 per cent. By referring to Table 8, it will be seen that an equally large variation occurred between the plants when the whole plant was sampled. In the 351 analyses the nitrogen ranges from 1.20 to 5.85 per cent. This is due in the main to the ability of the plant to gather nitrogen from the soil. In no one of the experiments to ascertain the effect of nitrogenous manures on the composition of wheat has there been an increase of more than a few tenths of 1 per cent, even when the nitrogenous fertilizer was added to an exhausted soil. It is, therefore, not likely that such large variation in nitrogen content could be due to irregularities in the supply of soil nitrogen. If this ability of the plant to store up a large amount of nitrogen in the kernel is hereditary, as results given later indicate, there is ample opportunity to develop by selection a strain of wheat of high nitrogen content.

A BASIS FOR SELECTION TO INCREASE THE QUANTITY OF PROTEIDS IN THE ENDOSPERM OF THE KERNEL.

White bread flour, which constitutes the major portion of the wheat flour consumed in this country, is derived entirely from the endosperm of the wheat kernel. The portions of the kernel not entering into the flour are the germ and the seed coat, attached to each of which discarded constituents are portions of the endosperm. The larger part of the aleurone layer either adheres to the hull and constitutes the "bran" of commerce, or appears in the product known as "shorts," and sometimes in low-grade flour.

As it is the flour in which it is desired to increase the nitrogen, and as the flour consists entirely of the endosperm, it becomes desirable to have some way to determine the nitrogen content of the endosperm alone and to select for reproduction plants possessing a large amount of nitrogen in this portion of the kernel.

It is a question how this can best be done. A determination of gluten by the ordinary method of washing, to carry off the starch and fiber while the gluten is being worked in the hand, is not well adapted for use with the small quantities of wheat obtainable from a single plant. This also has the disadvantage that it gives no indication as to the quality of the gluten.

Determinations of gliadin and glutenin promise to be of some help in affording a basis for selection from individual plants. It has been shown by Osborne and Voorhees[a] that the gluten of wheat is composed of gliadin and glutenin. It does not necessarily follow, however, that the sum of these two substances is a measure of the gluten content of the sample analyzed. Osborne and Campbell[b] have stated that the embryo of the wheat kernel does not contain either gliadin or glutenin. This being the case, the sum of the gliadin and glutenin would represent these proteids in the endosperm, with, perhaps, a small amount in the hull.

A recent investigation by Nasmith[c] leads him to conclude that gliadin exists in all portions of the endosperm, including the aleurone layer, but that glutenin is contained only in the starch-bearing portion of the endosperm. A determination of glutenin may, therefore, give an indication of the gluten content of the wheat.

Table 19 shows the percentage of proteid nitrogen, the sum of the gliadin and glutenin nitrogen, the amounts in grams of proteid and of gliadin-plus-glutenin nitrogen in the average kernel, and the grams of proteid and of gliadin-plus-glutenin nitrogen in all of the kernels on each plant. The plants are grouped into those having

[a] American Chem. Jour., 1893, pp. 392–471.

[b] Connecticut Experiment Station Report, 1899, p. 305.

[c] Trans. Canad. Inst., 7 (1903), Univ. Toronto Studies, Physiol. Ser. (1903), No. 4.

from 1 to 2 per cent proteid nitrogen, those having 2 to 2.5 per cent proteid nitrogen, etc. Table 20 gives the averages for each of the groups in Table 19.

TABLE 19.—*Relation of gliadin-plus-glutenin nitrogen to proteid nitrogen.*

Record number.	Percentage of—		Number of kernels	Weight (in grams) of—					
	Proteid nitrogen.	Gliadin-plus-glutenin nitrogen.		Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
1 TO 2 PER CENT PROTEID NITROGEN.									
55307	1.89	1.56	342	5.6864	0.01663	0.10747	0.08871	0.0003142	0.0002594
80305	1.81	1.77	729	15.7835	.02165	.28569	.27937	.0003919	.0003832
81705	1.98	1.96	465	9.7922	.02106	.19388	.19193	.0004170	.0004128
Average	1.89	1.76	512	10.4207	.01978	.19568	.18667	.0003744	.0003518
2 TO 2.5 PER CENT PROTEID NITROGEN.									
21212	2.16	0.19	84	1.7216	0.02049	0.03718	0.00327	0.0004427	0.0000389
27205	2.41	1.70	891	16.4061	.01841	.39539	.27890	.0004437	.0003130
27206	2.36	1.46	777	19.1854	.02469	.45276	.28010	.0005827	.0003605
27505	2.12	1.65	539	12.0399	.02183	.24942	.19866	.0004627	.0003602
33107	2.35	2.12	318	6.1026	.01919	.14341	.12643	.0004510	.0004163
33605	2.39	1.92	301	7.0596	.02345	.16872	.13554	.0005605	.0004502
39205	2.11	1.84	1,031	21.5399	.02089	.45435	.39635	.0004407	.0003844
48106	2.38	1.80	608	11.6655	.01919	.27765	.20997	.0004567	.0003454
48409	2.02	1.50	314	6.4302	.02048	.12989	.09645	.0004137	.0003072
55309	2.48	1.97	167	2.5160	.01507	.06240	.04957	.0003736	.0002969
55908	2.42	1.96	562	12.2210	.02175	.29575	.23953	.0005262	.0004263
55909	2.30	1.66	302	9.2120	.03050	.21187	.15292	.0007016	.0005063
56206	2.42	1.95	509	9.3093	.01829	.22529	.18153	.0004426	.0003566
56207	2.34	1.83	462	10.9073	.02361	.25522	.19960	.0005524	.0004321
57508	2.21	2.05	380	12.0728	.03177	.26680	.24750	.0007021	.0006513
65306	2.41	1.68	544	9.8298	.01807	.23690	.16514	.0004355	.0003036
65307	2.28	1.81	373	7.0051	.01878	.15971	.12680	.0004282	.0003399
65308	2.09	1.95	583	11.7066	.02008	.24468	.22828	.0004197	.0003916
74606	2.30	2.05	464	9.6451	.02079	.22184	.19772	.0004781	.0004262
81707	2.34	.64	786	18.3614	.02336	.42965	.11750	.0005466	.0001495
81708	2.41	1.64	287	7.3993	.02578	.17833	.12135	.0006213	.0004228
Average	2.30	1.68	489.6	10.5874	.02173	.24272	.17872	.0004991	.0003652
2.5 TO 3 PER CENT PROTEID NITROGEN.									
20706	2.78	2.05	163	3.3138	0.02033	0.09212	0.06793	0.0005652	0.0004168
20707	2.77	1.85	444	9.9070	.02282	.27443	.18328	.0006181	.0004222
20710	2.83	2.00	867	17.1115	.01974	.48428	.34222	.0005586	.0003948
21207	2.96	.17	118	2.3066	.01955	.06804	.00392	.0005766	.0000332
21305	2.67	1.97	313	6.2514	.02004	.16691	.12315	.0005353	.0003948
21306	2.90	.97	226	4.1516	.01837	.12039	.04027	.0005327	.0001782
21805	2.69	.23	1,232	20.9290	.01699	.56299	.04704	.0004569	.0000391
21807	2.73	2.11	377	9.4172	.02498	.25709	.19870	.0006664	.0005271
21808	2.57	1.96	1,156	19.7446	.01708	.50741	.38700	.0004389	.0003348
21809	2.73	2.18	418	8.0214	.01919	.21898	.17487	.0005238	.0004183
21905	2.64	2.18	791	14.3111	.01809	.37781	.31198	.0004777	.0003944
22205	2.81	1.97	283	2.6965	.00953	.07577	.05312	.0002677	.0001877
22207	2.77	1.82	169	3.2787	.01940	.09082	.05967	.0005374	.0003531
26905	2.76	2.09	326	6.4102	.01966	.17692	.13398	.0005427	.0004109
26906	2.71	1.82	228	4.2376	.01859	.11484	.07712	.0005037	.0003383
26908	2.96	2.16	192	3.9797	.02073	.11780	.08596	.0006135	.0004478
26909	2.80	1.88	180	2.9999	.01667	.08400	.05640	.0004667	.0003134
27005	2.63	1.90	866	16.4120	.01895	.43164	.31182	.0004984	.0003600
27207	2.92	1.95	166	3.3266	.02004	.09712	.06487	.0005850	.0003908
27305	2.58	1.73	267	5.5666	.02085	.14362	.09630	.0005379	.0003607
27307	2.53	.82	167	3.0850	.01847	.07805	.02530	.0004674	.0001515
27506	2.70	1.98	444	10.0005	.02252	.27003	.19809	.0006082	.0004459
27508	2.61	2.22	251	5.5724	.02287	.14608	.12835	.0006037	.0005106
27509	2.90	1.09	243	5.5615	.02206	.15549	.05841	.0006399	.0002405

TABLE 19.—*Relation of gliadin-plus-glutenin nitrogen to proteid nitrogen*—Continued.

2.5 TO 3 PER CENT PROTEID NITROGEN—Continued.

Record number.	Percentage of		Number of kernels.	Weight (in grams) of					
	Proteid nitrogen.	Gliadin-plus-glutenin nitrogen.		Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
28805..........	2.91	1.55	87	2.1851	0.02512	0.06359	0.03387	0.0007309	0.0003894
33105..........	2.91	5.50	132	2.5601	.01939	.07450	.08960	.0005644	.0006787
37305..........	2.96	2.29	309	6.1394	.01987	.18173	.14060	.0005881	.0004550
37705..........	2.64	1.26	461	8.0905	.01972	.23998	.10194	.0005327	.0002485
37707..........	2.93	2.10	193	3.3004	.01710	.09670	.06931	.0005010	.0003591
38005..........	2.84	1.23	139	2.5134	.01808	.07138	.03091	.0005135	.0002224
38606..........	2.63	1.39	401	8.4605	.02110	.22251	.11760	.0005549	.0002933
38608..........	2.82	1.73	158	3.0228	.01913	.08522	.05229	.0005394	.0003309
38609..........	2.74	1.34	293	6.7665	.02309	.18540	.09067	.0006475	.0003094
39405..........	2.88	1.44	447	9.3541	.02093	.21399	.13470	.0006027	.0003014
39506..........	2.93	2.06	67	1.9218	.02869	.05631	.03959	.0008404	.0005910
40505..........	2.82	2.19	170	4.1546	.02444	.11716	.09099	.0006892	.0005352
43405..........	2.92	1.18	124	2.8000	.02258	.08176	.03304	.0006594	.0002664
44505..........	2.94	.70	340	5.9990	.01764	.17637	.04199	.0005187	.0001235
44606..........	2.90	1.29	124	2.5235	.02035	.07318	.03255	.0005902	.0002625
46107..........	2.54	2.08	478	8.3935	.01756	.21319	.17458	.0004460	.0003652
48305..........	2.87	1.77	473	12.0278	.02543	.34524	.21289	.0007299	.0004501
48806..........	2.70	.75	517	9.8346	.01798	.26553	.07376	.0004877	.0001348
55008..........	2.60	1.58	944	17.4226	.01846	.45299	.27528	.0004799	.0002917
55206..........	2.56	1.87	578	11.3592	.01965	.29079	.21241	.0005031	.0003675
55308..........	2.54	.65	397	9.5078	.02395	.24150	.06180	.0006225	.0001557
55506..........	2.80	2.20	866	17.8506	.02062	.49995	.39272	.0005773	.0004536
55507..........	2.63	2.07	504	9.8228	.01949	.25834	.20333	.0005126	.0004034
55605..........	2.64	1.96	500	10.9180	.02184	.28823	.21400	.0005765	.0004281
55606..........	2.58	1.49	503	11.0930	.02205	.28580	.16529	.0005690	.0002609
55905..........	2.67	1.75	331	5.7948	.01751	.15470	.10141	.0004674	.0003064
55906..........	2.81	1.47	499	7.9968	.01603	.22471	.11755	.0004503	.0002356
55907..........	2.59	1.61	749	19.3966	.02590	.50238	.31229	.0006707	.0004170
56105..........	2.73	2.12	336	5.7431	.01709	.15679	.12175	.0004667	.0003622
56106..........	2.57	2.09	644	12.0161	.01866	.30881	.25174	.0004795	.0003900
56107..........	2.96	2.23	872	14.4556	.01658	.42790	.32236	.0004907	.0003697
56205..........	2.51	1.85	333	6.5232	.01959	.16373	.12068	.0004917	.0003624
56208..........	2.61	1.95	563	13.5720	.02356	.34616	.26465	.0006149	.0004594
56209..........	2.59	2.21	950	15.8086	.01664	.40945	.34937	.0004310	.0003677
57007..........	2.65	2.09	88	1.5364	.01746	.04164	.03211	.0004731	.0003649
57406..........	2.75	2.13	135	2.4923	.01846	.06854	.05309	.0005077	.0003932
57407..........	2.62	1.86	762	14.9992	.01968	.39297	.27898	.0005157	.0003660
57408..........	2.61	1.64	596	12.2004	.02047	.31842	.20008	.0005343	.0003557
57506..........	2.80	2.34	180	2.7616	.01534	.07733	.06462	.0004296	.0003590
57507..........	2.85	1.55	359	6.9861	.01946	.19905	.10828	.0005545	.0003016
57805..........	2.87	2.68	270	4.8988	.01814	.14060	.13126	.0005207	.0004861
58805..........	2.74	2.11	1,158	23.1471	.01999	.63422	.48839	.0005464	.0004218
63106..........	2.79	2.20	165	3.3006	.02001	.09208	.07261	.0005581	.0004402
66005..........	2.63	2.18	370	7.6690	.02073	.02017	.16714	.0005451	.0004519
81505..........	2.94	2.65	146	2.8327	.01940	.08328	.07507	.0005704	.0005141
81706..........	2.71	2.03	722	15.3928	.02132	.41715	.31248	.0005778	.0004328
Average..	2.74	1.79	419.3	8.2271	.01991	.22222	.14658	.0005468	.0003557

3 TO 3.5 PER CENT PROTEID NITROGEN.

20709..........	3.05	2.31	258	5.3229	0.02063	0.16235	0.12296	0.0006292	0.0004766
20805..........	3.32	2.26	697	14.6942	.02157	.48784	.33208	.0006999	.0004875
21205..........	3.16	.22	123	2.3642	.01922	.07471	.00520	.0006074	.0000423
21208..........	3.24	2.15	287	5.1594	.01798	.16712	.11093	.0005824	.0003866
21307..........	3.04	.46	143	2.5691	.01796	.07810	.01182	.0005461	.0000826
21906..........	3.18	2.10	408	10.4800	.02563	.33402	.22008	.0008168	.0005382
21907..........	3.35	2.15	158	2.9248	.01851	.09798	.06288	.0006201	.0003980
22206..........	3.22	2.11	146	2.5712	.01720	.08086	.05425	.0005538	.0003629
22208..........	3.18	2.14	118	1.9090	.01619	.06071	.04084	.0005144	.0003465
22210..........	3.17	1.55	298	6.0173	.02019	.19075	.09327	.0006401	.0003129
22211..........	3.17	1.69	561	11.5675	.02062	.36671	.19548	.0006537	.0003485
26808..........	3.09	2.28	222	3.8811	.01748	.11992	.08849	.0005402	.0003985
28206..........	3.07	2.42	219	4.3698	.01996	.13415	.10575	.0006126	.0004830
28806..........	3.02	1.86	685	14.4630	.02111	.43679	.26901	.0006376	.0003926
33305..........	3.41	2.41	150	3.1346	.02090	.10689	.07554	.0007126	.0005037
33607..........	3.22	2.45	136	2.8903	.02125	.09307	.07081	.0006843	.0005206
48306..........	3.29	2.13	157	2.6571	.01692	.08742	.05660	.0005568	.0003604
48506..........	3.20	2.17	556	9.4585	.01701	.30267	.20525	.0005444	.0003691

TABLE 19.—*Relation of gliadin-plus-glutenin nitrogen to proteid nitrogen*—Continued.

3 TO 3.5 PER CENT PROTEID NITROGEN—Continued.

Record number.	Percentage of— Proteid nitrogen.	Percentage of— Gliadin-plus-glutenin nitrogen.	Number of kernels.	Weight (in grams) of— Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
48705	3.13	1.56	264	4.3615	0.01652	0.13652	0.06804	0.0005171	0.0002577
48706	3.00	.71	379	6.1983	.01635	.18596	.04401	.0004906	.0001161
55005	3.05	1.99	393	7.9684	.02028	.24303	.15857	.0006185	.0004036
55006	3.16	1.75	451	7.1852	.01593	.22705	.12574	.0005034	.0002788
55508	3.11	1.96	216	3.7407	.01732	.11636	.07332	.0005386	.0003395
57905	3.18	2.92	221	2.4731	.01118	.07859	.07221	.0003556	.0003264
58207	3.09	2.49	307	4.2207	.01375	.13042	.10510	.0004248	.0003424
58705	3.01	2.47	235	2.5436	.01082	.07656	.06283	.0003258	.0002673
Average	3.16	1.95	299.5	5.5817	.01817	.17602	.10889	.0005741	.0002916

3.5 TO 4 PER CENT PROTEID NITROGEN.

Record number.	Proteid nitrogen.	Gliadin-plus-glutenin nitrogen.	Number of kernels.	Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
17506	3.52	2.23	93	2.2881	0.02460	0.08044	0.05102	0.0008660	0.0005486
18905	3.81	1.54	103	1.4864	.01143	.05663	.03315	.0005498	.0003218
21811	3.75	2.16	567	11.9114	.02101	.44666	.25728	.0007877	.0004538
21908	3.82	1.88	173	3.5574	.02056	.13589	.06688	.0007855	.0003955
26107	3.92	1.35	144	2.0390	.01416	.07993	.02753	.0005551	.0001912
38505	3.61	1.77	563	12.1088	.02252	.43713	.21432	.0007764	.0003986
42205	3.63	2.73	94	1.8434	.01967	.06713	.05049	.0007142	.0005370
45005	3.58	1.36	235	3.2340	.01376	.11575	.04398	.0004927	.0001871
48505	3.66	1.76	137	1.9154	.01398	.07010	.03371	.0005117	.0002460
66006	3.54	1.38	366	6.0090	.01642	.21272	.08292	.0005812	.0002266
Average	3.68	1.82	247.5	4.6399	.01811	.17024	.08613	.0006620	.0003506

4 TO 4.5 PER CENT PROTEID NITROGEN

Record number.	Proteid nitrogen.	Gliadin-plus-glutenin nitrogen.	Number of kernels.	Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
21812	4.26	2.02	983	14.8137	0.01507	0.63107	0.29934	0.0006420	0.0003044
21813	4.04	2.14	216	4.0258	.01877	.16377	.08615	.0007582	.0004017
21909	4.43	1.98	525	12.1819	.02317	.53889	.29846	.0010265	.0005677
34405	4.33	2.44	207	4.1281	.01994	.17875	.10073	.0008635	.0004865
55007	4.21	2.21	118	2.1571	.01828	.09082	.04767	.0007696	.0004040
76206	4.45	2.03	447	5.4411	.01217	.24213	.11046	.0005417	.0002471
Average	4.29	2.14	416	7.1230	.01790	.20757	.15714	.0007669	.0004019

MORE THAN 4.5 PER CENT PROTEID NITROGEN.

Record number.	Proteid nitrogen.	Gliadin-plus-glutenin nitrogen.	Number of kernels.	Kernels.	Average kernel.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel.	Gliadin-plus-glutenin nitrogen in average kernel.
21206	5.23	0.22	149	2.8564	0.01917	0.14939	0.00628	0.0010026	0.0000422
21210	5.03	1.34	237	3.9143	.01577	.19689	.05245	.0007934	.0002113
40205	4.69	3.07	194	3.6302	.01871	.17026	.11145	.0008776	.0005744
48406	4.87	2.25	249	3.2964	.01324	.16053	.08168	.0006447	.0002979
69805	5.82	1.94	110	2.4420	.02220	.14213	.04738	.0012921	.0004307
72607	5.59	2.51	188	3.4442	.01832	.19253	.08645	.0010241	.0004598
92306	4.93	4.06	347	6.0091	.01732	.29625	.24397	.0008539	.0007032
Average	5.16	2.198	210.6	3.6561	.01782	.18685	.08995	.0009269	.0003885

TABLE 20.—*Summary of analyses, showing relation of gliadin-plus-glutenin nitrogen to proteid nitrogen.*

Range of percentage of proteid nitrogen	Number of analyses.	Percentage of— Proteid nitrogen	Gliadin-plus-glutenin nitrogen	Number of kernels	Weight (in grams) of— Kernels.	Average kernel	Proteid nitrogen in kernels	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in average kernel	Gliadin-plus-glutenin nitrogen in average kernel.
1 to 2	3	1.89	1.76	512.0	10.4207	0.01978	0.19568	0.18667	0.0003744	0.0003518
2 to 2.5	21	2.30	1.68	489.6	10.5874	.02173	.24272	.17872	.0004991	.0003652
2.5 to 3	70	2.74	1.73	419.3	8.2271	.01991	.22222	.13918	.0005468	.0003442
3 to 3.5	26	3.16	1.95	299.5	5.5817	.01817	.17602	.10889	.0005741	.0003516
3.5 to 4	10	3.68	1.82	247.5	1.6399	.01811	.17024	.08613	.0006620	.0003506
4 to 4.5	6	4.29	2.22	116.0	7.1230	.01790	.30757	.15714	.0007669	.0004019
4.5 and over	7	5.16	2.20	210.6	3.6561	.01782	.18685	.08995	.0009269	.0003886

The figures in Table 20 show that while gliadin-plus-glutenin nitrogen increases with proteid nitrogen it does not do so in the same ratio, the increase in proteid nitrogen being due in large measure to an increase in other proteids.

The same analyses are tabulated in Table 21 according to the increase in gliadin-plus-glutenin nitrogen, and the averages for each group are stated in Table 22. In the latter table the increase in proteid nitrogen does not keep pace with the increase in gliadin-plus-glutenin nitrogen, there being 1.74 per cent other proteid nitrogen in the first group and 1.25 per cent in the last.

It thus becomes evident that a determination of proteid nitrogen in the kernel is not an accurate guide to the content of gliadin plus glutenin, and that a direct determination of these substances is necessary.

It is, furthermore, apparent that a determination of gliadin-plus-glutenin nitrogen will permit of the selection of kernels having a large percentage of these substances.

TABLE 21.—*Relation of proteid nitrogen to gliadin-plus-glutenin nitrogen.*

GLIADIN-PLUS-GLUTENIN NITROGEN, 1 TO 1.5 PER CENT.

Record number.	Percentage of— Gliadin-plus-glutenin nitrogen.	Proteid nitrogen.	Number of kernels.	Weight (in grams) of— Kernels.	Average kernel.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Proteid nitrogen in average kernel.
21210	1.34	5.03	237	3.9143	0.01575	0.05245	0.19689	0.0002113	0.0007934
26107	1.35	3.92	144	2.0390	.01416	.02753	.07993	.0001912	.0005551
27205	1.46	2.36	777	19.1854	.02469	.28010	.45276	.0003605	.0005827
27509	1.09	2.90	243	5.3615	.02206	.05844	.15549	.0002405	.0006599
37705	1.26	2.64	461	8.0905	.01972	.10194	.23998	.0002485	.0005327
38005	1.23	2.84	139	2.5134	.01808	.03091	.07138	.0002224	.0005135
38606	1.39	2.63	401	8.1605	.02110	.11760	.22251	.0002933	.0005549
38609	1.34	2.71	293	6.7665	.02309	.09067	.18540	.0003094	.0006479
39405	1.44	2.88	447	9.3541	.02093	.13470	.21399	.0003014	.0006027
43405	1.18	2.92	124	2.8000	.02258	.03301	.08176	.0002664	.0006594
44606	1.29	2.90	124	2.5235	.02035	.03255	.07318	.0002625	.0005902
45005	1.36	3.58	235	3.2340	.01376	.04398	.11575	.0001871	.0004927
55606	1.49	2.58	505	11.0930	.02205	.16529	.28580	.0002609	.0005690
55906	1.17	2.81	499	7.9968	.01603	.11755	.22171	.0002356	.0004503
66006	1.38	3.54	366	6.0090	.01642	.08292	.21272	.0002266	.0005812
Average	1.34	3.08	333	6.6228	.01939	.09198	.18718	.0002545	.0005843

TABLE 21.—*Relation of proteid nitrogen to gliadin-plus-glutenin nitrogen*—Continued.

GLIADIN-PLUS-GLUTENIN NITROGEN, 1.5 TO 2 PER CENT.

Record number.	Percentage of—		Number of kernels.	Weight (in grams) of—					
	Gliadin-plus-glutenin nitrogen.	Proteid nitrogen.		Kernels.	Average kernel.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Proteid nitrogen in average kernel.
18905	1.54	3.81	103	1.4864	0.01443	0.03315	0.05663	0.0003218	0.0005498
20707	1.85	2.77	444	9.9070	.02282	.18328	.27443	.0004222	.0006181
21305	1.97	2.67	312	6.2514	.02004	.12315	.16691	.0003948	.0005350
21808	1.96	2.57	1,156	19.7446	.01708	.38700	.50744	.0003348	.0004389
21908	1.88	3.82	173	3.5574	.02056	.06688	.13589	.0003955	.0007855
21909	1.98	4.13	525	12.1819	.02317	.29846	.53889	.0005677	.0010265
22205	1.97	2.81	283	2.6965	.00953	.05312	.07577	.0001877	.0002677
22207	1.82	2.77	169	3.2787	.01940	.05967	.09082	.0003531	.0005376
22210	1.55	3.17	298	6.0173	.02019	.09327	.19075	.0003129	.0006401
22211	1.69	3.17	561	11.5675	.02062	.19548	.36671	.0003485	.0006537
26906	1.82	2.71	228	4.2376	.01859	.07712	.11484	.0003383	.0005037
26909	1.88	2.80	180	2.9999	.01667	.05640	.08400	.0003134	.0004667
27005	1.90	2.63	866	16.4120	.01895	.31182	.43164	.0003600	.0004984
27205	1.70	2.41	891	16.4061	.01841	.27890	.39539	.0003130	.0004437
27207	1.95	2.92	166	3.3266	.02004	.06487	.09712	.0003908	.0005850
27305	1.73	2.58	267	5.5666	.02085	.09630	.14362	.0003607	.0005379
27505	1.65	2.12	539	12.0399	.02183	.19866	.24942	.0003602	.0004627
27506	1.98	2.70	444	10.0005	.02252	.19800	.27003	.0004459	.0006082
28805	1.55	2.91	87	2.1851	.02572	.03887	.06359	.0003894	.0007309
28806	1.86	3.02	685	14.4630	.02111	.26901	.43679	.0003926	.0006376
33605	1.92	2.39	301	7.0596	.02345	.13554	.16872	.0001502	.0005605
38505	1.77	3.61	563	12.1088	.02252	.21432	.43713	.0003986	.0007764
38608	1.73	2.82	158	3.0228	.01913	.05229	.08522	.0003309	.0005394
39205	1.84	2.11	1,031	21.5399	.02089	.39635	.45435	.0003844	.0004407
48106	1.80	2.38	608	11.6655	.01919	.20997	.27765	.0003454	.0004567
48305	1.77	2.87	473	12.0278	.02543	.21289	.34524	.0004501	.0007299
48409	1.50	2.02	314	6.4302	.02048	.09645	.12989	.0003072	.0004137
48505	1.76	3.66	137	1.9154	.01398	.03371	.07010	.0002460	.0005117
48705	1.56	3.13	264	4.3615	.01652	.06804	.13652	.0002577	.0005171
55005	1.99	3.05	393	7.9684	.02028	.15857	.24303	.0004036	.0006185
55006	1.75	3.16	451	7.1852	.01593	.12574	.22705	.0002788	.0005034
55008	1.58	2.60	944	17.4226	.01846	.27528	.45299	.0002917	.0004799
55206	1.87	2.57	578	11.3592	.01965	.21241	.29079	.0003675	.0005031
55305	1.97	2.48	167	2.5160	.01507	.04957	.06240	.0002969	.0003736
55307	1.56	1.89	342	5.6864	.01663	.08871	.10747	.0002599	.0003142
55508	1.96	3.11	216	3.7407	.01732	.07332	.11636	.0003395	.0005386
55605	1.96	2.64	500	10.9180	.02184	.21400	.28823	.0004281	.0005765
55905	1.75	2.67	331	5.7948	.01751	.10141	.15470	.0003064	.0004674
55907	1.61	2.59	749	19.3966	.02590	.31229	.50238	.0004170	.0006707
55908	1.96	2.42	562	12.2210	.02175	.23953	.29575	.0004263	.0005262
55909	1.66	2.30	302	9.2120	.03050	.15292	.21187	.0005063	.0007016
56205	1.85	2.51	333	6.5232	.01959	.12068	.16373	.0003624	.0004917
56206	1.95	2.42	509	9.3093	.01829	.18153	.22529	.0003566	.0004426
56207	1.83	2.34	462	10.9073	.03361	.19960	.25522	.0004321	.0005524
56208	1.95	2.61	563	13.5720	.02356	.26465	.34616	.0004594	.0006149
57407	1.86	2.62	762	14.9992	.01968	.27898	.39297	.0003660	.0005157
57408	1.64	2.61	596	12.2004	.02047	.20008	.31842	.0003357	.0005343
57507	1.55	2.85	359	6.9861	.01946	.10828	.19905	.0003016	.0005545
65306	1.68	2.41	544	9.8298	.01807	.16514	.23690	.0003036	.0004355
65307	1.81	2.28	373	7.0051	.01878	.12680	.15971	.0003399	.0004282
65308	1.95	2.09	583	11.7066	.02008	.22828	.24468	.0003916	.0004197
69805	1.94	5.82	110	2.4420	.02220	.04738	.14213	.0004307	.0002921
80305	1.76	1.81	729	15.7835	.02165	.27937	.28569	.0003832	.0003919
81705	1.96	1.98	465	9.7922	.02106	.19193	.19388	.0004128	.0004170
81708	1.64	2.41	287	7.3993	.02578	.12135	.17833	.0004228	.0006213
Average	1.80	2.76	442.5	9.0243	.02016	.16392	.23801	.0003653	.0005538

GLIADIN-PLUS-GLUTENIN NITROGEN, 2 TO 2.5 PER CENT.

17506	2.23	3.52	93	2.2881	0.02460	0.05102	0.08044	0.0005486	0.0008660
20706	2.05	2.78	163	3.3138	.02033	.06793	.09212	.0004168	.0005652
20709	2.31	3.05	258	5.3229	.02063	.12296	.16235	.0004766	.0006292
20710	2.00	2.83	867	17.1115	.01974	.34222	.48428	.0003948	.0005586
20805	2.26	3.32	697	14.6942	.02157	.33208	.48784	.0004875	.0006999
21208	2.15	3.24	287	5.1594	.01798	.11093	.16712	.0003866	.0005824
21807	2.11	2.73	377	9.4172	.02498	.19870	.25709	.0005271	.0006664
21809	2.18	2.73	418	8.0214	.01919	.17487	.21898	.0004183	.0005238
21811	2.16	3.75	567	11.9114	.02101	.25728	.44666	.0004538	.0007877
21812	2.02	4.26	983	14.8139	.01507	.29934	.63107	.0003041	.0006420
21813	2.14	4.04	216	4.0258	.01877	.08615	.16377	.0004017	.0007582
21905	2.18	2.64	791	14.3111	.01809	.31198	.37781	.0003941	.0004777

TABLE 21.—*Relation of proteid nitrogen to gliadin-plus-glutenin nitrogen*—Continued.

GLIADIN-PLUS-GLUTENIN NITROGEN, 2 TO 2.5 PER CENT—Continued.

Record number.	Percentage of— Gliadin-plus-glutenin nitrogen.	Percentage of— Proteid nitrogen.	Number of kernels.	Weight (in grams) of— Kernels.	Weight (in grams) of— Average kernel.	Weight (in grams) of— Gliadin-plus-glutenin nitrogen in kernels.	Weight (in grams) of— Proteid nitrogen in kernels.	Weight (in grams) of— Gliadin-plus-glutenin nitrogen in average kernel.	Weight (in grams) of— Proteid nitrogen in average kernel.
21906	2.10	3.18	408	10.4800	0.02563	0.22008	0.33403	0.0005382	0.0008168
21907	2.15	3.35	158	2.9248	.01851	.06288	.09798	.0003980	.0006201
22206	2.11	3.22	146	2.5712	.01720	.05425	.08086	.0003629	.0005538
22208	2.14	3.10	118	1.9090	.01619	.04084	.06071	.0003465	.0005144
26808	2.28	3.09	222	3.8811	.01748	.08849	.11992	.0003985	.0005402
26905	2.09	2.76	326	6.4102	.01966	.13398	.17692	.0004109	.0005427
26908	2.16	2.96	192	3.9797	.02073	.08596	.11780	.0004478	.0006135
27508	2.32	2.64	251	5.5324	.02287	.12835	.14608	.0005306	.0006037
28206	2.42	3.07	219	4.3698	.01996	.10575	.13415	.0004830	.0006126
33107	2.12	2.35	318	6.1026	.01919	.12643	.14341	.0004163	.0004510
33305	2.41	3.11	150	3.1346	.02090	.07554	.10689	.0005037	.0007126
33607	2.45	3.22	136	2.8902	.02125	.07081	.09307	.0005206	.0006843
34405	2.44	4.33	207	4.1281	.01994	.10073	.17875	.0004865	.0008635
37305	2.29	2.96	309	6.1394	.01987	.14060	.18173	.0004550	.0005881
37707	2.10	2.93	193	3.3004	.01710	.06931	.09670	.0003591	.0005010
39506	2.06	2.93	67	1.9218	.02869	.03959	.05631	.0005910	.0008404
40505	2.19	2.82	170	4.1546	.02444	.09099	.11716	.0005352	.0006892
46107	2.08	2.54	478	8.3935	.01756	.17458	.21319	.0003652	.0004460
48306	2.13	3.29	157	2.6571	.01692	.05660	.08742	.0003604	.0005568
48406	2.25	4.87	249	3.2964	.01324	.08168	.16053	.0002979	.0006447
48506	2.17	3.20	556	9.4585	.01701	.20525	.30267	.0003691	.0005444
55007	2.21	4.21	118	2.1571	.01828	.04767	.09082	.0004040	.0007696
55506	2.20	2.80	866	17.8506	.02062	.39272	.49995	.0004536	.0005773
55507	2.07	2.63	504	9.8228	.01949	.20333	.25834	.0004034	.0005126
56105	2.12	2.73	356	5.7431	.01709	.03503	.15679	.0001042	.0004667
56106	2.09	2.57	644	12.0161	.01866	.05768	.30881	.0000896	.0004795
56107	2.23	2.96	872	14.4556	.01658	.10553	.42792	.0001210	.0004907
56209	2.21	2.59	950	15.8086	.01664	.34937	.40945	.0003677	.0004310
57007	2.09	2.65	168	1.5364	.01746	.03211	.04164	.0003649	.0004731
57406	2.13	2.75	135	2.4923	.01846	.05309	.06854	.0003932	.0005077
57506	2.34	2.80	180	2.7616	.01534	.06462	.07733	.0003590	.0004296
57508	2.05	2.21	380	12.0728	.03177	.24750	.26680	.0006513	.0007021
58207	2.49	3.09	307	4.2207	.01375	.10510	.13042	.0003424	.0004248
58705	2.47	3.01	235	2.5436	.01082	.06283	.07656	.0002673	.0003258
58805	2.11	2.74	1,158	23.1471	.01999	.48839	.63422	.0004218	.0005464
63106	2.20	2.79	165	3.3006	.02001	.07261	.09208	.0004402	.0005581
66005	2.18	2.63	370	7.6690	.02073	.16714	.20170	.0004519	.0005451
74606	2.05	2.30	464	9.6451	.02079	.19772	.22184	.0004262	.0004781
76206	2.03	4.45	447	5.4411	.01217	.11046	.24213	.0002471	.0005417
81706	2.03	2.71	722	15.3928	.02132	.31248	.41715	.0004328	.0005778
Average	2.18	3.08	380.1	7.2520	.01935	.14641	.21535	.0004063	.0005872

GLIADIN-PLUS-GLUTENIN NITROGEN, 2.5 TO 3 PER CENT.

Record number.	Gliadin-plus-glutenin nitrogen.	Proteid nitrogen.	Number of kernels.	Kernels.	Average kernel.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Proteid nitrogen in average kernel.
42205	2.73	3.63	94	1.8494	0.01967	0.050049	0.06713	0.0005370	0.0007142
57805	2.68	2.87	270	4.8988	.01814	.13126	.14060	.0004861	.0005207
57905	2.92	3.18	221	2.4731	.01118	.07221	.07859	.0003264	.0003556
72607	2.51	5.59	188	3.4442	.01832	.08645	.19253	.0004598	.0010241
81505	2.65	2.94	146	2.8327	.01940	.7507	.08328	.0005141	.0005704
Average	2.698	3.64	183.8	3.0696	.01734	.08310	.11243	.0004647	.0006370

GLIADIN-PLUS-GLUTENIN NITROGEN, 3 PER CENT AND OVER.

Record number.	Gliadin-plus-glutenin nitrogen.	Proteid nitrogen.	Number of kernels.	Kernels.	Average kernel.	Gliadin-plus-glutenin nitrogen in kernels.	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Proteid nitrogen in average kernel.
40205	3.07	4.69	194	3.6302	0.01871	0.11145	0.17026	0.0005744	0.0008776
92706	4.06	4.93	347	6.0091	.01732	.24397	.29625	.0007032	.0008539
Average	3.56	4.81	270.5	4.8196	.01801	.17771	.23325	.0006388	.0008657

TABLE 22.—*Summary of analyses, showing relation of proteid nitrogen to gliadin-plus-glutenin nitrogen.*

Range of percentage of gliadin-plus-glutenin nitrogen.	Percentage of—		Number of—		Weight (in grams) of					
	Gliadin-plus-glutenin nitrogen.	Proteid nitrogen.	Analyses.	Kernels.	Kernels.	Average kernel	Gliadin-plus-glutenin nitrogen in kernels	Proteid nitrogen in kernels.	Gliadin-plus-glutenin nitrogen in average kernel.	Proteid nitrogen in average kernel.
1 to 1.5.......	1.34	3.08	15	333	6.6228	0.01939	0.09198	0.18748	0.0002545	0.0005843
1.5 to 2.......	1.80	2.76	55	442.5	9.0243	.02016	.16392	.23801	.0003653	.0005518
2 to 2.5.......	2.18	3.08	52	380.1	7.2520	.01935	.14641	.21535	.0004063	.0005872
2.5 to 3.......	2.70	3.64	5	183.8	3.0696	.01734	.08310	.11243	.0004647	.0006570
3 and over....	3.56	4.81	2	270.5	4.8196	.01801	.17771	.23325	.0006388	.0008657

IMPROVEMENT IN THE QUALITY OF THE GLUTEN.

It is well known that large differences exist in the bread-making values of different varieties of wheats even when they have approximately the same gluten content and are raised in the same locality. This fact is generally attributed to differences in the quality of the gluten.

W. Farrar[a] points out the difference in the bread-making qualities of two wheats due to the quality of the gluten. He compares Saxon Fife wheat, which had a gluten content of 9.92 per cent, and which produced 309 pounds of bread from 200 pounds of flour, with Purple Straw Tuscan wheat, which had a gluten content of 9.94 per cent, and which produced only 278 pounds of bread from the same quantity of flour.

In this case it was not the amount but the quality of the gluten that determined the greater excellence of the Saxon Fife wheat.

It has further been stated by Girard,[b] Snyder,[c] and Guthrie[d] that the ratio in which gliadin and glutenin exist in the gluten determines its value for bread making.

It was considered desirable to ascertain whether the proportions of these two constituents remain about the same in wheats of high and of low content. If the quality of the gluten remains constant as the quantity increases, the value of the wheat for bread making will improve in about the same ratio. If, on the other hand, there is a tendency for the quality to deteriorate as the quantity increases, there would be greater difficulty in effecting improvement.

In Table 23, analyses of the crop of 1903 are arranged in groups according to their content of gliadin plus glutenin. The first group comprises all plants having less than 1 per cent, and each succeeding group increases by 0.25 per cent. It is followed by Table 24, which is a summary of Table 23.

[a] Agricultural Gazette of New South Wales, 9 (1898), pp. 241–250.

[b] Compt. Rend., 1897, p. 876.

[c] Minnesota Experiment Station Bulletins 54 and 63.

[d] Agricultural Gazette of New South Wales, 9 (1898), pp. 363–374.

TABLE 23.—*Ratio of gliadin to glutenin as the content of their sum increases.*

Record number.	Percentage of— Gliadin-plus-glutenin nitrogen.	Percentage of— Gliadin nitrogen.	Percentage of— Glutenin nitrogen.	Proportion of— Gliadin.	Proportion of— Glutenin.	Percentage of— Proteid nitrogen.	Percentage of— Other proteid nitrogen.
GLIADIN-PLUS-GLUTENIN NITROGEN, BELOW 1 PER CENT.							
21205	0.216	0.111	0.102	0.528	0.472	3.16	2.944
21206	.218	.142	.076	.651	.349	5.23	5.012
21207	.170	.099	.071	.582	.118	2.96	2.790
21212	.192	.109	.083	.567	.433	2.16	1.968
21306	.975	.505	.470	.518	.482	2.90	1.925
21307	.461	.255	.206	.447	.553	3.04	2.579
21805	.230	.126	.104	.548	.452	2.69	2.460
27307	.821	.806	.015	.982	.018	2.53	1.709
48806	.748	.018	.730	.024	.976	2.70	1.952
55308	.655	.629	.026	.960	.040	2.54	1.885
81707	.636	.237	.399	.372	.628	2.34	1.704
Average	.484	.276	.208	.562	.438	2.93	2.448
GLIADIN-PLUS-GLUTENIN NITROGEN, 1 TO 1.25 PER CENT.							
27509	1.087	1.072	0.015	0.986	0.014	2.90	1.813
38005	1.227	.593	.634	.483	.517	2.84	1.613
43405	1.184	1.078	.106	.910	.090	2.92	1.736
Average	1.166	.914	.252	.793	.207	2.89	1.721
GLIADIN-PLUS-GLUTENIN NITROGEN, 1.25 TO 1.50 PER CENT.							
26107	1.352	0.108	1.244	0.080	0.920	3.92	2.568
27206	1.465	.815	.650	.556	.444	2.36	.895
37705	1.265	.715	.550	.565	.435	2.64	1.375
38606	1.387	.725	.662	.522	.478	2.63	1.243
38609	1.336	.586	.750	.439	.561	2.74	1.404
39405	1.439	.818	.621	.568	.432	2.88	1.441
44606	1.287	1.057	.230	.821	.179	2.90	1.613
45005	1.361	1.240	.121	.911	.089	3.58	2.219
55606	1.493	.899	.594	.602	.398	2.58	1.087
55906	1.470	.443	1.027	.301	.699	2.81	1.340
Average	1.385	.741	.645	.536	.463	2.90	1.518
GLIADIN-PLUS-GLUTENIN NITROGEN, 1.50 TO 1.75 PER CENT.							
18905	1.537	0.143	1.394	0.093	0.907	3.81	2.273
22210	1.555	.801	.754	.515	.485	3.17	1.615
22211	1.692	1.002	.690	.592	.408	3.17	1.478
27205	1.700	1.073	.627	.631	.369	2.41	.710
27305	1.735	1.075	.660	.619	.381	2.58	.845
27505	1.651	1.032	.619	.625	.375	2.12	.469
28805	1.555	.958	.597	.616	.384	2.91	1.355
38608	1.731	.962	.769	.556	.444	2.82	1.089
48409	1.504	.690	.814	.459	.541	2.02	.516
48705	1.563	.057	1.506	.036	.964	3.13	1.567
55008	1.581	.687	.894	.435	.565	2.60	1.019
55307	1.561	.908	.653	.582	.418	1.89	.329
55907	1.608	.632	.976	.393	.607	2.59	.982
55909	1.658	.810	.848	.488	.512	2.30	.642
57408	1.639	1.177	.462	.717	.283	2.61	.971
57507	1.546	1.141	.405	.738	.262	2.85	1.304
65306	1.683	.965	.718	.573	.427	2.41	.727
81708	1.641	1.221	.420	.744	.256	2.41	.769
Average	1.619	.852	.767	.523	.477	2.65	1.037

TABLE 23.—*Ratio of gliadin to glutenin as the content of their sum increases*—Continued.

GLIADIN-PLUS-GLUTENIN NITROGEN, 1.75 TO 2 PER CENT.

Record number.	Gliadin-plus-glutenin nitrogen.	Percentage of— Gliadin nitrogen.	Percentage of— Glutenin nitrogen.	Proportion of— Gliadin.	Proportion of— Glutenin.	Percentage of— Proteid nitrogen.	Percentage of— Other proteid nitrogen
20707	1.855	1.046	0.809	0.564	0.436	2.77	0.915
20710	1.996	1.125	.871	.564	.436	2.83	.834
21305	1.969	1.049	.920	.533	.467	2.67	.701
21808	1.963	1.046	.917	.533	.467	2.57	.607
21908	1.876	1.015	.861	.541	.459	3.82	1.944
21909	1.976	1.367	.609	.697	.303	4.43	2.454
22205	1.969	1.185	.784	.602	.398	2.81	.841
26906	1.819	.988	.831	.543	.457	2.71	.891
26909	1.879	.996	.883	.531	.469	2.80	.921
27005	1.904	1.066	.838	.559	.441	2.63	.726
27207	1.946	1.278	.668	.652	.348	2.92	.974
27506	1.977	1.147	.830	.580	.420	2.70	.723
28806	1.864	.902	.962	.484	.516	3.02	1.156
33605	1.919	1.124	.795	.585	.415	2.39	.471
38505	1.766	.862	.904	.488	.512	3.61	1.844
39205	1.845	1.117	.728	.605	.395	2.11	.265
48106	1.805	1.035	.770	.573	.427	2.38	.575
48305	1.766	.996	.770	.564	.436	2.87	1.104
48505	1.757	.965	.792	.549	.451	3.66	1.903
55005	1.987	1.102	.885	.555	.445	3.05	1.063
55006	1.754	1.099	.655	.626	.374	3.16	1.406
55206	1.866	.840	1.026	.450	.550	2.56	.694
55305	1.974	1.042	.932	.528	.472	2.48	.506
55508	1.959	1.037	.922	.529	.171	3.11	1.151
55605	1.959	1.044	.915	.533	.467	2.64	.681
55905	1.750	.575	1.175	.328	.672	2.67	.920
55908	1.957	1.075	.882	.549	.451	2.42	.463
56205	1.850	.883	.967	.477	.523	2.51	.660
56206	1.949	1.089	.860	.559	.441	2.42	.471
56207	1.827	.987	.840	.540	.460	2.34	.513
56208	1.946	1.127	.819	.579	.421	2.61	.664
57407	1.858	.935	.923	.503	.497	2.62	.762
65307	1.815	1.052	.763	.579	.421	2.28	.465
65308	1.946	1.090	.856	.560	.440	2.09	.144
69805	1.937	1.142	.795	.589	.411	5.82	3.883
80305	1.770	1.159	.611	.661	.339	1.81	.040
81705	1.956	1.048	.908	.535	.465	1.98	.024
Average	1.889	1.044	.845	.552	.448	2.82	.929

GLIADIN-PLUS-GLUTENIN NITROGEN, 2 TO 2.25 PER CENT.

Record number.	Gliadin-plus-glutenin nitrogen.	Percentage of— Gliadin nitrogen.	Percentage of— Glutenin nitrogen.	Proportion of— Gliadin.	Proportion of— Glutenin.	Percentage of— Proteid nitrogen.	Percentage of— Other proteid nitrogen
17506	2.226	1.458	0.768	0.655	0.345	3.52	1.294
20706	2.053	1.089	.964	.530	.470	2.78	.727
21208	2.146	1.154	.992	.537	.463	3.24	1.094
21807	2.110	1.174	.936	.556	.444	2.73	.620
21809	2.178	1.183	.995	.543	.457	2.73	.552
21811	2.156	1.144	1.012	.531	.469	3.75	1.594
21812	2.023	1.139	.884	.563	.437	4.26	2.237
21813	2.141	1.045	1.096	.488	.512	4.04	1.899
21905	2.181	1.344	.837	.616	.384	2.64	.459
21906	2.096	1.208	.888	.576	.424	3.18	1.084
21907	2.146	1.187	.959	.553	.447	3.35	1.204
22206	2.113	1.271	.842	.601	.399	3.22	1.107
22208	2.142	1.309	.833	.611	.389	3.18	1.038
26905	2.087	1.197	.890	.573	.427	2.76	.673
26908	2.158	1.250	.908	.579	.421	2.96	.802
33107	2.123	1.283	.840	.604	.396	2.35	.227
37707	2.097	1.044	1.053	.498	.502	2.93	.833
39506	2.065	1.281	.784	.620	.380	2.93	.865
40505	2.189	1.143	1.046	.522	.478	2.82	.631
46107	2.076	1.164	.912	.561	.439	2.54	.464
48306	2.135	1.130	1.005	.529	.471	3.29	1.155
48406	2.249	1.290	.959	.574	.426	4.87	2.621
48506	2.171	1.104	1.067	.508	.492	3.20	1.029
55007	2.211	1.248	.963	.564	.436	4.21	1.999
55506	2.197	1.136	1.061	.517	.483	2.80	.603
55507	2.070	1.079	.991	.521	.479	2.63	.560
56105	2.118	1.277	.841	.603	.397	2.73	.612
56106	2.091	1.091	1.000	.522	.478	2.57	.479
56107	2.234	1.033	1.201	.462	.538	2.96	.726
56209	2.208	1.161	1.047	.526	.474	2.59	.382

TABLE 23.—*Ratio of gliadin to glutenin as the content of their sum increases*—Continued.

GLIADIN-PLUS-GLUTENIN NITROGEN, 2 TO 2.25 PER CENT—Continued

Record number.	Percentage of— Gliadin-plus-glutenin nitrogen.	Percentage of— Gliadin nitrogen.	Percentage of— Glutenin nitrogen.	Proportion of— Gliadin.	Proportion of— Glutenin.	Percentage of— Proteid nitrogen.	Percentage of— Other proteid nitrogen.
57007	2.093	1.159	0.934	0.553	0.447	2.65	0.557
57406	2.134	1.080	1.054	.506	.494	2.75	.616
57508	2.053	1.124	.929	.547	.453	2.21	.157
58805	2.112	1.060	1.052	.501	.499	2.74	.628
63106	2.199	1.186	1.013	.539	.461	2.79	.591
66005	2.181	1.142	1.039	.528	.472	2.63	.449
74606	2.046	1.016	1.030	.496	.504	2.30	.254
76206	2.029	1.223	.806	.602	.398	4.45	2.421
81706	2.034	1.701	.333	.816	.184	2.71	.676
Average	2.130	1.187	.943	.557	.443	3.05	.921

GLIADIN-PLUS-GLUTENIN NITROGEN, 2.25 TO 2.50 PER CENT.

Record number.	Gliadin-plus-glutenin nitrogen.	Gliadin nitrogen.	Glutenin nitrogen.	Gliadin.	Glutenin.	Proteid nitrogen.	Other proteid nitrogen.
20709	2.313	1.307	1.006	0.565	0.435	3.05	0.737
20805	2.259	1.215	1.044	.538	.462	3.32	1.061
25808	2.281	1.377	.904	.604	.396	3.09	.809
27508	2.324	1.247	1.077	.537	.463	2.64	.316
28206	2.424	1.366	1.058	.563	.437	3.07	.646
33305	2.407	1.182	1.225	.491	.509	3.41	1.003
33607	2.446	1.391	1.055	.569	.431	3.22	.774
34405	2.443	1.230	1.213	.503	.497	4.33	1.887
37305	2.293	1.208	1.085	.527	.473	2.96	.667
57506	2.344	1.203	1.141	.511	.489	2.80	.456
58207	2.492	1.313	1.179	.526	.474	3.09	.598
58705	2.467	1.195	1.272	.484	.516	3.01	.543
Average	2.374	1.268	1.105	.535	.465	3.16	.791

GLIADIN-PLUS-GLUTENIN NITROGEN, 2.50 PER CENT AND OVER.

Record number.	Gliadin-plus-glutenin nitrogen.	Gliadin nitrogen.	Glutenin nitrogen.	Gliadin.	Glutenin.	Proteid nitrogen.	Other proteid nitrogen.
40205	3.069	1.850	1.219	0.603	0.397	4.69	1.621
42205	2.728	1.480	1.248	.542	.458	3.63	.902
57805	2.684	1.303	1.381	.485	.515	2.87	.186
57905	2.918	1.573	1.345	.539	.461	3.18	.262
72607	2.515	1.459	1.056	.579	.421	5.59	3.075
81505	2.652	1.066	1.586	.401	.599	2.94	.288
92306	4.063	2.388	1.675	.587	.413	4.93	.867
Average	2.947	1.588	1.358	.534	.466	3.98	1.029

TABLE 24.—*Summary of analyses, showing the ratio of gliadin to glutenin as the content of their sum increases.*

Range of percentage of gliadin-plus-glutenin nitrogen.	Percentage of gliadin-plus-glutenin nitrogen.	Number of analyses.	Percentage of— Gliadin nitrogen.	Percentage of— Glutenin nitrogen.	Proportion of— Gliadin.	Proportion of— Glutenin.	Percentage of— Proteid nitrogen.	Percentage of— Other proteid nitrogen.
Below 1	0.484	11	0.276	0.208	0.562	0.438	2.93	2.448
1 to 1.25	1.166	3	.914	.252	.793	.207	2.89	1.721
1.25 to 1.50	1.385	10	.741	.645	.536	.463	2.90	1.518
1.50 to 1.75	1.619	18	.852	.767	.523	.477	2.65	1.037
1.75 to 2	1.889	37	1.044	.845	.552	.448	2.82	.929
2 to 2.25	2.130	39	1.187	.943	.557	.443	3.05	.921
2.25 to 2.50	2.374	12	1.268	1.105	.535	.465	3.16	.791
2.50 and over	2.947	7	1.588	1.358	.534	.466	3.98	1.029

It will be seen from Table 24 that the ratio of gliadin to glutenin remains practically the same as the percentage of their sum increases.

It would therefore be safe to assume that an increase in the gluten content of a given variety of wheat raised in the same region would carry with it a corresponding improvement in its value for bread making, although there might be fluctuations from year to year in quality of gluten, as there is in the quantity.

If the quality of gluten is determined by the ratio of gliadin and glutenin of which it is composed, it is likely that there is some certain proportion that is most desirable. Unfortunately, the investigators who have taken up this subject do not by any means agree upon the proper ratio. Should this be ascertained there would be ample opportunity for the selection of individual plants in which the proportion of gliadin and glutenin would approximate the ideal. There would thus be possible a much more rapid improvement in the quality of wheat than can be accomplished by confining selection to an increase in the gluten.

An obstacle to the usefulness of these determinations in the whole wheat appears in the announcement by Nasmith, already cited, that while gliadin occurs in all portions of the endosperm, glutenin does not appear in the aleurone cells. That being the case, it is difficult to believe that any given ratio between these constituents in the whole wheat could be taken as the one most desirable. The ratio in the gluten alone may, however, have an important influence on its quality, and a certain definite proportion of each may produce an ideal gluten.

In the light of the present knowledge on the subject, a mechanical determination of gluten would seem to be most useful, if it can be made with such small quantities of wheat as are obtained from single plants, while determinations of gliadin and glutenin in the gluten would afford a means of judging of its quality.

SOME RESULTS OF BREEDING TO INCREASE THE CONTENT OF PROTEID NITROGEN.

Selected plants have been grown on a large scale for two years. From these results it is very apparent that a high percentage of nitrogen and the qualities that go with it are transmissible from one generation to another.

In Table 25 are analyses of the plants of the crop of 1902, grouped according to their proteid nitrogen content into classes of from 1 to 2 per cent, 2 to 2.5 per cent, and increasing by 0.5 per cent up to 4.5 per cent and above. Opposite the plant number of each plant of the crop of 1902 are stated its percentage of proteid nitrogen and weight of proteid nitrogen in kernels. On the same line are the plant numbers for the entire progeny in 1903, and following these are the percentage of proteid nitrogen, weight of proteid nitrogen per average kernel, and average weight of kernel for all of these progeny.

The averages for each group are given in Table 26.

TABLE 25.—*Analyses showing transmission of nitrogen from one generation to another.*[a]

1 TO 2 PER CENT PROTEID NITROGEN.

1902				1903			
Record number.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).	Record number.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).
32201	1.51			32206-7	2.64	0.0010055	0.03874
32601	1.99			32605-6 and 8	2.62	.0015963	.07560
63501	1.98			63505-6	2.17	.0007499	.03502
69501	1.94			69505-6	2.39	.0009348	.03894
69701	1.97			69705	2.50	.0003874	.01550
73301	1.12			73306-8	2.586	.0016918	.06582
91901	1.83			91905-6	3.09	.0010830	.03513
92401	1.33			92405-9	2.628	.0024129	.09109
92901	1.67			92905-9	2.811	.0024540	.08814
94101	1.38			94105	2.67	.0006790	.02543
94201	1.63			94205-9	2.576	.0022132	.08738
94401	1.73			94406-7	2.27	.0008092	.03538
94601	1.89			94605-6	1.87	.0016125	.08851
94901	1.99			94905-9	2.85	.0025361	.08899
95501	1.92			95505-10	2.498	.0026506	.10605
Average	1.658			Average	2.587	.0004960	.019907

[a] In this table the average percentage of proteid nitrogen for all plants raised in 1903, resulting from plants of 1 to 2 per cent, 2 to 2.5 per cent, etc., in 1902 is determined by adding together analyses of all plants in that group and dividing by the total number, irrespective of families.

2 TO 2.5 PER CENT PROTEID NITROGEN.

17401	2.45			1740[5-6] [8-10]	2.646	0.0025803	0.09807
34201	2.28			34205-8	2.857	.0023077	.08075
57301	2.33	0.000601	0.02585	57305-8	2.54	.0018351	.07010
Average	2.353	.000601	.02585	Average	2.68	.00051716	.019146

2.5 TO 3 PER CENT PROTEID NITROGEN.

21701	2.50			21705-11	2.78	0.0042343	0.15101
33401	2.73			33405-8	1.977	.0014277	.07274
Average	2.615			Average	2.487	.0005147	.02032

3 TO 3.5 PER CENT PROTEID NITROGEN.

17301	3.04			17305-8	3.207	0.0025519	0.07920
17501	3.14			17505-7	4.006	.0021778	.05595
18901	3.31			18905-6	3.64	.0010439	.02863
20701	3.22			20705-10	2.86	.0034181	.12074
20801	3.49			20805	3.32	.0006999	.02157
21301	3.05			21305-8	3.015	.0021798	.07278
21801	3.10			21805-13	3.13	.0054513	.17668
21901	3.17			2190[5-9] [11-13]	3.527	.0060008	.16783
26901	3.28			26905-9	2.768	.0025943	.09357
27001	3.24			27005	2.63	.0004984	.01895
27201	3.12			27205-7	2.56	.0016114	.06314
27301	3.00			27305-8	2.93	.0022229	.07654
28801	3.31			28805-6	2.96	.0013685	.01623
33101	3.06			33105-7	2.73	.0015199	.05574
33301	3.33			33305	3.41	.0007126	.02090
33601	3.22			33605-7	2.606	.0017186	.06614
34401	3.08	0.000909	0.02956	34405	4.33	.0008635	.01994
34601	3.46	.000948	.02749	34606	3.12	.0006904	.02213
36901	3.18	.000827	.02602	36905	3.88	.0007295	.01880
37301	3.13	.000854	.02731	37305	2.96	.0005881	.01987
37701	3.44	.000685	.01995	37705-7	2.636	.0015390	.05837
37901	3.21	.000831	.02599	37905-6	2.48	.0009112	.03641
38501	3.09	.000814	.02732	38505-6	3.25	.0013476	.01227
38701	3.33	.000693	.02081	38706	2.59	.0005148	.01988
39401	3.31	.000933	.02820	39405	2.88	.0006027	.02093
40201	3.11	.001017	.03271	40205	4.69	.0008776	.01871
40301	3.11	.000914	.02942	40305	3.11	.0006255	.02011

TABLE 25.—*Analyses showing transmission of nitrogen from one generation to another*—Continued.

3 TO 3.5 PER CENT PROTEID NITROGEN—Continued.

1902				1903			
Record number.	Percentage of proteid nitrogen in kernel.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).	Record number.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).
40401	3.32	0.001039	0.03136	40405	3.17	0.0001352	0.01373
40501	3.23	.001050	.03250	40505	2.82	.0006892	.02411
42201	3.46	.000972	.02813	42205-6	2.51	.0008988	.03231
42901	3.37	.000933	.02766	42905	3.17	.0005447	.01866
43401	3.24	.000907	.02800	43105	2.92	.0006594	.02258
43501	3.37	.000772	.02299	43505	4.13	.0006423	.01555
44601	3.33	.000899	.02701	44605-7	2.73	.0016171	.05890
48101	3.16	.000853	.02701	48106	2.38	.0004567	.01919
48301	3.49	.001005	.02882	48305-6	3.08	.0012867	.01235
48501	3.16	.000866	.02748	48505-8	3.065	.0021750	.07253
48701	3.36	.000820	.02445	48705-6	3.06	.0010077	.03287
48801	3.43	.000888	.02595	48806	2.70	.0004877	.01798
49501	3.19	.000791	.02488	49505	3.24	.0006149	.01898
50701	3.36	.000937	.02797	50705-6	3.17	.0010793	.03329
51001	3.33	.000789	.02377	51005	1.34	.0002422	.01804
55001	3.09	.000902	.02928	55005-8	3.255	.0023714	.07295
55201	3.45	.000928	.02697	55205-6	2.83	.0010373	.03688
55301	3.25	.000859	.02661	55305-8	2.27	.0017313	.07496
55901	3.05	.000930	.03052	55905-9	2.558	.0028162	.11169
56101	3.22	.000805	.02507	56105-7	2.75	.0014369	.05233
56201	3.26	.000808	.02485	56205-9	2.495	.0025326	.10169
57001	3.10	.000787	.02548	57005-7	2.706	.0013974	.05174
57101	3.35	.000958	.02860	57105	2.76	.0002527	.00916
57401	3.31	.000894	.02941	57405-8	2.49	.0019599	.07892
57501	3.30	.000785	.02381	57506-9	2.60	.0021279	.08396
58201	3.15	.000781	.02485	58206-7	2.88	.0006767	.02318
58501	3.14	.000832	.02665	58505	2.95	.0008052	.02730
58701	3.23	.000920	.02846	58705	3.01	.0003258	.01082
58901	3.05	.000723	.02379	58905	2.43	.0003292	.01355
59601	3.30	.000990	.03000	59605-6	2.14	.0007684	.03592
62801	3.14			62805	3.25	.0003938	.01212
65301	3.15			65305-8	2.925	.0024199	.08003
66001	3.46			66005-6, 8	3.25	.0017773	.05529
69301	3.12			69305	4.42	.0008767	.01984
69801	3.16			69805-6	3.74	.0016495	.04373
71901	3.02			71905	2.47	.0005531	.02239
72401	3.22			72405-6	3.155	.0019005	.05892
72601	3.17			72605-7	4.04	.0021643	.05274
72701	3.03			72705-8	2.937	.0026515	.08981
72801	3.31			72806	3.01	.0005738	.01906
72901	3.26			72905	2.48	.0003930	.01585
74301	3.13			74305	1.98	.0004054	.02047
74501	3.25			74506-8	2.78	.0014234	.05084
74601	3.17			74605-7	2.486	.0013768	.05562
76201	3.06			76205-6	3.40	.0009400	.02912
80301	3.23			80305	1.81	.0003919	.02165
81401	3.36			81405-6	2.965	.0010576	.03583
81501	3.42			81505	2.94	.0005704	.01940
84401	3.39			84405	2.48	.0005067	.02043
84901	3.10			84905-6	2.875	.0011244	.03902
85201	3.36			85205-6	2.63	.0007556	.02937
86101	3.38			86105-6	2.595	.0008522	.03244
88601	3.24			88605-9	2.566	.0026832	.11179
88901	3.14			88905-6	2.74	.0009933	.03625
92201	3.48			92205-8	2.67	.0020214	.07575
92301	3.49			92305-6	3.93	.0012908	.03223
95701	3.29			95705-7	2.58	.0013009	.05017
Average	3.239	.000875	.02700	Average	2.932	.00056037	.019189

3.5 TO 4 PER CENT PROTEID NITROGEN.

18801	3.55			18805	2.02	0.0003164	0.01567
21201	3.50			21205-12	3.567	.0054768	.15672
22201	3.65			22205-11	3.165	.0037042	.11711
25201	3.63			25205-6	2.735	.0011894	.04347
26101	3.76			26105-7	3.19	.0015273	.05113
27501	3.58			27505-9	2.688	.0028791	.10761

TABLE 25.—*Analyses showing transmission of nitrogen from one generation to another*—Continued.

1902				1903			
Record number.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).	Record number.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).
3.5 TO 4 PER CENT PROTEID NITROGEN—Continued							
33901	3.59	....	....	33905-6	2.21	0.0008932	0.04115
38001	3.82	0.000806	0.02110	38005	2.84	.0005135	.01808
38601	3.79	.001046	.02765	38605-9	3.718	.0036318	.09917
39201	3.98	.001039	.02616	39205	2.11	.0004407	.02089
39501	3.65	.001048	.02877	39506-7	2.975	.0013536	.04568
39601	3.55	.000927	.02619	39606	2.37	.0003177	.01341
42401	3.63	.001327	.02838	42405	3.07	.0006927	.02251
44501	3.57	.000796	.02531	44505	2.94	.0005187	.01764
45001	3.79	.001020	.02690	45005	3.58	.0004927	.01376
45601	3.87	.001238	.03205	45605-6	2.365	.0006777	.02995
45701	3.55	.000865	.02435	45705	4.18	.0007155	.01712
45801	3.87	.001146	.02963	45805	1.84	.0002700	.01234
48401	3.53	.000993	.02822	48405-9	2.90	.0020794	.07511
49901	3.61	.001043	.02898	49905	3.62	.0010640	.02939
55501	3.55	.001020	.02866	55506-8	2.846	.0016285	.05743
55601	3.79	.001050	.02775	55605-8	2.555	.0022356	.08822
57601	3.76	.001030	.02750	57606-8	2.37	.0015451	.06535
57801	3.80	.000891	.02353	57805	2.87	.0005207	.01814
57901	3.64	.000852	.02348	57905	3.18	.0003556	.01118
58801	3.80	.000904	.02384	58805-6	2.31	.0009317	.04048
60601	3.53	.000759	.02155	60605	1.87	.0003180	.01701
63101	3.91	....	....	63105-7	2.82	.0016570	.05951
81701	3.78	....	....	81705-10	2.27	.0031019	.13635
91301	3.57	....	....	91305	3.21	.0007197	.02242
92501	3.56	....	....	92505-7	3.32	.0017483	.05312
Average	3.68	.000990	.02650	Average	2.906	.0005508	.019204
4 TO 4.5 PER CENT PROTEID NITROGEN.							
26801	4.07	....	....	26805-8	2.825	0.0023073	0.08179
28201	4.30	....	....	28206	3.07	.0006126	.01996
46101	4.00	0.000988	0.02472	46105-7	2.69	.0014772	.05495
Average	4.123	.000988	.02472	Average	2.806	.0005496	.019588
MORE THAN 4.5 PER CENT PROTEID NITROGEN.							
50901	4.95	0.001074	0.02171	50905-6	3.435	0.0008992	0.02001
Average	....	....	....	Average	3.435	.0004496	.010005

TABLE 26.—*Summary of analyses, showing transmission of nitrogen from one generation to another.*

Range of percentage of proteid nitrogen.	1902				1903			
	Percentage of proteid nitrogen in kernels.	Number of analyses.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Number of analyses.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).
1 to 2	1.66	15	....	....	2.59	46	0.0004960	0.01991
2 to 2.5	2.35	3	0.000601	0.02585	2.68	13	.0005172	.01915
2.5 to 3	2.61	2	....	....	2.49	11	.0005147	.02032
3 to 3.5	3.24	84	.000875	.02700	2.93	199	.0005604	.01919
3.5 to 4	3.68	31	.000990	.02650	2.91	79	.0005508	.01920
4 to 4.5	4.12	3	.000988	.02472	2.81	8	.0005496	.01959
4.5 and over	4.95	1	.001074	.02171	3.43	2	.0004496	.01000

In Table 26 the averages for each group are stated. This table is designed to show whether there has been a tendency for plants of a certain class to reproduce the qualities pertaining to that class, or whether these are lost in the offspring.

It is unfortunate that there are not a greater number of analyses of plants of medium and of low nitrogen content. The plants selected for reproduction in 1903 were largely those of high nitrogen content, and, consequently, comparatively few analyses of the low nitrogen and medium nitrogen plants of 1903 are at hand.

Table 25 shows that in the main there is a tendency for each class of plants to reproduce in the same relation to the other classes, but that there is less difference between the extreme classes in the offspring than in the parent plants. In other words, while all plants tend to reproduce their own qualities, those plants varying widely from the average produce, in general, offspring varying from the average less widely than did the parents. Although this is a rule, its application to the individual is not universal. Certain plants may be found whose tendency to variation extends through both generations. There is also wide variation between certain plants of the same parent. For instance, the plants numbered from 21205 to 21212, all of which come from the same parent, vary from 2.16 to 5.23 per cent in proteid nitrogen content, while plants 69805 and 69806 vary from 5.82 to 1.66 per cent in this constituent.[a]

It would seem, therefore, entirely reasonable to believe that a very considerable increase in the proteid nitrogen content of wheat may be effected by careful and continuous reproduction from plants of high proteid nitrogen content.

Table 27 contains the analyses of plants raised in 1902 and their progeny raised in 1903, arranged according to the number of grams of proteid nitrogen contained in the average kernel of the former.

TABLE 27.—*Analyses showing transmission of proteid nitrogen in average kernel.*

Range of proteid nitrogen in average kernel (gram).	1902				1903			
	Proteid nitrogen in average kernel (gram).	Number of analyses.	Percentage of proteid nitrogen in kernels.	Weight of average kernel (gram).	Proteid nitrogen in average kernel (gram).	Number of analyses.	Percentage of proteid nitrogen in kernels.	Weight of average kernel (gram).
0.000600 to 0.000700	0.000659	3	3.03	0.02220	0.000496	8	2.59	0.01895
0.000700 to 0.000800	.000776	9	3.29	.02405	.000444	15	2.68	.01673
0.000800 to 0.000900	.000850	18	3.33	.02576	.000544	38	2.91	.01875
0.000900 to 0.001000	.000938	18	3.37	.02796	.000514	35	2.89	.01784
0.001000 and over	.001077	15	3.71	.02880	.000593	28	3.06	.01905

[a] Table 25 represents the properties of each plant grown in 1903 arranged according to immediate families. For instance, plants numbered 17305–17308 are all the offspring of the same plant grown in 1902. The parent bears the number 17301. This is the system of records devised by Prof. W. M. Hays, formerly of the University of Minnesota.

TABLE 28.—*Analyses showing transmission of kernel weight.*

Range of weight of average kernel (gram).	1902				1903			
	Weight of average kernel (gram).	Number of analyses.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).	Weight of average kernel (gram).	Number of analyses.	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in average kernel (gram).
Below 0.024	0.02253	12	3.61	0.000811	0.01684	19	2.69	0.000450
0.024 to 0.026	.02515	12	3.28	.000813	.01740	28	2.88	.000503
0.026 to 0.028	.02709	18	3.43	.000927	.01947	38	2.91	.000562
0.028 to 0.030	.02878	16	3.41	.000993	.01875	31	2.98	.000573
0.030 and over	.03152	6	3.31	.001044	.01869	12	2.96	.000548

Table 28 shows the analyses of plants raised in 1902 and their progeny raised in 1903, arranged according to weight of average kernel. There is more variation in this table than in the preceding one, but the tendency toward transmission of proteid nitrogen in the average kernel may be noted. The averages for 1902 are much higher than for 1903, owing partly to the higher percentage and partly to greater kernel weight.

The weight of the average kernel shows some tendency toward transmission, although there are some variations. It will be noticed that the kernels average much heavier in 1902 than in 1903, and that in spite of this the percentage of proteid nitrogen is higher in 1902. The relation of light kernel and high percentage of nitrogen does not therefore appear to hold as between crops of different years.

All of the qualities of which determinations have been made in both years appear to be transmitted. It may be safely assumed that certain plants will have greater power to transmit these qualities than will the average plant. Such plants will assert themselves in the course of three or four generations. From these plants individuals may be selected that have a combination of the desired qualities.

YIELD OF GRAIN AS AFFECTED BY SUSCEPTIBILITY TO COLD.

As has already been stated, a large number of plants on the breeding plots were killed during the winter of 1902–3. This afforded an opportunity to ascertain the effect of the severe weather upon the surviving plants. The question arose whether the surviving plants of a family of which a large percentage of members were killed yielded less per plant than the plants of a family of which but a small percentage had succumbed. As each spike of the crop of 1902 was represented by a number of plants, and as records of each plant were available, there were very extensive data at hand from which to secure information on the subject.

In Table 29 the surviving plants of each immediate family, or, in other words, the surviving plants descended from the same plant of the previous year, are classified according to the percentage of plants that survived the winter. Thus all plants of which only from 10 to 20 per cent survived are grouped together. In the next class are all plants of which from 20 to 30 per cent survived. The other classes increase by 10 per cent surviving plants until 70 per cent is reached. All plants of which more than 70 per cent survived form the last class.

Table 30 gives a summary of Table 29, the averages for each class being shown. From this table it will be seen that with an increase in the proportion of surviving plants there is an increase in the weight of grain per plant and in the number of kernels per plant. It is therefore to be concluded that decrease in yield from winter-killing is due not only to the loss of plants that are destroyed, but also to a decreased yield from most of the surviving plants.

Table 30 also shows that the weight of the average kernel is not affected by the freezing of a large proportion of the family, the decreased yield being due, it may be assumed, to the decreased number of kernels, owing to a decreased ability to tiller.

With an increase in the proportion of surviving plants there is, perhaps, a slight decrease in the percentage of proteid nitrogen in the kernels and in the number of grams of proteid nitrogen in the average kernel, although this is so slight and so irregular that it would not be safe to draw any conclusions from it. The total production of proteid nitrogen per plant naturally increases.

TABLE 29.—*Yields of plants, arranged according to percentage killed in each family.*

10 TO 20 PER CENT.

Record number for 1902.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (gram).	Number of kernels.	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels (gram).	Proteid nitrogen in average kernel (gram).
18801	11.1	2.1462	137	0.01567	2.02	0.04335	0.0003164
20801	10.0	14.6942	697	.02157	3.32	.48784	.0006999
25201	18.2	7.7295	363	.02173	2.73	.20732	.0005947
33301	16.7	2.9905	156	.01858	2.73	.07566	.0005066
37301	16.7	6.1394	309	.01987	2.96	.18173	.0005881
38001	14.3	2.5134	139	.01808	2.84	.07138	.0005135
39201	16.7	21.5399	1,031	.02089	2.11	.45435	.0004407
39401	16.7	9.3541	447	.02093	2.88	.21399	.0006027
40201	14.3	3.6302	194	.01871	4.69	.17026	.0008776
40401	16.7	.6316	46	.01373	3.17	.02002	.0004352
42901	16.7	1.2499	67	.01866	3.17	.03650	.0005447
43401	16.7	2.8000	124	.02258	2.92	.08176	.0006594
44501	16.7	5.9990	340	.01764	2.94	.17637	.0005187
45001	16.7	3.2340	235	.01376	3.58	.11575	.0004927
45701	14.3	.7532	44	.01712	4.18	.03148	.0007155
45801	16.7	1.5298	124	.01231	1.84	.02815	.0002700
49501	14.3	1.2716	67	.01898	3.21	.04120	.0006149
49901	14.3	.6760	23	.02939	3.62	.02436	.0010640
51001	16.7	15.5835	862	.01804	1.31	.20881	.0002422
57101	16.7	3.7263	407	.00916	2.76	.10285	.0002527
58501	16.7	7.4516	273	.02730	2.95	.21982	.0008052
58701	16.7	2.5436	235	.01082	3.01	.07656	.0003258
58901	16.7	2.3031	170	.01355	2.43	.05596	.0003292
60601	16.7	.5952	35	.01701	1.87	.01113	.0003180
62801	16.7	1.3151	111	.01212	3.25	.04272	.0003938
69301	16.7	2.0430	103	.01984	4.42	.09030	.0008767
74301	16.7	4.4222	216	.02047	1.98	.08756	.0004054
84401	16.7	8.7448	128	.02013	2.48	.21687	.0005067
91301	14.3	3.0940	158	.02242	3.21	.09932	.0007197
94101	14.3	.5595	22	.02543	2.67	.01494	.0006790
Average	15.78	4.7098	251.1	.01856	2.91	.12294	.00054366

TABLE 29.—*Yields of plants, arranged according to percentage killed in each family*—Cont'd.

20 TO 30 PER CENT.

Record number for 1902.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (gram).	Number of kernels.	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels (gram).	Proteid nitrogen in average kernel (gram).
18901	20.0	1.2046	84	0.01431	3.64	0.04437	0.0005219
27001	20.0	16.1120	866	.01895	2.63	.43164	.0004984
34601	28.6	6.1962	280	.02213	3.12	.19332	.0006904
36901	20.0	5.0200	267	.01880	3.88	.19478	.0007295
39601	28.6	4.6383	346	.01341	2.37	.10967	.0003177
40301	25.0	3.6003	179	.02011	3.11	.11197	.0006255
40501	20.0	4.1546	170	.02444	2.82	.11716	.0006892
42201	25.0	1.0827	59	.01615	2.54	.03587	.0004494
42401	20.0	1.4892	66	.02251	3.07	.04572	.0006927
43501	25.0	1.1464	93	.01555	4.13	.05974	.0006423
48701	28.6	5.2800	321	.01643	3.06	.16124	.0005038
48801	25.0	9.8346	547	.01798	2.70	.26553	.0004877
57801	20.0	4.8988	270	.01814	2.87	.14060	.0005207
57901	25.0	2.4731	221	.01118	3.18	.07859	.0003556
58801	28.6	12.5470	626	.02024	2.31	.33541	.0004658
71901	20.0	28.2136	1,260	.02239	2.47	.69688	.0005531
80301	20.0	15.7835	729	.02165	1.81	.28569	.0003919
81501	20.0	2.8327	146	.01940	2.94	.08328	.0005704
91901	22.2	3.4961	199	.01756	3.09	.10771	.0005415
94601	28.6	6.2877	106	.04425	1.87	.11373	.0008062
Average	23.5	6.84457	341.75	.019779	2.88	.18065	.0005527

30 TO 40 PER CENT.

26101	33.3	1.9790	122	0.01704	3.19	0.06318	0.0005091
28201	33.3	4.3698	219	.01996	3.07	.13415	.0006126
28801	33.3	8.3240	386	.02311	2.96	.25019	.0006842
33901	33.3	6.7169	313	.02057	2.21	.12186	.0004466
37901	33.3	.5757	28	.01820	2.48	.01447	.0004556
38501	37.5	5.03306	252	.01814	3.25	.24284	.0006738
38701	33.3	7.2545	365	.01988	2.59	.18789	.0005148
48301	33.3	7.3424	315	.02117	3.08	.21633	.0006433
50901	33.3	2.0631	167	.01000	3.43	.07041	.0004496
59601	33.3	8.4456	474	.01796	2.14	.18099	.0003842
69701	33.3	3.7810	244	.01550	2.50	.09453	.0003874
88901	33.3	7.6051	419	.01812	2.74	.20632	.0004966
92301	33.3	4.1975	253	.01611	3.93	.18308	.0006454
Average	33.6	5.2065	273.6	.01813	2.89	.15125	.0005310

40 TO 50 PER CENT.

17501	42.9	1.1495	55	0.01865	4.01	0.04268	0.0007259
21301	44.4	4.6950	259	.01819	3.01	.14144	.0005449
33101	42.9	2.9905	156	.01858	2.73	.07566	.0005066
44601	42.9	1.8251	93	.01963	2.73	.04998	.0005390
50701	40.0	.5329	32	.01664	3.17	.01712	.0005396
72401	40.0	8.3672	321	.02946	3.15	.26913	.0009502
72801	40.0	2.0970	110	.01906	3.01	.06312	.0005738
72901	40.0	2.6462	167	.01585	2.48	.06563	.0003930
76201	40.0	6.9409	472	.01456	3.40	.22024	.0004700
81401	40.0	2.9064	156	.01791	2.96	.07905	.0005288
86101	40.0	5.3261	314	.01622	2.59	.14008	.0004261
92201	44.4	4.1705	238	.01894	2.67	.11199	.0005053
92501	42.9	5.4034	297	.01771	3.32	.16649	.0005828
94401	42.9	8.6610	484	.01769	2.27	.20640	.0004046
Average	41.7	4.1223	225.3	.01843	2.96	.11736	.0005493

Table 29.—*Yields of plants, arranged according to percentage killed in each family*—Cont'd.

50 TO 60 PER CENT.

Record number for 1902.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (gram).	Number of kernels.	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels (gram).	Proteid nitrogen in average kernel (gram).
17301	50.0	3.0000	156	0.01980	3.21	0.09556	0.0006380
17401	54.5	11.7777	581	.01961	2.65	.30051	.0005161
20701	50.0	6.6626	327	.02012	2.85	.18906	.0005697
27201	50.0	12.9727	611	.02105	2.56	.31569	.0005371
33401	50.0	5.2333	271	.01818	1.98	.10621	.0003569
33601	50.0	6.0463	273	.02205	2.61	.14759	.0005729
34201	57.1	6.8220	328	.02019	2.86	.18949	.0005769
37701	50.0	4.1993	237	.01946	2.64	.12164	.0005130
39501	50.0	1.9040	89	.02284	2.97	.05663	.0006768
45601	50.0	2.3719	140	.01497	2.36	.04852	.0003388
46101	50.0	4.8728	273	.01832	2.69	.13084	.0004924
55201	50.0	6.0242	309	.01844	2.83	.15608	.0005186
57601	57.1	9.3804	435	.02178	2.37	.18680	.0005150
63101	50.0	4.7193	224	.01984	2.82	.12281	.0005523
69801	50.0	7.2278	334	.02186	3.74	.17078	.0008247
85201	50.0	4.2040	295	.01468	2.63	.11078	.0003778
88601	57.1	5.6295	266	.02236	2.57	.14178	.0005366
Average	51.5	6.0616	302.9	.01974	2.73	.15237	.0005361

60 TO 70 PER CENT.

Record number for 1902.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (gram).	Number of kernels.	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels (gram).	Proteid nitrogen in average kernel (gram).
21201	66.7	2.5064	137	0.01956	3.57	0.09431	0.0006846
32201	60.0	5.8304	288	.01937	2.64	.11603	.0005027
32601	66.7	2.9653	166	.01890	2.62	.05309	.0006177
48101	66.7	11.6655	608	.01919	2.38	.27765	.0004567
48501	66.7	6.0446	341	.01813	3.06	.18124	.0005437
55001	66.7	8.6833	476	.01824	3.25	.25347	.0005928
55301	66.7	5.4606	280	.01874	2.27	.12536	.0004328
55501	66.7	10.4714	529	.01914	2.85	.29155	.0005428
57001	60.0	5.0125	319	.01725	2.71	.13688	.0004658
57301	66.7	7.7761	443	.01752	2.54	.20018	.0004588
57401	66.7	7.6312	383	.01973	2.49	.19910	.0004900
57501	66.7	8.1116	382	.02099	2.60	.20327	.0005320
63501	60.0	4.1723	229	.01791	2.17	.06748	.0003749
66001	66.7	5.9586	309	.01919	3.25	.17590	.0005924
72601	60.0	4.6412	265	.01758	4.04	.14328	.0007214
72701	66.7	9.3629	396	.02245	2.94	.28276	.0006629
73301	66.7	7.7977	354	.02194	2.59	.21334	.0005639
74601	60.0	8.3679	451	.01854	2.49	.20681	.0004589
84901	66.7	4.1284	209	.01951	2.87	.13763	.0005622
92901	62.5	4.6848	258	.01763	2.81	.12877	.0004908
95701	60.0	5.4211	318	.01672	2.58	.14079	.0004336
Average	64.6	6.5092	340	.01896	2.80	.17280	.0005324

70 PER CENT AND OVER.

Record number for 1902.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (gram).	Number of kernels.	Weight of average kernel (gram).	Percentage of proteid nitrogen in kernels.	Proteid nitrogen in kernels (gram).	Proteid nitrogen in average kernel (gram).
21701	87.5	9.75524	447	0.02157	2.78	0.30200	0.0006049
21801	80.0	11.5721	622	.01963	3.13	.35575	.0006057
21901	88.9	8.3406	398	.02114	3.53	.30995	.0007501
22201	87.5	4.0677	229	.01674	3.16	.12604	.0005292
26801	80.0	7.1981	329	.02045	2.82	.20306	.0005768
26901	71.4	3.8910	206	.01871	2.77	.10870	.0005189
27301	80.0	6.6162	343	.01913	2.93	.18438	.0005447
27501	71.4	6.8618	310	.02152	2.69	.17267	.0005758
38601	71.4	3.9532	186	.01983	3.72	.11558	.0007264
48401	83.3	4.1668	277	.01502	2.90	.10033	.0004159
55601	83.3	10.2785	435	.02244	2.55	.29008	.0005589
55901	83.3	10.9242	489	.02234	2.56	.27788	.0005632
56101	75.0	10.7383	617	.01744	2.75	.29783	.0004790
56201	83.3	11.2241	563	.02034	2.49	.27997	.0005065
58201	75.0	2.8081	227	.01159	2.88	.08385	.0003383
65301	83.3	7.5858	394	.02001	2.92	.18248	.0006050
74501	100.0	3.4799	191	.01695	2.78	.10355	.0004745
81701	100.0	12.7593	569	.02272	2.27	.29500	.0005170
92401	71.4	4.4131	231	.01822	2.63	.12426	.0004826
94201	83.3	5.9603	339	.01748	2.58	.16548	.0004426
94901	75.0	7.0172	388	.01780	2.85	.21294	.0005072
95501	100.0	7.2956	374	.01767	2.50	.18689	.0004418
Average	82.4	7.3275	371.2	.01902	2.83	.20357	.0005348

TABLE 30.—*Summary of yields of plants, arranged according to percentage killed in each family.*

Percentage of plants grouped according to survivors of 1903 from 1902.	Number of analyses.	Percentage of plants in 1903 surviving from 1902.	Weight of kernels on plant (grams).	Number of kernels per plant.	Weight of average kernel (gram)	Percentage of proteid nitrogen in kernels.	Proteid nitrogen (gram) in—	
							Kernels.	Average kernel.
10 to 20	30	15.8	4.7098	251	0.01856	2.91	0.12294	0.0005437
20 to 30	20	23.5	6.8446	342	.01978	2.88	.18065	.0005527
30 to 40	13	33.6	5.2065	274	.01813	2.89	.15125	.0005310
40 to 50	14	41.7	4.1223	225	.01843	2.96	.11736	.0005493
50 to 60	17	51.5	6.0616	303	.01971	2.73	.15237	.0005361
60 to 70	21	64.6	6.5092	340	.01896	2.80	.17280	.0005324
70 and over	22	82.4	7.3275	371	.01902	2.83	.20357	.0005348

YIELD AND NITROGEN CONTENT OF GRAIN AS AFFECTED BY LENGTH OF GROWING PERIOD.

Early-maturing varieties of wheat are, in general, better yielding sorts in Nebraska than are later maturing ones. There are some exceptions to this rule, however, Turkish Red yielding better than any earlier maturing variety. The advantages from early maturity have usually been ascribed to the cooler weather and greater supply of moisture that obtain in the early summer. The hot, dry weather common in July is thought to prevent the filling out of the kernel and to cause light yield and light volume weight.

Each wheat plant on the breeding plots was harvested separately in 1903, and a record was kept of the date of harvesting of each of these plants. These data have been tabulated for the purpose of showing the relation between the length of the growing season and the yield of grain from individual plants of the same variety.

Table 31 contains these data, tabulated according to the date of ripening. Plants ripening between the 7th and 11th of July, 1903, form the first class, those ripening between July 11 and 15 the second class, and the succeeding classes increase by four days until July 27, all ripening after that date constituting the last class. The dates of ripening thus extend over a period of three weeks.

The season of 1903 was a very wet and cool one. The effect of this upon the wheat crop is shown by the fact that the crop in the field was not ready to harvest until July 10, while usually it is harvested between the 20th and 30th of June. Even at the close of the ripening period the weather did not become dry or hot as compared with the normal season. It will therefore be seen that the ordinary advantages from early maturity did not obtain, or at least not in the customary way. It may also be said that some of the later maturing wheats yielded as well in 1904 as did the Turkish Red.

Table 32 is a summary of Table 31, with a statement of the average for each class.

Table 33 is a summary of the same plants, tabulated according to the yield of grain per plant.

Table 34 is a summary of the same plants, tabulated according to the percentage of proteid nitrogen.

It is very evident from these tables that the early-maturing plants are the most prolific. The weight of the average kernel remains very uniform, so that the later maturing plants do not appear to have produced shrunken kernels. Evidently the plants ripening during the first four days produced the largest amounts of grain, and their kernels were as heavy as those produced later. The smaller productiveness of the later maturing plants in the season of 1903 does not appear to have been due to a shrunken or light kernel.

The percentage of proteid nitrogen appears to be somewhat less in the grain of the early-maturing plants. The number of grams of proteid nitrogen in the average kernel is likewise less in these early-maturing plants.

The relation of length of growing season to both yield and composition of grain is contrary to what might have been supposed. A long growing period without excessively hot or dry weather might naturally be thought to increase the yield and increase the percentage of carbohydrates in the grain.

The season of 1904 was very similar to that of 1903 up to time of wheat harvest. The data for 1904, when tabulated, will serve as a check on the results obtained in 1903.

TABLE 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period.*

DATES RIPE: JULY 7 TO 11, 1903.

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
					Kernels.	Average kernel.
21805	July 10	20.9290	2.69	0.01699	0.56299	0.0004569
21806	do	14.2450	2.71	.02378	.38604	.0006444
21807	do	9.4172	2.73	.02498	.25709	.0006664
21808	do	19.7446	2.57	.01708	.50744	.0004389
21809	do	8.0214	2.73	.01919	.21898	.0005238
21810	do	1.0304	2.69	.019816	.02772	.0005330
21811	do	11.9111	3.75	.021007	.44666	.0007877
21812	do	14.8139	4.26	.01507	.63107	.0006420
21813	do	4.0258	4.04	.01877	.16377	.0007582
55506	July 8	17.8506	2.80	.02062	.49995	.0005773
55507	do	9.8228	2.63	.01949	.25834	.0005126
55605	do	10.9180	2.64	.02184	.28823	.0005765
55606	do	11.0930	2.58	.02205	.28580	.0005690
55607	do	2.3931	2.69	.01734	.06437	.0004665
55608	do	22.5848	2.31	.02699	.52194	.0006236
55905	do	5.7948	2.67	.01751	.15470	.0004674
55906	July 7	7.9968	2.81	.01603	.22471	.0004503
55907	July 8	19.3966	2.59	.02590	.50238	.0006707
55908	do	12.1221	2.42	.02175	.29575	.0005262
55909	July 9	9.2120	2.30	.03050	.21187	.0007016
56106	July 8	12.0161	2.57	.01866	.30881	.0001795
56107	July 7	14.4556	2.96	.01658	.42790	.0004907
56206	July 8	9.3093	2.42	.01829	.22529	.0004426
56207	do	10.9073	2.34	.02361	.25522	.0005524
56208	do	13.5720	2.61	.02356	.34616	.0006149
56209	do	15.8086	2.59	.01661	.40945	.0001310
81505	July 10	2.8327	2.94	.01940	.08328	.0005704
81706	July 8	15.3928	2.71	.02132	.41715	.0005778
81707	do	18.3614	2.34	.02336	.12965	.0005466
81708	do	7.3993	2.41	.02578	.17833	.0006213
81709	do	16.4692	2.28	.02175	.37548	.0004960

TABLE 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period*—Continued.

DATES RIPE: JULY 7 TO 11, 1903—Continued.

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
					Kernels.	Average kernel.
81710	July 8	9.1411	1.92	0.02308	0.17550	0.0004432
88605	July 10	1.6362	2.80	.02731	.04581	.0007640
88606	....do...	9.9456	2.53	.02068	.25162	.0005231
88607	....do...	5.1584	2.61	.02205	.13463	.0005754
88608	....do...	1.5355	2.47	.02075	.03793	.0005125
88609	....do...	9.8719	2.42	.02100	.23890	.0005082
94907	....do...	12.1918	2.94	.01948	.35844	.0005726
94908	....do...	2.3678	1.96	.01894	.04641	.0003713
94909	July 9	3.6977	3.60	.01696	.13312	.0006106
95505	....do...	.3146	2.81	.00850	.00884	.0002389
95506	....do...	11.0548	2.74	.01852	.30291	.0005074
95507	....do...	12.1592	2.59	.02029	.31492	.0005515
95508	....do...	14.4617	2.56	.01954	.37023	.0005003
95509	....do...	2.9475	2.48	.02136	.07310	.0005297
95510	....do...	2.8356	1.81	.01783	.05132	.0003228
95705	July 10	10.3426	2.54	.01626	.26270	.0004131
95706	....do...	5.1629	2.73	.01934	.14095	.0005279
95707	....do...	.7577	2.47	.01457	.01872	.0003599
Average	July 8.9	9.9067	2.69	.02024	.26475	.0005356

DATES RIPE: JULY 11 TO 15, 1903.

21905	July 13	14.3111	2.64	0.01809	0.37781	0.0004777
21906	....do...	10.4800	3.18	.02563	.33403	.0008168
21907	....do...	2.9248	3.35	.01851	.09798	.0006201
21908	....do...	3.5574	3.82	.02056	.13589	.0007855
21909	....do...	12.1819	4.43	.02317	.53889	.0010265
21911	....do...	8.4593	5.48	.02209	.46356	.0012103
21912	....do...	9.7236	2.31	.01907	.22461	.0004404
21913	....do...	10.1925	3.01	.02072	.30680	.0006235
22205	....do...	2.6965	2.81	.00953	.07577	.0002677
22210	....do...	6.0173	3.17	.02019	.19075	.0006401
22211	....do...	11.5675	3.17	.02062	.36671	.0006537
27005	....do...	16.4120	2.63	.01895	.43164	.0004984
27205	....do...	16.4061	2.41	.01841	.39539	.0004437
27206	....do...	19.1854	2.36	.02469	.45276	.0005827
27207	....do...	3.3266	2.92	.02004	.09712	.0005850
27305	....do...	5.5666	2.58	.02085	.14362	.0005379
27306	....do...	13.3011	3.47	.01945	.32853	.0004803
27307	....do...	3.0850	2.53	.01847	.07805	.0004674
27308	....do...	4.5123	4.15	.01777	.18726	.0007373
27505	....do...	12.0399	2.12	.02183	.24942	.0004627
27506	....do...	10.0005	2.70	.02252	.27003	.0006082
27508	....do...	5.5[illegible]24	2.64	.02287	.14608	.0006037
48406	....do...	3.2964	4.87	.01324	.16053	.0006447
48407	....do...	11.2890	1.50	.01572	.16933	.0002358
48408	....do...	.3485	2.81	.01291	.00979	.0003627
48409	....do...	6.4302	2.02	.02048	.12989	.0004137
48506	....do...	9.4585	3.20	.01701	.30267	.0005444
48507	....do...	1.6036	2.64	.02296	.04233	.0006062
48508	....do...	11.2008	2.76	.01858	.30986	.0005127
48806	....do...	9.8346	2.70	.01798	.26553	.0004877
55005	....do...	7.9684	3.05	.02028	.24303	.0006185
55006	....do...	7.1852	3.16	.01593	.22705	.0005034
55305	....do...	2.5160	2.48	.01507	.06240	.0003736
55306	....do...	4.1323	2.18	.01931	.09008	.0004210
55307	....do...	5.6864	1.89	.01663	.10747	.0003142
55308	....do...	9.5078	2.54	.02395	.24150	.0006225
56105	....do...	5.7431	2.73	.01709	.15679	.0004667
56205	....do...	6.5232	2.51	.01959	.16373	.0004917
57005	....do...	1.5364	2.71	.01746	.04164	.0004731
57006	....do...	10.1836	2.76	.01453	.28197	.0004010
57007	....do...	3.3176	2.65	.01975	.08792	.0005233
57105	....do...	3.7263	2.76	.00916	.10285	.0002527
57305	....do...	8.5777	3.19	.01666	.29188	.0005826
57306	....do...	7.9772	2.86	.01838	.22815	.0005257
57307	....do...	4.7117	2.43	.01801	.11445	.0004387
57308	....do...	9.8378	1.69	.01705	.16626	.0002881
57405	....do...	.8328	1.98	.02031	.01649	.0004022
57406	....do...	2.4923	2.75	.01846	.06854	.0005077
57407	....do...	14.9992	2.62	.01968	.39297	.0005157

Table 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period*—Continued.

DATES RIPE: JULY 11 TO 15, 1903—Continued.

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in Kernels.	Proteid nitrogen (gram) in Average kernel.
57408	July 13	12.2004	2.61	0.02047	0.31842	0.0005343
57506	do	2.7616	2.80	.01534	.07733	.0004296
57507	do	6.9861	2.85	.01946	.19905	.0005545
57508	do	12.0728	2.21	.03177	.26680	.0007021
57509	do	10.6261	2.54	.01739	.26990	.0004417
57606	do	3.0790	2.74	.02333	.08436	.0006391
57607	do	16.4433	1.73	.02234	.24847	.0003865
57608	do	8.6189	2.64	.01968	.22756	.0005195
58206	do	1.3961	2.67	.00943	.03728	.0002519
58207	do	4.2207	3.09	.01375	.13042	.0004248
65305	do	1.8018	4.92	.02310	.08865	.0011365
65306	do	9.8298	2.41	.01807	.23690	.0004355
65307	do	7.0051	2.28	.01878	.15971	.0004282
65308	do	11.7006	2.09	.02008	.24468	.0004197
94905	July 11	4.4423	2.35	.01553	.10439	.0003650
94906	do	12.3862	3.41	.01808	.42236	.0006166
Average	July 13	7.6611	2.81	.01887	.20820	.0005290

DATES RIPE: JULY 15 TO 19, 1903

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in Kernels.	Proteid nitrogen (gram) in Average kernel.
18906	July 15	0.9229	3.48	0.01420	0.03212	0.0004941
21706	do	19.3318	4.71	.02390	.91052	.0011283
21707	do	12.3685	2.19	.02125	.27086	.0004654
26105	do	1.8242	3.02	.01393	.05508	.0003662
33406	July 18	4.6045	2.87	.01627	.13215	.0004670
34206	do	1.5940	3.73	.01968	.05946	.0007340
34208	do	2.9886	2.13	.01916	.06366	.0004081
37906	July 15	.2062	2.44	.01086	.00503	.0002649
45005	do	3.2340	3.58	.01376	.11575	.0004927
45605	do	.7081	2.82	.01161	.01997	.0003273
48405	do	.9701	3.31	.01276	.03211	.0004225
48505	do	1.9154	3.66	.01398	.07010	.0005117
51005	do	15.5835	1.34	.01804	.20881	.0002422
63105	July 18	1.5452	3.24	.01717	.05007	.0005563
63106	do	3.3006	2.79	.02001	.09208	.0005581
66006	do	6.0090	3.54	.01642	.21272	.0005812
72605	do	1.1166	4.65	.01718	.05192	.0007988
72806	do	2.0970	3.01	.01906	.06312	.0005738
74605	do	7.1181	2.60	.01784	.18507	.0004638
81705	do	9.7922	1.98	.02106	.19388	.0004170
88905	July 16	5.3069	2.83	.01811	.15019	.0005126
88906	do	9.9034	2.65	.01814	.26245	.0004807
91905	do	3.4436	3.36	.01739	.11570	.0005844
91906	do	3.5486	2.81	.01774	.09972	.0004986
92205	do	5.2616	2.74	.01525	.14417	.0004179
92206	do	1.1074	2.67	.02407	.02957	.0006428
92207	do	3.6926	2.55	.01767	.09416	.0004505
92208	do	6.6206	2.72	.01876	.18008	.0005102
92305	do	2.3859	2.93	.01491	.06991	.0004369
92306	do	6.0091	4.93	.01732	.29625	.0008539
92406	do	8.2366	3.11	.02168	.25616	.0006741
92407	do	.8983	1.66	.01695	.01491	.0002814
92408	do	3.7820	2.97	.01827	.11233	.0005426
92409	do	5.7131	2.30	.01814	.13140	.0004171
92506	do	3.8709	4.39	.01690	.16993	.0007421
92507	do	9.6779	2.58	.01916	.24969	.0004944
92905	do	2.7000	3.50	.01534	.09450	.0005369
92906	do	2.8816	2.99	.01592	.08616	.0004760
92907	do	4.4673	2.56	.02040	.11436	.0005220
92908	do	3.2388	2.32	.01732	.07514	.0004018
92909	do	10.1363	2.70	.01916	.27367	.0005173
94105	July 15	.5595	2.67	.02543	.01494	.0006790
94205	July 16	1.2117	1.65	.01893	.01999	.0003124
94206	do	7.5006	2.78	.01866	.20851	.0005187
94207	do	13.7057	2.86	.01909	.39199	.0005460
94208	do	3.7828	3.10	.01175	.11727	.0003642
94406	do	10.5556	2.47	.01923	.26073	.0004749
94407	do	6.7664	2.07	.01615	.14007	.0003343
94605	do	.7319	1.95	.01307	.01427	.0002549
94606	do	11.8435	1.80	.07544	.21319	.0013576
Average	July 16.2	5.1354	2.87	.01869	.11452	.0005222

TABLE 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period*—Continued.

DATES RIPE: JULY 19 TO 23, 1903.

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in— Kernels	Proteid nitrogen (gram) in— Average kernel.
17409	July 21	14.8957	2.75	0.01857	0.40964	0.0005108
17505	July 20	.3885	4.70	.01340	.01826	.0006296
18805	July 21	2.1462	2.02	.01567	.04335	.0003164
20707	do	9.9070	2.77	.02282	.27443	.0006181
20708	July 20	2.4690	2.58	.02024	.06399	.0005221
21211	July 21	.2806	3.15	.02806	.00884	.0008839
21306	July 20	4.1516	2.90	.01837	.12039	.0005327
21308	do	5.8080	3.45	.01641	.20038	.0005660
21710	July 21	.8478	2.59	.01437	.02196	.0003722
21711	do	17.1820	2.71	.01968	.46563	.0005334
22209	do	.4336	3.84	.01399	.01665	.0005371
26806	July 20	2.7255	2.60	.01793	.07086	.0004662
26807	do	17.2324	2.80	.02390	.48250	.0006692
26808	do	3.8811	3.09	.01748	.11992	.0005402
26906	July 22	4.2376	2.71	.01859	.11481	.0005037
26907	July 20	1.8276	2.61	.01792	.04995	.0004677
26909	do	2.9999	2.80	.01667	.08400	.0004667
32606	July 22	2.0162	2.88	.02145	.05807	.0006177
33105	July 21	2.5601	2.91	.01939	.07450	.0005644
33905	do	11.1476	1.61	.02194	.17948	.0003533
33906	do	2.2862	2.81	.01921	.06424	.0005399
38606	do	8.4605	2.63	.02110	.22251	.0005549
38607	do	.3037	4.55	.01598	.01382	.0007273
38608	do	3.0228	2.82	.01913	.08522	.0005394
38609	do	6.7665	2.74	.02319	.18540	.0006475
38706	July 20	7.2545	2.59	.01988	.18789	.0005148
40405	July 21	.6316	3.17	.01373	.02002	.0004352
42206	do	.3161	1.46	.01264	.00462	.0001846
44607	July 20	1.8246	2.44	.01806	.04452	.0004408
48106	July 21	11.6655	2.38	.01919	.27765	.0004567
48305	July 20	12.0278	2.87	.02543	.34521	.0007299
48306	do	2.6571	3.29	.01692	.08742	.0005568
48706	do	6.1989	3.00	.01635	.18595	.0004906
55007	do	2.1571	4.21	.01828	.09082	.0007696
55008	July 21	17.4226	2.60	.01846	.45299	.0004799
55206	do	11.3592	2.56	.01965	.29079	.0005031
58805	July 20	23.1471	2.74	.01999	.63422	.0005464
59606	do	9.7081	2.16	.01712	.20970	.0003698
63107	do	9.3120	2.43	.02233	.22628	.0005426
63505	July 21	4.0230	1.90	.01934	.07644	.0003674
66008	July 20	3.1555	3.59	.01814	.11328	.0006510
69305	do	2.0430	4.42	.01984	.09030	.0008767
71905	do	28.2136	2.47	.02239	.69688	.0005531
72606	do	9.3629	1.89	.01724	.18538	.0003414
72607	do	3.4412	5.59	.01832	.19253	.0010241
72705	do	9.1522	2.13	.02191	.19936	.0004668
72706	do	14.6802	3.86	.02484	.56666	.0009588
72707	July 21	4.5806	3.49	.02036	.15986	.0007105
72708	July 20	9.0386	2.27	.02270	.20518	.0005154
74507	July 21	9.2130	3.02	.01869	.27823	.0005644
76206	July 20	5.4411	4.45	.01217	.24213	.0005417
84905	do	.7130	2.32	.01927	.01654	.0004471
84906	do	7.5438	3.43	.01975	.25873	.0006773
85206	July 21	4.9315	2.66	.01312	.13118	.0003332
92405	do	3.4356	3.10	.01605	.10650	.0004977
94209	do	3.6006	2.49	.01895	.08965	.0004719
Average	July 20.1	6.5399	2.93	.01886	.18064	.0005482

DATES RIPE: JULY 23 TO 27, 1903.

17305	July 23	3.6302	3.03	0.01984	0.10999	0.0006010
17306	do	3.9968	3.09	.01645	.12350	.0005082
17308	do	1.2275	3.25	.02012	.03994	.0006540
17406	do	2.0907	3.29	.01686	.06878	.0005547
17408	do	9.2038	2.18	.01852	.20065	.0004037
17410	do	16.9987	2.88	.02285	.48957	.0006580
20705	do	1.8517	3.09	.01698	.05722	.0005249
20706	do	3.3138	2.78	.02033	.09212	.0005652
20710	do	17.1115	2.83	.01974	.48428	.0005586
20805	do	14.6942	3.32	.02157	.48784	.0006999

Table 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period*—Continued.

DATES RIPE: JULY 23 TO 27, 1903—Continued.

Record number.	Date ripe.	Yield (grams).	Percentage of protein nitrogen.	Weight of average kernel (gram).	Protein nitrogen (gram) in Kernels.	Protein nitrogen (gram) in Average kernel.
21307	July 24	2.5691	3.04	0.01796	0.07810	0.0005461
21705	July 23	1.5420	2.45	.02659	.03778	.0006514
21708	....do...	9.2850	2.33	.02381	.21634	.0005547
21709	....do...	7.7296	2.47	.02141	.19092	.0005289
22206	....do...	2.5712	3.22	.01720	.08086	.0005538
22208	....do...	1.9090	3.18	.01619	.06071	.0005114
26905	July 24	6.4102	2.76	.01966	.17692	.0005427
26908	....do...	3.9797	2.96	.02073	.11780	.0006135
27507	July 23	1.3746	3.08	.01833	.04234	.0005646
27509	....do...	5.3615	2.90	.02206	.15549	.0006399
28805	....do...	2.1851	2.91	.02512	.04359	.0007309
28806	....do...	14.4630	3.02	.02111	.43679	.0006376
33106	....do...	.3089	2.94	.01716	.00908	.0005045
33107	....do...	6.1026	2.35	.01919	.14341	.0004510
33405	....do...	8.1268	2.03	.01930	.16498	.0003919
34205	....do...	9.1498	2.73	.01972	.24979	.0005383
34207	....do...	13.5556	2.84	.02219	.38505	.0006273
38506	July 24	1.6799	2.89	.01975	.04855	.0005712
38605	July 23	1.2124	5.85	.01987	.07093	.0011627
40205	....do...	3.6302	4.69	.01871	.17026	.0008776
40305	....do...	3.6003	3.11	.02011	.11197	.0006255
42905	....do...	1.2499	3.17	.01866	.03650	.0005447
44505	....do...	5.9990	2.94	.01764	.17637	.0005187
44606	....do...	2.5235	2.90	.02035	.07318	.0005902
45606	....do...	4.0358	1.91	.01834	.07708	.0003504
45705	....do...	.7532	4.18	.01712	.03148	.0007155
45805	....do...	1.5298	1.84	.01234	.02815	.0002700
46107	....do...	8.3935	2.54	.01756	.21319	.0004460
50705	....do...	.5958	3.54	.01986	.02109	.0007032
50706	....do...	.4701	2.80	.01343	.01316	.0003761
50905	....do...	2.3982	3.30	.01085	.07914	.0003581
55205	July 24	.6893	3.10	.01723	.02137	.0005342
57805	....do...	4.8988	2.87	.01814	.14060	.0005207
57905	....do...	2.4731	3.18	.01118	.07859	.0003556
58505	July 23	7.4516	2.95	.02730	.21982	.0008052
58705	....do...	2.5436	3.01	.01082	.07656	.0003258
60605	....do...	.5952	1.87	.01701	.01113	.0003180
62805	....do...	1.3451	3.25	.01212	.04272	.0003938
74606	....do...	9.6451	2.30	.02079	.22184	.0004781
74607	....do...	8.3406	2.56	.01699	.21352	.0004349
91305	July 24	3.0940	3.21	.02242	.09932	.0007197
92505	....do...	2.6615	3.00	.01706	.07985	.0005118
Average..	July 23.2	4.9015	2.93	.01878	.13654	.0005544

DATES RIPE: JULY 27, 1903, OR LATER.

17307	July 27	3.1454	3.46	0.02279	0.10883	0.0007886
17405	....do...	15.6996	2.13	.02127	.33441	.0004531
17506	....do...	2.2881	3.52	.02460	.08044	.0008660
17507	....do...	.7720	3.80	.01795	.02934	.0006822
18905	....do...	1.4864	3.81	.01443	.05663	.0005498
20709	....do...	5.3229	3.05	.02063	.16235	.0006292
21205	....do...	2.3642	3.16	.01922	.07471	.0006074
21206	....do...	2.8564	5.23	.01917	.14939	.0010026
21207	....do...	2.3066	2.96	.01955	.06804	.0005766
21208	....do...	5.1594	3.24	.01798	.16712	.0005824
21209	....do...	1.4484	3.61	.01627	.05228	.0005875
21210	....do...	3.9143	5.03	.01577	.19689	.0007934
21212	....do...	1.7216	2.16	.02049	.03718	.0004427
21305	....do...	6.2514	2.67	.020037	.16691	.0005350
22207	....do...	3.2787	2.77	.01940	.09082	.0005374
25205	....do...	10.7836	2.71	.02066	.28560	.0005599
25206	....do...	4.6754	2.76	.02281	.12904	.0006295
26106	....do...	2.0737	2.63	.02304	.05454	.0006060
26107	....do...	2.0390	3.92	.01416	.07993	.0005551
26805	....do...	4.9456	2.81	.02248	.13897	.0006317
28206	....do...	4.3698	3.07	.01996	.13415	.0006126
32206	....do...	10.4036	1.81	.02052	.18831	.0003714
32207	....do...	1.2573	3.48	.01822	.04375	.0006341
32605	....do...	5.2268	1.20	.02323	.06272	.0002788

TABLE 31.—*Yield and nitrogen content of grain, tabulated according to length of growing period*—Continued.

DATES RIPE: JULY 27, 1903, OR LATER—Continued.

Record number.	Date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
					Kernels.	Average kernel.
32608	July 27	1.0183	3.78	0.01851	0.03849	0.0006998
33305	do	3.1346	3.41	.02090	.10689	.0007126
33407	do	7.0889	1.62	.02271	.11223	.0003679
33408	do	1.1132	1.39	.01446	.01547	.0002009
33605	do	7.0596	2.39	.02345	.16872	.0005605
33606	do	8.1890	2.21	.02144	.18098	.0004738
33607	do	2.8903	3.22	.02125	.09307	.0006843
34405	do	4.1281	4.33	.01994	.17875	.0008635
34606	do	6.1962	3.12	.02213	.19332	.0006904
36905	do	5.0200	3.88	.01880	.19478	.0007295
37305	do	6.1394	2.96	.01987	.18173	.0005881
37705	do	8.0905	2.64	.01972	.23998	.0005327
37706	do	1.2069	2.34	.02155	.02824	.0005053
37707	do	3.3004	2.93	.01710	.09670	.0005010
37905	Aug. 4	.9452	2.53	.02555	.02391	.0006433
38005	July 27	2.5134	2.84	.01808	.07138	.0005135
38505	do	12.1088	3.61	.02252	.43713	.0007764
39205	do	21.5399	2.11	.02089	.45435	.0004407
39405	do	9.3541	2.88	.02093	.21399	.0006027
39506	Aug. 4	1.9218	2.93	.02869	.05631	.0008404
39507	July 27	1.8862	3.02	.01699	.05696	.0005132
39606	do	4.6383	2.37	.01341	.10967	.0003177
40505	do	4.1546	2.82	.02444	.11716	.0006892
42205	do	1.8494	3.63	.01967	.06713	.0007142
42405	do	1.4892	3.07	.02251	.04572	.0006927
43405	do	2.8000	2.92	.02258	.08176	.0006594
43505	Aug. 4	1.4464	4.13	.01555	.05974	.0006423
44605	July 27	1.1271	2.86	.02049	.03223	.0005861
46105	do	4.6146	3.00	.01775	.13843	.0005324
46106	do	1.6103	2.54	.01964	.04090	.0004988
48705	do	4.3615	3.13	.01652	.13652	.0005171
49505	do	1.2716	3.24	.01898	.04120	.0006149
49905	do	.6760	3.62	.02939	.02436	.0010640
50906	do	1.7280	3.57	.01516	.06169	.0005411
55508	do	3.7407	3.11	.01732	.11636	.0005386
58806	do	1.9469	1.88	.02049	.03660	.0003853
58905	do	2.3031	2.43	.01355	.05596	.0003292
59605	do	7.1828	2.12	.01880	.15228	.0003986
63506	do	2.3986	2.44	.01568	.05853	.0003825
66005	do	7.6690	2.63	.02073	.20170	.0005451
69506	do	13.5696	2.50	.02047	.33923	.0005117
69805	do	2.4420	5.82	.02220	.14213	.0012921
69806	do	12.0136	1.66	.02153	.19943	.0003574
72405	do	8.4415	3.36	.03963	.28363	.0013316
72406	do	8.2929	2.95	.01929	.24464	.0005689
72905	do	2.6462	2.48	.01585	.06563	.0003930
73307	do	.5572	2.39	.02229	.01332	.0005327
73308	do	14.2986	2.92	.02291	.41752	.0006539
74305	do	4.4222	1.98	.02047	.08756	.0004054
74506	do	.4096	2.73	.01781	.01118	.0004862
74508	do	.8172	2.60	.01434	.02125	.0003728
76205	do	8.4407	2.35	.01695	.19836	.0003982
80305	do	15.7835	1.81	.02165	.28569	.0003919
81405	do	4.5737	2.62	.01862	.11710	.0004879
81406	do	1.2391	3.31	.01721	.04101	.0005697
84405	do	8.7448	2.48	.02043	.21687	.0005067
85205	do	3.4766	2.60	.01625	.09039	.0004224
86105	do	3.0282	2.56	.01495	.07964	.0003923
86106	do	7.6241	2.63	.01749	.20052	.0004599
Average	July 27.2	4.6636	2.94	.01992	.12854	.0005800

TABLE 32.—*Summary of yield and nitrogen content of grain, tabulated according to length of growing period.*

Plants grouped according to date ripe.	Number of analyses.	Average date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
						Kernels.	Average kernel.
July 7 to 11	49	July 8.9	9.9067	2.69	0.02024	0.26475	0.0005356
July 11 to 15	65	July 13	7.6611	2.81	.01887	.20820	.0005290
July 15 to 19	50	July 16.2	5.1354	2.87	.01869	.14452	.0005222
July 19 to 23	56	July 20.1	6.5399	2.93	.01886	.18064	.0005482
July 23 to 27	52	July 23.2	4.9015	2.93	.01878	.13654	.0005544
July 27, or later	83	July 27.2	4.6636	2.94	.01992	.12854	.0005800

TABLE 33.—*Summary of nitrogen content, etc., tabulated according to yield per plant.*

Plants grouped according to yield (in grams).	Number of analyses.	Average date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
						Kernels.	Average kernel.
Below 1	31	July 20.2	0.6049	2.91	0.01683	0.01731	0.0004916
1 to 2.5	67	July 21.9	1.7673	3.09	.01852	.05456	.0005730
2.5 to 5	88	July 20	3.5683	3.03	.01796	.10794	.0005445
5 to 10	94	July 18.3	7.6706	2.68	.01997	.20270	.0005351
10 to 15	52	July 15.1	12.2573	2.71	.02168	.33433	.0005774
15 to 20	20	July 15.1	17.1908	2.54	.02103	.43921	.0005382
More than 20	4	July 14.5	23.7186	2.55	.02159	.60401	.0005450

TABLE 34.—*Summary of yield, etc., tabulated according to nitrogen content.*

Plants grouped according to percentage of nitrogen.	Number of analyses.	Average date ripe.	Yield (grams).	Percentage of proteid nitrogen.	Weight of average kernel (gram).	Proteid nitrogen (gram) in—	
						Kernels.	Average kernel.
Below 1.5	4	July 22.5	5.8099	1.35	0.01709	0.07290	0.0002266
1.5 to 2	25	July 18.5	2.7423	1.80	.02124	.11620	.0003867
2 to 2.25	18	July 19.8	8.9542	2.12	.02030	.19070	.0004325
2.25 to 2.5	47	July 17.3	7.3389	2.39	.02000	.18478	.0004773
2.5 to 2.75	82	July 16.3	8.0817	2.63	.01938	.21280	.0005102
2.75 to 3	67	July 19.6	5.9093	2.85	.01910	.16609	.0005454
3 to 3.25	47	July 21.2	4.4497	3.11	.01824	.13847	.0005667
3.25 to 3.5	20	July 20.7	4.6756	3.37	.01870	.15189	.0006213
3.5 to 4	23	July 21.5	3.6486	3.68	.01852	.13513	.0006807
More than 4	25	July 19.5	4.5431	4.72	.01819	.21239	.0008639

RELATION OF SIZE OF HEAD TO YIELD, HEIGHT, AND TILLERING OF PLANT.

The size of the head has always been considered to be closely connected with the productiveness of wheat. The well-known work of Hallet in increasing the yielding qualities of wheat is perhaps the best example of wheat improvement by the selection of plants having large heads. Whether large heads or a large number of medium-sized heads on a plant are more desirable is still a question.

Table 35 gives the yields, etc., of between 300 and 400 plants, tabulated according to the number of kernels on the head. Table 36 is a summary of these, while Tables 37 and 38 consist of the same data tabulated according to the yield per plant and yield per head, respectively.

It will be seen from Table 36 that the heads of slightly more than medium size produced the largest yields of grain; that the weight of the average kernel did not increase with the size of the head, nor did it decrease except on the very largest heads; that the plants with somewhat more than average-sized heads were the tallest, and that the plants with medium-sized heads or slightly less tillered most largely.

Table 37 shows that with an increased yield per plant there is a constant increase in the height and tillering of the plant.

Table 38 indicates that the yield per head and yield per plant do not increase together, but that the largest yielding plants are those of medium yield per head. The same would seem to be true of the height and tillering of the plant. The weight of the average kernel increases quite uniformly with the yield per head.

In considering these results it must be borne in mind that these plants were grown 6 inches apart each way, and were therefore not under the conditions that would obtain in a thickly drilled or broadcasted field, where lack of ability to tiller would be compensated for by the larger number of plants. However, the variety of wheat yielding best in Nebraska is one having only a medium-sized or even small head, as compared with most wheats, but it is a strong-tillering variety.

TABLE 35.—*Relation of size of head to yield, height, and tillering of plant.*

SIZE OF HEAD, BELOW 16 KERNELS.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
17308	15.2	1.2275	0.3069	0.02012	59	5
17406	15.5	2.0907	.2613	.01686	65	11
18805	15.2	2.1462	.2385	.01567	65	18
20708	13.6	2.4690	.2743	.02024	60	11
21211	10.0	.2806	.2806	.02806	45	2
22209	15.5	.4336	.2168	.01399	70	6
26805	15.7	4.9456	.3533	.02248	68	26
32207	13.8	1.2573	.2515	.01822	47	5
37905	12.3	.9452	.3151	.02555	52	3
39506	11.2	1.9218	.3203	.02869	48	6
42206	12.5	.3161	.1580	.01264	63	5
44607	12.6	2.5235	.2281	.02035	52	12
48408	13.5	.3485	.1742	.01291	45	3
49905	11.5	.6760	.3380	.02939	49	2
50705	15.0	.5958	.2979	.01986	40	3
73307	12.5	.5572	.2786	.02229	46	4
74506	12.5	.4096	.2048	.01781	68	2
94105	11.0	.5595	.2797	.02543	51	1
Average	13.3	1.3169	.2654	.02059	55.2	6.9

SIZE OF HEAD, 16 TO 20 KERNELS.

17410	19.1	16.9987	0.4358	0.02285	84	46
21205	17.6	2.3642	.3378	.01922	55	10
21305	16.4	6.2514	.3290	.02004	65	21
21307	17.9	2.5691	.3211	.01796	53	10
21705	19.3	1.5420	.5140	.02659	73	3
21710	19.7	.8478	.2826	.01437	59	5

Table 35.—*Relation of size of head to yield, height, and tillering of plant*—Continued.

SIZE OF HEAD, 16 TO 20 KERNELS—Continued.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
21807	18.8	9.4172	0.4709	0.02498	77	25
22207	18.8	3.2787	.3643	.01940	65	16
22208	16.8	1.9090	.2727	.01619	57	8
26906	19.0	4.2376	.3531	.01859	70	16
26909	18.0	2.9999	.3000	.01667	50	10
28206	19.9	4.3698	.3972	.01996	80	26
33106	18.0	.3089	.3089	.01716	43	2
37706	18.7	1.2069	.4023	.02155	42	4
37906	19.0	.2063	.2063	.01086	50	2
38005	19.8	2.5134	.3591	.01808	53	7
38607	19.0	.3037	.3037	.01598	56	2
38608	17.6	3.0228	.3359	.01913	60	11
38609	19.5	6.7665	.4511	.02309	65	6
42205	18.8	1.8494	.1699	.01967	68	6
44605	18.3	1.1271	.3757	.02049	53	3
44606	17.7	2.5235	.3605	.02035	52	8
48405	19.0	.9701	.2425	.01276	55	5
50706	17.5	.4701	.2350	.01343	38	2
55905	18.4	5.7948	.3219	.01751	75	34
55906	19.2	7.9968	.3076	.01603	85	40
56105	17.7	5.7431	.3023	.01709	70	35
56207	17.7	10.9073	.4195	.02361	84	42
57307	16.3	4.7117	.2945	.01801	67	17
69705	17.4	3.7810	.2701	.01550	88	28
74508	19.0	.8172	.2724	.01434	50	1
81708	19.1	7.3933	.4933	.02578	86	20
88608	18.5	1.5355	.3839	.02075	69	4
92207	19.0	3.6926	.3357	.01767	73	15
92505	17.3	2.6615	.2957	.01706	68	12
95510	19.9	2.8356	.3514	.01783	70	8
Average	18.4	3.7758	.3383	.01862	64.1	13.7

SIZE OF HEAD, 20 TO 24 KERNELS.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
17305	22.9	3.6302	0.4538	0.01984	61	12
17408	23.7	9.2038	.4383	.01852	73	24
17507	21.5	.7720	.3860	.01795	78	4
20705	21.8	1.8517	.3703	.01698	55	6
20706	23.3	3.3138	.4734	.02033	61	7
20707	21.1	9.9070	.4718	.02282	75	22
20709	23.5	5.3229	.4839	.02063	67	13
21207	23.6	2.3066	.4613	.01955	60	6
21212	21.0	1.7216	.4304	.02049	50	5
21305	22.6	1.1516	.4152	.01837	60	11
21707	23.3	12.3685	.4947	.02125	90	24
21708	20.5	9.2850	.4887	.02381	85	26
21809	20.9	8.0214	.4011	.01919	84	25
21811	21.0	11.9114	.4412	.02101	87	29
21812	22.9	14.8139	.3445	.01507	90	54
21907	22.6	2.9248	.4178	.01851	82	8
22205	23.6	2.6965	.2217	.00953	80	54
26106	22.5	2.0737	.5181	.02304	60	9
26806	21.7	2.7255	.3894	.01793	56	12
26807	21.8	17.2324	.5222	.02390	76	40
27207	20.7	3.3266	.4158	.02004	75	9
27307	23.8	3.0850	.4407	.01847	80	10
27505	21.6	12.0399	.4815	.02183	84	38
28805	21.7	2.1851	.5463	.02512	65	6
33105	22.0	2.5601	.4267	.01939	65	12
33405	23.4	8.1268	.4515	.01930	68	20
33407	21.8	7.0889	.5063	.02271	67	18
33906	23.8	2.2862	.4572	.01921	67	9
38606	22.3	8.4605	.4700	.02110	71	24
38706	21.5	7.2545	.4267	.01988	75	30
40405	23.0	.6316	.3158	.01373	54	3
43505	23.2	1.4464	.3616	.01555	45	3
45605	20.3	.7081	.2360	.01161	55	6
45705	22.0	.7532	.3766	.01712	58	6
48106	21.0	11.6655	.4023	.01919	79	39
48305	23.6	12.0278	.6014	.02543	81	28
48406	22.6	3.2964	.2997	.01321	68	13
48507	23.3	1.6036	.5345	.02296	63	7

Table 35.—*Relation of size of head to yield, height, and tillering of plant*—**Continued.**

SIZE OF HEAD, 20 TO 24 KERNELS—Continued

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
48806	21.0	9.8346	0.3782	0.01798	78	12
55205	20.0	.6893	.3446	.01723	56	6
55606	22.9	11.0930	.5042	.02205	92	24
55907	21.4	19.3966	.5542	.02590	95	42
55908	23.4	12.2210	.5092	.02175	95	40
55909	21.5	9.2120	.6580	.03050	85	31
56205	23.8	6.5232	.4659	.01959	82	29
56206	20.4	9.3093	.3724	.01829	86	42
56208	22.5	13.5720	.5429	.02356	88	51
56209	21.1	15.8086	.3513	.01664	90	67
57005	22.0	1.5364	.3841	.01746	73	7
57105	23.9	3.7263	.2192	.00916	85	40
57305	22.8	8.5777	.3899	.01666	78	30
57306	21.7	7.9772	.3989	.01838	80	23
57308	21.4	9.8378	.3644	.01705	80	40
57506	22.5	2.7616	.3452	.01534	72	18
57507	23.9	6.9861	.4657	.01946	78	26
57508	22.3	12.0728	.7102	.03177	85	22
63105	22.5	1.5452	.3883	.01717	68	8
63106	23.6	3.3006	.4715	.02001	77	9
63107	21.9	9.3120	.4901	.02233	80	25
72605	21.7	1.1166	.3722	.01718	52	3
72705	21.9	9.1522	.5384	.02191	68	20
74305	21.6	4.4222	.4422	.02047	60	11
74507	20.5	9.2130	.3839	.01869	70	27
74605	21.0	7.1181	.3746	.01784	69	27
74606	23.2	9.6451	.4822	.02079	75	24
76205	21.7	8.4407	.3670	.01695	70	26
81405	21.8	4.5737	.4158	.01862	70	11
81705	21.1	9.7922	.4451	.02106	82	27
81706	21.2	15.3928	.4527	.02132	90	40
81707	23.8	18.3614	.5564	.02336	96	53
81709	20.5	16.4692	.4451	.02175	90	45
84405	23.8	8.7448	.4858	.02043	75	19
88607	23.1	5.1584	.5158	.02205	73	15
91905	22.0	3.4436	.3826	.01739	72	12
91906	22.2	3.5486	.3943	.01774	74	11
92206	23.0	1.1074	.5537	.02407	66	3
92305	22.9	2.3859	.3408	.01491	65	11
92306	23.1	6.0091	.4006	.01732	75	19
92506	22.9	3.8709	.3871	.01690	77	16
92507	22.0	9.6779	.4208	.01916	82	29
Average.	22.2	6.8466	.4355	.01953	73.8	21.4
SIZE OF HEAD, 24 TO 28 KERNELS.						
17306	24.3	3.9968	0.3997	0.01645	66	12
17405	25.1	15.6996	.5414	.02127	72	34
17409	24.3	14.8957	.4514	.01857	85	39
20710	25.5	17.1115	.5032	.01974	77	39
21206	24.8	2.8564	.4761	.01917	62	6
21308	25.3	5.8080	.4149	.01641	54	14
21706	26.9	19.3318	.6444	.02390	88	38
21709	25.8	7.7296	.5521	.02141	85	23
21711	24.2	17.1820	.4773	.01968	85	51
21806	24.9	14.2450	.5935	.02378	91	32
21808	25.7	19.7446	.4388	.01708	96	57
21810	26.0	1.0304	.5152	.01982	55	4
21913	27.3	10.1925	.5662	.02072	84	27
22210	27.1	6.0173	.5470	.02019	78	31
26808	24.7	3.8811	.4312	.01748	64	11
26905	25.1	6.4102	.4931	.01966	66	15
26908	24.0	3.9797	.4974	.02073	62	9
27205	26.2	16.4061	.4825	.01841	87	57
27305	24.3	5.5666	.5061	.02085	80	22
27506	21.7	10.0005	.5556	.02252	85	23
27507	25.0	1.3746	.4582	.01833	50	4
27508	27.9	5.5324	.6137	.02287	78	19
32608	27.5	1.0183	.5093	.01851	50	2
33107	21.5	6.1026	.4694	.01919	73	29
33305	25.0	3.1346	.5224	.02090	53	7
33406	25.7	4.6045	.4186	.01627	72	16
33408	25.7	1.1132	.3711	.01446	56	4

TABLE 35.—*Relation of size of head to yield, height, and tillering of plant*—Continued.

SIZE OF HEAD, 24 TO 28 KERNELS—Continued.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams)	Weight of average kernel (grams).	Height (cm.).	Tillering.
33605	27.4	7.0596	0.6418	0.02345	65	14
33606	27.3	8.1890	.5489	.02144	72	17
33607	27.2	2.8903	.5781	.02125	58	6
33905	26.7	11.1476	.5867	.02194	77	23
34207	26.6	13.5556	.5894	.02219	77	22
37705	25.6	8.0905	.4195	.01972	60	22
39507	27.8	1.8862	.4715	.01699	59	4
45606	24.4	4.0358	.4481	.01834	59	13
48306	26.2	2.6571	.4428	.01692	58	7
48407	26.6	11.2890	.4181	.01572	82	53
48409	26.2	6.4302	.5358	.02048	74	19
48505	27.4	1.9154	.3831	.01398	70	7
48508	27.4	11.2008	.5091	.01858	80	36
55506	27.1	17.8506	.5578	.02062	95	58
56107	24.9	14.4556	.3023	.01658	90	49
57509	27.8	10.6261	.4830	.01739	84	37
57606	26.4	3.0790	.6158	.02333	78	8
57607	27.3	16.4433	.6090	.02234	87	18
57608	24.3	8.6189	.4788	.01968	83	38
58206	24.7	1.3961	.2327	.00943	75	29
63506	25.5	2.3986	.3998	.01568	64	7
65305	26.0	1.8018	.6006	.02310	65	10
65306	25.9	9.8298	.4681	.01807	75	28
65308	26.5	11.7066	.5321	.02008	77	35
66008	24.9	3.1555	.4505	.01814	76	8
69505	25.5	4.7116	.4712	.01847	66	13
69805	27.5	2.4420	.6105	.02220	62	7
69806	27.9	12.0136	.6007	.02153	75	28
72606	27.1	9.3629	.4681	.01724	82	26
72607	26.9	3.4442	.4920	.01832	74	8
72905	27.8	2.6462	.1410	.01585	59	5
74607	25.8	8.3406	.4390	.01699	76	31
80305	25.1	15.7835	.5442	.02165	70	33
81406	24.0	1.2391	.4130	.01721	55	3
81710	24.7	9.1411	.5713	.02308	90	21
84906	25.5	7.5438	.5029	.01975	65	16
85205	26.7	3.4766	.4386	.01625	65	11
86105	25.4	3.0282	.3785	.01495	68	4
86106	27.2	7.6241	.4765	.01749	76	25
88606	25.3	9.9456	.5234	.02068	85	23
88609	24.7	9.8719	.5196	.02100	74	26
88905	26.6	5.3069	.4821	.01811	82	17
92205	26.5	5.2616	.4047	.01525	72	18
92405	26.7	3.4356	.4294	.01605	78	10
92407	26.5	.8983	.4491	.01695	68	2
92907	24.3	4.4673	.4964	.02040	84	10
94206	25.1	7.5006	.4688	.01866	76	19
94208	24.8	3.7828	.2909	.01175	71	19
94407	26.2	6.7664	.4229	.01615	82	23
94907	27.2	12.1918	.5301	.01948	85	23
94908	25.0	2.3678	.4736	.01894	73	9
94909	24.2	3.6977	.2631	.01696	72	9
95506	25.9	11.0548	.4806	.01852	86	25
95507	26.0	12.1592	.5527	.02029	90	22
95508	25.5	14.4617	.4987	.01954	97	31
95705	26.5	10.3426	.4309	.01626	80	31
95707	26.0	.7577	.3788	.01457	67	4
Average.	25.9	7.5207	.4848	.01874	73.8	21.2

SIZE OF HEAD, 28 TO 32 KERNELS.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams)	Weight of average kernel (grams).	Height (cm.).	Tillering.
17505	29.0	0.3885	0.3885	0.01340	46	7
17506	31.0	2.2881	.7627	.02460	55	6
20805	31.7	14.6942	.6679	.02157	85	30
21208	28.7	5.1594	.5159	.01798	63	11
21209	29.7	1.4481	.4828	.01627	51	6
21210	29.6	3.9143	.1893	.01577	59	8
21805	29.3	20.9290	.4983	.01699	91	48
21905	28.2	14.3111	.5111	.01809	92	62
21906	31.4	10.4800	.8062	.02563	88	27
21908	28.8	3.5574	.5929	.02056	92	9
21909	30.9	12.1819	.7166	.02317	86	29
21911	29.5	8.4593	.6597	.02209	90	23

TABLE 35.—*Relation of size of head to yield, height, and tillering of plant*—Continued.

SIZE OF HEAD, 28 TO 32 KERNELS—Continued.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
22206	29.2	2.5712	0.5142	0.01720	70	9
22211	28.0	11.5675	.5781	.02062	88	59
26107	28.8	2.0390	.4078	.01416	67	6
27005	28.9	16.4120	.5471	.01895	77	40
27206	28.8	19.1854	.7106	.02469	90	49
27306	28.5	13.3011	.5542	.01945	88	48
27308	31.7	4.5123	.5640	.01777	88	11
27509	30.4	5.3615	.6702	.02206	73	9
32206	28.2	10.4036	.5779	.02052	71	26
32505	28.1	5.2268	.6533	.02323	71	9
32606	31.3	2.0162	.6721	.02145	69	3
34205	30.9	9.1498	.6100	.01972	78	19
34208	31.2	2.9886	.5977	.01916	66	5
37305	30.9	6.1394	.6139	.01987	58	12
38505	29.6	12.1088	.6373	.02252	70	21
38506	28.3	1.6799	.5600	.01975	54	3
38605	30.5	1.2124	.6062	.01987	55	2
39405	31.9	9.3511	.6681	.02093	74	18
39606	31.4	4.6383	.4217	.01341	64	18
40305	29.8	3.6003	.6000	.02011	62	6
41505	30.9	5.9990	.5453	.01764	69	25
45005	29.4	3.2340	.4042	.01376	66	9
45805	31.0	1.5298	.3824	.01234	48	4
46107	31.9	8.3935	.5595	.01756	79	27
50905	31.6	2.3982	.3426	.01085	68	10
50906	28.5	1.7280	.4320	.01516	58	5
55005	30.2	7.9684	.6129	.02028	75	19
55006	30.1	7.1852	.4790	.01593	80	19
55007	29.5	2.1571	.5393	.01828	65	7
55206	30.4	11.3592	.5978	.01965	82	27
55306	30.6	4.1323	.5903	.01931	77	17
55307	31.1	5.6864	.5169	.01663	80	19
55507	31.5	9.8228	.6139	.01949	95	28
56106	28.0	12.0161	.5224	.01866	90	33
57006	30.5	10.1836	.4427	.01153	88	41
57407	31.8	14.9992	.6250	.01968	92	41
58207	30.7	4.2207	.4221	.01375	75	18
58505	31.1	7.4516	.6210	.02730	80	18
58806	31.7	1.9469	.6489	.02049	65	7
59606	29.8	9.7084	.5109	.01712	80	37
63505	29.7	4.0230	.5747	.01934	66	8
65307	31.1	7.0051	.5838	.01878	74	17
66005	30.8	7.6690	.6391	.02073	75	22
69506	30.1	13.5696	.6168	.02047	73	24
71905	29.3	28.2136	.6561	.02239	80	46
72406	30.7	8.2929	.5923	.01929	70	15
72706	29.5	14.6802	.7340	.02484	80	27
72707	28.1	4.5806	.5726	.02036	72	8
76206	29.8	5.4411	.3627	.01217	73	30
88906	30.3	9.9034	.5502	.01811	80	21
92408	29.6	3.7820	.5403	.01827	81	7
92908	31.2	3.2388	.5398	.01732	76	7
94205	31.3	1.2117	.4039	.01893	55	6
94207	29.9	13.7057	.5711	.01909	83	31
94209	31.7	3.6006	.6001	.01895	75	7
94406	28.9	10.5556	.5556	.01923	82	22
94605	28.0	.7319	.3659	.01307	68	7
94606	29.9	11.8435	.5383	.07544	84	23
94905	31.8	4.4123	.4936	.01553	75	11
94906	29.8	12.3862	.5385	.01808	91	24
95706	29.7	5.1629	.5736	.01934	82	9
Average.	30.1	7.4992	.5598	.01958	74.5	19.4

TABLE 35.—*Relation of size of head to yield, height, and tillering of plant*—Continued.

SIZE OF HEAD, 32 TO 36 KERNELS.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
17307	34.5	3.1154	0.7863	0.02279	70	8
18905	34.3	1.4864	.4955	.01443	50	4
26105	32.7	1.8242	.4560	.01393	69	13
26907	34.0	1.8276	.6092	.01792	55	8
28806	34.2	14.4630	.7232	.02111	75	30
34405	34.5	4.1281	.6881	.01994	62	8
34606	35.0	6.1962	.7745	.02213	61	13
36905	33.4	5.0200	.6275	.01880	58	7
39205	32.2	21.5399	.6731	.02089	82	10
42405	33.0	1.4892	.7446	.02251	60	2
42905	33.5	1.2499	.6249	.01866	68	4
48506	32.7	9.4585	.5564	.01701	82	30
49505	33.5	1.2716	.6358	.01898	60	3
51005	34.5	15.5835	.6233	.01804	75	32
55008	33.7	17.4226	.6222	.01846	82	30
55305	33.4	2.5160	.5032	.01507	75	12
55308	33.1	9.5078	.7923	.02395	79	28
55605	33.3	10.9180	.7279	.02184	89	23
55607	34.5	2.3931	.5983	.01734	77	7
55608	33.5	22.5848	.9034	.02699	95	31
57007	33.6	3.3176	.6635	.01975	90	9
57406	33.7	2.4923	.6231	.01846	92	14
57408	35.0	12.2004	.7177	.02047	90	26
58805	35.1	23.1471	.7014	.01999	78	51
60605	35.0	.5952	.5952	.01701	57	4
69305	34.3	2.0130	.6810	.01984	70	7
72405	35.5	8.4415	1.4069	.03963	67	6
72708	33.2	9.0386	.7532	.02270	78	12
73308	34.7	14.2986	.7944	.02291	74	23
85206	34.2	4.9315	.4483	.01312	69	13
88605	34.5	1.6362	.8181	.02731	70	3
91305	34.5	3.0910	.7755	.02242	76	6
92208	35.3	6.6206	.6621	.01876	78	17
92406	34.5	8.2366	.7488	.02168	81	17
92409	35.0	5.7131	.6348	.01814	81	13
92905	35.2	2.7000	.5400	.01534	75	6
92909	33.1	10.1363	.6335	.01916	86	21
95509	31.5	2.9475	.7369	.02136	74	4
Average.	34.1	7.2530	.6868	.02023	73.9	15.4

SIZE OF HEAD, 36 KERNELS AND OVER.

Record number.	Size of head.	Yield per plant (grams).	Yield per head (grams).	Weight of average kernel (grams).	Height (cm.).	Tillering.
18906	65.0	0.9229	0.9229	0.01420	67	5
21813	43.2	4.0258	.8051	.01877	80	21
34206	40.5	1.5910	.7970	.01968	74	5
37707	38.6	3.3004	.6601	.01710	64	5
40205	38.8	3.6302	.7260	.01871	65	11
40505	42.5	4.1546	1.0386	.02144	60	4
43405	41.3	2.8000	.9333	.02258	64	3
46105	37.1	4.6146	.6592	.01775	73	8
48705	41.0	4.3615	.7269	.01652	80	7
48706	47.4	6.1986	.7748	.01635	78	12
55508	36.0	3.7407	.6222	.01732	73	12
57405	41.0	.8328	.8328	.02031	73	1
57805	38.6	4.8988	.6998	.01814	76	17
57905	36.8	2.4731	.4122	.01118	74	17
58705	58.7	2.5436	.6359	.01082	68	11
58905	42.5	2.3031	.5758	.01355	66	13
59605	38.2	7.1828	.7183	.01880	77	30
62805	37.0	1.3451	.4484	.01212	70	14
66006	52.3	6.0090	.8584	.01642	73	12
72806	36.7	2.0970	.6990	.01906	62	5
73306	37.6	8.5373	.7761	.02062	78	20
81505	48.7	2.8327	.9442	.01910	78	7
84905	37.0	.7130	.7130	.01927	47	4
92906	36.2	2.8816	.5763	.01592	75	7
95505	37.0	.3146	.3146	.00850	79	3
Average.	42.1	3.3723	.7148	.01710	71.0	10.2

TABLE 36.—*Summary of relation of size of head to yield, height, and tillering of plant.*

Classification according to number of kernels on head.	Number of plants	Average number of kernels on spike.	Yield per plant (grams).	Yield per head (gram).	Weight of average kernel (gram)	Height (cm.).	Tillering.
Below 16	18	13.3	1.3169	0.2654	0.02059	55.2	6.9
16 to 20	36	18.1	3.7758	.3383	.01862	64.1	13.7
20 to 24	80	22.2	6.8466	.4355	.01953	73.8	21.4
24 to 28	84	25.9	7.5207	.4848	.01874	73.8	21.2
28 to 32	73	30.1	7.4992	.5598	.01958	74.5	19.4
32 to 36	38	34.1	7.2530	.6868	.02023	73.9	15.4
More than 36	25	42.1	3.3723	.7148	.01710	71.0	10.2

TABLE 37.—*Relation of yield of plant to height and tillering, and to the yield per head.*

Classification according to yield per plant, in grams.	Number of plants.	Yield per plant (grams).	Height (cm.).	Tillering.	Yield per head (gram).
Below 1	31	0.6050	56.5	3.7	0.3553
1 to 2.5	67	1.7673	62.2	7.0	.4740
2.5 to 5	87	3.5526	69.1	11.6	.4917
5 to 10	93	7.6485	75.4	22.1	.5320
10 to 15	51	12.2862	84.4	32.3	.5592
15 to 20	20	17.1908	84.6	42.9	.5310
More than 20	5	23.2829	85.2	43.2	.6865

TABLE 38.—*Relation of yield per head to yield, height, and tillering of plant, and to weight of average kernel.*

Classification according to yield per head, in grams.	Number of plants.	Yield per head (gram).	Yield per plant (grams).	Height (cm.).	Tillering.	Weight of average kernel (gram).
Below 0.300	30	0.2484	1.6939	60.8	11.4	0.01586
0.300 to 0.400	62	.3567	3.7365	65.6	15.5	.01737
0.400 to 0.500	98	.4524	6.7326	72.8	19.9	.01847
0.500 to 0.600	78	.5477	9.5646	76.6	21.8	.02073
0.600 to 0.700	50	.6372	7.6214	71.3	17.3	.02056
0.700 to 0.800	25	.7456	4.4523	75.2	18.6	.02179
More than 0.800	12	.9229	5.7687	73.7	10.3	.02151

SUMMARY AND CONCLUSIONS.

As between wheat kernels of the same variety raised under similar conditions, those kernels having a high percentage of proteid material have a lower specific gravity, weigh slightly less, and occupy a smaller volume than kernels having a smaller percentage of proteids.

As between individual spikes and individual plants, the same relations obtain.

As between individual plants in different years, these relations do not hold.

The quality of high proteid content and its correlated properties may be due to immaturity in the kernel, or they may belong to the normal and fully ripened kernel.

As between kernels, spikes, and plants, those kernels of greater weight contain a larger weight of proteids—this in spite of the fact that they contain a lower percentage.

Plants bearing the largest number of kernels have kernels of more than medium but not the greatest weight, as do also plants producing the greatest weight of kernels. The same is true of plants producing the greatest weight of proteid matter and gluten.

Heavy seed wheat drilled at the rate of $1\frac{1}{2}$ bushels per acre produced a much larger crop of seed the first year of the separation than did light seed drilled at the same rate, but by continuing the separation of the respective crops and selecting heavy seed from the crop grown from heavy seed, and light seed from the crop grown from light seed, the difference in yield in three or four years was small.

After the first year of separation the light seed produced a greater amount of proteids per acre than did the heavy seed.

A determination of the total or of the proteid nitrogen content in the kernels on one row of spikelets of wheat affords a fairly close estimate of the same constituents in the kernels on the other row of spikelets.

A determination of the total or of the proteid nitrogen content in the kernels on one-half of the spikes on a wheat plant will give a very good estimate of the same constituents in the kernels on the other spikes, provided there are at least an average number of spikes on the plant.

There may be quite a large variation in the proteid nitrogen content of different spikes on the same wheat plant.

Determinations of the proteid nitrogen content of 800 spikes of wheat of the same variety representing different plants showed a variation of from 1.12 to 4.95 per cent of proteid nitrogen, and 351 plants of the same variety the following year varied from 1.20 to 5.85 per cent.

The proportion of gluten to proteids in kernels of different wheat plants may vary considerably. A determination of proteid nitrogen is therefore not always a guide to the gluten content of the wheat. Selection for improvement should be based on the determination of gluten.

Wheat plants having kernels high in gluten contain a smaller proportion of other proteids than do plants of medium or low gluten content.

In wheat of the same variety, raised in the same field in the same year, the ratio of gliadin to glutenin was practically the same in plants of low, medium, and high proteid nitrogen content.

It may therefore be assumed that an increase in the gluten content of a given variety of wheat raised in the same region would carry with it a corresponding improvement in its value for bread making, although there might be fluctuations from year to year in the quality of the gluten.

The content of proteid nitrogen, the kernel weight, and the total proteid nitrogen production by the wheat plant are hereditary qualities.

There is a tendency for plants possessing any of these qualities in an extreme degree to produce progeny in which the same qualities approach more closely to the average, but certain exceptional plants may transmit the same or more extreme qualities.

The yield of grain per plant after a severe winter was decreased in proportion to the susceptibility of the plant to cold. The effect of the cold caused the plant to produce a less number of heads, or, in other words, to tiller less.

The early-maturing plants yielded the most grain, and those ripening later produced in each case less when grouped into ripening periods of four days, extending through more than three weeks' time.

The early-maturing plants produced grain of slightly lower nitrogen content than the later maturing plants, and the number of grams of proteid nitrogen in the average kernel was likewise less in the early-maturing plants.

Plants with heads of slightly more than medium size produced the largest yields of grain, and were taller than plants with either larger or smaller heads. Plants with heads of medium size, or slightly less, tillered most extensively.

The weight of the average kernel did not increase with the size of the head, nor did it decrease, except on the very largest heads.

The largest yielding plants were the tallest and tillered most.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 79.

B. T. GALLOWAY, *Chief of Bureau.*

THE VARIABILITY OF WHEAT VARIETIES IN RESISTANCE TO TOXIC SALTS.

BY

L. L. HARTER,

SCIENTIFIC ASSISTANT, LABORATORY OF PLANT BREEDING.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED JULY 27, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 79.

B. T. GALLOWAY, *Chief of Bureau.*

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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[c] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 1, 1905.

Sir: I have the honor to transmit herewith a technical paper entitled "The Variability of Wheat Varieties in Resistance to Toxic Salts," and to recommend that it be published as Bulletin No. 79 of the series of this Bureau.

This paper was prepared by Mr. L. L. Harter, Scientific Assistant in the Laboratory of Plant Breeding, Vegetable Pathological and Physiological Investigations, and was submitted by the Pathologist and Physiologist with a view to publication. The subject-matter of the bulletin will be of interest to experimenters who are working on the problems of securing alkali-resistant strains of agricultural crops.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The main object of the accompanying paper is to prove that different varieties of a single species behave differently in the presence of the harmful salts that are present in the so-called alkali soils of the western United States. The work has been done with varieties of wheat on account of the great importance of that crop in the region indicated and because, being grown under a great diversity of conditions as regards climate and soil, wheat varieties would be expected to differ much among themselves in their power to withstand the effect of excessive amounts of salts in the soil, just as they differ widely in their capability of withstanding drought, cold, and parasites.

The experiments were made with young seedlings, their roots being exposed for periods of twenty-four hours to the action of pure solutions of the salts used, the greatest strength of solution in which the root tips could survive being taken as representing the limit of endurance of each variety to each salt. The salts used were the carbonate, bicarbonate, sulphate, and chlorid of sodium, and the sulphate and chlorid of magnesium. These are salts that are generally present in the largest quantity in alkali soils. Nine varieties of wheat, both from the Old World and the New, representing widely different climates and soils, were compared.

It was found that the varieties differed greatly in their ability to withstand the poisonous action of the salts used. This was more strikingly brought out in the case of some salts than of others. To magnesium sulphate, for example, some varieties are three times as resistant as are others. Tables are given in the following paper showing the limit of concentration of each of the nine varieties for each of the six salts. It was also clearly demonstrated that the different individuals of each variety differ much in resistance, and the limits of the varieties as established are only the means of the limits for all the individuals tested. Analyses of the ash of each lot of seed used were obtained from the Bureau of Chemistry, but no correlation could be shown between ash composition and resistance to action of toxic salts. On the other hand, it was clearly demonstrated that with few exceptions the varieties that have originated in arid regions, where the soils are usually more saline than in humid regions, are those that are most resistant to pure solutions of sodium and magnesium salts. Three varieties of southeastern Russia, with one exception, were found to be the most resistant of all those tested.

It is believed that the laboratory work upon which this paper is based has a direct practical bearing, as it gives us an indication of what varieties are most likely to succeed in arid regions where the soils are more or less salty. Furthermore, as some one salt—e. g., sodium chlorid—sometimes strongly predominates in the soils of a particular region, and as these experiments show clearly that, while one variety may be more resistant than another to sodium chlorid, the second is often more resistant than the first to sodium carbonate or to magnesium sulphate, we can thus obtain information as to which of the many varieties of a great crop can be sown with the best chance of success upon a given type of alkali soil. In other words, a few weeks of simple laboratory experiment may save years of costly trial in the field, although, of course, the water-culture experiments can not be considered as giving more than an indication of what we can expect each variety to do, and the final test must be the growing of the crop upon a practical scale.

The great individual variability in resistance brought out in these experiments shows that not merely have we found a guide as to which of existing varieties are best adapted to different types of saline soils, but that there is an excellent opportunity for increasing their resistance by selecting seed from the most resistant individuals. The present investigation affords further evidence that it is practicable to apply plant-breeding methods to the "alkali problem" and adapt crops by selection to the unfavorable conditions presented by soils that contain excessive amounts of soluble salts.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., April 26, 1905.

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THE VARIABILITY OF WHEAT VARIETIES IN RESISTANCE TO TOXIC SALTS.

INTRODUCTION.

It has been shown quite conclusively in recent years that different species and genera differ very much in their ability to resist the influence of toxic salt solutions. Numerous investigations of the action of acids and salts upon plants have been made, especially during the last four or five years. Investigations of this nature are not only of great scientific interest, but promise in some cases to be of considerable practical importance. One phase of this subject which is especially interesting from this latter point of view is that of the relation of plants, particularly cultivated plants, to the components of the saline or alkaline soils that are so common in the arid part of the United States and of many other parts of the world.

A preliminary investigation of this phase of the subject was made by Messrs. Kearney and Cameron,[a] who showed by a large number of experiments on *Lupinus albus* and *Medicago sativa* that the death limit of the root tips was very different for different salts. For instance, the limit for *Lupinus albus* in sodium chlorid was found to be 0.02 of a normal solution, and in magnesium sulphate 0.00125. For *Medicago sativa*, in mixed solutions containing an excess of two calcium salts, the limit was 0.35 in magnesium sulphate and 0.20 in sodium chlorid.[b]

Much work has been done in comparing different botanical species as to their resistance to the effect of salt solutions,[c] but the compara-

[a] Report No. 71, U. S. Dept. of Agriculture (1902).

[b] Messrs. Kahlenberg and True, who have done considerable work along this line, particularly with salts and acids, give some very interesting results. They found (On the Toxic Action of Dissolved Salts and Their Electrolytic Dissociation, Bot. Gaz., 22: 81, 1896) that *Lupinus albus* would just survive in $\frac{1}{51200}$ gram mol. per liter of copper salts. They found the same limits with ferrous sulphate ($FeSO_4$), nickel sulphate ($NiSO_4$), and cobalt sulphate ($CoSO_4$), but for mercuric chlorid ($HgCl_2$) $\frac{1}{12800}$, and mercuric cyanid ($HgCn_2$) only $\frac{1}{102400}$ gram.

[c] The experiments of Heald (On the Toxic Effect of Dilute Solutions of Acids and Salts upon Plants, Bot. Gaz., 22: 125, 1896), and later those of Moore and Kellerman, are among the most interesting in this connection.

Heald, in a series of experiments resembling those of Kahlenberg and True, obtained some valuable results with *Cucurbita pepo*, *Zea mays*, and *Pisum sati-*

tive resistance of different varieties, or races, of a single species has received little attention.[a]

During the autumn of 1903, and again in 1904, the writer had occasion to repeat, at the Department of Agriculture, Washington, D. C., the experiments previously conducted by Kearney and Cameron with

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rum. He found the limit of *Pisum sativum* to be $\frac{1}{51200}$ gram mol. per liter for copper sulphate ($CuSO_4$) as the strength which will barely permit the roots to live, and that for *Zea mays* to be $\frac{1}{25600}$. He obtained results with various salts, but this will suffice to show the variability between plants widely separated in relationship.

Moore and Kellerman (A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies, Bul. 64, Bureau of Plant Industry, U. S. Department of Agriculture, 1904) say:

> In dealing with algæ the toxic concentration varies greatly for different genera, even for different species of the same genus. Nägeli demonstrated the extreme sensitiveness of *Spirogyra nitida* and *S. dubia* to the presence of copper coins in the water. *Oscillatoria*, *Cladophora*, *Œdogonium*, and the diatoms succumb in six hours to a copper-sulphate solution of 1 to 20,000 and in two days to 1 to 50,000 according to Bokorny. * * * According to Ono, weak solutions of the salts of most of the metals encourage the growth of algæ and fungi. Mercury and copper, however, at 0.00005 per cent and 0.00001 per cent, respectively, distinctly inhibit growth. This was the case with *Stigeoclonium*, *Chroococcus*, and *Protococcus*.

Moore and Kellerman have obtained results with algæ which serve very well to illustrate the variability of these organisms in the presence of the toxic copper sulphate. They found that with this salt 1 to 25,000, 1 to 75,000, and 1 to 100,000 were sufficient to kill *Raphidium polymorphum* in four days, *Desmidium swartzii* in three days, and *Navicula* sp. in five days, respectively. One part of salt to 300,000 of water and 1 to 1,000,000 were fatal to *Conferva bombycinum* in three days and *Synura uvella* in a few minutes. *Closterium moniliferum* was killed in four days in a 1 to 500,000 solution, and *Anabæna flos-aquæ* in a 1 to 5,000,000 solution in seventy-two hours. The most sensitive of all was *Uroglena americana*, practically all of which were killed in a 1 to 10,000,000 solution in sixteen hours.

[a] J. F. Breazeale informs the writer that in water-culture experiments in the laboratory of the Bureau of Soils, United States Department of Agriculture, he has found a very wide variation in the development of seedlings of different varieties of wheat when grown in the same artificial nutrient solutions and also aqueous extracts of soil, and W. H. Heileman, in the same laboratory, has shown very similar results to those presented in this investigation when using different varieties of wheat in pot cultures of natural and artificial alkali soils. It has also been shown that the vigor and rate of germination of seeds of different varieties are very different when previously soaked in any given solution of an electrolyte.

Cameron and Breazeale (The Toxic Action of Acids and Salts on Seedlings, Journal Phys. Chem., vol. 8, No. 1, p. 1, Jan., 1904) have shown a wide variation in the toxic action of different salts and acids on seedlings of plants widely separated in relationship.

From certain points of view, especially as bearing on current chemical theories, the paper of Dandeno (American Journal of Science, Vol. XVII, June, 1904) in this field is especially interesting, but a direct comparison of results in toxic salt solutions can not be made, owing to the fact that seedlings of different plants have been used.

Lupinus albus. Although the order of toxicity of the various salts remained the same in the three series of experiments, quite different limits of endurance were obtained, those in the first series made by the writer being much higher than those obtained by Kearney and Cameron and by the writer in his second series. The idea was at once suggested by these results that while possibly the second lot of seed may have differed only in being younger or otherwise more vigorous it was also possible that different varieties or even merely strains from different sources of the same species might differ considerably in their power to resist toxic salt solutions. It was therefore with a view of determining whether or not this was true that the series of experiments which forms the subject of this paper was undertaken with different varieties of wheat.

Attention should be directed at the outset to an important condition under which this work was carried on. Most of the work of this kind has been conducted with comparatively few seedlings. But individual variation in resistance is well known to be exceedingly great, and enough seedlings must be tested to eliminate all such differences. The average of the resistances of a large number of seedlings must be ascertained. The writer has in every case used from 50 to 100 seedlings, and more in some cases, the number tested being considered sufficiently large to eliminate individual variation and give fairly consistent results. The total number of seeds experimented with aggregated nearly 5,000.

The work, the results of which are shown in this paper, was taken up at the suggestion of Mr. Thomas H. Kearney, Physiologist, of the Laboratory of Plant Breeding of the Department of Agriculture.

SALTS USED.

It was decided to employ the same salts used by Kearney and Cameron in their work with *Lupinus albus*, i. e., sodium chlorid ($NaCl$), sodium sulphate (Na_2SO_4), sodium carbonate (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), magnesium sulphate ($MgSO_4$), and magnesium chlorid ($MgCl_2$). A basis for direct comparison is thus obtained. It was thought best to use these salts, also, because of their common occurrence in saline soils, and their tendency, in a greater or less degree, to inhibit vegetable growth.

VARIETIES SELECTED.

The selection of the varieties of wheat to be used in this work has not been an easy matter, there being a number of details to consider in making the choice. To prove whether there is a difference in the power of different varieties of the same species to resist the action of toxic salt solutions it was decided to use varieties representing very different conditions of climate and soil, and selections were made, with the aid of Mr. M. A. Carleton, Cerealist of the Bureau of Plant Industry, with this end in view. All conditions under which wheat is grown are not, of course, represented. Wheat is raised in nearly every portion of the temperate zone and under as diverse conditions of soil and climate as could well be imagined. An attempt has been made, however, to obtain varieties representative of the regions presenting the greatest contrast in these respects. Cerealists have discovered that wheats well adapted to a humid region will not thrive in an arid or semiarid region, nor will varieties that are best adapted to the latter conditions thrive in a humid environment. Varieties representing each of these different climatic types were used in the experiments. Unquestionably the soils of the various regions from which the seeds were obtained differed chemically to a great extent, but in most cases data as to soil composition were not obtainable. The influence of climatic and soil factors is complicated by the fact that seeds are often transferred from one region to another. For example, a certain variety might have been grown for a number of years in strongly saline soil to which it has become thoroughly adapted, and then transferred to a semiarid region and a soil containing less salt. Were the seed procured from the new region soon after the transfer, while the variety was not yet adapted to the new conditions, probably it would still show the high degree of resistance acquired under the former conditions. In some cases it was possible to learn the exact history, for several generations, of the seed used, but in others it was impossible to obtain such definite information. To meet the conditions of the experiments it was thought advisable to select varieties from regions widely separated geographically. Therefore, one variety from Africa, two from Europe, one from Asia, and six from America were obtained. Two of the varieties are durum wheats and consequently of a different species; the rest are soft grained.

The following descriptions of the individual varieties will render more intelligible the conditions under which they grew originally:

PRESTON.

The variety of wheat known as Preston (*Triticum vulgare*) is a hybrid, produced by Dr. William Saunders, of the agricultural experiment station at Ottawa, Canada. In the spring of 1888 Doctor Saunders crossed the varieties Red Fife and Ladoga, obtaining a new sort, which was called Preston. Red Fife was taken as the male and Ladoga as the female parent. The progeny, he says, resembles somewhat both parents. The grain is very much like Red Fife. Both the parent varieties are well established in that part of Canada and were grown there with great success for many years previous to the origin of this hybrid. Preston has proved to be a better variety than either of its parents, both in yield and in range of adaptability. The region in which its parent varieties grow is very humid. Doctor Saunders claims that Preston ripens its grain from three to four days earlier than either of its parents. In view of this fact it is reasonable to conclude that it is better adapted to regions having diminished rainfall during the latter part of the season, and experience has justified the conclusion. Preston has given the best results of all the spring wheats introduced into the Northwest. It is to-day grown successfully in the southern part of Canada and in a part of the United States that includes North Dakota, eastern Montana, Minnesota, South Dakota, and Wisconsin.[a]

TURKEY.

Turkey wheat (*Triticum vulgare*) is considered the hardiest variety grown at the present time in the United States. It is a bearded sort, with white chaff, small head, and red grain. It is especially well adapted to semiarid regions, as is readily seen from the region in which it is grown. This variety was introduced into Kansas about twenty-five years ago. For a while it was confined to a small district of that State, but during the past twelve or fifteen years its excellent quality has become generally known, and consequently it is grown on a much larger area. It came originally from Crimea and other portions of Taurida, in southern Russia. That country does not differ greatly from the section of the United States in which the variety has given such good results. Though it is not a variety giving unusually heavy yields, it is well adapted to resist droughts and may be depended upon for a greater average yield than any other variety grown in Kansas. It ripens rather early, and thus escapes the excessive droughts which frequently prevail during the latter part of the wheat season in that district. It is especially adapted to the Great Plains region, including, roughly, Kansas, Oklahoma, southern Nebraska, southern Iowa, northern Texas, and portions of Missouri and Arkansas.[b]

ZIMMERMAN.

The variety known as Zimmerman (*Triticum vulgare*) is grown to some extent in the same region as the one just described. However, it has a number of essential points of difference and some char-

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[a] Dr. William Saunders, Cereals and Root Crops, Ottawa, Canada, 1902.

[b] Carleton, M. A., Basis for the Improvement of American Wheats. Bul. 24, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1900.

acteristics that make it preferable for the experiments described here. As a whole, it is inferior to the Turkey wheat, being less resistant to drought, and it is grown principally in regions which have a greater annual rainfall. Zimmerman wheat has two good qualities to recommend it—it is beardless and ripens from four days to a week earlier than other varieties in the same locality. It is a fairly hardy sort, and is as resistant as the average variety to the cold of severe winters. It is best adapted for cultivation in southern Kansas, Oklahoma, northern Texas, Missouri, Kentucky, Tennessee, Arkansas, and farther southward. This region has a much larger annual rainfall than the one inhabited by the Turkey variety, with the exception of the States in common—Kansas, Oklahoma, and Texas.

KHARKOF.

The seed used of the Kharkof variety of wheat (*Triticum vulgare*) was obtained by the United States Department of Agriculture from the Agricultural Society of Kharkof, Russia, in the Starobielsk district. Kharkof is in the southern part of Russia, about 300 miles north of the Black Sea and about 350 miles west of the Volga River. The winters are very dry and at no season of the year is the rainfall great. Kharkof is a red-bearded, hardy winter wheat. The seed was obtained from the crop grown in Russia during the season of 1902.

PADUI.

Seed of the Padui variety (*Triticum vulgare*) was obtained from Saratof, in eastern Russia. Saratof is located on the Volga River, about 400 miles from its outlet into the Caspian Sea. Padui is a soft or semihard winter wheat, and is adapted to all northern winter-wheat States from New York to Kansas and southward to the thirty-fifth parallel. The seed with which these tests have been made was imported directly from Russia. Padui is very resistant to drought, the rainfall in the region where it is grown falling as low as 12 to 15 inches per annum. This variety is cultivated to some extent in the same region as Kubanka (described later), and, therefore, is subjected to the same climate and probably to the same soil conditions.

CHUL.

Dr. E. A. Bessey describes the conditions under which the Chul variety (*Triticum vulgare*) is grown in Turkestan and in the southern part of central Asia, about Samarkand. It is found more or less in this whole steppe region, from which it derives its name, Chul meaning steppes. It is a hard grain and grows without irrigation, yields two harvests, and can be sown as either winter or spring wheat. The seed for these experiments was obtained by Doctor Bessey for the Department of Agriculture from its native country, being taken from the crop of 1902.

BUDAPEST.

The variety known as Budapest (*Triticum vulgare*) is one of the hard winter wheats imported originally from Hungary. It is now grown in Michigan and adjoining States with great success. Of all the varieties imported from Hungary, Budapest has proved the best. It is well suited for cultivation in the North Central States, including Michigan, Illinois, Indiana, Ohio, western New York, Kentucky, and perhaps farther south. It is a bearded wheat, with white chaff and red, medium hard grain. It is a success only in regions with a fairly large rainfall.

KUBANKA.

The two varieties of durum wheat (*Triticum durum*), Kubanka and Maraonani, were selected outside of the species *vulgare* in order to find types grown under extremely arid conditions. The seed of Kubanka was obtained originally from Russia. The seed used was of the fourth generation grown in the United States and should show something of the effect of soil and climatic conditions here, provided these differ essentially from those of the country where it originated. Four years is doubtless sufficient time to acclimatize the variety fairly well. Kubanka is grown in an extensive area of eastern Europe and western Asia, especially along the Volga River. The best Kubanka is found east of the Volga, on the border of the Kirghiz Steppe. It is about the only variety found along the Siberian border, where it is impossible to grow any ordinary sort because of drought, and is grown extensively by the Turgai and Kirghiz people. The rainfall over this whole region often does not exceed 10 inches per annum. The Kubanka variety matures very quickly, an absolute necessity in a region where the rainfall is very slight and often confined to a small part of the year. Because it is drought-resistant and matures early it is now being grown throughout the Volga territory from Kazan to the Caspian Sea and east to the Kirghiz Steppe and Turkestan. It is a macaroni wheat, and takes its name from Kuban territory. In this country it is best adapted for the northern plains region as far south as Kansas.

There is little doubt that the varieties Kubanka and Padui, in some regions at least, grow on soil containing considerable salt. Both varieties have become well adapted to the region just north of the Caspian Sea along the Volga River. Here salt abounds in great quantities. West of the Volga and about 100 miles from the Caspian

Sea is a great salt marsh covering a considerable area. On the other side of the river, for a couple of hundred miles along its course, there are both salt marshes and lakes. The great Khaki salt marsh along the borders of the Kirghiz Steppe covers several hundred square miles. Northward and westward from this marsh there is a series of small salt lakes, the largest of which is Elton Salt Lake. It would naturally be expected that in a region with such extensive salt marshes and lakes the arable soil would likewise contain a large proportion of salt.

MARAOUANI.

The Maraouani variety of durum winter wheat (*Triticum durum*) has been grown in northern Africa probably for centuries. As far as can be ascertained, it originated there and has long been one of the most valuable sorts of that country. The seed used in these experiments came directly from the Chéliff Valley, an arid region with very little rainfall, in the western part of Algeria. The wheat land there is cultivated for the most part without irrigation. The soil is largely a heavy clay loam, and probably contains in nearly all sections a more or less excessive amount of readily soluble salts. Maraouani is very hardy, is resistant to rusts, and has the reputation of being the best of the durum wheats now grown in that region. In the Department of Oran it is most successful when sown in November; it then matures about June. It is thought by expert cerealists that this variety would succeed well in the spring-wheat regions of the northern United States and as a winter wheat in the Southwest.

METHODS OF EXPERIMENTS.

Wheat seeds are small compared with lupines, beans, peas, etc., with which most of the work of other experimenters has been done. The rootlets of the wheat seedlings are so small that at first it was feared that some difficulty would be experienced in marking off the rapidly growing zone with india ink, the readiest method for accurate determination of the death point. In view of this difficulty the work was begun without marking. It required but a few trials, however, to prove that it would be practically impossible to obtain satisfactory results in such a way. Wheat rootlets have a hard surface and do not become flaccid in salt solutions unless these are of a concentration much beyond the toxic limit, in which case the roots become yellow and the cells somewhat broken down. However, one or two attempts at marking showed that with a little practice and care this could be effected without inflicting any injury. By rupturing the epidermis very slightly a sufficiently conspicuous mark, which will last forty-eight to seventy-two hours, can be made without injury to the roots.

The seeds were put in sphagnum moss finely broken up and kept sufficiently moist to preclude lateral branching or superfluous development of root hairs. They germinate readily in about forty-eight to seventy-two hours at an ordinary room temperature. The rootlets and leaves make their appearance almost at the same time. The number of roots varies with the variety, but is usually from three to seven. Three is the average number, five is rather common, and seven not very rare. Only one root of each seedling was marked. The initial or central one was always preferred when otherwise fit for the purpose. However, it was found after a large number of tests that the central one was most likely to become deformed while in the sphagnum moss, the tips becoming enlarged and blunt, in which case the root soon ceases to grow. When this happened side roots were preferred for marking. Rootlets which are smooth and uniform in thickness, with a rather sharp point, are most vigorous and give best results. Only experience in this work can teach one which of several roots is preferable for marking. The seeds were taken from the moss, marked, and transferred quickly to the solution. Care was taken in every way possible to avoid change of conditions during the process of making. These details will be discussed more fully in another part of this paper.

The solutions during the period of experiment were kept in the best nonsoluble beakers that could be obtained, each being large enough to hold about 300 c. c. After the solutions had been used once or twice[a] the glassware was thoroughly rinsed in distilled water before being used for the next test. Nearly every other day the beakers were thoroughly sterilized by boiling in distilled water. The beaker used is about 6½ cm. wide at the mouth, and was closed by a tight-fitting cork about 1 cm. in thickness. Each cork was perforated, and into the holes five small glass rods were inserted, bent at one end, and drawn to a sharp point. The rods were inserted with their hooked points on the inner side of the cork, and upon each a single seed was placed. The rods, as well as the corks, fit tightly and thus prevent any important amount of evaporation from the solution. They are free enough, however, to permit of the rods being raised or lowered in or out of the solution as occasion may demand. In no case were the glass rods allowed to come in contact with the solution.

Normal solutions, made with Merck's best chemically pure salts, were prepared under the supervision of Dr. F. K. Cameron, of the Bureau of Soils of the Department of Agriculture. From the nor-

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[a] Careful titration showed no appreciable change in the concentration of the solution after several seedlings had been kept in it for twenty-four hours, or even when the same volume was used during a second period of twenty-four hours.

mal solutions stock solutions were made up by dilution, and were kept for use as required. The solutions actually used in the experiments were made from the stock solutions by diluting with distilled water. It might seem at first that two successive dilutions would permit of an error. This, however, has been avoided in the case of chlorids and carbonates by titrating each stock solution before using. The concentration of the solutions of sulphates was frequently verified by analysis in the Bureau of Soils. Sodium carbonate and sodium bicarbonate were both titrated against N/20 hydrogen potassium sulphate, using methyl orange as an indicator. In the case of the bicarbonate solutions it was necessary to charge them with an excess of carbon dioxid to prevent their becoming alkaline. The nonalkalinity of the bicarbonate solutions was often tested by the addition of a drop of alcoholic phenolphthalein, which would indicate the presence of alkalis by forming the well-known red color. Sodium chlorid and magnesium chlorid were titrated against N/10 of silver nitrate. Whenever, upon titration, any stock solution was found to be either too dilute or too concentrated, it was corrected by the addition of more of the normal solution or by further dilution with distilled water. The water used in these experiments was distilled in the Laboratory of Plant Pathology, and near the close of the work was found by analysis in the Bureau of Chemistry to contain some slight amount of a toxic substance. That this was for all practical purposes neutralized and played no part in the toxic action of the solutions used is demonstrated in the fuller discussion of this point on page 39 of this paper.

All seeds for these experiments were germinated in sphagnum moss. After being finely broken up the moss was placed in a bucket and kept sufficiently moist for seed germination. It was found that the seedlings were injured if kept too moist, the roots showing an enlargement at the apex, developing into a very blunt tip, and when affected in this way they usually stopped growing and new roots were put forth. The initial radicle was more easily affected in this way. Only seedlings having healthy and vigorous rootlets were used in the experiments. The seeds were first soaked in hydrant water from four to six hours before being placed in the sphagnum moss. After about three days in the temperature of an ordinary room they were ready for use. They were most easily manipulated when the radicles were from three to four centimeters long. The root itself might well be longer, but the apical bud appears almost at the same time as the root, and when more than one or two centimeters long interferes with easy adjustment in the beakers. It was sometimes necessary to pinch off the ends of the leaves, a practice which in no way interfered with the development of the rootlets. When the radicles had reached the length mentioned above, the seedlings were taken out of the sphagnum and placed in beakers containing the solution, the tips of the roots being immersed in the liquid. One rootlet of each seedling was marked with india ink 15 mm. from the apex, which should include practically all of the rapidly growing zone. The amount of elongation during a given period could thus be determined, and this is the best means of knowing whether the root has been actually killed. Unless the concentration of the solution be far above the toxic limit the root does not become flaccid, as is the case with lupines and some other seedlings. After the roots were marked with india ink the seeds were carefully hooked on to the glass rods prepared for that purpose. As much of the root was immersed in the solution as was possible without allowing the seeds or rods to come in contact with the liquid. In all cases the entire length of the marked zone was immersed. The length of the portion of the root in the solution depended, of course, upon the total length of the root. It might at first glance seem that a variation in this respect could affect the result of the experiment, some roots having a larger surface exposed to the solution than others; but it is believed that the large number of seedlings used in each experiment practically eliminated this source of error.

All cultures were left in the solution twenty-four hours, when they were taken up and the amount of elongation of the marked portion of the root was measured and recorded. They were then transferred to a beaker containing hydrant water and allowed to remain there for another twenty-four hours, when they were taken up and the elongation again measured. The radicles which made an additional growth the second twenty-four hours in the hydrant water over the growth in the first twenty-four hours in the salt solution were considered to have survived in the solution and were thus recorded. Those making no additional growth the second twenty-four hours were considered dead and recorded in this way. Coupin and others have intimated that twenty-four hours is not sufficient to kill the plant. This objection is set aside by the consideration that only the death of the apex of the root is regarded in these experiments and not the point at which the whole plant succumbs. The object of this work is merely one of comparison of the effect of a solution of given concentration, during a definite period of time, upon different varieties. Whether this effect is expressed in the death of the whole plant or only that of a single organ is immaterial.

Control experiments were carried on every day, one in hydrant water and one in distilled water, both under conditions identical with those in the salt solutions. The results in hydrant water have been uniform from day to day and in only a few cases were they proved unsatisfactory. In such cases the whole series was discarded, the inference being that some unfavorable condition (of temperature, for example) had interfered.

A word as to the conditions of illumination and temperature during the experiments will not be out of place at this point. When in solutions the roots were exposed to the light during the day. When in the salt solutions during the first 24 hours they were kept on a shelf in the rear of a room with northern exposure only. When in hydrant water during the second 24 hours they were kept on a table at the window, under a moderately strong light. Preliminary experiments were made when commencing the work with lupines, which showed that the strength of the light, at least within the limits involved in these experiments, had no influence on the growth of the roots. Of three series of cultures, all in a solution of the same salt at the same concentration, one was placed in total darkness, another in subdued light, and a third in bright light. Otherwise they were under the same conditions. The elongation of the roots was measured at the end of 24 hours and there was no appreciable difference in the three sets of cultures.

It was impossible to keep a uniform temperature in the laboratory during the winter months, though this factor did not vary enough in either direction to cause any injury in germination or to the roots in the solution. A thermograph was kept running in the room, and a review of the records shows no temperature below 18° or above 30° C. The average temperature during the experiments was about 23° C. When making the experiments with illumination referred to above, similar ones were made to determine the influence of temperature upon the roots. The three different series of cultures (all in the same salt solution, at the same concentration) were exposed for 24 hours to temperatures of 10°, 20°, and 30° C., respectively. Results showed that the roots that had been exposed to a temperature of 20° and 30° C. showed about the same elongation, while the elongation in a temperature of 10° C. was somewhat less.

All solutions were made with water distilled from ordinary hydrant water. The receiver of the still is a porcelain tub and has been used for several years in the Laboratory of Plant Pathology of the Bureau of Plant Industry. At times the distilled water may have contained some slight traces of ammonia and doubtless some other impurities. An analysis of the water was made in the Bureau of Chemistry, and it was found to contain, in parts per million—

Zinc	Trace.
Free ammonia	0.125
Albuminoids	.014
Nitrates	None.
Nitrites	Faint traces.
Total solids (consisting of calcium, sodium, carbonates, sulphates, and chlorids)	7.4

A further discussion of the water used will be found on page 39.

METHOD OF ESTABLISHING THE TOXIC LIMITS.

Before going into details of the results obtained in the simple solutions, the methods of determining the limits of endurance of each variety to each salt will be explained. At one time the writer had thought of fixing the limit of endurance in toxic salt solutions at the concentration in which none of the marked radicles would survive at the end of twenty-four hours. A few experiments, however, showed that this was not the proper method, for occasionally one of the rootlets would be sound and healthy at the end of twenty-four hours in a concentration far above that which would permit the roots of a majority of the plants to survive. In other words, individual variation plays such an important part that the strength of a solution which would permit no root tips to survive would be far above that representing the limit of endurance for the variety as a whole. Attention is thus once more directed to the fact that results obtained from a few individuals are as a rule very inaccurate and unreliable. The characters of a variety (and resistance to toxic effects is one of its characters) are the mean of those of the whole number of individuals composing it. Of course all the individuals of a variety can not be examined, but the number of seedlings experimented with should be large enough to overcome the effect of marked individual variation. It was this consideration that urged the writer to make such a large number of tests. On the other hand, a concentration which would just permit all root tips to survive would not represent the general limit for the variety because of those few individuals which are far inferior to the average in their ability to resist toxic salt solutions. The limit of endurance for the mean of the largest possible number of individuals is the end sought.

After consideration, it seemed that the most perfect idea of the limit for each variety could be obtained by taking the concentration in which about half the seeds survived and about half died. For instance, if 60 seeds were tested in a 0.01 normal solution of magnesium sulphate and 30 survived and 30 died, the toxic limit would be represented by that concentration. Of course it was seldom possible to secure such an equal division, but a slight excess one way or the other would not materially alter the results. In practice it was, furthermore, often found expedient to take the mean of the concentrations actually tested as representing the toxic limit.

To illustrate: The roots were often found dead in a 0.01 normal solution of magnesium chlorid, and alive in a 0.0075 normal. The approximate toxic limit was fixed at the concentration intermediate between these two, although no solutions intermediate in concentration between 0.01 and 0.0075 of a normal solution were actually made up.

The writer does not claim that the limits thus fixed are absolute, but he believes that further experiments would change them very little. To obtain absolutely exact results it would be necessary to employ an indefinite number of solutions of intermediate concentration, and to make tests with a very large number of seedlings. The results recorded here, it is safe to assume, will answer all practical purposes. The different strengths of solution of the same salt differed from each other by 0.005 of a normal solution for sodium chlorid, sodium sulphate, and sodium bicarbonate, and by 0.0025 of a normal solution for sodium carbonate, magnesium sulphate, and magnesium chlorid. That is to say, experiments were made with solutions of a concentration of 0.015, 0.01, 0.005, etc., for sodium chlorid, sodium sulphate, and sodium bicarbonate, and of a concentration of 0.01, 0.0075, 0.0025, etc., for magnesium chlorid, magnesium sulphate, and sodium carbonate, intermediate concentrations being disregarded in practice.

As mentioned earlier in this paper, the death point was determined largely by the elongation of the roots beyond the point 15 mm. from the tip, marked off by india ink. If the roots showed no additional elongation the second 24 hours in hydrant water, they were considered dead. In some cases, however, it has been possible to determine this point by other means.

In the case of the two magnesium salts a solution of a concentration considerably above the limit blackens about 1 or 2 millimeters of the root tip, and often causes the end of the root to bend in the shape of a hook. An appearance of this kind is conclusive evidence that the solution is much too concentrated. Both sodium carbonate and sodium bicarbonate in very strong solution cause a yellowing of the whole body of the root in the solution, and more or less loss of turgor, due, doubtless, to plasmolysis. It is very seldom that rootlets which show that condition at the end of twenty-four hours in the solution will revive when placed in hydrant water.

To make the results herein contained exactly comparable with those furnished by Kearney and Cameron from their studies on lupines, the toxic limits are given in this paper both in fractions of a normal solution and in parts of salt per 100,000 of solution. In addition, the mean of the limits of all the varieties is given under each salt, so that a glance will show how much above or below this point any particular variety may be in regard to each salt used.

The salts have been found harmful in pure solutions in about the order in which they follow each other in the succeeding part of this report—that is, sodium sulphate is less harmful than sodium chlorid when both are in equivalent concentration, and magnesium sulphate is more harmful than sodium bicarbonate when in the same proportion. A concentration of 0.0075 normal magnesium sulphate usually produces about the same effect as 0.025 sodium bicarbonate. Therefore one would say that magnesium sulphate is three times as injurious as sodium bicarbonate when in equivalent concentration.

RESULTS OF EXPERIMENTS.

RESULTS WITH MAGNESIUM SULPHATE.

The results obtained for the different varieties with pure solutions of magnesium sulphate are shown by the following table:

Name of wheat variety.	Maximum limit of endurance.	
	Parts per 100,000 of solution.	Fractional part of a normal solution.
Zimmerman	42	0.0075
Kharkof	25	.00625
Padui	42	.0075
Kubanka	42	.0075
Turkey	56	.01
Maraouani	42	.0075
Budapest	56	.01
Preston	28	.005
Chul	28	.005
Average for all varieties	40	.00736

A glance at the above table is sufficient to show the considerable difference between the varieties in their ability to resist the toxic influence of magnesium sulphate. The least resistant of all the varieties are Chul and Preston, of which about half the seedlings survived in a 0.005 normal solution. Contrasted to these are the two most resistant ones, viz, Budapest and Turkey, surviving equally well in a solution twice as concentrated.

A comparison of these results with wheat with those obtained by Kearney and Cameron using *Lupinus albus* with the same salt will show the great diversity between these two plants. The toxic limit for lupines in a pure solution was found to be 0.00125 of a normal solution. Accepting the results shown by these figures, magnesium sulphate is four times as toxic to lupines as it is to the Chul and Preston wheats, and eight times as toxic as for the Budapest and Turkey varieties. It may be said in this connection that from experiments made by Kearney[a] with maize there is reason to believe that the Gramineæ as a family are much less sensitive to the effect of magnesium salts than the Leguminosæ. Magnesium sulphate has been found in the course of these experiments with wheat to be on an

[a] Science, N. S., 17: 386 (1903).

average much the most toxic of the salts used. It was the most injurious in every case except in two instances, in one of which sodium carbonate and in the other magnesium chlorid proved more toxic. It required a solution of magnesium sulphate twice as concentrated as that of sodium carbonate to be equally toxic to the Budapest variety, the limits in this case being 0.01 normal magnesium sulphate and 0.005 normal sodium carbonate. The other instance referred to is not so marked. Magnesium chlorid is found to be somewhat more toxic than magnesium sulphate for one variety—Turkey—the limits being for magnesium chlorid 0.0075 normal and for magnesium sulphate 0.01 normal.

Comparing the average toxic limit for each salt, as stated in the tables that follow, magnesium sulphate is one and two-sevenths times as injurious as magnesium chlorid, one and three-sevenths times as injurious as sodium carbonate, three and five-sevenths times as injurious as sodium bicarbonate, little more than six times as toxic as sodium sulphate, and seven and five-sevenths times as injurious as sodium chlorid.

Magnesium sulphate in the soil is not considered injurious to any appreciable extent, but this is no doubt due to the neutralizing effect of other salts with which it is associated. Kearney and Cameron, in their experiments on *Lupinus albus* and *Medicago sativa*, found magnesium sulphate in pure solutions to be the most toxic of all the salts. The writer found the same true for the lupines. But when other salts are added to a solution of magnesium sulphate, toxicity, both absolute and relative, is altered. Kearney and Cameron [a] say:

> Addition of sodium sulphate, which itself is injurious in pure solution, raises the limit of magnesium sulphate three times, while the presence of calcium sulphate allows a small proportion of the roots to barely survive during twenty-four hours in a solution of magnesium sulphate 480 times as concentrated as that which in pure solutions represents the limits of endurance.

To lower classes of plant life magnesium sulphate is apparently much less toxic. Dr. B. M. Duggar [b] has made some experiments with marine algæ to determine the nutrient value of the salts of some of the alkalis and alkali earths when added to sea water. He found that after the acids and some of the salts of the heavy metals the potassium phosphates proved most toxic. The least toxic were the salts of sodium and magnesium, while the sulphate of magnesium was the least injurious of all the salts used. The less injurious effect

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[a] Some Mutual Relations Between Alkali Soils and Vegetation. Report No. 71, U. S. Department of Agriculture (1902).

[b] The Toxic Effect of Some Nutrient Salts on Certain Marine Algæ. Science, N. S., 17: 159 (1903).

of the magnesium salts is probably due to the presence of neutralizing salts in the sea water to which he added the magnesium compounds, although we are not yet in a position to say that magnesium may not be far less toxic to the Algæ than to the Leguminosæ or Gramineæ.

To show the relative toxic effect of magnesium sulphate to some of the other salts, Loew [a] has made some interesting observations, and states that Spirogyra died within four or five days in a 1-per-mille solution of magnesium sulphate, but remained alive for a long time in corresponding solutions of the sulphates of sodium, potassium, and calcium. Upon the roots of some higher plants the same investigator made similar observations, and says that Vicia and Pisum do not start lateral roots when kept in a solution of 0.5 per cent of magnesium sulphate or nitrate, and the root cap and epidermal cells die after a few days. Seedlings of Phaseolus placed in a solution of 0.1 per cent magnesium sulphate with 0.1 per cent of monopotassium phosphate showed injury to the roots after five days, and the entire plant succumbed soon afterwards.

Coupin [b] found during the course of some experiments with wheat that magnesium chlorid was more toxic than magnesium sulphate. He gives the limit for magnesium sulphate at 1 per cent and for magnesium chlorid at 0.8 per cent.

RESULTS WITH MAGNESIUM CHLORID.

The following table shows the results obtained for the different varieties with pure solutions of magnesium chlorid:

Name of wheat variety.	Maximum limit of endurance.	
	Parts per 100,000 of solution.	Fractional part of a normal solution.
Zimmerman	72	0.015
Kharkof	48	.01
Padui	48	.01
Kubanka	42	.00875
Turkey	36	.0075
Maraouani	48	.01
Budapest	60	.0125
Preston	24	.005
Chul	24	.005
Average for all varieties	40	.00831

[a] The Physiological Rôle of Mineral Nutrients in Plants. Bul. 45, Bureau of Plant Industry, U. S. Department of Agriculture (1903).

[b] Sur la Toxicité du Chlorure de Sodium et de l'Eau de Mer a l'Egard des Végétaux. Revue Générale de Botanique, 10: 188 (1898).

Magnesium chlorid, like the sulphate, seldom occurs alone in nature in sufficient quantity to be of very great consequence. It is nearly, if not always, associated in the soil with some other salts, such as those of sodium and calcium, which tend to neutralize its effect upon plants. In these experiments with wheat, as in those with lupines, it was found to rank next to magnesium sulphate as a toxic agent when in pure solutions.

The average limit of concentration of magnesium chlorid for wheat seedlings is 0.00931 of a normal solution, as against 0.00736 for magnesium sulphate. Again, referring to Kearney and Cameron's results with the same salts for lupines, we find some variations. As is easily seen with the writer's results with wheat, magnesium sulphate is only about one-third more toxic than magnesium chlorid, while Kearney and Cameron's results show the sulphate twice as toxic as the chlorid. The investigators named found the roots of lupines to barely survive in 0.0025 of a normal solution of magnesium chlorid, while Kearney showed that *Zea mays* would live in a solution a little more than thirty times as concentrated. Magnesium chlorid is twice as toxic to the white lupine as to the least resistant variety of wheat tested, and six times as toxic to the lupine as to the most resistant variety of wheat. It is a surprising fact that some varieties of wheat are six times as resistant and that maize is thirty times as resistant to this salt as *Lupinus albus*.

It will be seen that the variation of the wheat varieties among themselves is more pronounced in the chlorid than in the sulphate. While the toxic limit for the least resistant of the varieties is the same (0.005 of a normal solution) for the two salts, that of the most resistant variety (0.015 normal) is much higher in magnesium chlorid than in the sulphate. The ratio of variation between the two extremes of resistance with magnesium sulphate was 2 to 1, as against 3 to 1 with the chlorid.

RESULTS WITH SODIUM CARBONATE.

The following table gives the results with pure solutions of sodium carbonate:

Name of wheat variety.	Maximum limit of endurance. Parts per 100,000 of solution.	Maximum limit of endurance. Fractional part of a normal solution.
Zimmerman	65	0.0125
Kharkof	78	.015
Padui	52	.01
Kubanka	39	.0075
Turkey	78	.015
Maraouani	41	.008
Budapest	26	.005
Preston	65	.0125
Chul	65	.0125
Average for all varieties	57	.0109

The results shown by the above table are not materially different from those with magnesium chlorid. Sodium carbonate in pure solutions is slightly less harmful, as shown by the comparison of the average of all the varieties, being in the case of magnesium chlorid 0.0093 and for sodium carbonate 0.0109 of a normal solution. The extremes in both cases are the same, though there are two varieties with a resistance of 0.015 for sodium carbonate as against one for magnesium chlorid. Five varieties in the case of sodium carbonate have a resistance above the average as against four in the case of magnesium chlorid. One variety alone, Budapest, has a resistance of only 0.005 as against two for magnesium chlorid.

Of the three salts so far described, sodium carbonate is in the soil generally the most harmful, (1) because in excessive quantity it is more widely distributed, and (2) because it is less easily neutralized by other salts with which it is usually associated.

The opinions of experimenters differ considerably as to the relative toxic effect of this salt. Kearney and Cameron showed that, in the case of *Lupinus albus* at least, sodium carbonate is but little more injurious than sodium sulphate, the toxic limit in each case being 0.005 and 0.0075 of a normal solution, respectively. It will be seen that the limit for the lupine obtained by them with sodium carbonate is the same as the resistance for Budapest wheat, but only one-third of that for the Turkey and Kharkof varieties. The limit of concentration for the lupine, as shown by their report, is about equivalent to one-half of the average for the several wheat varieties, in the same salt solution. Kearney found *Zea mays* to survive in the same salt at a concentration three times as great as that representing the limit for the lupine, and equal to that for the most resistant varieties of wheat.

Coupin[a] found the toxic limit of wheat in sodium carbonate to be about 1.1 per cent. In view of the fact, however, that he noted the death of the whole plant and not the root tips, the limit of concentration as determined by him would necessarily be much higher.

RESULTS WITH SODIUM BICARBONATE.

The limits in pure solutions of sodium bicarbonate are shown in the following table:

Name of wheat variety.	Maximum limit of endurance.	
	Parts per 100,000 of solution.	Fractional parts of a normal solution.
Zimmerman	234	0.028
Kharkof	251	.03
Padui	230	.0275
Kubanka	209	.025
Turkey	230	.0275
Maraouani	188	.0225
Budapest	209	.025
Preston	209	.025
Chul	209	.025
Average for all varieties.	219	.026

Of all the salts used sodium bicarbonate seems to bring out the least variation in resistance so far as these experiments are concerned. The least resistant variety was Maraouani and the most resistant Kharkof, which were able to survive in a 0.0225 and 0.03 normal solution, respectively. These results do not differ to an important extent from those of Kearney and Cameron for *Lupinus albus*, the toxic limit of which was slightly lower (0.02) than that for Maraouani wheat.

The writer finds sodium carbonate to be about two and six-tenths times as injurious to wheat when in equivalent concentration as sodium bicarbonate. Kearney found the difference to be even greater in the case of maize, the ratio being about 4 to 1. Coupin[b] reverses the relative toxic order of these two salts. This difference in the

[a] Sur la Toxicité du Chlorure de Sodium et de l'Eau de Mer a l'Egard des Végétaux. Revue Générale de Botanique, 10: 180 (1898).

[b] Sur la Toxicité des Composés de Potassium et de l'Ammonium a l'Egard des Végétaux Supérieurs. Revue Générale de Botanique, 12: 180 (1900).

criterion of toxic action, i. e., the death of the whole plant rather than of the root tip alone, should not affect the relative toxic influence of the two salts. Coupin's results showed that it required a 1.1 per cent solution of sodium carbonate to kill wheat seedlings, while only 0.6 per cent was necessary to produce the same effect when sodium bicarbonate was employed.

As to the relative toxic order of the carbonate and bicarbonate, the results recorded agree quite well with those of Sigmund,[a] who found that wheat development was retarded and germinating seeds of vetch and rape were killed in a 0.5 per cent solution of sodium carbonate, while the same concentration of sodium bicarbonate was quite harmless.

Kearney and Cameron found sodium bicarbonate somewhat less toxic than sodium chlorid for the lupine, and, further, that a 0.02 normal solution of sodium bicarbonate permits plants to survive in much better condition than in the corresponding concentration of the chlorid. Kearney has also shown by experiments that the bicarbonate is less toxic to maize than is sodium chlorid, the death point for the bicarbonate being established at 0.05 and for the chlorid at 0.04 of a normal solution.

In view of all these differences it will be no easy matter to decide the relative harmfulness of these sodium salts. Experiments will have to be performed on a large number of plants of widely different relationship before any definite conclusions can be reached. There is great probability that the order of their toxicity is not the same for all species of plants. This is very well demonstrated by a comparison of the writer's results with those of Kearney and Cameron, who found sodium sulphate more toxic to *Lupinus albus* than sodium bicarbonate, while the writer found the reverse to be true for wheat. There is a tendency among physiological experimenters to draw general conclusions for the whole plant kingdom from the results obtained for a few varieties, species, or genera, which is absolutely unjustifiable. Too much emphasis can not be used in condemning such inferences. The results here obtained, it is thought, will hold good for these particular varieties of wheat, but they are not indicative except within rather wide limits of what others show.[b] They

[a] Ueber die Einwirkung Chemischer Agentien auf die Keimung, Landw. Vers. Stat., 47: 2 (1896).

[b] This point is brought out in a most marked way by the work of Cameron and Breazeale upon the effect of acids on wheat, maize, and clover, respectively. (The Toxic Action of Acids and Salts on Seedlings, Journal Phys. Chem., vol. 8, No. 1, p. 1, Jan., 1904.)

will serve for making comparisons, but not for drawing conclusions as to the behavior of plants in general.

RESULTS WITH SODIUM SULPHATE.

The comparative effect of pure solutions of sodium sulphate upon the different varieties is shown in the table which follows:

Name of wheat variety.	Maximum limit of endurance.	
	Parts per 100,000 of solution.	Fractional parts of a normal solution.
Zimmerman	353	0.05
Kharkof	300	.0425
Padui	318	.045
Kubanka	353	.05
Turkey	300	.0425
Maraouani	336	.0475
Budapest	265	.0375
Preston	242	.035
Chul	283	.04
Average for all varieties	305	.0433

In sodium sulphate, as in sodium bicarbonate, the toxic limits for the different varieties show less variation than in the case of other salts used. The least resistant to this comparatively harmless salt, as to most of the others used in these experiments, is the Preston wheat. This variety has been grown for a number of years in a semihumid region where alkali soils do not occur. In view of these facts one would expect this variety to be somewhat less resistant to these salts. Since there is no excess of soluble salts in the soils of this region, Preston has had no opportunity to develop salt resistance. The varieties most resistant to sodium sulphate are Zimmerman and Kubanka, both surviving as well in a 0.05 normal solution as Preston in 0.035. As to the origin of these varieties, also, it is just what would be expected from their resistance to salts. Both sorts came from arid or semiarid regions, where saline soils are abundant. Kubanka is grown in regions containing numerous salt marshes and lakes, and that it should have acquired ability to resist salts in the soil is only natural. Zimmerman likewise was obtained from a region having soils of more or less saline character, and to this is probably due its power of resistance in salt solutions. It is not unlikely that the soils from the regions from which the remaining varieties were obtained contain a less amount of sodium sulphate proportionate to their smaller resistance to this salt as shown in these water cultures. This can not definitely be known until experiments have been made correlating the amount of the different salts in the soil upon which the different varieties grew, with their resistance in pure solutions.

Some interesting differences can be noted here between the resistance of wheat and of lupines to sodium sulphate. The Preston variety is $4\frac{2}{3}$ times as resistant, and Zimmerman and Kubanka $6\frac{2}{3}$ times as resistant, as *Lupinus albus*, the toxic limit of the latter having been established by Kearney and Cameron at 0.0075. They found sodium sulphate more toxic to Lupinus than sodium bicarbonate, while for every variety of wheat in these experiments the reverse is true. With maize Kearney showed that the seedling would survive equally well in both salts, and established the limit at 0.05 of a normal solution.

Hilgard states that few plants can bear as much as 0.1 per cent in the soil of sodium carbonate, or about 3,500 pounds per acre to the depth of 1 foot. For sodium chlorid the limit in the soil is about 0.25 per cent. In the case of sodium sulphate, most plants can grow in the presence of 0.45 to 0.50 per cent in the soil. In view of this fact sodium chlorid under soil conditions would seem to be more toxic to most plants than the sulphate.

Stewart [a] has made a number of interesting tests on the power of seeds to germinate in the presence of sodium carbonate, sodium sulphate, and sodium chlorid. He found the carbonate and the chlorid to be more injurious than the sulphate. With one exception (rye seeds in the presence of the chlorid), 0.50 per cent of either carbonate or chlorid proved fatal to germination. Stewart showed that sodium sulphate is far less injurious than either of the other salts. The character of his experiments indicates, however, that they are not directly comparable with such as are here described. His seeds were placed for germination in sand on tin plates and watered, the nature of the water used not being stated. Kearney and Cameron have shown that these salts are decidedly different in the degree to which their toxic effect can be neutralized by the addition of other salts, such as the chlorid or sulphate of calcium. It is possible that the sand or the water, or both, used by Stewart contained more or less calcium salts. The results of Kearney and Cameron, above referred to, show that the toxic effect of sodium carbonate, and next to it that of sodium chlorid, are neutralized far less effectively by calcium sul-

[a] Effect of Alkali on Seed Germination. Ninth Annual Report, Utah Agricultural Experiment Station, p. 26 (1898).

phate than is sodium sulphate. They found that the resistance of sodium sulphate was raised 60 times by adding calcium sulphate. In the light of these facts it is easy to accept Stewart's results. In fact, Kearney and Cameron showed that when other salts were added the limit for *Lupinus albus* in sodium sulphate could be raised to 0.30 of a normal solution, and that for sodium chlorid only to 0.20, while in pure solutions the limit for sodium sulphate was a concentration of 0.0075 and for sodium chlorid 0.02. This also explains Hilgard's results as to the comparative harmlessness of sodium sulphate in the soil where other salts are always present.

RESULTS WITH SODIUM CHLORID.

The results obtained by the writer with pure solutions of sodium chlorid are shown in the following table:

Name of wheat variety.	Maximum limit of endurance.	
	Parts per 100,000 of solution.	Fractional part of a normal solution.
Zimmerman	377	0.065
Kharkof	319	.055
Padui	333	.0575
Kubanka	333	.0575
Turkey	290	.05
Maraouani	319	.055
Budapest	275	.0475
Preston	319	.055
Chul	261	.045
Average for all varieties	314	.0542

That sodium chlorid is the least toxic to wheat of all the salts used is evinced by the table above. Next to it, of course, is sodium sulphate. Comparing the results with those obtained by Kearney and Cameron for lupines, the varieties of wheat are two and one-half to three times as resistant. Coupin[a] also found wheat more resistant to sodium chlorid than the white lupines. He has experimented with several species of plants and found the whole plant to be killed in the following concentrations: Wheat, 1.8 per cent; peas, 1.2 per

[a] Sur la Toxicité du Chlorure Sodium et de l'Eau de Mer a l'Egard des Végétaux. Revue Générale de Botanique, 10: 178 (1898).

cent; vetch, 1.1 per cent; maize, 1.4 per cent, and white lupine, 1.2 per cent.[a]

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[a] Guthrie, F. B., and Holmes, R. (Roy. Soc. New South Wales, Oct. 8, 1902), conducted some experiments on wheats in two kinds of soils. To one of the soils was added a fertilizer consisting of a mixture of 15 grams of sulphate of ammonia, 6 grams of superphosphate, 4 grams of sulphate of potash, and varying quantities of other substances. The composition of the first soil was as follows:

	Per cent.
Moisture	3.83
Organic matter	13.75
Nitrogen	.208
Soluble in hydrochloric acid:	
Lime	.165
Potash	.065
Phosphoric acid	.107
Magnesia	.072

The soil was found to contain 0.016 per cent of sodium chlorid in addition to the substances enumerated above.

The composition of the second soil was as follows:

	Per cent.
Moisture	2.91
Organic matter	8.33
Nitrogen	.070
Soluble in hydrochloric acid:	
Lime	.440
Potash	.077
Phosphoric acid	.110

No fertilizer was added and the soil was originally free from chlorids. It was found that in the first soil the seeds germinated and grew well when enough sodium chlorid was added to the soil to give it a content of 0.066 per cent of that salt. Further, that in the second soil, to which no fertilizer was added, in the presence of 0.05 per cent of sodium chlorid, germination was slightly retarded, but the plants finally recovered and grew well. As to the results, these authors say:

From 0.01 to 0.02 per cent of sodium chlorid is without effect on the wheat plant, the grain germinating well and the plant growing vigorously. With 0.05 to 0.10 per cent of sodium chlorid the germination is somewhat retarded, the plants are less vigorous, but recover and grow well. With 0.15 the germination is still more affected and the plants would probably not recover under less favorable conditions than those of the experiment. Two-tenths per cent of sodium chlorid in the soil is fatal to the growth of wheat.

An experiment performed by Messrs. E. Charabot and A. Hébert (Compt. Rend. Acad. Sci. Paris, 134: 181, 1902), which shows the chemical influence of sodium chlorid upon more mature plants, is a very interesting one. These investigators found that by adding sodium chlorid some chemical properties are decreased.

The writer finds that a 2 per cent solution of sodium chlorid saturated with calcium sulphate is sufficient to kill moss growing on the soil in two weeks' time. At the end of one week no change is noticeable, except that growth is retarded. One week longer, however, suffices to kill the moss completely and turn it a brownish color. The solution was added to the pots on which the moss grew in the laboratory every other day for about that length of time.

SUMMARY OF TABLES.

In order to make more easily comparable the differences of resistance of the several varieties to the various salts, the results as a whole have been brought together in the following table. At the bottom of the columns is given the average, for each salt, of the toxic limits of all the varieties; so it requires only a glance to see which varieties are above or below the average in their resistance to the toxic effect of each salt.

Name of wheat variety.	Magnesium sulphate.	Magnesium chlorid.	Sodium carbonate.	Sodium bicarbonate.	Sodium sulphate.	Sodium chlorid.
Zimmerman	0.0075	0.015	0.0125	0.028	0.05	0.065
Kharkof	.00625	.01	.015	.03	.0425	.055
Padui	.0075	.01	.01	.0275	.045	.0575
Kubanka	.0075	.00875	.0075	.025	.05	.0575
Turkey	.01	.0075	.015	.0275	.0425	.05
Maraouani	.0075	.01	.008	.0225	.0475	.055
Budapest	.01	.0125	.005	.025	.0375	.0475
Preston	.005	.005	.0125	.025	.035	.055
Chul	.005	.005	.0125	.025	.04	.045
Average	.00736	.0093	.0109	.026	.0433	.0542

A glance at the above table shows that the Zimmerman variety is much the most resistant. This, however, does not necessarily mean that it is most resistant to every salt. On the contrary, Zimmerman is less resistant to magnesium sulphate than Budapest and Turkey, less resistant to sodium carbonate than Turkey and Kharkof, and less resistant to sodium bicarbonate than Kharkof. This same variety, however, is very resistant to the influence of sodium chlorid, sodium sulphate, and sodium carbonate, which brings up its average to a considerable extent. The least resistant variety is Chul, which runs low for all salts except sodium carbonate, in which its resistance is slightly above the average of the varieties with which experiments were made. The low resistance of this variety was unexpected, in view of the character of the country from which it came.

A further consideration of this table shows how nearly equal the Padui and Kubanka varieties are in their resistance. A comparison of the two varieties for the same salts shows but a slight variation. Taking into consideration the original habitat of the two varieties, we would expect very little difference. Both are Russian varieties and subjected to very similar climatic and soil conditions. Both varieties are very resistant to salt solutions, and in view of the fact that they both come from regions containing much saline soil their similarity in this respect is not surprising.

Good examples for contrast to Padui and Kubanka are furnished in Budapest and Preston. Budapest is a naturalized Michigan variety and Preston a variety from Canada. The soil and climatic conditions are very similar. Both regions are comparatively humid, with little or no saline soil. Both of these varieties are low in resistance to salt solutions, just as would be expected.

A comparison of the resistance of the different varieties with the region from which they came in respect to soil and climatic conditions shows that their resistance to saline solutions can probably be correlated with the natural habitat of the varieties; that is, the results herein obtained indicate that a variety grown in a locality having little or no excess of salts in the soil has a comparatively low resistance in saline water cultures. It further shows that varieties grown in regions having more saline soils have a much greater resistance in saline water cultures.

COMPARISON OF RESULTS WITH DIFFERENT SPECIES.

The results obtained for the lupines by Kearney and Cameron and those for maize by Kearney have frequently been referred to in the foregoing pages. It has been possible to compare them to the writer's results with wheat only in a fragmentary way. Since there are some very surprising differences in the toxicity of the same salts to the three plants, the results have been brought together in one table for comparison. Kearney and Cameron used but one variety of the lupine and of maize, their results being shown in the following table. The writer in his experiments on wheat has used nine different varieties, but in the following table only the mean resistance of all the varieties has been taken.

The limit of concentration of the salts which can be endured by wheat, lupine, and maize is as follows, the results being stated both in fractions of a normal solution and in parts of salt per 100,000 of solution:

Salt.	Degree of concentration.					
	Wheat.		Lupine.		Maize.	
	Parts of a normal solution.	Parts per 100,000 of solution.	Parts of a normal solution.	Parts per 100,000 of solution.	Parts of a normal solution.	Parts per 100,000 of solution.
Magnesium sulphate	0.007	39	0.00125	7	0.25	1,400
Magnesium chlorid	.009	108	.0025	12	.08	384
Sodium carbonate	.01	52	.005	26	.015	78
Sodium bicarbonate	.026	217	.02	167	.05	417
Sodium sulphate	.043	302	.0075	53	.05	353
Sodium chlorid	.054	313	.02	116	.04	232

It is remarkable that while magnesium sulphate is the most toxic to the wheat and the lupine of all the salts used it is the least injurious to maize, being thirty-five times and two hundred times, respectively, more toxic to wheat or lupine than to maize.

Magnesium sulphate and magnesium chlorid differ but little in the concentration necessary to kill the root tips of wheat seedlings, while a solution of the former only half as strong as the latter is sufficient to kill the lupines in the same length of time. In contrast to this, a solution of magnesium chlorid only about one-third as concentrated as the critical solution of magnesium sulphate is the strongest that can be endured by the root tips of maize, the order of toxicity of the two salts being reversed. The root tips of the lupines have been killed by every salt used, at a less concentration than that which can be endured by wheat and maize, a solution of sodium carbonate one-half and one-third as concentrated as that necessary to kill wheat and maize, respectively, being fatal to the lupine. It will be noticed, however, that the least amount of diversity is evinced by the three plants in the presence of sodium carbonate and sodium bicarbonate.

Wheat and maize show very little difference in resistance to sodium sulphate, but a solution about one-sixth as concentrated as that necessary to kill maize is toxic to the lupine.

It is a very surprising fact that the variation between the three plants is so great. The salts of magnesium which are the most toxic to wheat and lupines are the least toxic to maize, the difference being as is 200 to 1. Maize is on the whole much more resistant to pure salt solutions than is wheat or the white lupine, while the root tips of the lupines are killed by each of the salts at a much less concentration than that necessary to destroy the root tips of wheat seedlings.

Especially interesting results in this connection have been brought out by Cameron and Breazeale[a] with some experiments concerning the action of acids and salts upon maize, wheat, and clover. The salts employed were not the same as those used by the writer, but the results for both the acids and salts are sufficient to show the difference in resistance between different species and also the different action of different salts and acids on the same species.

Cameron and Breazeale found that N/850 and N/600 solutions of acetic and succinic acids, respectively, were the toxic limit for seedlings of maize, but wheat and clover in the same acids would endure only N/20000. They found the variations in salt solutions to be equally as great, but in some ways reversed. In potassium chlorid the toxic limit for wheat and clover is the same, each having a greater concentration than that necessary to kill seedlings of maize. In potassium oxalate, wheat was found to endure a concentration six times as great as that for clover. It is interesting to note here that the more toxic the acids the more uniform are the results, while for the salt solutions the reverse is true. The writer obtained similar results for the salts used in the experiments described in this paper.

[a] The Toxic Action of Acids and Salts on Seedlings, Journal Phys. Chem., vol. 8, No. 1, p. 1 (January, 1904).

ASH ANALYSES.

To determine whether or not the amount or the composition of the ash in the seed could be correlated with the resistance of the seedlings to saline solutions, analyses of seeds of each variety used and of the same origin as those used in the culture experiments were obtained through the Bureau of Chemistry of the Department of Agriculture. The results fail to show any correlation between the ash constituents of the seeds and the resistance of the seedlings in water cultures. As the absence of such correlation is important, the table of analyses is inserted. It is a surprising fact that some of the ash constituents run very low for varieties such as Padui and Kharkof, in which one would expect them to be high.

Table of analyses of the ash constituents of wheat seedlings.

Variety.	H_2O.	Crude ash.	CO_2.	MgO.	K_2O.	Na_2O.	P_2O_5.	SO_3.	Cl.
Zimmerman	8.34	1.72	0.080	0.22	0.45	0.050	0.85	0.037	0.054
Kharkof	8.25	1.35	.066	.18	.41	.050	.56	.040	.054
Padui	8.72	1.40	.048	.18	.43	.052	.57	.040	.042
Kubanka	7.68	1.93	.064	.22	.53	.056	.93	.043	.054
Turkey	7.54	1.73	.064	.20	.51	.046	.78	.041	.054
Maraouani	9.70	1.66	.028	.15	.51	....	.70	.043	.054
Budapest	8.38	1.91	.048	.21	.53	.042	.94	.040	.054
Preston	8.48	1.35	.040	.23	.47	.045	.97	.057	.054
Chul	7.78	1.98	.088	.28	.50	....	.78	.042	.054

INDIVIDUAL VARIABILITY.

Individual variation within the different varieties is a subject deserving some attention in this connection. Some very striking instances have been noted during the course of these experiments. Since it has been demonstrated beyond dispute that the varieties differ one from another in resistance to toxic salts, it is only natural to suppose that the individuals of the same variety would show diversity in this respect. It is the existence of this individual variability that has made it impossible to obtain reliable results without testing a large number of seedlings. As soon as this factor was eliminated it became comparatively easy to establish the toxic limit. In some instances it was more difficult than in others, and some varieties were especially troublesome in this respect. The reasons for this are difficult to determine.

No experiments have been conducted for the exclusive purpose of demonstrating the range of individual variation, and only results are here recorded which have been brought out incidentally during the tests for varietal variation. The writer does not doubt that experiments with this end in view would bring out instances of individual variability much more striking than any so far obtained. Nearly all varieties, however, have shown exceeding diversity in the resistance of individual plants, and it will be interesting to mention a few of them. In the experiments to determine the toxic limits for the different varieties the results were based on averages, e. g., in a solution of sodium carbonate of a concentration that was taken to represent the toxic limit 23 seeds were alive in a 0.01 solution and 27 dead. It is not known how many of those seedlings which were alive might have survived in a solution still more concentrated, perhaps of twice the strength, nor is it known how many of those that were killed would have been killed in a solution only half as concentrated.[a]

Instead of making tables to show the individual variation, as was first suggested, only striking instances will be referred to under the names of the different varieties. A series of tables would require more space than can here be given to the subject.

Budapest.—In connection with the experiments with the Budapest variety two striking instances have been noted, one with sodium bicarbonate and the other with magnesium sulphate. The toxic limits for these two salts are 0.025 and 0.01 of a normal solution, respectively. In one experiment, out of a number of seedlings in 0.015 normal sodium bicarbonate two died. In the case of magnesium sulphate, in one experiment all the rootlets were dead in 0.015 normal except one, which survived. Here are two instances with remarkable extremes. In the former case the two seeds were of exceedingly low vitality, while in the latter instance one seed had remarkably great vitality.

Chul.—No very marked individual variations presented themselves during the experiments with the Chul variety.

Turkey.—Few remarkable variations were observed with the Turkey variety. But one instance deserves special attention. The average toxic limit in magnesium sulphate is 0.01 normal, but in a number of tests a few seedlings were readily killed in a solution only half as concentrated as the solution in which one-half of the total number of individuals exposed to it survived.

Preston.—The experiments with magnesium salts brought out two interesting cases with the Preston variety. The toxic limit for this

[a] Moore and Kellerman (Bul. 64, Bureau of Plant Industry, U. S. Dept. of Agriculture) have given some excellent instances of individual variability with respect to resistance to toxic agents. They have made numerous experiments with copper sulphate upon different algæ which are found in water supplies. They found that 1 part of copper sulphate to 2,000 of water was sufficient to kill one-half of the individuals of *Chlamydomonas piriformis* exposed to it in two days, while the same concentration was sufficient to kill only one-tenth of the same form in three following days, and in three other days only one-fourth. With *Desmidium swartzii* 1 part of copper to 100,000 was sufficient to destroy one-half and three-fourths, respectively, of the individuals involved in two different sets of experiments. Numerous other instances might be cited, but these will suffice to show that individual variation in this respect is not confined to wheat alone.

variety with both the chlorid and the sulphate of magnesium is 0.005 normal. In both salts, however, rootlets of some of the plants survived in solutions twice as concentrated. In the case of magnesium chlorid, 8 out of 25 survived, while with the sulphate only 2 out of the same number survived.

Kharkof.—In solutions of sodium chlorid and sodium sulphate of a concentration of 0.045 and 0.035 normal, respectively, one seedling of the Kharkof variety was dead in each, the limits fixed for these two salts being 0.055 and 0.0425. The root tips of two seedlings were killed in 0.02 normal of sodium bicarbonate, for which the average toxic limit is 0.03.

Zimmerman.—The Zimmerman variety, while the most resistant of all, shows some very marked individual variation. A striking instance occurred with magnesium chlorid, the average toxic limit of which is 0.015 normal. In a solution one-third as concentrated (0.005 normal) 2 seedlings out of 20 could not survive. The limit of concentration for this variety in sodium chlorid is 0.065 normal, but the rootlets of one seedling could not survive in 0.015. Similar to this are the results with sodium sulphate, the toxic limit being 0.05, but the root tips of two individuals did not survive in 0.035 normal solution.

Padui.—No variation of any importance.

Maraouani.—The rootlets of two seedlings of the Maraouani variety were killed in 0.005 normal magnesium sulphate, while 3 out of 20 individuals survived in 0.015. The average toxic limit for this salt is 0.0075 of a normal solution.

Kubanka.—No important variations.

NEUTRALIZING EFFECT OF THE SALTS EMPLOYED UPON OTHER TOXIC SUBSTANCES.

Because of a discovery which was made when these experiments were almost completed it is necessary to add a few remarks upon the neutralizing effect upon other toxic substances of the salts of sodium and magnesium. During the whole course of the experiments the writer was unable to get seedlings to grow or even to live for twenty-four hours in the distilled water used. This seemed unaccountable, as it quite disagreed with the results of other experimenters. Coupin found the roots of wheat seedlings to thrive well in perfectly distilled water, and Dehérain and Demoussy[a] showed absolutely pure water to be perfectly harmless to root growth. Numerous experiments have been made to determine this point, with more or less varying results. Certain experimenters have held that distilled water was not conducive to good growth.

[a] Sur la Germination dans l'Eau Distillé, Compt. Rend., Paris, 132: 523 (1901).

This is probably an error so far as young seedlings are concerned. The seed contains everything necessary for the early growth of the plant, and the absence of all minerals or other nutrient compounds in the surrounding solution should produce no bad effect during the earliest stages of growth. Those who claim that distilled water is injurious will probably find, upon closer observation, that it is some injurious substance in the water which is really toxic to the roots. In the case of many plants one of the most toxic substances known is copper, and it is more than likely that it is present in much of the water which experimenters have found to be injurious. Coupin states that one part of copper to 700,000,000 of water is sufficient to retard the root growth of wheat seedlings. A mere trace of copper is sufficient to retard growth in many cases.

As a result of an analysis made in the Bureau of Chemistry of the Department of Agriculture of the distilled water used in these experiments, it was found to contain a considerable quantity of zinc, but no trace of copper. The harmful effect probably should be attributed to zinc alone. The water used in these experiments was distilled but once, and was collected in a porcelain tub as a receiver.

It was thought while the work with wheat seedlings was in progress that copper or zinc might be the cause of the injurious effects, but the writer used the water from the same still for all experiments with *Lupinus albus*, and no toxic effect of the distilled water was noticeable. Control checks with lupines were carried in both distilled and hydrant water, and no difference was found in the rate of growth. It was this observation which at the outset of the work with wheat gave the writer confidence in the quality of the distilled water. This is apparently another indication that different species of plants vary greatly in their ability to resist the influence of toxic salts. Wheats are apparently much more sensitive than lupines to pure solutions of zinc salts, although much less sensitive to pure solutions of sodium and magnesium salts.

At first thought one would conclude that since the distilled water used contained harmful substances the experiments above described are practically without value; but such is not the case, as will be seen before this discussion is completed. In order to compare closely the water used during most of the experiments with absolutely pure water, some experiments were made. To secure absolute purity in the water a new still was made of the best nonsoluble glassware, having no metal in any of its parts. The same water that had been previously used was redistilled for the purpose. The wheat seedlings were treated in every way as before. A control was also carried in Potomac River water for comparison, and each lot of seed was taken up each day and the elongation of the roots measured and recorded for four consecutive days. In the twice-distilled water they grew about as well as in hydrant water. In order to show to what extent the impurity of the water used would affect former experiments, salt solutions of a dilution far below the toxic limits, as already established, were made, using the water which was but once distilled. The results showed that the toxic element in the water was effectively neutralized by the addition of even minute quantities of any one of the salts used in the experiments. For comparison equal numbers of seeds were tested at the same time in the water distilled twice, in that distilled but once (that used throughout the above-described experiments), and in dilute salt solutions made up with the once-distilled water.

The following table embodies the results obtained with very dilute solutions of the salts, with distilled water, and with hydrant water:

Water or solution.	Elongation of roots at the end of a given time.			
	First day.	Second day.	Third day.	Fourth day.
	mm.	*mm.*	*mm.*	*mm.*
Water distilled once	2.2	2.2	2.2	2.2
Water distilled twice	11.4	26.2	33.7	36.3
Magnesium sulphate (0.001 normal)[a]	10.6	21.2	27	27.6
Magnesium chlorid (0.001 normal)[a]	16.8	30.8	37.6	38.2
Sodium carbonate (0.001 normal)[a]	11.3	14.5	16.8	17.8
Sodium bicarbonate (0.0075 normal)[a]	10.6	24	31	32.4
Sodium sulphate (0.015 normal)[a]	8.5	22	31.5	34.8
Sodium chlorid (0.015 normal)[a]	7.8	15	19	22
Hydrant water	9.4	23.8	37.4	46

[a] The mean toxic limit of all varieties of wheat tested in the presence of the salts here employed is shown as follows:

	Parts of normal solution.
Magnesium sulphate	0.00736
Magnesium chlorid	.00931
Sodium carbonate	.0109
Sodium bicarbonate	.026
Sodium sulphate	.0432
Sodium chlorid	.0542

A comparison of these figures with the table above shows that from one-third to one-tenth the concentrations of the solutions which represent the limit of endurance of the wheat varieties is sufficient to neutralize the harmful effect of the zinc present in the distilled water.

The above table shows that after an elongation of 2.2 mm. during the first day in the water distilled once no further growth took place. A comparison of that with absolutely pure water (in this case redistilled) shows that there was some element in the first water which hindered growth and which was not found in the second. This, as the chemical analysis above referred to showed, is probably zinc.

The results in the dilute salt solutions which were made up with the injurious once-distilled water showed that there was no material difference in the elongation made in them and in the checks in redistilled and hydrant water. It is not assumed that these dilute solutions were in the exact proportion that would have permitted the greatest elongation. The object was merely to show that at the concentrations used in these experiments the salts of magnesium and of sodium effectively neutralize the injurious element present in the once-distilled water. The only noticeable difference was in the case of sodium carbonate and sodium chlorid, in which the elongation was somewhat below the average in the pure-water check and in the solutions of other salts. The use of a more dilute or a more concentrated solution would doubtless have removed this difference. On the other hand, a 0.001 normal magnesium chlorid was conducive to better development than any of the others, with the single exception of hydrant water. It will be noticed that at the end of the third day there was even a slight advantage in favor of magnesium chlorid over river water.

The elongation the fourth day was but a slight increase over that at the end of the third, with the one exception of the seeds in the hydrant water. This is just what was to be expected. During these four days the seeds were compelled to live on the nutriment stored up in the endosperm. This had been practically all used up at the end of the third day; hence the cessation of growth. With hydrant water the conditions were different. Certain nutritive substances are contained in this water upon which the roots can draw when those contained in the endosperm have been exhausted.

In view of the experiments, small quantities of these sodium and magnesium salts, instead of being injurious when present in the soil, might be actually beneficial in case the soil contains very toxic substances, e. g., zinc or copper. In fact, these salts are injurious only when present in excessive quantities, as in the so-called "alkali soils" of the West.

DILUTE SOLUTIONS AS STIMULANTS.

Incidentally, throughout these experiments, evidences of stimulation in dilute solutions were obtained. This has been shown to occur by many investigators with other salts and with some acids.[a]

Kearney and Cameron, who made similar observations when experimenting with *Lupinus albus*, say:

In the case of certain salts, when plants are exposed to pure solutions which are much too dilute to produce any toxic effect, there occurred a decidedly

---

[a] Some fungi have been known to be stimulated by the presence of small quantities of poisons. The germination of spores has likewise been hastened when in the presence of acids or salts. Townsend (Bot. Gaz., 27: 458–466, 1899) found that the germination of various seeds and spores has been stimulated by the presence of traces of ether, and (Bot. Gaz., 31: 241–264, 1901) that the presence of hydrocyanic acid for a brief period of time accelerates germination and subsequent growth.

stimulating effect upon growth, as compared with that in the distilled water control during a corresponding period. This was shown to be the case for salts of calcium, both the chlorid and the sulphate acting as stimuli.

These investigators found decisive evidence of such stimulating action with both the carbonate and the bicarbonate of sodium. Sodium sulphate and sodium chlorid gave purely negative results. Very marked results of this kind were observed by Cameron and Breazeale when working with acids. Hydrochloric, sulphuric, and nitric acids in concentrations but little below the toxic limit produced enormous stimulation, especially with wheat.

Copeland[a] shows that zinc and copper in water cultures accelerate growth when the solutions are not much more dilute than those that are distinctly toxic. Similar observations have been made by many earlier investigators.

In the experiments with wheat all the salts were found to stimulate growth except sodium chlorid and sodium carbonate, which were indifferent at the lowest concentration used. It is not unlikely, however, that if the proper dilution of the carbonate were employed it would be found to act as a stimulus with wheats just as it did with lupines. In fact, it was found that the same concentration of certain salts which was decidedly toxic for some varieties of wheat will act as a stimulant to another variety. Especially is this true of the chlorid and sulphate of magnesium. In a 0.005 solution of each of these salts the elongation of the roots of Turkey wheat was equal to that in the control of hydrant water during the period of twenty-four hours. The toxic limits for this variety are 0.0075 normal for the chlorid and 0.01 normal for the sulphate. As will be seen, two-thirds and one-half the concentration of the toxic limit, respectively, not only were not toxic but actually acted as a stimulating influence. There is a possibility, in view of these results, that dilutions not very much below the toxic limit are more likely to have a stimulating effect than are much more dilute solutions. This, however, is not a question to be settled at this time, but will require to determine it a series of special experiments.

A 0.015 normal solution of sodium sulphate caused an elongation about one and one-half times as great as that in hydrant water. The same dilution of sodium chlorid gave results somewhat less striking, but the elongation was well above the average of that in the hydrant-water checks.

As before stated, it would seem that instead of being injurious, dilute solutions of these salts might be decidedly advantageous, yet if they cause an unnatural growth their presence must be considered as detrimental rather than beneficial. Copeland calls attention to

[a] Chemical Stimulation and the Evolution of Carbon Dioxide. Bot. Gaz., 35: 81–98 (1903).

this fact, and is of the opinion that substances acting as stimulants are in the long run injurious.

It is of course an established fact that certain of these salts are beneficial and even necessary in particular cases. It has been claimed that chlorids are indispensable to buckwheat. The plant thrives well until it has passed the blooming stage, at a period when potassium chlorid seems necessary to complete the fruiting stage. This fact has apparently been demonstrated by experiment. Loew[a] says that fungi grown in culture solutions containing only traces of magnesia form no spores, but by increasing the amount of lethicin and thus adding more magnesium to the culture solution spores will be formed. Magnesium salts are as indispensable to fungi as to higher plants, but an exceedingly small amount is sufficient when the solution has an acid reaction.

Plants are often benefited by sodium salts.[b] While three of these salts—the chlorid, bicarbonate, and carbonate—are not indispensable to the plant, they accelerate ripening in some of the cereals.

Loew asserts that sodium, manganese, and silicon are often beneficial but not indispensable to phanerogams. Sodium salts are not essential in the physiological processes of plants, but are indispensable to animals.

PRACTICAL VALUE OF RESULTS.

There is certainly a very practical lesson to be drawn from the results described in this paper. It has of course long been known that plants of different genera and species show very different

[a] The Physiological Rôle of Mineral Nutrients in Plants. Bul. 45, Bureau of Plant Industry, U. S. Dept. of Agriculture (1903).

[b] Chittenden and Wachsman are of the opinion that the conversion of starch into dextrin and sugar (diastase) is more vigorous in the presence of small quantities of sodium chlorid (0.24 per cent). Several investigators, prominent among whom are Sprengel and Liebig, have shown that various crops, and more especially beans, are much benefited by the application of small quantities of common salt.

Pethybredge (Bot. Centralbl., No. 33, 1901) is authority for the statement that the color of wheat leaves is intensified when sodium chlorid is applied.

S. Suzuki (Bul. Coll. Agric., Tokyo, 5: No. 2, p. 199) showed that potassium iodid, even in very high dilutions, exerted a stimulating action on the growth of the pea; and (ibid., No. 4, p. 473) that dilute quantities of potassium iodid stimulated oats. In opposition to these stimulating effects the same investigator has found (ibid., No. 4, p. 513) that vanadin sulphate, even in very dilute quantities, produced little or no stimulating action on barley, though he states that a very weak stimulating action on the roots seemed to have taken place in a 0.01 per mille of vanadin sulphate. He further shows (ibid., No. 2) that potassium ferrocyanid acts as a poison on plants in water cultures even in very high dilutions.

behavior when brought into relation with saline or alkaline soils. But the species itself may include a great number of different varieties or races, as in the case of wheat. It is not enough to know that wheat in general is better adapted to a certain region because of soil or climatic conditions than is Indian corn or cotton, but in addition it is necessary to know which of the many varieties of wheat is best suited to that region. Such knowledge might save many years of constant selection with a view to acclimatization.

Soils are often known to contain sodium chlorid or magnesium sulphate or some other salt in such quantity as to be fatal to some varieties, while permitting others to flourish. Now, it has been possible by these experiments to determine that some varieties of wheat are much more resistant to a particular salt than others, and they are the ones which would be expected a priori to thrive best in a region where that salt predominates, other conditions being equal. By some of the experiments it was found that some varieties would thrive equally well in three times the concentration of sodium carbonate as others. A simple deduction from such results would be that for a region containing large quantities of "black alkali" the variety shown to have the greatest resisting power should be selected.

A knowedge of the limits of individual variation within each variety is likewise very essential. Often the most resistant varieties are not always the most desirable in other respects and a sort which is less resistant would be preferable. In case such a sort has a great individual variation in resistance to salts it should be comparatively easy to introduce it by gradual selection of the most resistant individuals, though a little more time would naturally be required than in introducing a variety that is already more resistant, as a smaller percentage of the plants would survive to furnish seed for the next crop.

It is believed, therefore, that the results of these experiments afford additional proof that the adaptation of useful cultivated plants to saline or alkaline soil conditions is one of the most promising of plant-breeding problems.

SUMMARY.

(1) The salts with which the experiments were made are injurious to wheat seedlings in the following order: Magnesium sulphate, magnesium chlorid, sodium carbonate, sodium bicarbonate, sodium sulphate, and sodium chlorid. This is asserted as true only of wheat, and a quite different order might possibly be established for other plants.

(2) The results obtained from a few individual seedlings are inaccurate and unreliable. A large number must be tested in order that

individual variation may be eliminated. Usually about ten days of experiment and from 60 to 100 seedlings were employed to establish the toxic limit for each variety in each salt.

(3) Wheat is one and a half to six times as resistant as white lupines, according to the salt used. In sodium bicarbonate the least and in magnesium sulphate and sodium carbonate the greatest difference in resistance between these two plants is shown.

(4) Different varieties, representing the two extremes, vary in the ratio of 1 to 3 in their resistance to the toxic effect of different salts. This is especially true for sodium carbonate and magnesium chlorid. In magnesium sulphate they vary in the ratio of 1 to 2.

(5) The variety most resistant as a whole is not necessarily the most resistant to every salt. The variety that averages least in resistance may be twice as resistant to some one particular salt as that which averages highest. In this fact may be found the secret of selecting a variety for a locality where the soil contains an excess of some one salt.

(6) The least resistant variety is not always the least resistant for every salt used. It may be exceedingly resistant to one or more salts and yet have a very low sum total resistance.

(7) It is not possible from the results with a few varieties to draw general conclusions for all sorts of wheat. Each will have to be worked out for itself.

(8) Varieties which come from localities where saline salts abound are the most resistant in water cultures to these toxic salts. Varieties from humid regions are less resistant.

(9) In general, the more toxic the salt the greater is the ratio of resistance of one variety to another. The less toxic the salt the smaller is the ratio. For sodium carbonate and magnesium chlorid the ratio of resistance is greatest, being as 1 to 3. For the remaining salts it is smaller.

(10) Individual variation is more prevalent and makes the establishment of the toxic limit much more difficult in some varieties than in others.

(11) All the salts used act as stimulants in dilute solutions except sodium carbonate and sodium chlorid, which were neutral even in very dilute solutions. In some cases the elongation in dilute solutions was nearly twice that occurring in the controls of hydrant water.

(12) Absolutely pure distilled water does not hinder development, but traces of zinc are sufficient to kill the root tips in twenty-four hours.

(13) The economic importance of these results is based upon the fact that water-culture experiments may be a means for saving several years of selection by indicating whether a certain variety is adapted to soil conditions in a particular region.

BIBLIOGRAPHY.

CAMERON, F. K., and BREAZEALE, J. F. The toxic action of acids and salts on seedlings. Journal Phys. Chem., vol. 8, No. 1, p. 1 (Jan., 1904).

CARLETON, M. A. Basis for the improvement of American wheats. Bul. 24, Div. Vegetable Physiology and Pathology, U. S. Dept. of Agriculture (1900).

CHARABOT, E., and HÉBERT, A. Contribution a l'etude des modifications chemiques chez la plante soumise a l'influence du chlorure de sodium. Compt. Rend., Paris, 134: 181 (1902).

COPELAND, E. B. Chemical stimulation and the evolution of carbon dioxide. Bot. Gaz., 35: 81–98 (1903).

COUPIN, HENRI. Sur la sensibilite des végétaux supérieurs à des doses tr faibles de substances toxiques. Compt. Rend., Paris, 132: 645 (1901).

——— Sur la toxicité du chlorure de s dium et de l'eau de mer, à l'egard des végétaux. Revue Générale de Botanique, 10: 188 (1898).

——— Sur la toxicité des composés de sodium, de potassium, et de l'ammonium à l'égard des végétaux supérieurs. Revue Générale de Botanique, 12: 180 (1900).

DANDENO, J. B. The relation of mass action and physical affinity to toxicity, with incidental discussion as to how far electrolytic dissociation may be involved. Amer. Journal of Science, vol. 17 (June, 1904).

DEHERAIN and DEMOUSSY. Sur la germination dans l'eau distillé. Compt. Rend., Paris, 132: 523 (1900).

DUGGAR, B. M. The toxic effect of some nutrient salts on certain marine algæ. Science, 459 (1903).

ESCHENHAGEN. Ueber den einfluss von lösungen verschiedener concentration auf den wachstum der schimmelpilze. Stolp (1889).

GUTHRIE and HELMS. Pot experiments to determine the limits of endurance of different farm crops for certain injurious substances. Roy. Soc., New South Wales, 36: 191 (1902).

HEALD, F. D. On the toxic effect of dilute solutions of acids and salts upon plants. Bot. Gasz., 22: 125 (1896).

KAHLENBURG and TRUE. On the toxic action of dissolved salts and their electrolytic dissociation. Bot. Gaz., 22: 81 (1896).

KEARNEY and CAMERON. Some mutual relations between alkali soils and vegetation. Rept. No. 71, U. S. Dept. of Agriculture (1902).

LOEW, OSCAR. The physiological rôle of mineral nutrients in plants. Bul. 45, Bureau of Plant Industry, U. S. Dept. of Agriculture (1903).

MOORE and KELLERMAN. A method of destroying or preventing the growth of algæ and certain pathogenic bacteria in water supplies. Bul. 64, Bureau of Plant Industry, U. S. Dept. of Agriculture (1904).

PETHYBREDGE. Beiträge zur kenntniss der einwirkung der anorganischen salze auf die entwickelung und den bau der pflanzen. Bot. Centralb., 87: 235, No. 23 (1901).

RAULIN, J. Etudes chimiques sur la végétation. Ann. des Sci. Nat. Botanique, 5e Sér., 11 : 93.

SAUNDERS, WILLIAM. Cereals and root crops (1902).

SIGMUND, W. Ueber die einwirkung chemischer agentien auf keimung. Landw. Vers. Stat., 47 : 2 (1896).

STEWART, JOHN. Effect of alkali upon seed germination. Ninth Ann. Rep., Utah Agric. Exp. Sta. (1898).

SUZUKI, S. On the action of highly diluted potassium iodide on agricultural plants. Bul. Coll. Agric. Tokyo. 5 : No. 2, p. 199 (1902).

——— On the influence of potassium iodide on oats. Ibid. No. 4, p. 473 (1903).

——— On the action of vanadin compounds on plants. Ibid. No. 4, p. 513 (1903).

——— On the poisonous action of potassium ferrocyanide on plants. Ibid, 5 : No. 2, p. 213 (1902).

TOWNSEND, C. O. The effect of ether upon the germination of seeds and spores. Bot. Gaz., 27 : 458–466 (1899).

——— The effect of hydrocyanic acid gas upon grains and other seeds. Bot. Gaz., 31 : 241–264 (1901).

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 80.

B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURAL EXPLORATIONS IN ALGERIA.

BY

THOMAS H. KEARNEY,

Physiologist, Vegetable Pathological and Physiological Investigations, Bureau of Plant Industry,

AND

THOMAS H. MEANS,

Formerly of the Bureau of Soils.

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

ISSUED AUGUST 19, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

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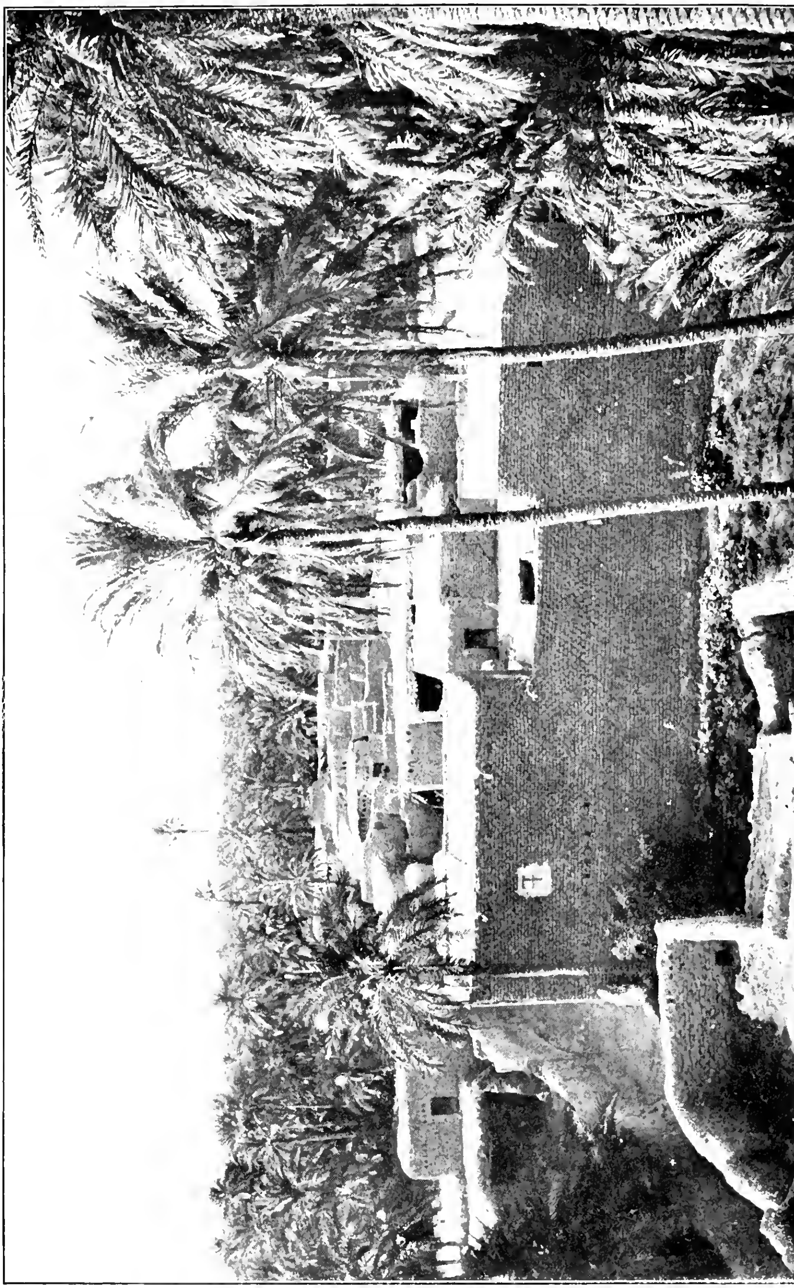

OASIS OF BISKRA, ALGERIA, SHOWING DATE PALMS.

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Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., April 24, 1905.

SIR: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 80 of the series of this Bureau, the accompanying manuscript entitled "Agricultural Explorations in Algeria."

This paper was prepared by Thomas H. Kearney, Physiologist, Vegetable Pathological and Physiological Investigations, Bureau of Plant Industry, and Thomas H. Means, at that time in charge of Soil Survey, Bureau of Soils, and has been submitted by the Botanist in Charge of Seed and Plant Introduction and Distribution, under whose direction the explorations described were conducted, with a view to its publication.

The four half-tone plates are necessary to a complete understanding of the text of this bulletin.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

While the agricultural explorers sent out by this Office are, as a rule, sent for the purpose of securing some special seeds or plants desired for introduction into the United States, they are also expected to make themselves as familiar as possible with the agricultural practices of the countries they visit and with the crops that succeed under the conditions described. That some of the practices observed may be profitably followed in those parts of the United States having similar soil and climatic conditions is more than probable, and that certain of these crops will prove useful has already been demonstrated.

The American farmer of to-day wants to know what is being done elsewhere, and he is especially interested in hearing how other people meet difficulties similar to those with which he has to contend. The reports of our agricultural explorers, we believe, will therefore fill a distinct place in agricultural literature. This report points out clearly the close similarity in climate existing between certain portions of the Southwestern States and Algeria, making it plain that we must look to that country for the introduction of many useful plants into our arid and semiarid districts.

We have, indeed, already availed ourselves of the opportunities thus offered. The date palms so far secured have come largely from Algeria; certain grains from that country, now being tested, give promise of unusual value; and the writers of this report brought back a quantity of alfalfa seed from salt-resistant plants, which has already been tested and gives promise of decided usefulness in Arizona and California.

To throw as much light as possible upon the conditions under which crops are grown in Algeria, chapters upon the topography, climate, irrigation, and soils are included. These, together with the brief historical and political sketch, have been prepared by Thomas H. Means. The remainder of the report was written by Thomas H. Kearney.

The writers wish to acknowledge the services cordially rendered them by the following-named gentlemen in the prosecution of their work: Mr. Henri Vignaud, of the United States embassy in Paris; the Governor-General of Algeria, and the French Resident at Tunis; Dr. L. Trabut, of the botanical service of the government of Algeria;

the Commandant of the Bureau des Affaires Indigènes at Algiers; the commandants of the military circles of Biskra and Tougourt; Lieutenant Beréaud, Chef du Bureau Arabe at the latter place; M. Colombo, of the Compagnie de l'Oued Rirh at Biskra; Mr. Daniel Kidder, United States consul at Algiers; M. Vilmorin, of the seed firm of Vilmorin-Andrieux & Co., and M. Emerich, agent of that firm for America.

A. J. PIETERS,
Botanist in Charge.

OFFICE OF SEED AND PLANT
INTRODUCTION AND DISTRIBUTION,
Washington, D. C., February 17, 1905.

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AGRICULTURAL EXPLORATIONS IN ALGERIA.

INTRODUCTION.

The principal object of the writers' visit to Algeria was to secure for trial in the "alkali" lands of the western United States seed of such of the important field crops as might show indication of an unusual degree of resistance to salt in the soil. There was reason to believe that in northern Africa, if anywhere in the world, useful plants would be found to have developed such resistance through long cultivation in saline soils under a dry, hot climate.

Agriculture is too new in the arid part of America to make it likely that races in which the quality of resistance to "alkali" has become fixed should as yet have arisen there without direct efforts to breed them. But in the Sahara Desert, and in adjacent regions, all the conditions are favorable to the production of such races through natural selection. There we find the greatest continuous body of desert land in the world. The cultivated soils and the water used in irrigation often contain an excess of soluble salts. Finally, agriculture has been practiced there for thousands of years, and well-marked varieties of various cultivated plants have been developed.

As a matter of fact, it is already known to the Department of Agriculture that such salt-resistant races exist in northern Africa. Several of the agricultural explorers sent out by the Department have reported this to be true of Algerian wheats and barleys. Mr. W. T. Swingle brought back with him from the oases of the Sahara seed of alfalfa that was growing in soils containing a high percentage of salt. It was desirable, however, to determine just how resistant this Algerian alfalfa is and to obtain a larger quantity of the seed, in order that it could be fairly tested in the southwestern United States.

It is believed that this object was accomplished. The fact that alfalfa in the oases withstands a greater amount of soluble salts in the soil than ordinary American alfalfa was established beyond reasonable question. A sufficient quantity of seed was obtained to insure a thorough trial of it in parts of our country where a similar climate prevails. At the same time a careful search was made in various parts of Algeria for such other cultivated plants as might prove useful for salt soils. Incidentally the writers procured all possible information as to the character of the saline soils of Algeria, the way in which they are handled, and such attempts as have been made to reclaim them.

The coast region of Algeria strikingly resembles the corresponding part of California in climate, in physiography, and in the crops grown. The interior of California, and of the extreme southwestern United States generally, corresponds in many ways to the steppe and the desert regions of northern Africa. It is true that in some respects agriculture has reached a more advanced stage of development in California than in Algeria; yet there are probably some matters in which the French colony can give lessons to the American State. For this reason it seems advisable to present a sketch of Algerian agriculture as a whole, in addition to a more detailed account of the special subjects which the writers were sent out to investigate. The writers' stay in Algeria was limited to one month, from July 20 to August 20, 1902. It is fully realized that this length of time was entirely inadequate for anything like a thorough study of agriculture in the colony, especially as the mild winter permits crops to be grown at all seasons of the year. The date of the writers' visit to Algeria was determined partly by the necessity of reaching Egypt in time to study cotton at the height of its development, and partly by their desire to visit the oases of the Sahara at the season when the seed crop of alfalfa is being made. The information they could obtain by direct observation was necessarily fragmentary in the extreme. To supplement this, recourse has been had to the rather extensive literature of Algerian agriculture. In the preparation of this report the excellent work of Battandier and Trabut, entitled "L'Algérie" (Paris, 1898), has been freely consulted. Much information has also been drawn from papers upon special subjects by Doctor Trabut and others,[a] from the important "Manuel Pratique de l'Agriculteur Algérien" (Paris, 1900) of Rivière and Lecq, and from various other sources.

TOPOGRAPHY.

The French colony of Algeria is situated in northern Africa, between Morocco on the west and Tunis on the east. In general outline it is a rectangle, of which the greatest length—that from east to west—is about 650 miles. The area of Algeria is about 230,000 square miles, of which approximately 20,000,000 acres are under cultivation. The Mediterranean forms the northern boundary, while on the south the

[a] Published chiefly in the "Bulletin Agricole de l'Algérie et de la Tunisie."

frontier extends well into the great desert of Sahara, the present outposts being from 300 to 500 miles from the coast.

The vast desert to the southward cuts off Algeria physically as well as politically from tropical Africa. The influence of the sea upon its climate and the fact that almost unbroken overland communication with Europe by way of Morocco and Gibraltar has always been easy make Algeria rather an outpost of Europe than an integral part of Africa. In climate, physiography, flora, and agriculture Algeria is closely related to the countries that border the northern shore of the Mediterranean—Spain, southern France, and southern Italy. Indeed, geologists tell us that northern Africa was separated from southern Europe at only a comparatively recent period.

The part of the United States which Algeria most nearly resembles is California. The climate, agriculture, and state of development of the two countries are remarkably similar. In their general aspects they are much alike. In both, the coast region, being limited to a narrow strip by a range of mountains that parallels the seashore, has a comparatively mild, equable climate. In both countries this zone is preeminently adapted to fruit growing. Citrus fruits, olives, figs, and vines flourish there. A striking analogy exists between the great plain-like valleys of Algeria, occupied largely by vineyards and fields of cereals, and the San Joaquin and Sacramento valleys of California. Finally, the conditions obtaining in the Desert of Sahara are in great part reproduced in the Colorado and Mohave deserts. But to the steppe or high plateau region that occupies the central part of Algeria it would be more difficult to find a counterpart in California, portions of Nevada, Arizona, and New Mexico presenting a closer resemblance.

If we take into consideration biological—including agricultural—conditions, as well as the topographical features of the country, there are three principal regions into which Algeria can be divided for convenience of description. These are (1) the coast region, extending to the crests of the series of mountain ranges which follow the coast, (2) the high plateau or steppe region, occupying the central portion of the colony between the two great mountain systems and comprising the southern slope of the northern ranges and the northern slope of the southern chains, and (3) the desert region, comprising the Algerian Sahara and the southern slopes of the mountain system which forms the northern boundary of the Sahara.

The second and third regions are, on the whole, more homogeneous than the first, or, at any rate, their agricultural importance is too small to make it desirable to subdivide them. Three subdivisions of the coast region are, however, to be recognized, (1) the littoral zone, comprising the immediate coast and the lower slopes of the hills and mountains which border it, (2) the valley and plain zone, comprising the larger, often plain-like, valleys of the coast region which lie inside the line of hills that follows the seashore, and (3) the mountain zone, including the higher elevations of the coast region southward to the crest of the ranges that form the northern boundary of the high plateau region.

COAST REGION.

The "Tell," as the coast region is known among the Arabs, is, from an agricultural point of view, the most important part of Algeria. A great proportion of it is capable of cultivation. It has been estimated that a population of 12,000,000 could be supported in this region alone. It strikingly resembles the Mediterranean coast of Europe, and is no less close in its likeness to the coast region of California, so that a description of one will answer in many respects for both. The immediate seashore is bordered by hills and mountains, such as the Sahel of Algiers, the lower slopes of which are occupied largely by orchards and vineyards. In the higher elevations in the mountains agriculture is more difficult. Here there are extensive areas of grass land, grazed by flocks and herds, and important forests. Opening back from the coast and mainly parallel to it are a number of large valleys. Some of these, like the Mitidja, near Algiers, and the Chéliff, in the western part of the colony, are so extensive and so level of surface as to be practically plains with great areas of cereals and vineyards. The San Joaquin and Sacramento valleys in California are remarkably like these great valleys of Algeria. Smaller valleys, like the Mina and the Habra, where the bordering ranges of hills and mountains are not so far apart and there is less level surface, may be compared to the Santa Clara, Pajaro, and Salinas valleys in California.

These valleys and the lower slopes of the hills and mountains are the most highly cultivated part of the country, and support the densest population.

The more distinctively mountainous regions are naturally less adapted to agriculture; yet in the country known as Great Kabylia, the "Switzerland of Algeria," which contains the highest mountains of the colony, there is a very large population, the greater part of which is devoted to farming. This district lies to the east of Algiers. It forms an arc, of which the Djurdjura range of mountains is the chord and the seacoast is the circumference. For a long distance the crest of the Djurdjura range does not fall below 4,000 feet, while there are several peaks that exceed 7,000 feet in elevation. Lella Khedidja, the highest summit, has an altitude of 7,611 feet. Between this great chain and the coast there is a succession of high ridges separated by deep, narrow valleys and gorges. Anyone who has seen both regions will be struck by the resemblance between Great Kabylia and the Santa Lucia Mountains district of the western part of Monterey County, in California.

Numerous streams arise in the mountains of the coast region, traverse the Tell, and empty into the sea. Most of these are torrents, discharging large volumes of water in winter, but in summer dwindling to mere rivulets. Not infrequently no water is to be seen in the channel, but in that case it is generally to be found under the bed of the stream. Owing to their relatively great fall, and the denuded condition of much of the soil, the amount of erosion accomplished by Algerian water courses is disproportionately large. These characteristics are especially marked in western Algeria. In the eastern part of the colony, where the rainfall is better distributed and more of the surface of the country is forested, the flow of the streams is more regular. The small importance of Algerian water courses is doubtless to be accounted for by the fact that most of the precipitation occurs on or near the coast, while the interior of the country is extremely arid.

Only one river of the Tell region also traverses the high plateau region. That is the Chéliff, the most important water course in Algeria, which rises in the mountains that border the Sahara on the north. It has a total length of about 330 miles, draining an area of about 7,500,000 acres. Its flow in summer is only 100 to 175 cubic feet per second, although in winter from 500 to 2,000 cubic feet are discharged. It is obvious that only a small portion of the valley of the Chéliff can be irrigated throughout the year. Not even this stream is navigable, except, near its mouth, for small boats.

HIGH PLATEAU OR STEPPE REGION.

Between the two chief mountain systems of Algeria extends a vast region of elevated plains, with an average elevation of a little more than 3,000 feet above sea level. The greatest width of the high plateau in Oran Department is about 125 miles, whence it diminishes gradually toward the east until on the frontier of Tunis a narrow river valley is all that remains. In topography, and to some extent in vegetation, this region greatly resembles parts of Nevada and New Mexico. In its widest part it consists of a gently rolling expanse, sometimes without a hill to break the monotonous horizon. In other places isolated mountain groups rise like islands out of the sea. Near its northern and southern borders spurs from the mountain chains that bound it extend into the plain. Toward the east the mountains are higher and approach nearer together. In the Department of Constantine the distinctive character of the high plateau is lost, and it breaks up into a series of valleys a few miles wide, with gently sloping sides, separated by high hills and mountains. The great masses of the Aurés and

Babors groups, which border this part of the region, reach altitudes of 7,000 feet.

A marked feature of the steppe region is the frequently occurring "dayas" and "chotts"—salt ponds or lakes without outlet—which receive the drainage from the southern slopes of the coast mountains and the northern declivities of the Saharan range. They occupy basin-like depressions, and are often dry or merely marshy in summer, their beds being then covered with a shining crust of salt. The "bolson" plains of the Sonoran region in North America have a similar hydrography.

There is very little water in the high plateau region suitable for drinking or for the irrigation of crops. Occasional wells occur, and here and there are small pools where sheep and cattle drink. As a rule, however, travelers in this region must carry with them their supply of drinking water. Attempts to find artesian water have generally been unsuccessful.

In places the topography of the steppe region becomes almost identical with that of the desert—notably where areas of sand dunes occur and the vegetation is very scanty. Such localities differ from the desert proper only in their greater elevation and more severe winter climate.

DESERT REGION.

A considerable portion of the largest desert in the world, the Sahara, lies within the boundaries of Algeria. Contrary to the general notion, the mean elevation of this desert above sea level is considerable, being placed by some authorities as high as 1,540 feet. Broadly speaking, the surface of the desert is convex, the central portion being generally higher than the borders. The desert is commonly pictured as a vast billowy expanse of sand blown about by the sirocco and dotted with oases. This conception is only partly true. As a matter of fact, the topography of the Sahara is as diversified as that of most areas of equal extent in other parts of the world. In this respect it is to be compared with the desert regions of the southwestern part of the United States. The Sahara contains mountains nearly 7,000 feet high, upon whose summits snow remains throughout the winter. Other parts are considerably below sea level. Much of its surface is broken by ranges of sand dunes and of rocky hills, between which lie narrow ravines or wide valleys. In other quarters extensive plateaus occur. The courses of streams that must once have carried a considerable volume of water can be traced in many places. The infrequent rains that fall in the Sahara sometimes fill the bottoms of these channels with water for a few brief hours. But even such transient torrents can effect a tremendous amount of erosion in the loose soils of the desert, there being little vegetation to hold them in place. Lakes and ponds are numerous in the lower portion. Here and there, but forming only a small fraction of the entire area, are oases, watered by springs and wells, where groves of date palms flourish.

Schirmer[a] gives a graphic description of the Sahara. He writes:

> The desert, more than any other part of the surface of the globe, has the appearance of immobility. The implacable climate has depopulated the land. The great plains have an aspect of absolute emptiness. The mountains are like skeletons from which the sun has devoured the flesh. The dunes look like solidified waves of dull gold. The absence of sound is such that, as one traveler has put it, "One hears the silence." Everything appears unchangeably fixed in the intense light.

Pomel estimates that only about one-ninth of the total area of the Sahara is covered with sand dunes. The higher dunes occur in more or less regular chains, which have often been likened to the waves of the sea, caught and petrified. These sand hills sometimes reach a height of 1,000 feet. Smaller dunes, very regular in their rounded outline, often cover extensive areas, as, for example, between Biskra and the Melrirh Chott. Dunes of this character are generally formed by various desert shrubs and herbs that are able to send up new shoots through the sand which drifts over them from time to time, thus continually raising the height of the dune. The largest sand hills are often formed about rocks and cliffs, which arrest the drifting sand. The soil of the dunes is a fine and remarkably homogeneous sand.

Contrary to the general notion, the larger dunes are not continually shifting their position, but are sufficiently permanent features of the landscape to have received in many cases names that are handed down by the Arabs from generation to generation. For this reason, and because drinkable water and vegetation are more apt to occur near the dunes than elsewhere, the caravan routes in the Sahara follow the dunes wherever possible.

In western Algeria the desert is high. Hills and mountains of sun-scorched rock, with smooth surfaces and sharp, unworn edges, rise out of stony plains. Jagged cliffs, often of the most fantastic form, stand sentinel over the deep canyons and gorges that have been cut out by occasional torrents. Oases are few and far between. This is, indeed, the most barren and inhospitable part of the desert.

Toward the east the altitude of the desert decreases until, near the frontier of Tunis, a region of chotts, or salt lakes, lying below sea level, is reached. During most of the year the bottoms of these basins are dry or, at most, muddy beneath a crust of glittering white salt, which gives rise to remarkable displays of mirage. But during the winter they are partly filled by streams that descend from the mountains on the west and north. The eastern part of the Sahara in Algeria is mainly flat or gently rolling. Its surface is covered with sand,

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[a] Schirmer, Le Sahara, p. 139 (1893).

often collected into dunes of greater or less size (erg). There are also extensive areas where the nearly plane surface is composed of smooth rock or hardened alluvial clay (hamada).

A great valley, some 60 miles long and about 12 miles wide, known as the "Oued Rirh," forms the most valuable portion of the Sahara of Algeria. It is really the bed of an extinct river. It is largely below or only slightly above sea level, the maximum depression—the extensive salt lake known as "Chott Melrirh"—being 107 feet below sea level. Subterranean streams of considerable volume underlie the surface in this region. These are doubtless fed by water which flows down from the mountains and sinks through the desert sands until it meets an impermeable layer of clay or of rock, over which it flows. The Oued Rirh Valley has been described as a "small Egypt with a subterranean Nile." By means of wells this water has been utilized in the creation of oases, where hundreds of thousands of date palms flourish.

The idea, once generally held, that the entire Sahara is the bed of an ancient sea has been abandoned. Only for the part known as the Oued Rirh, a small fraction of the whole desert, is this theory still entertained by some authorities. Here there is a series of large salt lakes, some of them below the level of the sea, which extends across Tunis almost to the Gulf of Gabès.

CLIMATE.

The greater part of Algeria has a warm, temperate climate, very similar to that of California. The climates of both countries are determined in large measure by the combined influence of three factors—the ocean, the mountains, and the desert. In Algeria, as in California, most of the rainfall occurs during the mild winter, while the long summer is almost perfectly dry. Furthermore, the direction of the prevailing winds at different seasons is in both countries largely effective in regulating conditions of temperature and of rainfall. The lower part of the coast region has a wet and a dry rather than a warm and a cold season. The higher mountains, however, and the high plateau are characterized by a decidedly cold winter. Algeria would be wholly a desert were it not for the northwest winds, charged with humidity, which blow from the sea, especially during the winter and spring. Their influence is, of course, most marked in the coast region, which has, in consequence, the heaviest rainfall, the most humid atmosphere, and the most luxuriant vegetation of any of the three zones.

The mountain chains which follow the coast line intercept a large part of the moisture carried by the sea winds, so that, while their northern, seaward slope has a comparatively heavy rainfall, their southern slopes and the high plateau region beyond are quite arid. What moisture passes across the mountains of the first system is largely withdrawn from the atmosphere when it reaches the second, which bounds the steppe region on the south. Consequently, the desert beyond receives an insignificant share of atmospheric moisture from the Mediterranean.

Winds that come from the opposite direction—out of the Great Sahara—are, of course, at all seasons extremely dry. It is in late summer—especially in September—that the dreaded sirocco, the hot, sand-laden wind of the desert, is strongest and most frequent. Then it blows for days at a time over the high plateau and the two mountain ranges that form its boundaries, into the Tell, and even across the Mediterranean into southern Europe.

The three principal physiographical regions coincide with the most important climatic regions of the colony. For a further examination of this subject it will therefore be advisable to take up each in its turn, beginning with the coast region, or Tell.

In the tables given below, climatic data from Algerian localities are copied from Thevenet's "Essai de Climatologie Algérienne." For comparison, data from various places in the western United States where similar conditions obtain are also included. These are taken from publications of the United States Weather Bureau. Much information regarding the climate of Algeria has also been drawn from the excellent little work of Battandier and Trabut, previously mentioned. Owing to the paucity of accurate records and the small agricultural importance of the high plateau region, no tables are given for that part of the colony. It should be remarked, however, that Sétif, which has an elevation of 3,560 feet, although here included in the tables for the coast region, is sometimes considered as belonging to the high plateau, and the climatic data from this point are doubtless fairly applicable to the uncharacteristic eastern portion of that region. Again, Bou Saada, figures from which locality are given in the tables of climate of the desert region, really belongs to the extremely desert-like portion of the high plateau.

COAST REGION.

TEMPERATURE.

The littoral zone of the coast region has a mild winter, resembling that of the California coast. Temperatures at noon of 70° to 75° F. for fifteen days or a month at a time are not of rare occurrence in winter. The temperature never descends much below freezing, and does not remain at that point for any length of time. Still, temperatures of 23° F., such as are sometimes recorded by thermometers placed 4 inches above the surface of the ground, can do considerable damage to the winter crops of garden vegetables, although the soil itself is never frozen to any considerable depth. The cold often seems more intense than is actually the case, because of the humidity of the atmosphere and the lack of facilities for heating the houses. A temperature of 45° F. is considered very disagreeable. A few miles back from the shore line, behind the first range of hills, for example, in the Mitidja plain, near Algiers, light frosts are frequent and have been known to occur as late as May. Snow, which has never remained on the ground for an entire day at Algiers, has lain for three days to a depth of 7.5 inches in the country only a few miles back from the coast.

In summer, except during the sirocco, the shade temperature of the littoral zone rarely exceeds 86° F., but sometimes rises to 105° F. when the wind from the desert is blowing. At such times the nights are often as hot as the days. The moderate summer temperatures are largely due to the sea breeze, which rises every morning at about 10 o'clock. As far inland as the influence of this wind is felt comparatively mild summer temperatures prevail.

The climate of the littoral zone is much like that of the coast of southern Europe; but fall-sown crops mature even earlier than there, by reason of the milder winter and the higher temperatures in spring. Hay is harvested in May and cereals in June in this zone.

The valley and plain zone of the coast region has a more extreme climate than the littoral zone. This difference has already been indicated in comparing the Mitidja Valley with Algiers, on the neighboring coast. The great Chéliff Valley, farther west, presents a still more marked contrast. Here, owing to the greater dryness of the atmosphere, frosts are more frequent and more severe in winter and spring than along the coast. On the other hand, in summer the hills which bound these valleys on the north shut off the sea breeze, and the heat is consequently more intense. Sunstroke and prostration from heat are by no means unknown in the Chéliff Valley. The sirocco, also, is more severely felt than in the littoral zone, which is partly protected against this south wind by the rampart of hills that rises a short distance back from the shore. More elevated places, like Sétif, have even severer winters, resembling those of the high plateau region. Sharp frosts are frequent as late as April and May. The summer temperatures are often very high in the daytime, but the air is fresher than in the valleys and the nights are nearly always cool.

The mountain zone of the coast region is not dissimilar in climate to mountainous regions of southern Europe. The winter, especially at the higher altitudes, is much more severe than in the littoral zone. On the crest of the Djurdjura range, at 7,000 feet elevation, snow often reaches a depth of 3½ feet and remains on the ground until the latter part of July. The summer temperatures are almost invariably moderate in the mountain region, except when the sirocco is blowing.

The smaller relative humidity also contributes toward making the summer climate an agreeable one. Springs with a mean annual temperature of 45° or 50° F. are not infrequent at high elevations in the Djurdjura range.

TABLE 1.—*Mean temperatures (in degrees Fahrenheit) of localities in the coast region of Algeria, as compared with the California coast.*

Month.	Algeria.					California.					
	Oran.	Orléansville.	Algiers.	Fort National.	Sétif.	Los Angeles.	San Luis Obispo.	San Francisco.	Fresno.	Sacramento.	Colfax.
January	50.9	45.8	54.0	41.2	39.0	53.0	51.2	50.1	45.2	45.2	44.3
February	51.8	47.7	54.0	42.2	40.4	54.4	55.3	52.2	51.5	49.6	45.8
March	55.4	53.1	56.5	46.8	46.0	56.4	52.2	53.6	54.0	54.3	49.1
April	59.2	55.8	59.5	50.2	49.8	60.0	56.0	55.0	60.9	59.0	54.2
May	64.0	63.5	64.6	55.9	56.7	62.0	57.6	57.0	67.3	64.5	61.7
June	69.4	71.6	70.0	66.6	66.7	65.9	62.9	59.0	74.6	70.0	71.4
July	74.1	80.1	75.4	74.7	74.8	70.8	66.2	58.8	82.1	73.6	75.1
August	75.4	79.7	76.1	75.4	73.4	72.0	65.0	59.3	81.4	70.6	77.0
September	71.1	72.3	72.9	67.3	65.5	68.5	65.4	60.9	74.2	70.0	69.7
October	63.7	61.0	65.8	56.1	53.6	64.0	62.0	59.9	63.4	60.0	59.8
November	57.2	53.2	60.4	48.9	45.2	60.0	57.8	56.4	54.7	53.4	51.4
December	51.6	46.8	51.0	42.2	39.6	56.4	52.6	51.6	46.3	47.2	46.3
Year	62.0	60.9	63.6	55.6	54.2	62.0	58.7	56.2	63.0	59.7	58.8

A comparison of the temperatures of localities in Algeria and in California, as given in Table 1, is instructive. Of the Algerian stations, Oran and Algiers are situated on the seaboard, the first in western, the second in central Algeria. Data from these localities should be representative of conditions along the coast, except in the extreme eastern part of the colony. With them are to be compared San Francisco, San Luis Obispo, and Los Angeles, representing the coast of California. Orléansville is the metropolis of the great valley, or rather plain, of the Chéliff, the most important of the large inland valleys of the coast region in Algeria. Sétif, as has already been remarked, lies south of the mountain chain that bounds the coast region, and has an elevation of over 3,000 feet. Topographically, and in some of its climatic peculiarities, it belongs rather to the high plateau than to the coast region, although agriculturally it is more nearly related to the latter. Fresno and Sacramento are representative points in the two great interior valleys of California—the San Joaquin and the Sacramento. They should afford an interesting comparison, especially with Orléansville. Fort National, at an elevation of over 3,000 feet, in the heart of the most mountainous region of Algeria, is to be compared with Colfax, in the foothills of the Sierra Nevada, north of the center of California.

Oran has the same mean yearly temperature as Los Angeles, but has higher mean temperatures for the summer and lower for the winter months, so that Los Angeles has the more equable climate. At Algiers the yearly mean temperature is not very different from that at Oran, but the mean temperatures for the winter months are generally higher. San Francisco and San Luis Obispo fall considerably below the Algerian coast towns in yearly mean temperature. The mean temperatures for the summer months also are decidedly lower at the California localities. The mean temperatures in winter correspond more closely.

Orléansville shows a remarkable resemblance in distribution of temperatures to the similarly situated town of Fresno, in California, and in this repect somewhat less to Sacramento. In yearly mean temperature, however, Orléansville is nearer Sacramento. Sétif, as would be expected, differs considerably from Orléansville, Fresno, and Sacramento in yearly and monthly means of temperature. Its resemblance to the high plateau is expressed in the fact that the nights are always cool in summer and the winter temperatures are low, falling at times to 12° F. The mountain stations, Fort National and Colfax, show a close approximation in monthly and yearly mean temperatures.

HUMIDITY.

The relative atmospheric humidity in the littoral zone is fairly uniform throughout the year. Owing to the proximity of the sea it is at all seasons considerable, the average for the year being 73 per cent. This condition of humidity is interrupted only when, generally in late summer and in early autumn, the sirocco blows for a day or more at a time. The humidity is far greater in the eastern than in the western part of the colony. The large percentage of moisture in the atmosphere causes the discomfort from cold in winter, and from heat in summer, to be out of all proportion to the actual temperature.

The dry season, so far as the littoral zone is concerned, owes its character to the lack of actual precipitation rather than to the absence of humidity in the air. Night fogs are frequent when east or northeast winds are blowing, and in August it is often 9 o'clock in the morning before they disappear. Dew is also copious at this season.

Atmospheric humidity, like precipitation, decreases as one goes farther from the coast. It is already perceptibly less in the mountains and in the great valleys of the coast region than along the seaboard.

PRECIPITATION.

In Algeria precipitation is almost synonymous with rainfall, except in the higher mountains, for elsewhere the amount of precipitation in the form of snow is unimportant. Hailstorms are fairly frequent, occurring, on an average, seven times a year. Market gardens of the littoral zone sometimes suffer severely from spring hailstorms, and, in exceptional localities, vineyards and orchards are occasionally damaged. Hail is more important for this reason than as contributing much to the total precipitation.

In the coast region of Algeria, as in many warm temperate and tropical countries, the distribution of the rainfall is more important than that of heat in determining the characteristics of the principal seasons of the year. Its distribution is largely controlled by the direction of the prevailing winds. In winter strong northwest winds, blowing from the Mediterranean, are of frequent occurrence and bring most of the rainstorms. They begin in the autumn, sometimes as early as the first of September, and usually cease in May or June. Even in midwinter, however, a clear sky for fifteen or thirty days at a time is not a rare event. During the summer there is a light sea breeze during the day, but winds of greater violence come almost wholly from the south, and are dry and hot.

More rain falls annually on the coast of Algeria, especially on the eastern coast between Algiers and Tunis, than in a great part of Europe. Notwithstanding this, Algeria has a decidedly more arid summer than any part of Europe, except, perhaps, extreme southern Italy and portions of Spain. This is due to the unequal distribution of the rain among the different seasons.

In the littoral zone winter is a wet rather than a cold season. It is then that most of the native vegetation, as well as crops that are not irrigated, must make their growth. The dry season is a period of rest for soils that are not artificially watered. Light showers of brief duration, such as occasionally fall during the summer, are of small importance in their effect upon the climate and vegetation. In the large inland valleys of the coast region the summer drought is still more pronounced than on the coast.

In the mountain zone, particularly at the higher elevations, rain is more evenly distributed, and the seasons are more like those of middle Europe. The rainfall in March and April is particularly heavy. In Great Kabylia thunderstorms and hail, which in the littoral zone occur only in winter, are not infrequent throughout the summer. This, with the partial protection from the sirocco afforded by the higher ranges, makes the summer drought less pronounced than in the littoral zone and in the valley and plain zone. But the total amount of precipitation in summer is, after all, comparatively insignificant. Even in the mountains, summer retains its characteristics as the dry season of the year. In winter the rainfall is quite considerable. The northern slopes of the Djurdjura range receive the heaviest precipitation occurring in the country—over 40 inches a year. These high mountains form a barrier which intercepts most of the cloud-laden winds from the sea, so that the country immediately to the south of them is extremely arid.

Rainfall is very unevenly distributed in different parts of the coast region and even of the littoral zone proper. One reason for this is the great difference in latitude—about two degrees—between the easternmost and the westernmost point of the Algerian coast. While the total annual precipitation on the coast near the Tunisian border amounts to nearly 40 inches, on the frontier of Morocco it is less than 16 inches. From year to year, also, the total amount and the distribution vary enormously.

TABLE 2.—*Rainfall (in inches) of localities in the coast region of Algeria, as compared with the California coast.*

Month.	Algeria.					California.					
	Oran.	Orléansville.	Algiers.	Fort National.	Sétif.	Los Angeles.	San Luis Obispo.	San Francisco.	Fresno.	Sacramento.	Colfax.
January	3.05	1.73	4.35	5.58	1.62	2.93	5.69	4.92	1.53	3.82	8.81
February	2.64	1.85	3.68	3.49	1.68	3.27	1.55	3.49	1.33	2.80	6.89
March	2.12	2.28	3.42	6.24	2.34	2.98	3.46	3.22	1.74	2.86	6.78
April	1.67	2.15	2.36	5.20	2.05	1.36	.93	1.84	1.11	2.13	4.48
May	1.42	1.38	1.40	2.99	1.82	.43	.35	.73	.50	1.01	2.36
June	.29	.55	.57	1.13	1.08	.10	.19	.14	.18	.17	.62
July	.07	.06	.06	.22	.28	.02	.01	.02	Trace.	.02	.03
August	.08	.08	.28	.28	.79	.03	.03	.02	.01	.01	..01
September	.65	.76	1.12	1.75	1.17	.08	.36	.22	.26	.32	.53
October	1.61	1.78	3.11	4.51	1.44	.74	1.62	1.02	.67	1.11	1.95
November	2.38	2.29	4.37	4.99	1.52	1.38	1.16	2.72	1.15	2.20	4.40
December	2.90	2.48	5.49	7.30	2.05	3.98	3.08	4.99	1.78	3.69	8.70
Year	19.18	17.39	30.21	43.68	17.84	17.30	18.43	33.33	10.27	20.14	45.56

When we compare Algeria with California as to rainfall, we find that the annual total precipitation at the two coast towns. Oran and San Luis Obispo, is very nearly the same. At Los Angeles it is somewhat less. January is the month of greatest rainfall at Oran and San Luis Obispo, February at Los Angeles. July is the month when the least rain falls at all three points. The precipitation is much heavier, and nearly the same in total amount at Algiers and at San Francisco. There is also considerable similarity in the distribution during the year of the rainfall at these two places.

The rainfall at Orléansville greatly exceeds that at Fresno, but is somewhat less than that at Sacramento. Sétif agrees closely with Orléansville in yearly total and in distribution of the precipitation. As for the mountainous districts of the two countries, as represented by Fort National and Colfax, there is a very close correspondence in yearly totals, but in respect to distribution the resemblance is less striking. The rainfall in summer at Fort National is greater and that in winter less than at Colfax.

WIND.

Winds from every point of the compass occur at different seasons in the coast region. As has already been mentioned, the characteristic winter wind is from the northwest, off the Mediterranean. This often rises to the height of a gale, and is of sufficient importance to decide the direction in which trees along the seashore are bent. West winds are also common in winter. In summer, the most violent wind is the occasional sirocco, from the Desert of Sahara, an extremely hot, dry wind, which sometimes blows day and night for several days at a time, filling the air with the fine dust it carries. It often does great harm to crops, vineyards and ripening grain being particularly liable to injury. The sirocco also blows in winter, but its violence is less at that season and it is cooler and moister. The regular summer wind is, however, the sea breeze from the northeast, which springs up every morning and is of great importance in moderating the temperature. East winds are also frequent in summer. At night, on the other hand, the prevailing wind is from the south. Absolute calm is not infrequent. In proportion as we travel farther from the coast, the effect of winds from the sea becomes less perceptible and that of the desert winds more pronounced. This difference becomes strongly marked after the northern mountain system is crossed.

The sirocco is the most striking climatic feature in which Algeria differs from California. In southern California a wind from the desert, known as the "Santa Ana" wind, blows occasionally, but in duration and severity it is not to be compared with the Algerian sirocco.

HIGH PLATEAU REGION.

The small agricultural importance of the high plateau region makes it unnecessary to discuss its climate at any great length. Owing to its greater elevation and distance from the sea, conditions are more extreme than in the coast region. The winters are colder and the summers hotter. Winter temperatures as low as 7° F. have been known, while in summer a temperature of 105° F. is often experienced. Daily variations amounting to 85 degrees have been recorded. In its severe winters the high plateau region resembles the highest altitudes of the mountain zone of the coast region, but differs in its hotter temperatures in the daytime in summer. In the latter respect it resembles the desert region, but there the nights are warmer in summer and the winter is much milder. Battandier and Trabut[a] mention one point in the high plateau region, at an elevation of about 4,700 feet, where the mean temperature for ten years was about 44.5° F. in winter, 55.5° F. in spring, 79° F. in summer, and 62° F. in autumn. The yearly mean temperature was 62° F.

The rainfall is much less than in the coast region, but no exact data on this point are available. Rain falls usually in sudden and violent showers. Storms are more frequent during the summer than is the case along the coast. The amount of precipitation is trivial, although sometimes sufficient to moisten the ground. During the winter the soil, especially in depressions, contains enough water in occasional years to bring a crop of barley without irrigation. The atmospheric humidity is almost always very small.

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[a] L'Algérie, p. 118.

DESERT REGION.

TEMPERATURE.

If we had no other data concerning the climate of the Sahara than the mean annual temperature, we should suppose it to be a very mild one. The variations from the yearly, monthly, and daily means are, however, enormous. Winter temperatures of 18° F. and summer temperatures of 112° F. are by no means uncommon. The daily range sometimes exceeds 86 degrees. The unshaded soil—sandy or rocky—becomes heated up to 160° F. At Biskra, which is by no means extreme in its summer climate, it is said to be possible sometimes to cook an egg in the sand. In the Oued Rirh region, on the other hand, ice sometimes forms in winter in the irrigation ditches. Evaporation is undoubtedly very great, but no accurate records of this phenomenon have been kept in the Sahara.

TABLE 3.—*Mean temperatures (in degrees Fahrenheit) of localities in the desert region of Algeria, as compared with similar localities in the southwestern United States.*

Month.	Algeria.				United States.			
	Tougourt.	Biskra.	Ouargla.	Bou Saada.	Yuma, Ariz.	Phoenix, Ariz.	Tucson, Ariz.	Volcano Springs, Cal.
January	47.3	50.5	46.8	44.4	54.1	49.8	49.6	55.9
February	49.8	53.2	51.8	45.8	58.6	54.3	53.6	60.5
March	54.9	58.3	59.9	51.1	63.9	53.9	59.4	68.4
April	64.0	63.1	66.4	56.8	69.9	67.0	65.6	79.7
May	74.8	71.8	73.6	65.1	76.9	74.4	74.5	87.5
June	86.0	80.6	82.4	75.0	84.4	83.9	84.0	96.6
July	92.1	87.1	90.7	83.1	91.2	90.2	87.7	101.3
August	85.1	85.8	86.0	82.8	90.4	88.2	85.9	99.7
September	83.7	78.8	78.1	73.0	84.3	81.4	80.8	89.5
October	68.4	67.6	63.5	60.3	72.4	69.3	70.4	78.4
November	58.5	57.2	52.9	50.0	62.3	58.5	58.5	67.0
December	48.9	51.3	45.0	44.0	55.9	52.3	51.6	57.4
Year	67.8	67.1	66.4	60.9	72.0	68.6	68.5	78.5

Of the stations in the Algerian desert comprised in the accompanying table of temperatures, Bou Saada, at an elevation of 2,194 feet, belongs rather to the high plateau region, lying north of the mountain chain which forms the boundary of the Sahara. It is in a region, however, where the conditions are entirely desert-like, closely resembling those of the higher western part of the Sahara. The other three stations are in the low eastern part of the Sahara proper. Biskra can hardly be regarded as a typical locality, being just within the limits of the desert, only a few miles south of the mountains which form the northern boundary of the Sahara. Biskra is 407 feet above sea level. Tougourt, 120 miles farther south, in the Oued Rirh country, is the center of some 40 oases, where hundreds of thousands of date palms are grown. Its altitude above mean sea level is 226 feet. Ouargla, well into the Sahara, 120 miles still farther south, has the same elevation.

Among the localities in the extreme southwestern United States selected for comparison, Tucson, Ariz., with an elevation of 2,387 feet, resembles in situation Bou Saada. Phoenix (altitude, 1,100 feet) may be compared with Biskra. At Yuma (altitude, 137 feet), and still more at Volcano Springs (228 feet above sea level), conditions would be expected to resemble in many respects those prevailing at Tougourt and at Ouargla. A comparison of the figures in these tables shows that the Colorado Desert in southern California is warmer than the Sahara in Algeria. Volcano Springs has an annual mean temperature 10.7° F. higher than Tougourt, and in summer the maxima are higher. The extreme minimum temperatures in Arizona and California are lower than those in the Sahara. For example, the lowest recorded temperature at Biskra is 29.7° F., while at Phoenix, Ariz., the minimum frequently falls to 25° F., and has been as low as 12° F.[a]

HUMIDITY.

While the actual amount of water vapor in the air is sometimes quite appreciable in the Sahara, the relative humidity is always low, because of the high temperatures. In summer the average relative humidity is only 28 per cent, and for this reason the excessive heat is less uncomfortable than would otherwise be the case. So extreme is the dryness of the atmosphere that one's skin is seldom wet with perspiration, even on the hottest days. Dew is rarely precipitated, and although freezing temperatures are by no means unknown in winter, white frost is not common. The sky over the Sahara is generally cloudless and very clear, particularly in the night time.

TABLE 4.—*Mean relative humidity (in percentages) of localities in the desert region of Algeria, as compared with Yuma, Ariz.*

Month.	Algeria.			United States.	Month.	Algeria.			United States.
	Biskra.	Ouargla.	Bou Saada.	Yuma.		Biskra.	Ouargla.	Bou Saada.	Yuma.
January	61.6	60.1	65.5	45.4	August	35.6	25.3	26.4	47.7
February	55.3	67.5	60.7	43.8	September	44.1	28.6	39.1	44.7
March	52.0	55.0	50.7	43.0	October	51.2	52.0	47.6	46.2
April	48.2	47.0	46.9	35.1	November	58.5	62.1	57.8	43.3
May	42.9	37.3	42.0	36.7	December	62.5	66.4	64.8	51.4
June	36.4	35.6	34.1	34.7					
July	32.6	29.4	25.4	42.8	Year	48.4	47.2	46.8	42.9

The three stations in the Algerian Sahara where records of relative atmospheric humidity have been kept all show an annual mean higher

[a] For a detailed comparison of the climate of the Algerian Sahara with that of the extreme Southwestern States, see Bulletin No. 53 of the Bureau of Plant Industry, U. S. Department of Agriculture, The Date Palm and Its Utilization in the Southwestern States, by Walter T. Swingle, 1904, pp. 52–70.

than that of Yuma, the only locality in the desert region of the southwestern United States where accurate records have been kept. But, while in winter the humidity is greater in the Algerian Sahara than in southwestern Arizona, in summer the reverse is true.

PRECIPITATION.

A widely received explanation of the peculiar conditions of the Sahara, as regards atmospheric water, is as follows: The central portion of the desert is sufficiently elevated to be considerably colder in winter than the Atlantic Ocean to the west and the Mediterranean Sea northward. Consequently, the general direction of winds in winter is from the center toward the edge of the desert, which precludes the possibility of much rainfall at that season. In summer, on the other hand, the normal winds blow toward the highly heated center of the desert, although there are occasional siroccos in the contrary direction. These normal summer winds from the Atlantic and Mediterranean would cause rainfall in summer were it not that physiographical conditions intervene to prevent this. Winds from the west encounter a cold current that follows the Atlantic coast of northern Africa, and the greater part of the moisture they carry is condensed before they reach the mainland. The high summits of the coastal mountain system of Algeria intercept and condense most of the water vapor that is brought in by winds from the Mediterranean. What little moisture escapes this barrier and crosses the high plateau is mostly given up when the mountains along the northern border of the Sahara are encountered. Furthermore, in the desert itself there are few mountains of sufficient elevation to condense what water vapor passes the second barrier.

Notwithstanding these conditions, rain is by no means unknown in the Sahara. Heavy precipitation sometimes occurs, but its distribution is very irregular, both in point of time and of place. Localities in the desert are known which have received no appreciable amount of rain for ten years or more. At other times a cyclone may cause a sudden heavy downpour. Violent torrents are formed and a great amount of erosion is accomplished in a few hours. The higher elevations of the isolated mountain masses of the Sahara have a somewhat more regular rainfall, but it is believed that, on the whole, evaporation exceeds precipitation in the Sahara, and that its aridity is steadily, although imperceptibly, increasing.

TABLE 5.—*Rainfall (in inches) of localities in the desert region of Algeria, as compared with similar localities of the southwestern United States.*

Month.	Algeria.				United States.			
	Tougourt.	Biskra.	Ouargla.	Bou Saada.	Yuma, Ariz.	Phoenix, Ariz.	Tucson, Ariz.	Volcano Springs, Cal.
January	0.61	0.67	0.50	0.79	0.48	0.80	0.79	0.25
February	.54	.68	.30	.79	.11	.70	.90	.39
March	.80	.69	.88	1.32	.27	.58	.77	.07
April	.14	.83	.36	1.56	.08	.30	.27	Trace.
May	.39	.72	.13	1.55	.03	.13	.11	Trace.
June	.04	.31	.11	.67	.00	.10	.26	.00
July	.03	.12	.00	.32	.13	1.03	2.40	.12
August	.02	.14	.00	.31	.33	.88	2.60	.09
September	.31	.80	.00	.91	.15	.64	1.16	.00
October	.43	.59	.22	.87	.23	.37	.61	.12
November	.54	.12	.50	.61	.26	.51	.81	.07
December	.88	.71	.61	.88	.46	.86	1.00	.52
Year	5.01	6.73	3.61	10.61	2.83	6.93	11.71	1.61

A comparison of precipitation in the Algerian desert and that of the southwestern United States is instructive and interesting. Bou Saada has approximately the same annual total as Tucson, which it resembles in situation and elevation, but there is the same difference in distribution as was noted in the case of atmospheric humidity. More rain falls in winter and less in summer at the Algerian than at the Arizona locality. At Biskra and Phoenix very nearly the same total amount of rain falls during the year, and the distribution at the two points corresponds more closely than as between Bou Saada and Tucson. At Ouargla and at Tougourt the rainfall is considerably greater in yearly total than at Yuma and at Volcano Springs. In distribution, however, these four stations resemble each other to a considerable degree. On the whole, if we consider only localities which represent the most extreme conditions in both great arid regions, it would appear that the desert country of the southwestern United States is decidedly drier than the Sahara of Algeria.

IRRIGATION.

Algeria is less fortunately endowed than Egypt as regards water supply. She has no large river like the Nile, containing even at its lowest stage a very considerable volume of water for irrigating purposes. On the contrary, the water courses of the French colony are of a torrential character, running high after heavy rains but dwindling to mere rivulets in summer. Most of them are short, rising in the mountain ranges of the coast region, and thus not draining a sufficiently large area to gather a great volume of water. Their fall is heavy, and they accomplish a vast amount of erosion, so that when high their waters carry a large amount of silt. Even the Chéliff, which has its source in the mountains that form the northern boundary of the Sahara and traverses the entire width of the high plateau, is but an insignificant stream in summer. Rainfall is too scanty, even at a short distance from the coast, to feed large rivers. For this reason irrigation in Algeria must necessarily be on a more modest scale than in Egypt. As a matter of fact, the area under irrigation at present is only a small fraction of the total area of the colony.

The littoral zone of the coast region, particularly in the eastern part of the colony, receives quite enough precipitation in winter for the growing of most crops. In summer, however, there are very few parts of Algeria where field crops can be grown without irrigation, at least without a radical change in the methods of cultivation generally followed in the colony. Orchards and vineyards, however, can be made to pay in some places without artificial watering. This is notably the case in the mountain zone, where steep slopes, ill adapted to irrigation, are covered with fruit trees. In the valley and plain zone of the coast region irrigation is almost indispensable in summer, and even the winter cereal and forage crops are greatly benefited by an occasional watering. In the high plateau region nothing can be grown in summer without irrigation, and in winter it is only in an occasional depression that the natural moisture is sufficient to bring a crop. In the desert region artificial watering is at all times necessary for small crops, although sometimes it is of the simplest character. Thus, at the base of the mountains scanty crops of grains can be produced by throwing up a series of ridges to retain the sheets of flood water that in winter occasionally sweep down over the land.

There is no reason to believe that in ancient times, when northern Africa was the granary of the civilized world, conditions as to water supply were essentially different from those now prevailing, although there is evidence that, in eastern Algeria at least, crops were much more extensively grown without irrigation than is now the case. Under the Carthaginian régime, and later under the Roman rule, irrigation works abounded in the country that is now Algeria and Tunis. The remains of such structures, sometimes utilized as foundations for modern works, are numerous, particularly in the Department of Constantine and in Tunis. Indeed, more than one region that is now a barren desert must have been well populated and in a high state of cultivation two thousand years ago.

The works built at that period were generally of the simplest and rudest construction. Often merely a mass of earth or broken stone, held in place by a row of stakes, served to dam a small brook. For the most part these structures were evidently the work of the colonists who tilled the land under them, rather than of trained engineers. They were built sometimes by individuals, sometimes by associations. The plan usually followed was to dam up a mountain torrent near the point where it debouches upon the plain. In narrow ravines a succession of rough dams was often constructed, thus allowing the stream to drop from terrace to terrace, leaving a tiny reservoir at each stage, from which water could be taken at need for irrigating small gardens and orchards. At the mouth of the ravine was a larger distributing reservoir, with a dam of stone and masonry, for diverting water into the irrigation canals, which branched out over the lower lands beyond. The safety of the larger dam was assured by the presence of these smaller reservoirs farther up the stream. By this method not only was water secured for irrigation, but the force of the current in times of flood was effectually checked. For a roaring, muddy torrent, sweeping all before it and carrying away great masses of the soil, was substituted a gentle stream of clear water, incapable of destructive erosion.

During the long centuries of Arab domination most of these irrigation works fell into ruin. Some, however, were patched up from time to time, and were used by the Arabs to irrigate their small fields and gardens. Soon after the French conquest the all-importance of some provision for the artificial watering of the land was perceived, and the construction of large storage and diversion reservoirs along Algerian streams was begun. At first this work was done by the engineer service of the French army.

COAST REGION.

Irrigation in Algeria to-day reaches its maximum development in the larger valleys and plains of the coast region. A number of important irrigation districts have been established, and reservoirs and canals have been constructed. At Marengo, on the Meurad, the first storage reservoir constructed by the French was finished in 1857. The dam, built of earth, is 266 feet long and 90 feet high. The barrage of the Cheurfas is built across the Sig, a short distance south of St. Denis du Sig. It took the place of a Turkish dam which was washed out in 1858. The present reservoir stores 2,400 acre-feet and supplies water for the irrigation of 5,000 acres in winter and 2,000 acres in summer. A larger dam, 6 miles farther upstream, was completed in 1884. This dam was of masonry, 98.4 feet high, 62.2 feet thick at the base, and 13.1 feet thick at the top. The capacity of the reservoir was calculated at 14,600 acre-feet. On February 8, 1885, the dam broke, carrying with it also that farther downstream. This break is said to have been caused by the infiltration of water through the rock around the dam. The foundation was of soft sandstone, in many places hardly sufficiently indurated to warrant its being called rock. The dam which was then built on the site of the older one is on the same general plan as its predecessor, but instead of being built on a straight line, the new portion is at an angle of 128 degrees with the old work, the angle pointing downstream. The object of constructing the dam in this way was to obtain a better foundation. It is reported that seepage around and under the walls of the structure still causes trouble, and some engineers question the permanent safety of the work.

The largest storage dam in Algeria is that across the Habra River, 7 miles south of the town of Perrégaux. This structure, also, has been the scene of a catastrophe, and a much more serious one than that which occurred at St. Denis du Sig. The original dam, 1,506 feet long, was built in two sections at an angle of 30 degrees, with the angle pointing downstream. It was partly carried away on December 15, 1881, by excessive floods which overtopped the entire dam. This disaster is generally attributed to the giving way of the soft foundation material, and to water cutting around the east end through the soft material. As a result of the break in the eastern end of the dam 400 persons were drowned and immense damage was done to property.

The work of reconstruction was finished in 1886. The dam, as it now exists, is essentially in three parts. The spillway on the west end has a length of about 410 feet. The center of the dam crosses an island which divides the stream into two channels. The portion of the dam across the east channel is 13 feet higher than that over the west channel. The reconstructed dam has a height of 131 feet, is 1,443 feet long, 131 feet thick at the base, and 14.7 feet thick at the top. The highest part of the dam, in the eastern section, consists of a wall 7.9 feet high and 4.9 feet thick, resting upon the top of the dam proper. This was added to prevent overflow of the adjacent land by floods. The event has shown the wisdom of this precaution, for in 1900 water rose to within 2 feet of the top of the highest wall, and was 6 feet higher than the crest of the spillway. The total cost of the Habra dam, from the inception of the enterprise, has been about $1,080,000.

The reservoir formed by this structure has a capacity of 30,800 acre-feet, and is intended to provide for the irrigation of about 100,000 acres, although so large an area has never been taken up under it. The water from the reservoir is taken out at the base of the high or eastern portion of the dam. A complicated apparatus has been devised by which water passing through the sluice furnishes power to pump water into a tank, which is situated upon a hill about 100 feet high at the east end of the dam. The water thus elevated furnishes stored power for the operation of the sluice gate. The gate is supposed to be automatically raised and lowered as the water rises and falls in the reservoir, but the mechanism has never proved altogether satisfactory.

The Habra, with its tributaries, has a flow in summer of 18 second-feet, but during unusual floods the discharge has been known to exceed 25,000 cubic feet per second. Although the drainage basin above the Habra dam covers 3,859 square miles, the mean annual discharge of the stream is estimated to amount to only about three and one-half times the capacity of the reservoir. During the flood which occasioned the breaking of the dam, caused by a $6\frac{1}{2}$-inch rain over a great part of the watershed, the run-off in one night was more than three times the capacity of the reservoir.

Near the town of Relizane a small masonry dam has been built across the Mina River. This dam has a height of 45 feet above the the bottom of the rocky gorge in which it is built. It was originally planned to hold up a small storage reservoir, but this has become filled with sediment, and now the dam serves only for the direct diversion of the water of the stream. The discharge of the Mina is small. Though the canal system fed by this barrage covers an area of 20,000 acres, the land actually irrigated is not of large extent. The water of this stream, when examined toward the end of July, 1902, was found to carry 123 parts of soluble matter per 100,000 parts of water. Of this, 26 parts were bicarbonates, 1 part carbonate, 60 parts chlorids, and 36 parts sulphates.

Another masonry work of importance is that across the Djidiouïa River near St. Aimé, in western Algeria. It is 164 feet long, 55.8 feet high above the foundation, and 91.9 feet high, foundation included. The base has a thickness of 36.1 feet, and the top 13.1 feet. The reservoir has a capacity of 2,000 acre-feet, and is intended to irrigate from 7,500 to 10,000 acres.

Since it was built this reservoir has become almost completely filled with silt. In all reservoirs in Algeria the accumulation of silt has given trouble, but only at St. Aimé have attempts been made to remedy the evil. M. Jaudin, a hydraulic engineer, has invented a machine for stirring up and removing the silt. His apparatus consists of a metal tube or conduit 20 inches in diameter, the lower end of which penetrates the dam near its bottom. The free portion is kept afloat by buoys and is attached by flexible joints to a floating scow. The connections are made so as to allow the scow to float from side to side of the reservoir, and the end of the pipe can be raised and lowered as desired. The difference in level between the end of the pipe projecting through the dam and that attached to the scow produces a strong current through the pipe. As the pipe is moved along the mud is sucked into it and is carried below the dam. The clay drawn into the pipe is found to be so well packed and so stiff that it has to be cut out by a special cutting apparatus built like a steam screw. In spite of the cutting apparatus, the water thus removed carried only from 4 to 5 per cent of silt. The inventor claims that under favorable conditions he can remove water containing 16 per cent of silt. The expense of operating the apparatus is estimated at $35,000 a year, and the cost of installation for a fairly large dam would be $540,000. The inventor was under contract to remove the silt from this reservoir at 20 cents per cubic meter (15.4 cents per cubic yard).

In the Mitidja Valley, near Algiers, there is a reservoir which is capable of holding about 11,340 acre-feet of water. This is sufficient to irrigate 75,000 acres, but the area actually under irrigation is only one-third as large.

The irrigation works just described are more or less typical. At a number of other places dams are either in actual use or are under construction. Algeria has been unfortunate in regard to disasters to her irrigation works. This has tended to create distrust of them among farmers who practice irrigation. There were lean years for people who tried to farm below the canals while new works were building, and the memory of those trying times is still vivid. It seems that in the early days of colonization too much land was covered by the irrigation works. Consequently, there are now large uncultivated areas across which the canals and laterals have to be extended in order to reach land that is in crops.

There is reason to believe, as an eminent authority upon agriculture in Algeria has remarked, that more good might result from the construction of series of irrigation works on a small scale, after the fashion of the Carthaginian and Roman colonists, than from the building of elaborate engineering works such as have just been described. The peculiar torrential character of Algerian streams and the great quantity of silt they carry make them ill adapted to large structures of this kind; but small diversion reservoirs, that afford water only in winter, are a valuable supplement to the natural rainfall, particularly in the drier western part of the coast region. There it is found that one or two irrigations during the winter will very materially increase the yields of cereals and forage crops. Handled thus, with two irrigations in winter, an acre of wheat in the Chéliff Valley can sometimes be made to yield 44 bushels.

The most important direct diversion of water from a stream in Algeria is that on the Chéliff, 15 miles above Orléansville, where the irrigating water is taken from the west bank of the river by means of a canal with a capacity of about 50 cubic feet per second. One branch of this canal is carried across the river by a siphon to irrigate the right bank. On the left bank 6,000 acres, and 19,000 acres on the right bank, are irrigated by this canal. The entire system cost about $480,000. Those who use the water are required to construct the secondary canals, pay a rental to the government, and keep the works in repair. Of the 50 cubic feet of water per second available under this system, 13 only have been subscribed for, on account of the excessively high water rent asked. Similar difficulty in inducing farmers to subscribe to water at the rates demanded has been encountered elsewhere in the colony.

In the mountain zone, notably in Great Kabylia, there are many small diversion dams, cheaply constructed in narrow ravines out of such materials as are ready to hand. By means of these, streams that in summer appear to be dry, but really carry subterranean water, are made to serve for irrigation at that season. The bed is dug out until rock bottom is reached. A dam is then roughly fashioned out of stones. The trunk of a tree is laid across the top, which is slightly higher than the general level of the stream bed, and clay and stones are piled up behind the dike; or, sometimes, a mere double row of stakes, filled in with clay and stones, is made to answer the purpose.

Various devices are in use in Algeria for preventing water that falls upon cultivated hillsides from running off too rapidly. Particular attention has been paid to this question in vineyards. Sometimes shallow basins are dug in the center of each quadrangle formed by four vines. Another practice, which is also followed by the Kabyles in their orchards, is to run horizontal furrows or trenches across the hillside at regular intervals, throwing out the soil on the downhill side. It has been estimated that, at a cost of about $3, from 9,000 to 10,000 cubic feet of water, enough to cover the land to a depth of from 2 to 4 inches, can thus be saved annually in each acre of vineyard. In olive orchards, which cover steep hillsides in some parts of the colony, V-shaped trenches, pointing downhill, are dug so that the point of a trench is situated near the base of each tree. The soil around the tree is kept loose in order to facilitate absorption of the water thus carried to it.

The market gardens of the littoral zone are generally irrigated by means of the "noria," a water-lifting machine that has been in use for ages in the Mediterranean region. It consists of a vertical wheel, to the rim of which buckets are attached, and which turns by interlocking its cogs with those of a horizontal wheel. To the latter an animal, usually a horse or a donkey, is hitched, and is driven around in a circle. A second animal is kept to relieve the first, generally every two hours. By means of the noria one horse can raise 150 gallons of water 11 feet in a minute, which is equivalent to 0.33 second-foot. The water is collected in a basin that generally holds from 1,000 to 1,800 cubic feet. Even field crops and vineyards can be profitably irrigated with the noria if the water supply is ample and the lift does not exceed 40 feet. But its greatest usefulness is in connection with the intensively cultivated and very remunerative truck crops. The noria is said to be more economical for raising water than any hydraulic machine, only one-fifth of the total power expended being lost. Near Algiers, where the irrigation of gardens is most expensive, the annual cost of watering 1 acre with the noria is placed at $65.

The water used for irrigation in the coast region, except in some of the valleys of western Algiera, is generally very good, rarely containing a harmful quantity of salts. However, no attention has been given to the matter of drainage of irrigated lands. Particularly in western

Algeria, large areas of once fertile soil have in consequence become subirrigated and salty. In many cases considerable tracts have had to be abandoned for this reason.

HIGH PLATEAU REGION.

A very insignificant area is irrigated in the high plateau region. There are almost no running streams, except after an occasional heavy rain in winter. The water of the chotts or lakes that fill the depressions is far too salty to be used for irrigating purposes. Here and there a small patch of grain, forage plants, or garden vegetables is watered from a well, but artesian water seems to be generally lacking.

DESERT REGION.

Oases of greater or less extent occur in all parts of the Sahara. They are particularly numerous, however, in the lower eastern portion. In the region known as the Oued Rirh, a larger percentage of the total area is occupied by cultures than anywhere else in the desert. The oases (see Pl. I), almost without exception, are probably of artificial origin. The date palm, to which they owe their life, is believed to have been introduced into Algeria by man. In some places near the base of the mountains, as in the region of the Zibans, there is flowing water on the surface of the ground which can be diverted directly into canals. At most, a few rude dams are needed to raise its level a few inches. Elsewhere wells must be dug and the water must generally be raised by hand or by the noria in order to water the crops. The source of the water thus utilized is to be looked for in the high mountains adjacent to the Sahara, where the rainfall is much heavier than in the desert itself. This water flows down to the lower levels, at first over the surface of the ground, then beneath it. Subterranean streams of considerable volume must occur in the eastern part of the Sahara. There is no foundation for the idea sometimes entertained that the oases are natural subirrigated spots in the desert. Most of the desert soils are too saline to permit of subirrigation without injury to the crops. As a matter of fact, agriculture would be almost impossible in the Sahara were not careful provision made for drainage.

From very ancient times irrigation has been practiced in the desert. When the Romans governed northern Africa the area under cultivation in the Sahara was much larger than it is to-day. By many centuries of practice the natives of the Sahara have acquired great skill in procuring and managing water for irrigation. The art of well boring, as originally practiced in the Oued Rirh, is a dangerous one. The work is begun by scooping out a hole in the sand, the sides of which are incased with wood as fast as the digging proceeds. Finally, a layer of rock or of stiff clay, overlying the sheet of water, is reached.

This is broken through with a few strokes of the pick, and if the water ascends with considerable force, as is sometimes the case, the well digger runs considerable risk of being drowned. In the more accessible parts of the Sahara, modern well-boring machinery has largely replaced the ancient method.

The natives are very jealous of the water that is obtained with so much difficulty, and numerous quarrels arise over its distribution. In the Zibans oases, where a system of canals exists, the water is controlled by an association which decides in what quantity and upon what days it shall be allotted to each person. It is measured by laying the trunk of a date palm across the top of an earthen dam in the canal. Notches, corresponding to the width of the hand with the thumb closed, are cut into this trunk at intervals. The amount which passes each of these notches represents one share of water.

In the Oued Rirh region, since the French occupation, a great many artesian wells have been bored, under the direction of M. Jus, who became famous through his connection with this work. The first was sunk in 1856. In 1898 there were 120 metal-cased artesian wells from 160 to 330 feet deep, in addition to 500 wells dug by natives. The total discharge of all these wells was about 140 cubic feet per second, yet so far the water supply has suffered no perceptible diminution. With the water thus obtained the area in date palms has been greatly extended during the past thirty years. It is estimated that during the last three decades the population of the Oued Rirh has doubled, and the wealth of the region has been increased tenfold. There are probably few other parts of the Sahara where such development is possible.

Unlike the irrigating water of the coast region, that used in the desert region generally carries a high percentage of salts in solution. In fact, the water with which various crops are grown in the Algerian Sahara appears to be saltier than that used for this purpose anywhere else in the world. So far as is known, 500 parts of salts per 100,000 parts of water is the maximum concentration of water which is used with success in the United States, and, under ordinary circumstances, 300 parts is the limit for successful crop production. In the Sahara, however, water containing as much as 800 parts of salts (half of the total amount being sodium chlorid) per 100,000 parts of water is applied to soils that are themselves highly saline. A variety of cultivated plants—various fruit trees, garden vegetables, and alfalfa—thrive under these conditions.

It seems a fair inference that the maximum amount of soluble matter which can safely be allowed in irrigation water has been underestimated by American writers. Where the soil is light and underdrainage is provided for, as is the case in the Algerian oases, it is probable that many waters that have heretofore been condemned as too saline could safely be used in irrigating crops.

The date palm is the most salt-resistant cultivated plant of the Sahara, so far as is known. The maximum amount of salt in the irrigating water which this tree can endure without detriment to the crop has not been ascertained. It would appear, however, to be something less than 1,000 parts per 100,000, for water of a pond containing 1,044 parts per 100,000 of soluble salts, of which 1,036 parts was sodium chlorid, had been found to be too salty for irrigating a young date orchard.

A number of samples of artesian water used in irrigating the oases near Tougourt, in the Oued Rirh region, were taken by the writers and were analyzed in the laboratory of the Bureau of Soils of the Department of Agriculture. The results are stated in the following table:

TABLE 6.—*Chemical analyses of artesian water used in irrigating gardens in Saharan oases, Algeria.*

Constituent.	Well at Oasis Tabes-bes.	Well at Oasis Kudi Asli.	Well at garden of Ben Hadriah.
	Per cent.	*Per cent.*	*Per cent.*
Ions:			
Calcium (Ca)	9.92	4.19	9.86
Magnesium (Mg)	4.52	6.02	4.26
Sodium (Na)	14.03	20.48	14.18
Potassium (K)	4.27	2.35	2.72
Sulphuric acid (SO_4)	34.38	29.43	17.59
Chlorin (Cl)	28.06	36.21	27.05
Bicarbonic acid (HCO_3)	5.02	1.32	24.34
Conventional combinations:			
Calcium sulphate ($CaSO_4$)	33.04	14.23	24.90
Magnesium sulphate ($MgSO_4$)	13.63	24.29	7.04
Magnesium chlorid ($MgCl_2$)	7.23	4.41	16.72
Potassium chlorid (KCl)	8.12	4.48	5.19
Sodium bicarbonate ($NaHCO_3$)	6.92	1.81	33.54
Sodium chlorid (NaCl)	31.06	50.78	12.61
Total solids in 100,000 parts water	601.50	108.10	571.90

These are fair average samples of the irrigation waters in use, and do not represent by any means the maximum of salinity. Field tests showed as high as 816 parts to 100,000 in water in actual use on soils where garden vegetables were growing, while French authorities report the use of waters carrying 842 parts per 100,000.

SOILS.

The soils of Algeria are of many varieties and types, varying from the coarsest sands to heavy clays. The differences are due chiefly to two causes—the nature of the underlying rocks and the climatic conditions under which the soil was formed. Different classes of soils are found in each physiographic region and there are few types which are common to all three regions. In the littoral zone of the coast region much of the soil is of the adobe type, containing a considerable quantity of clay. In the alluvial bottoms, however, we find extensive areas of other kinds of soil. In the mountain zone the soils are not for the most part adobe-like. On the high plateau the soils are largely colluvial. In the desert we encounter vast areas of light, sandy soils, but there are also extensive tracts of marls, clays, and alluvial soils.

Very few samples of soil were collected, as no general investigation of the various types was attempted by the writers. It was observed, however, that in Algeria there appear to be no important soils which are not represented in California and Arizona by very similar types. Observations were largely directed toward the comparison of Algerian soils and their productivity with corresponding soils in America under similar climatic conditions.

COAST REGION.

LITTORAL ZONE.

An important and characteristic soil of the littoral zone is a bright-red "adobe," very common in the vicinity of Algiers, near Oran, and elsewhere along the coast. It is sticky when wet and forms very hard clods when dry, cracking to a depth of from 12 to 24 inches. This soil is often naturally poor in phosphoric acid, nitrogen, and lime, but responds readily to treatment. Its potash content is generally adequate. It is an excellent soil for vineyards, except in cases where a lime "hardpan" occurs too near the surface. Some of the best wines of Algeria are produced on soil of this type. The American soils which most nearly resemble it are the San Joaquin red adobe, as it occurs in the San Joaquin and Sacramento valleys, and the Fullerton sandy adobe of the coast region of southern California.

A mechanical analysis of one specimen of this soil is given on page 40, under No. 7663. This sample was collected a few miles south of Oran, and represents the heaviest phase of this red soil. We have not found in America a type of red adobe in which the average clay content is so high. The black adobes of the United States are sometimes very clayey, but most American adobes contain more silt than clay. The same soil type was also observed at Arzeu, in western Algeria, at various localities near Algiers, and, to a less extent, around Tizi Ouzou, in Great Kabylia.

River bottoms in the littoral zone are characterized by soils that are quite different from the red, clayey type just described; and are, in fact, mere continuations of the soils of the next zone. They are usually alluvial deposits, clayey or marly in texture, and are quite fertile. They contain an abundance of potash, though they are sometimes deficient in phosphoric acid.

VALLEY AND PLAIN ZONE.

The large valleys, which in some cases are so extensive as to be virtually plains, contain a great variety of soils. The plains of the

Mitidja, Chéliff, Mina, Habra, and Macta are typical of many other valleys and plains in Algeria. As before mentioned, they are similar in many ways to the interior valleys of California. The soils are mainly alluvial and are generally heavy. Around Relizane and Perrégaux, where the writers made most of their studies, the soil is similar to the San Joaquin black adobe. In the Mitidja the heavier soils are well supplied with potash and are fairly well provided with nitrogen and phosphoric acid. In the Chéliff Valley these elements are less abundant.

Sample No. 7658, in the table given below, shows the results of a mechanical analysis of the heaviest of the valley adobes. This sample was collected from a field which was very fertile twenty years ago, but which has since been ruined by the rise of salts, and is to-day valueless. This soil, before it had become saline, had exhibited great fertility during a long series of years. In former years it yielded grain of a superior grade and good crops of cotton. Sample No. 7660 represents a type of this adobe soil of medium heaviness. Soil of this kind is often planted to vines, fruits, and olives. The sample was collected near Perrégaux, at La Ferme Blanche, headquarters of one of the largest vineyards in Algeria. A still lighter type, one closely approaching a sandy loam, is represented by sample No. 7661. This type is usually found in the higher portions of the valleys, and is planted to vines and alfalfa.

MOUNTAIN ZONE.

The soils of the mountain zone of the coast region can be divided into (1) valley soils and (2) soils of the hills and mountain slopes. The hills and mountains are covered with either residual or colluvial soils. As a rule, these soils are more or less gravelly or stony, and are light and well drained. The lower slopes frequently have heavier adobe soils, similar in character to the adobes of the lower slopes of the Sierra Nevada and the coast range in California.

The soils of valleys in the mountain zone are generally alluvial, being composed of the waste from adjoining hills and mountains. The smaller valleys have light, usually well-drained, soils containing some gravel.

Table 7.—*Mechanical analyses of coast region soils.*

No.	Locality.	Depth in inches.	Organic matter.	Gravel, 2–1 mm.	Coarse sand, 1–0.5 mm.	Medium sand, 0.05–0.25 mm.	Fine sand, 0.25–0.1 mm.	Very fine sand, 0.01–0.05 mm.	Silt, 0.05–0.005 mm.	Clay, 0.005–0.001 mm.
7658	Relizane	0–21	0.01	......	0.08	0.12	0.66	2.00	10.22	56.92
7660	La Ferme Blanche, near Perrégaux	0–24	.22	......	.08	.10	2.00	20.11	54.66	22.94
7661	Debrousseville	0–12	1.34	0.16	1.08	3.06	28.60	30.62	20.40	16.08
7663	2 miles south of Misserghin	0–18	1.11	.12	.58	1.94	6.60	6.36	35.76	48.64
7688	15 miles east of Batna	......	......	.32	.28	.34	1.74	6.04	45.56	45.48

HIGH PLATEAU REGION.

The soils of this region, derived largely from cretaceous and tertiary rocks, are in great part alluvial deposits washed down from the neighboring mountains. Particularly in eastern Algeria, soils very rich in phosphates occur. These would be extremely fertile if water wherewith to irrigate them were available. Calcareous hardpan underlies a great deal of the surface of the high plateau. Where this impervious layer is quite near the surface the vegetation is sparse and woody plants are absent.

The high plateau soils grade from stony soils on the lower slopes of the mountains, through sandy loams and loams, to heavy clay loams and clays in the bottoms of the depressions. These depressions, known among the Arabs as "chotts," are a conspicuous feature of the steppes. While occasionally filled with water, the bottom is commonly dry and covered with a layer of salt. The chotts greatly resemble the "playa" lakes of the Great Basin region in Utah and Nevada and of the "bolson" plains of the southwestern United States and Mexico. The soil in the bottom of the chotts is always heavy and impervious.

DESERT REGION.

The soils of the western part of the Algerian Sahara—which is of very little agricultural importance—more or less resemble those of the very arid parts of the high plateau. In the eastern part of the desert, where numerous oases occur, the character of the soil becomes a matter of greater practical interest. The combined area of all the oases amounts to but a small fraction of 1 per cent of the total surface of the desert. The limited localities where oases occur are determined by the presence of water rather than by any exceptional fertility of the soil. As a matter of fact, there are vast tracts in the Sahara which are, probably, naturally more fertile than the oases and require only water to make them extremely productive.

The field observations made by the writers were confined to a number of typical areas in the Oued Rirh country. There are found the most important oases that are easily accessible from the Mediterranean coast. They are situated in what is probably the hottest part of the desert and their elevation above sea level is only a few feet. In fact, several of the oases occur in a part of the basin that is below sea level.

As a rule the soils of the oases in the eastern Sahara are light in texture. Sandy loams and sands predominate, though here and there are found soils heavy enough to be classed as true loams. Gypsum is an important constituent of nearly all the soils examined, in some cases the subsoil being practically pure gypsum. This often acts as a cementing material, uniting the finer soil grains into aggregates which give the soil a much more sandy appearance than would be suspected from the results of mechanical analyses. The data afforded by a number of analyses are given below.

The natural fertility of these sandy soils is not great. They are almost devoid of organic matter and after a few years of cultivation need fertilizing. This is supplied by the Arabs in the form of manure from donkeys, sheep, and camels. The soils of the date orchards that have been planted by the two French companies are also fertilized.

The following table gives the results of mechanical analyses of a number of samples of soil collected in the Oued Rirh region of the eastern Sahara. Chemical analyses have not been carried further than a determination of the water-soluble material.

TABLE 8.—*Mechanical analyses of soils from the Oued Rirh region in the Sahara Desert.*

No. of sample.	Locality.	Depth in inches.	Organic matter.	Gravel, 2-1 mm.	Coarse sand, 1-0.5 mm.	Medium sand, 0.5-0.25 mm.	Fine sand, 0.25-0.1 mm.	Very fine sand, 0.1-0.05 mm.	Silt, 0.05-0.005 mm.	Clay, 0.005-0.001 mm.
7686	Ourir. Hard crust among palms..	0-12	0.76	0.52	1.76	3.74	21.02	18.98	21.98	31.26
7687	Subsoil of 7686	12-26	.34	.20	1.88	1.84	29.52	21.42	15.48	25.40
7683	Ourlana palm orchard	0-12	.50	.54	.90	1.14	17.46	49.80	11.64	9.16
7684	Subsoil of 7683	12-36	.08	.48	1.64	3.70	26.84	29.30	7.64	9.92
7685	.....do	36-54	.04	.86	2.50	2.84	18.74	36.40	19.40	9.14
7665	Ourlana among 13-year-old palms.	0-12	.14	2.46	3.96	8.06	32.52	33.56	5.42	14.02
7666	Subsoil of 7665	12-36	.04	1.10	4.46	5.74	31.70	40.94	4.52	11.54
7667	Tougourt amid good alfalfa	0-12	1.10	.20	1.32	3.98	34.44	37.98	9.52	12.56
7668	Subsoil of 7667	12-24	.59	.16	1.30	3.06	28.58	45.92	8.72	12.12
7669	Tougourt amid alfalfa	0-12	.73	.15	1.93	4.63	27.71	33.59	7.98	24.01
7670	Subsoil of 7669	12-24	.62	.73	2.51	5.37	32.12	33.27	5.85	20.15
7671	Tougourt amid alfalfa	0-12	1.47	.26	2.01	4.98	28.22	30.91	11.21	22.41
7672	Subsoil of 7671	12-24	1.35	.12	1.41	4.07	28.33	29.82	7.54	28.71
7673	Ta-bes-bes Oasis	0-12	.41	1.56	2.03	1.72	20.24	32.53	6.37	35.55
7674	Subsoil of 7673	12-24	.16	.35	1.27	1.33	25.94	34.10	6.57	30.14
7676	Kuda Asli Oasis	0-12	.66	1.12	4.76	6.75	28.58	32.60	7.97	18.22
7677	Subsoil of 7676	12-24	.35	1.39	3.27	4.39	20.38	26.42	15.76	28.39
7678	Dune sand, border of Djadja Chott	....	.47	.00	5.08	12.80	51.54	18.40	1.22	7.62
7679	Oasis of Zoia de Temacin	0-12	6.30	.86	4.60	1.66	22.50	17.48	26.90	9.04
7680	Subsoil of 7679	12-24	.27	1.50	5.14	5.90	19.60	20.24	25.88	8.82
7681	Oasis of Zoia de Temacin	0-12	.44	1.54	6.16	4.24	22.70	39.10	14.50	5.76
7682	Subsoil of 7681	12-24	.21	.60	4.54	2.60	19.12	30.94	20.78	10.60

SALINE SOILS.

As in all arid countries, particularly where irrigation is practiced, saline soils are an important factor in the agriculture of Algeria. Extensive areas of the most fertile land of the colony have been injured by an excess of salts, and the alkali problem is to-day one of the most serious which confronts the Algerian farmer. Drainage is not generally practiced by the colonists in their large irrigation districts, and the lack of it has been the cause of a great deal of damage. On the other hand, the natives of the Sahara show the utmost ingenuity and skill in managing salty soils and in irrigating with saline waters. There is much in the methods practiced by these people that should interest the American farmer and that could be imitated by him with profit.

COAST REGION.

The littoral zone of the coast region comprises very little alkali or saline land. A few areas of salt marsh occur along the shore, but not much has been done toward their reclamation.

The most extensive areas of salt soil in the coast region are those found in the great valleys and plains. Certain of these areas have existed for a long time. Others, including some of the most serious, have been developed under irrigation within the last fifty years. The most important tracts of salt land seen by the writers were near the towns of Relizane and Perrégaux, in the Department of Oran.

At Relizane the area covered by the irrigation systems amounts to about 20,000 acres. As the water supply very frequently falls far short of the amount necessary for the irrigation of this large area, part of the land is ordinarily lying idle. The irrigation of surrounding fields, together with seepage from the canals and laterals, has so raised the water table in this uncultivated land as to permit a constant upward movement of the water by capillary force. The result has been that salts which were formerly confined largely to the subsoil, or which have been carried into the soil by subirrigation, have risen to the surface and have accumulated there. The same process of accumulation of salts in the upper layers of the soil has caused serious damage in many parts of western North America. Around Relizane the old story has been retold that land once fertile and producing luxuriant crops is to-day bare of everything but a few stunted salt-loving weeds. The remains of irrigating laterals, fences, and houses alone show that the land has ever been farmed.

At Perrégaux a similar state of affairs prevails, but a much larger area is affected. The salt land covers an extensive tract in the lower part of the valley and includes fields that a few years ago were highly productive. A few attempts at reclamation have been made, and some excellent fields were seen which were said to have been badly saline at one time; but no large areas have been improved.

The soil and other conditions of saline areas in the irrigated districts of Algeria have no important peculiarities which distinguish them from similar localities in America. The salts are generally "white alkali," i. e., salts of sodium (other than the carbonate), magnesium, and lime.

Chemical analyses of samples of these soils taken by the writers are given on page 46. The predominant salts are of the "white alkali" type, common salt (sodium chlorid) being the most abundant. Very little "black alkali" (sodium carbonate) has been found in the coast region of Algeria.

The question of salt land in Algeria has been discussed in a recent publication by Dugast, who devotes particular attention to the damage that has been wrought in the vineyards of western Algeria by the rise of salts in the soil. We may be excused for quoting at some length from this author.[a]

It is sea salt—that is, true salt—that is generally found in Algeria, but magnesium salts have also been found in several vineyards. As for the alkali salts, or "black alkali," we have not yet come across them. They probably appear, however, when circumstances favorable to their formation exist. * * * But if their existence is transient, if washing does not take place to separate them from the other salts, it is difficult to determine their presence.

In 1876 Pichard called attention to the presence of carbonate of sodium in several waters in Oran Department, accompanied by sulphates of sodium and calcium and chlorids of calcium and magnesium, sometimes by small quantities of alkali nitrates and traces of ammonium salts. These waters give an alkaline reaction and contain from 0.2 gram to 20 grams of sodium carbonate per liter.

While the salt is directly harmful, it is also indirectly injurious by hindering the nitrification of the nitrogenous matter existing in the soil or added to it by manure. Hence it interferes with the alimentation of plants.

In vineyards salt manifests itself in spots which differ in aspect according as they are old or new. When the salt is in small quantities in the soil, or, rather, when the soil still contains a considerable proportion of water, or when, again, the salt reaches only a part of the zone of soil occupied by the roots, the spots are characterized by a simple wilting of the vegetation.

At other times the damage caused by the salt is sudden and much more pronounced. The places attacked then take the form of circular spots. The branches of the vines that bear grapes lose their leaves and dry up, and the grapes do not reach complete maturity.

In 1898 and in 1899, at the time of our visit [to the vineyards of Oran Department], we saw numerous spots presenting these characteristics. Such spots were occupied by vines loaded with grapes, but the branches had completely lost their leaves. All around them the vines were green and were well loaded with a good crop of grapes.

In the older spots, which are sometimes very extensive, most of the vines are dead. We find, however, here and there, some vines that have resisted the salt and have been able to put out badly developed branches bearing a few grapes of poor quality. These old spots, although due to salt, much resemble those caused by phylloxera.

The reclaiming of salt land is difficult to accomplish in Algeria. The rainfall is always insufficient to bring about reclamation, and the supply of irrigation water is also scanty.

For the present we must try to get along with the salt, doing our best to prevent its becoming too injurious. This can be done by working the soil to a depth of 20 inches, so that the rain water can be stored in that depth of the soil. In this way the fresh water can be prevented from penetrating sufficiently deep to dissolve the salt and by its presence it restrains the salt from rising. It is necessary, of course, by superficial cultivation to break up the capillarity of the soil, so as to reduce evaporation to a minimum.

Drainage ditches can also be used in certain lands for carrying off the salty water of the lower depths of the soil. Ditches can also be used in certain cases to prevent the invasion of new land by the sheet of salt water.

Saline soils of purely natural origin are found in and near the chotts which occupy depressions and receive the drainage of the surrounding land. In such places salt has been accumulating through long ages.

[a] Agrologie de l'Algérie, 1900, pp. 56, 58, 59, 71, 72, 77, 78, 80, 81, 89, 90.

In the dry season the bottom of the basin is covered with a crust of salt, in some cases of sufficient thickness to make its exploitation profitable. In the wet season this gives place to a shallow lake of salt water. A number of such chotts occur near the coast in western Algeria. The writers visited one large salt lake near Arzeu and another near Oran. At the Salines d'Arzeu great quantities of commercial salt are prepared. These chotts correspond to similar salt, soda, and "playa" lakes of Utah, Nevada, and other western States.

Many salt lakes also occur in the high plateau region. In the eastern part of the Sahara the chotts cover extensive areas south of Tunis and of the Department of Constantine. There they are below sea level, and the country around them is very hot and dry.

DESERT REGION.

The saline soils of the Oued Rirh region in the Sahara, so far as they were examined by the writers, generally contain a large amount of gypsum. (See p. 46.) Sodium chlorid and sodium sulphate are the next most abundant salts, while magnesium salts are present only in small quantities. The Saharan soils are usually of very light texture, and their proper irrigation demands large quantities of water. The water used contains a high percentage of soluble matter. Consequently, where proper drainage facilities have not been provided, the salt has accumulated in the soil to an injurious degree. Yet, by digging open drains 3 feet deep at frequent intervals and irrigating once a week or oftener, the natives of the Sahara are able to maintain gardens containing a variety of plants not particularly resistant to salts in the soil.

More than this, using strongly saline water (see p. 38) they are able to reclaim land that contains an excessive amount of salts. The writers visited a garden which had been established on the slope of the bed of a salt lake, in which alfalfa, various garden vegetables, and a variety of young fruit trees were flourishing. The reclamation of this piece of land had been accomplished in three years by irrigating twice a week during that period.

TABLE 9.—*Chemical analyses of saline or "alkali" soils from Algeria.*

No. of sample.	Locality.	Depth in inches.	Calcium (Ca).	Magnesium (Mg).	Potassium (K).	Sodium (Na).	Sulphuric acid (H_2SO_4).	Chlorin (Cl).	Bicarbonic acid (HCO_3).
7658	Relizane, 3 miles NW	0-24	7.28	4.53	3.08	18.48	27.31	34.22	5.10
7659	.....do	0-1	2.11	12.15	1.10	15.83	9 70	56.86	1.95
7665	Ourlana, among 13-year-old palms	0-12	23.27	.91	1.92	4.77	59.13	8.35	1.65
7666	.....do	12-36	23.46	.49	2.24	4.33	65.30	2.09	2.09
7667	Tougourt Oasis, amid good alfalfa	0-12	23.81	.89	1.82	3.52	66.22	1.87	1.87
7668	.....do	12-24	25.23	.66	1.51	2.63	65.96	1.87	2.14
7669	Tougourt Oasis, amid poor alfalfa	0-12	23.90	.88	1.82	3.28	66.49	1.24	2.39
7670	.....do	12-24	21.71	.58	1.76	2.84	66.69	1.26	2.16
7671	Tougourt Oasis, amid yellowing alfalfa	0-12	23.72	1.13	1.68	3.90	61.35	6.46	1.76
7672	.....do	12-24	24.67	.68	1.93	2.86	66.28	1.76	1.82
7673	Ta-bes-bes Oasis, amid alfalfa	0-12	20.27	1.61	2.10	1.34	61.38	4.96	3.34
7674	.....do	12-24	19.11	1.53	1.91	7.84	61.13	5.27	3.18
7675	Kuda Oasis	Crust.	.56	.66	.29	37.03	3.82	56.99	.65
7676	Kuda Asli Oasis, amid good alfalfa	0-12	16.03	3.27	1.47	6.86	56.18	7.96	5.23
7677	.....do	12-21	19.75	1.96	2.49	6.03	61.83	4.79	3:15
7679	Zoia de Temacin Oasis, amid good alfalfa	0-12	22.83	1.21	1.56	1.51	63.90	4.02	1.97
7680	.....do	12-24	21.00	1.05	.76	3.92	65.30	2.95	2.02
7681	Zoia de Temacin Oasis, amid yellowing alfalfa	0-12	22.72	.97	1.94	1.90	61.66	5.08	2.73
7682	.....do	12-24	24.01	1.17	1.48	3.33	64.79	3.60	1.62
7683	Ourlana, among 20-year-old palms	0-12	23.38	1.04	.92	5.15	59.47	8.54	1.50
7684	.....do	12-36	26.08	.98	.85	2.15	64.97	2.82	2.15
7685	.....do	36-54	23.06	.99	.99	4.92	63.74	3.71	2.59
7686	Ourir, among palms	0-12	16.73	4.11	1.77	10.89	24.13	41.35	1.02
7687	.....do	12-26	23.84	1.20	1.16	3.90	62.10	5.81	1.99

TABLE 10.—*Conventional combinations of the data in Table 9.*

No. of sample.	Percent soluble matter.	Calcium sulphate ($CaSO_4$).	Magnesium sulphate ($MgSO_4$).	Magnesium chlorid ($MgCl_2$).	Potassium chlorid (KCl).	Sodium chlorid (NaCl).	Sodium bicarbonate ($NaHCO_3$).	Sodium sulphate (Na_2SO_4).	Other constituents.
7658	2.47	24.78	12.31	7.93	5.99	11.95	7.04	....	....
7659	6.14	8.17	4.91	43.78	2.41	38.36	2.67	....	....
7665	1.36	79.23	4.03	.18	3.67	10.65	2.24	....	....
7666	1.02	79.69	2.44	....	4.23	.15	2.88	10.61	....
7667	1.49	80.88	1.42	....	3.56	.32	2.58	8.24	....
7668	1.48	85.69	3.30	....	2.90	.80	2.94	1.37	....
7669	1.50	81.24	4.39	....	2.57	....	2.17	8.35	[a]1.28
7670	1.43	84.39	2.89	....	2.66	....	2.21	6.95	[a].90
7671	4.76	80.61	5.58	....	3.19	8.19	2.43	....	....
7672	4.62	83.75	3.42	....	3.70	....	2.50	6.63	....
7673	3.25	68.89	7.93	....	4.03	5.03	1.58	9.54	....
7674	3.39	64.97	7.55	....	3.71	5.72	4.36	13.69	....
7675	92.93	1.91	3.07	.16	.55	93.42	.89	....	....
7676	1.83	54.42	16.03	....	8.50	6.43	7.19	7.43	....
7677	3.05	67.01	9.64	....	1.72	4.20	1.33	10.10	....
7679	4.87	76.64	6.03	....	2.95	1.35	2.71	6.32	....
7680	4.72	81.65	5.19	....	1.43	3.76	2.78	5.19	....
7681	3.50	77.01	4.79	....	3.71	5.48	3.76	5.25	....
7682	1.44	81.64	5.54	....	2.83	3.69	2.20	1.10	....
7683	1.77	79.48	4.19	.79	1.76	11.73	2.05	....	....
7684	1.46	87.17	4.87	....	1.61	3.40	2.95	....	....
7685	1.63	78.37	4.92	....	1.90	4.62	3.54	6.65	....
7686	6.99	34.20	....	16.13	3.37	26.55	1.40	....	[b]18.35
7687	4.82	80.99	5.93	....	2.20	7.85	2.74	.29	....

[a] Potassium bicarbonate ($KHCO_3$). [b] Calcium chlorid ($CaCl_2$).

SOIL MANAGEMENT.

ROTATIONS.

In the grain-producing districts of Algeria the rotation—if it can be called such—commonly followed consists of a year (winter) in a cereal crop followed by a year of fallow. In other words, the land lies idle for sixteen or eighteen months out of twenty-four. This system was followed by the ancient Greeks and Romans, and is still in vogue among their descendants in the Mediterranean region. It is to be recommended only for countries where the rainfall and the supply of irrigating water are too scanty to permit rotation with a soil-restoring crop and where manure can not be had in any considerable quantity. Such is the case in the most important cereal-growing districts of Algeria. A larger net profit is often obtained from 2 acres of grain managed in this way than from 1 acre that is heavily manured. If deep and thorough plowing is included in this method of handling the soil, the benefit to the land that would accrue from the use of another crop in rotation can be partly compensated for.

No leguminous crop has yet been found which can be profitably grown on a large scale in Algeria in rotation with wheat and barley. The scarcity of irrigating water is chiefly responsible for this condition, and wherever water is abundant the question of rotation ceases to be a troublesome one. In that case a crop of horse beans or vetch—or, if manure is obtainable, of beets, potatoes, or tobacco—followed by two crops of grain is found to make a satisfactory rotation.

FERTILIZERS.

Whatever may have been their natural condition, the cropping of Algerian soils for thousands of years, often without intelligent effort to conserve their fertility, has resulted in greatly impoverishing them. In large areas the soil is low in phosphates and, to a greater or lesser extent, in nitrogen. Potash, on the other hand, is generally sufficiently abundant. In the coast region much of the soil can be benefited by liming.

During the first few years after the French conquest no particular attention was paid to questions of fertilizers and of rotation. Soon, however, under the influence of the more intensive farming practiced by Europeans, the yield of crops began to diminish, and it became necessary to look for a remedy. In the littoral zone of the coast region, where there is intensive cultivation of market gardens, orchards, and vineyards, the use of farm manure and of commercial fertilizers has become general. In 1896 the annual consumption of Algerian phosphates alone in the colony had reached 8,000 tons. In 1900 the total quantity of mineral fertilizers applied yearly to the soils of Algeria was estimated at 15,000 tons. The use of mineral fertilizers is limited almost entirely to the littoral zone.

In the large valleys of the coast region, where vineyards and fields of grain cover extensive areas, it is estimated that not one-twentieth of the total amount of cultivated land is given any fertilizer whatever. The supply of farm manure is exceedingly scanty, as the absence of cultivated forage crops prevents the raising of many cattle. Where farm manure is obtainable it is thought to be more beneficial than any commercial fertilizer, since Algerian soils are often deficient in organic matter and manure has a very beneficial physical effect upon them. It is considered good practice to apply manure in the autumn, after a year of fallow, thus obtaining an abundant crop of wild forage the following winter. Grain is then grown during the second and third winters after the application of manure.

PREPARATION OF THE LAND.

CLEARING AND LEVELING.

In the coast region some of the best land is still covered with a dense growth of brush, comprising lentisk, jujube, heath, broom, and other characteristic shrubs of the Mediterranean region. This shrubby vegetation is luxuriant in proportion to the depth and fertility of the soil. Its removal generally costs about $16 an acre. In the neighborhood of cities this expense can partly be met by the sale of the wood removed and of charcoal made from it. It costs still more, from $20 to $24 an acre, to clear land which bears a heavy growth of dwarf palm, a deep-rooted plant that still covers extensive areas in Algeria. The roots of the palms can be loosened by means of a steam plow, and then removed with a pick. In the work of clearing land, Spanish, Moroccan, and Kabyle laborers are most expert.

Leveling is done with scrapers, which are generally drawn by horses. The average expense of leveling an acre, if two men and three animals are employed, is about $8.

PLOWING.

The Arab plow, generally used in Algeria, has the forward part supported directly by the yoke or harness of the animal which draws it, while the working part is limited practically to the share. The Kabyle plow consists of two pieces of wood (often the forked branch of a tree) meeting at nearly a right angle, the upright piece being shaped so as to serve as a handle, while to the horizontal piece the iron share is fastened. Two wooden projections at the end of the horizontal piece, just above the share, serve to widen the furrow that is made. The beam is fastened, by means of a peg, into the angle made by the two pieces. One end of the beam is fastened by a strap directly to the wooden yoke of the animal which draws the plow. One man works the plow, driving the animal with one hand and holding the handle with the other. The instruments used by the natives break up the soil only to a very small depth. Among the European colonists improved modern plows are now coming into use. On the largest farms steam plows, operated by two 16-horsepower engines, are sometimes used. In some of the larger towns steam plows can be hired.

For cultivating vineyards, American gang plows are preferred. The use of the disk harrow is widespread.

In preparing for a crop of cereals the land is generally not plowed until fall. This is, however, a bad practice, for if there are heavy rains early in the autumn the land is sometimes too wet to permit of plowing before the first of the year. If, on the contrary, the rains are unusually late, the soil may be too dry and hard to make early plowing possible. In consequence, the crop is sown late and is often dried up by the hot winds of late spring and early summer. Spring plowing in preparation for a winter crop is therefore highly recommended by the best authorities. It is pointed out that as a result of this practice the soil loses less moisture during the summer fallow, besides being in excellent condition to absorb the first rain that falls upon it in the autumn. It is, indeed, advisable to keep the surface of the soil in a well-pulverized condition at all times when there is no crop in the land.

Deep plowing is found to have, up to a certain point, the same effect as rotation and the use of fertilizers. Beyond that point, however, the yield of crops will diminish, no matter how thoroughly the land is plowed, unless some other means is taken to restore the fertility of the soil. At Sétif good cultivation is made to take the place of irrigation, and excellent crops of cereals and of leguminous food and forage plants are produced without artificial watering.

In preparing land that is comparatively flat, in order to establish market gardens, vineyards, and orchards, it has been found that a steam plow, turning the soil to a depth of from 20 to 24 inches, can be used to advantage. In lieu of this an ordinary plow, followed by a subsoiler, will answer the purpose. On hillsides that are too steep for the plow the soil is loosened with picks, usually to a depth of from 24 to 28 inches. The expense of preparing an acre in this way averages about $50. Sometimes the pick is also used for loosening the soil in orchards where the trees are set very close together and in market gardens. The plow used in market gardens is generally a very light one.

GENERAL ECONOMIC CONDITIONS.

HISTORICAL AND POLITICAL.

According to the census of 1896, the population of Algeria, excluding the army, was 4,360,000, of which 86 per cent was Mohammedan. The great importance of agriculture is shown by the fact that four-fifths of the inhabitants live by farming or by raising animals, almost the whole of the native population being thus employed. The total area now under French dominion is about 150,000 square miles, but a large proportion of this area is a barren desert, without water for irrigation. An area of 3,460,000 acres, including most of the best arable land, is held by European colonists, while about 17,290,000 acres is still the property of natives. The remainder, including large forested areas and vast tracts of steppe covered with alfa grass, is government land. There is one inhabitant to every 17½ acres of land belonging to Europeans, and one inhabitant to every 5 acres held by natives.

California, with an area slightly exceeding that of Algeria (156,000 square miles), has a population of about 1,500,000. The combined populations of Arizona, California, Colorado, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming about equal that of Algeria. The traveler in Algeria does not, however, get the impression that the colony is well populated. On the contrary, it seems a new country, and capable of far greater agricultural development than has yet been attained.

LAND VALUES.

In a country like Algeria, where climate, soils, and crops, not to speak of means of communication and nearness to large commercial centers, vary so much in different regions, it is extremely difficult to generalize as to the value of the land. Within 20 miles of large towns, where there are good facilities for transportation by road or by railway, the best land is worth from $25 to $70 an acre. In proportion as remoteness from important centers and difficulties of communication increase, the value diminishes to $16 or less.

An acre in vines near Algiers, a region unaffected by phylloxera, is worth from $80 to $230. Orchard and truck land well supplied with artesian water sells for from $80 to $160, and the best market-garden land near Algiers at very much higher prices, sometimes as much as $230. Orange groves in full bearing are worth from $480 to $640 per acre. Olive orchards, in land of good quality but not capable of irrigation, range in value from $80 to $240 per acre. An acre of fig trees is valued at $115 to $230. Facilities for irrigation, of course, enhance these values.

FARM LABOR.

The great bulk of the farm work in Algeria is done by the native population—Arabs and Kabyles—either in the employ of European colonists or working for themselves on land they own or rent. The Kabyles, among whom the native agriculture of Algeria has reached its highest development, are generally more industrious and more skillful laborers than the Arabs.

Particularly in the littoral zone of the coast region, where the European population is densest, much of the labor in vineyards, orchards, and market gardens is performed by immigrants from southern France, Spain, Italy, the Balearic Islands, and Malta. In all those countries agricultural conditions resemble to a greater or less extent those prevailing along the African shore of the Mediterranean.

The wages paid native laborers vary according to the locality, the season, and the nature of the crop grown. Wages to natives are highest along the coast, where a day's labor in summer commands from 28 to 38 cents. Farther inland the wage varies between 24 and 28 cents. Harvest labor performed in the usual fashion, with a sickle, is paid at the rate of about 45 cents a day. When the scythe is used from 65 to 75 cents a day is earned. Laborers are sometimes employed by the month, receiving, without board, \$6.50 to \$7.50. If somewhat more skilled than the average they are paid as much as \$9.50 a month, or a smaller wage is given, together with a ration of about 2 pounds of bread daily, and each month 2 quarts of olive oil and a few pounds of dried figs and semolina. For tending small flocks owned by Europeans the native receives from \$1.50 to \$2.75 per month with food, or \$2.75 to \$4.75 without food. The employer always retains half of the wage agreed upon until the expiration of his contract with the shepherd, as security for the proper care of his flock. Men whose families live in the neighborhood are found to be the most trustworthy laborers among the natives.

European workmen are more intelligent and consequently better paid than natives. Their wages are higher in eastern Algeria and in the interior, where the conditions are less attractive to Europeans than in western Algeria. The heavier kinds of farm labor, if done by immigrants, fall to the share of Spaniards and Italians. French laborers are generally engaged in such work about the orchards and vineyards as requires more intelligence, and as overseers and foremen. The market gardens of the littoral zone, where large quantities of vegetables are grown not only for consumption in Algeria but for export to Europe, are rented and farmed for the most part by Mahonnais (natives of the Balearic Islands) and by Maltese.

Unskilled Spanish and Italian laborers, working by the day and finding their own provisions, earn from 45 to 55 cents a day in winter and as much as 75 cents a day in summer. The day's work in winter lasts nine or ten hours, with an hour's rest at noon. In summer the workday is twelve or thirteen hours, but with two hours' intermission at noon and a quarter of an hour for rest in the middle of the morning and again in the middle of the afternoon. The same kind of labor, if employed by the month, commands from \$5.50 to \$11.50, board included. The more intelligent French laborers naturally receive much higher wages.

AGRICULTURE OF THE NATIVE POPULATION.

AMONG THE ARABS.

The Arab, as a rule, is lazy and shows little skill and initiative in his farming. He works only to keep from starving, his ambition being satisfied as soon as he has enough to keep body and soul together. The Arabs of the coast region are chiefly tillers of the soil, living in rude huts or "gourbis," while those of the high plateau and desert regions are for the most part nomadic shepherds, dwelling in tents; but both pursuits—agriculture and stock raising—are often combined in the same family.

Agriculture, as practiced by the Arab who has not been influenced by European methods, is of the simplest description. His plow is made with a few strokes of a hatchet from the branch of a tree, and usually has no metal about it. Hitching to this rude instrument a horse, a camel, or, perchance, his wife, he merely scratches the soil in the autumn and scatters his wheat or barley seed. He then goes over the field a second time with a plow, covering the grain to a depth of 3 or 4 inches. After that is done he folds his hands and waits for the crop which may or may not come, satisfied that he can do no more and that the result is in the hands of Allah. In the spring, before the ground has dried out, he puts in sorghum or Indian corn in a similar fashion. The yields of grain thus obtained are naturally scanty at best, while in dry years the crops sometimes fail entirely and there is much suffering among the Arab population.

In better soils, especially where a little water can be had without much labor, beans, chick-peas, and melons are grown. Near streams the Arab often has a small orchard of figs, pomegranates, oranges, and apricots, or a vegetable garden. None of these crops receive any particular attention, and the yield and quality of the product are generally far inferior to those obtained by skillful European farmers.

AMONG THE KABYLES.

The Kabyles belong to the ancient Berber race that inhabited northern Africa before it was conquered by the Arabs—before even the Carthaginians and the Romans occupied the country. Nowadays they are confined chiefly to the mountainous districts. Their principal territory is the region known as Great Kabylia, lying between the Djurdjura range of mountains and the sea. Here a dense population is crowded into a comparatively small area, much of which is so mountainous and rugged that even these dauntless farmers can not make crops grow upon it. Since the French occupation of Algeria, however, large numbers of Kabyles have left their mountain fastnesses, seeking work as farm laborers in the valleys and plains, or as porters in cities.

Many of these emigrants, however, spend only a part of the year in the lowlands, returning home with their savings and putting in the rest of their time cultivating their own land. Unlike the Arab, the Kabyle is a patient and persistent workman. He is a true mountaineer—frugal, temperate, and hardy.

It is astonishing with how little the Kabyle can sustain life. He often inherits the merest patch of land, or only a single tree—sometimes only a branch of an olive tree that has its roots in another man's land. With this slender patrimony and what he can make by hiring his labor to others, he supports himself and his family. Now that Kabylia is thoroughly pacified and the tribal wars that formerly waged between almost every two neighboring villages have ceased, there is a much larger acreage available for cultivation than was formerly the case. Every inch of arable land is put into crops. Grain and forage plants are grown in the river valleys and lower slopes, figs and olives on the steeper hillsides.

It is in horticulture, especially, that the Kabyles excel, the country they inhabit being better adapted to orchard than to field crops. They are expert in grafting and other horticultural processes. Olive culture is a specialty of these mountaineers. Every year they graft large numbers of scions of improved varieties upon wild trees, and thus constantly extend the area of their olive orchards. Fig trees are also planted yearly in large numbers. They are handled with great skill, caprification being carefully attended to. Of olive and fig trees, as well as of grapes and other kinds of fruit, there are a number of varieties that are more or less peculiar to Kabylia. The dried leaves of the fig and the twigs of the olive that are removed in pruning, as well as the leaves of the ash and the elm, are utilized by the Kabyles as forage for their domestic animals. It is said that two-thirds of the population of these mountains depend absolutely upon the olive and the fig for subsistence. Where these trees are present there are three or four inhabitants to every 5 acres, while in parts of Kabylia where they are wanting, from 5 to 7 acres of land are required to support each person.

The Kabyles do not raise cereals in quantity sufficient to supply their own wants, and they must draw upon other parts of the colony for grain. Flour is made into semolina or baked in an earthenware tray into a sort of unleavened bread. Flour made from beans, nuts, Indian corn, and sorghum is mixed by the poorer classes with barley flour. Often wheat, barley, beans, and other plants are grown together in the same field. Fruits, excepting olives, figs, and grapes, are generally of poor quality, although apricots, pomegranates, peaches, pears, apples, and, in some sheltered valleys, oranges are grown.

Wheat, barley, and beans are sown in the autumn, sorghum and Indian corn in the spring. Otherwise, all these crops are handled in about the same way. Plowing is done with oxen, hitched to a rude, homemade plow of very ancient pattern, which turns up the soil to a depth of about 5 inches. The yoke is so adjusted that the steepest slopes and even the soil about the roots of a tree can be plowed. A man follows the plow, breaking up the clods with a pick. Sowing is done by hand. The fields are kept very clean, the weeds that are removed being used as forage. Harvesting is done with the sickle or even by hand. Grain is thrashed by treading out beneath the hoofs of oxen on a floor of hardened clay. It is winnowed by tossing into the air, the wind carrying away the chaff.

The valley lands are irrigated from the numerous streams that run bank full in the spring. The tiny garden, which every fairly well-to-do Kabyle possesses, is watered and manured with great care, and different vegetables follow one another in constant succession throughout the year. A plot of ground 40 by 80 feet is thus made to produce all the vegetables needed by a large family.

Owing to the small area of land in the mountains that can be spared for forage crops, the Kabyles purchase in the lowlands most of the animals they use in their farm work, fattening and reselling them when the spring plowing is over. Donkeys are generally used for carrying loads, and mules for riding. The Kabyle, unlike the Arab, takes the greatest care of his animals, stabling them at night in his own house and doing his best at all seasons to provide them with sufficient food.

AMONG THE SAHARANS.

The population of the oases in the eastern part of the Algerian Sahara, the only part of the desert that is of much agricultural interest, is of mixed origin. It combines strains of Berber, Sudanese, and Arab blood. In winter great numbers of nomadic Arabs descend into the Sahara with their flocks and herds, which range during the summer over the plains of the high plateau region. But there is also a resident population, which subsists entirely upon the products of the date palm and the various cultures that are grown in its shade. These, the true Saharans, are very skillful gardeners, understanding thoroughly the highly specialized culture of the date palm. They are adepts in the management of soils and irrigating waters that contain excessive amounts of salt. Despite these disadvantages, which are combined with the most unfavorable climatic conditions, they succeed in growing in the oases a variety of fruit trees, garden vegetables, forage plants, and cereals. Not only in their own gardens, but in the plantations of palms recently established by French capital, the labor is performed entirely by natives. The climatic conditions, together with the large quantity of more or less stagnant water that is always present, make the oasis environment, at least in summer, entirely unfit for European labor. Indeed, the Arabs of the coast and high plateau regions are hardly better inured to the summer conditions, which only the thoroughly acclimated natives of the Sahara can endure without suffering.

CROPS OF THE COLONY.

The greatest wealth-producing crop of Algeria is the vine. The climate and soils of a great part of Algeria, as of California, are perfectly adapted to viticulture. The French colonists have put by far the greater share of their energy and capital into the growing of wine grapes. In 1898 the average annual value of the product of Algerian vineyards was estimated at $5,000,000. The red and the white table wines of the colony are steadily improving in quality and are coming more and more into favor among foreign consumers. There is also a considerable production of early table grapes for the markets of Europe.

Various orchard crops are likewise a source of revenue. First and foremost stands the olive. Algeria is extending year by year the area planted to olives, a product for which northern Africa has always been famous. As the inability of Italy and Spain to supply the world's demand becomes more and more evident, the export of olive oil from Algeria and Tunis will doubtless steadily increase. Citrus fruits, particularly mandarin and other oranges, are exported in considerable quantities. In this industry, however, Algeria finds herself in competition with Spain, Sicily, and other countries which have the advantage of a larger or at least a better distributed rainfall. Figs are grown in most parts of the colony. In Kabylia they are dried and prepared for export, although the finest sorts of figs for drying are not grown in Algeria.

A considerable variety of other fruits is grown, chiefly for domestic consumption, among which may be mentioned pomegranates, apricots, almonds, peaches, cherries, plums, apples, and pears. Tropical fruits, such as the banana, pineapple, guava, and avocado, can be produced in the open only in a very few localities along the coast, and can never become crops of the first rank. The kaki and the loquat are more promising.

A restricted yet important industry in Algeria is the production of dates. Especially in the Sahara, dates form a staple food of the inhabitants, who eat great quantities of the ordinary sorts. The finer varieties are now being grown in some quantity for export to Europe, and a considerable amount of French capital has been invested in this enterprise.

Market gardens occupy a considerable area near the sea. Large quantities of vegetables are grown, not only for the use of the home population but for shipment to Europe to supply the winter and early spring markets. Of those which are exported, artichokes, potatoes, beans, and peas are the most important. The consumption of melons and watermelons in Algeria is very large during the summer.

The principal field crops of the colony are cereals. Wheat and barley occupy about 7,000,000 acres annually and supply a large export trade. Indian corn and sorghum are extensively grown by the natives. Cotton and sugar cane, crops to which Egypt owes so much of her wealth, are of small importance in Algeria. The only valuable "industrial" crops are tobacco and certain plants used in the manufacture of perfumery. The cork oak and the grass known as alfa, which contribute largely to the prosperity of the colony, are never artificially planted and hence are not, strictly speaking, agricultural products.

The acreage in forage crops is limited, particularly in summer, by the scanty water supply. Alfalfa is grown generally in small patches, although on the larger estates good-sized fields are sometimes put into this crop. Sulla has been frequently recommended but has not come into general use. The pods of the carob tree, or St. John's bread, are used for feeding stock. They are consumed in considerable quantities in the colony and are also exported. Sorghum is also grown extensively and affords a valuable supply of summer forage. In the autumn, in some localities, vetches are sown with oats or barley and are harvested in the spring. This mixture, either green or cured, is an excellent food for cattle. Oats are grown for export only, barley being the grain commonly fed to horses.

The greater number of the cattle and sheep of Algeria are raised upon the wild forage which covers the uncleared portion of the hills and plains or springs up in the cultivated fields after the crop of grain has been taken off. The supply of green pasturage is abundant during the winter and spring, but the hot, dry summer soon burns it dry. As cultivated forage is scarce in summer animals often have great difficulty in obtaining feed at that season.

GEOGRAPHICAL DISTRIBUTION.

COAST REGION.

The great diversity which the coast region exhibits in respect to climate, topography, and soils is paralleled by the great diversity of its agricultural conditions. A far greater variety of crops is grown there than in either of the other regions. The three zones—littoral, valley and plain, and mountain—are distinguished one from another by agricultural as well as by topographical and climatic peculiarities, so that it will be advisable to give a sketch of each in turn. Roughly speaking, the first is a zone of orchards and market gardens, the second of grain fields and vineyards, and the third of tree crops at lower elevations, giving place to pasturage on the higher slopes and crests of the mountains. But this generalization must not be carried too far. The lines that separate the three zones are vague at best, and the industries especially characteristic of each are shared to some extent by all.

LITTORAL ZONE.

Along the shore of the Mediterranean is practiced the most intensive agriculture of the colony, if we except the oases of the eastern Sahara. The alluvial soils of the valleys, which usually expand into small deltas as they approach the sea, are largely occupied, especially in the neighborhood of the principal cities, by highly cultivated market gardens.

The lower slopes of the hills and mountains that border the sea are occupied by orchards and vineyards. At slight elevations we find a great variety of fruits, every sort, in fact, that is commonly grown in warm temperate countries. In addition to the great vineyards of wine grapes, excellent table grapes are grown for European as well as for Algerian markets. Oranges of several kinds are produced in considerable quantity. Lemons, apricots, nectarines, and almonds thrive. The Japanese persimmon, the loquat, the pecan, and other tree crops not yet widely cultivated in that part of the world, promise to become a source of wealth. A few peculiarly favored situations, well sheltered from cold winds in winter and from the sirocco in summer, are adapted to fruits of a distinctly tropical character, such as bananas, guavas, and avocados. Attempts are being made to produce some of these fruits under glass in marketable quantity.

It must not be supposed, however, that the littoral zone is devoted wholly to growing fruits and garden vegetables. Where sufficiently extensive areas of alluvial soil occur, cereals are grown, giving larger yields than elsewhere because of the abundant supply of water. For the same reason cultivated forage plants do better in this zone than in the others. Alfalfa is the most important perennial forage crop, while, for winter forage, barley, often sown with vetches, is much used. As is also the case to some extent in the other zones of the coast region, natural meadows, furnishing green pasturage all the year round, occupy marshy places. Where such meadows occur, live stock can be kept in good condition throughout the summer, which is seldom possible in the high plateau region.

An industry of secondary importance, yet bringing a considerable yearly revenue into the colony, is that of growing plants used in the manufacture of perfumery, notably the rose geranium.

VALLEY AND PLAIN ZONE.

The large valleys of the coast region, especially in the western part of the colony, of which the Chéliff may be taken as a type, are given up in great part to grain production. Of the 12,500,000 acres in Algeria which bear a cereal crop every one or two years, by far the largest part is situated in this zone. Wheat, barley, and oats are grown, the last in much smaller quantity than the others and solely for export. The bulk of the wheat is of the hard or durum type, although soft wheats are also produced.

Where water for irrigation is to be had in summer—and this is the case in only a small fraction of the whole area—alfalfa, sorghum, and other forage plants, as well as tobacco, melons, etc., are grown. Cotton was extensively planted in some of the valleys of western Algeria during the civil war in the United States, and proved very remunerative for a while. Under present market conditions, however, it can not be grown with profit in the colony.

The wild forage that springs up on the extensive areas of grain land lying fallow every year is an important resource to the farmer, enabling him to keep his cattle in good condition during the winter. In summer, however, unless a forage crop is grown under irrigation, the conditions for animals in this zone are unfavorable.

MOUNTAIN ZONE.

The only extensive district of high mountains in Algeria where agriculture is highly developed is Kabylia. In discussing the agriculture of the "mountain zone" we are therefore, as a matter of fact, describing that district.

The lower elevations and the valleys of the larger streams present conditions not unlike those of the littoral zone. Even oranges can be grown in sheltered situations at low altitudes. On the higher slopes and the crests of the ridges, however, this is impossible. The nature of the surface is not adapted to large vineyards and grain fields; hence, agriculture becomes reduced to horticulture. Orchards of figs and olives cover the middle elevations, often on the steepest hillsides. Olive oil is produced in large quantities in the eastern part of this mountain region. It is extensively used by the inhabitants and is also an important article of export from Bougie, the principal seaport of the district. Other agricultural products of the mountain region which contribute to the export trade of the colony are dried figs, the pods of the carob, or St. John's bread, and capers. The last are not cultivated, but are gathered by women and children from the wild plants, the young flower buds being the part used in commerce. About 450,000 pounds of capers were exported in 1899. The mountaineers raise in small gardens such cereals, vegetables, and forage plants as they require for their own use. These gardens are generally situated at the bottoms of valleys and ravines, where some alluvial soil has collected.

The highest elevations of the mountain zone are not suitable for any sort of agriculture, but are largely covered with grass, which affords abundant pasturage to flocks of sheep and goats.

HIGH PLATEAU REGION.

In the typical steppe region of central Algeria agriculture is limited to occasional low places where, by means of the natural moisture of the ground or by irrigation with the water of a well, a crop of barley can be made in winter. If conditions are exceptionally favorable, a small garden can sometimes be established. At such points as Sétif and Batna, in the eastern part of the colony, there are extensive areas in winter cereals, where crops are produced without irrigation. But, as we have already seen, these places are not to be regarded as typical of the high plateau region. Agriculturally, they belong rather to the valley and plain zone of the coast region.

The two great industries of the high plateau region are grazing and the collection of alfa. Vast numbers of sheep and goats, as well as horses and camels, are pastured, especially in summer, on these elevated grassy plains. It is estimated that from 6 to 10 million head of sheep and 3,500,000 goats range the high plateau. These animals are almost without exception the property of Arabs. Many of them are wintered in the Sahara, and in spring are driven by their owners up to the high plateau, where pasturage is more abundant and the heat less intense. The hides, meat, wool, and other products of these animals are a very material source of wealth to the colony. Cattle are not raised in any considerable number.

Alfa, or esparto, covers vast areas of this region, often to the almost complete exclusion of other vegetation. The tough leaves of this grass form one of the most valuable exports of the colony, amounting annually to about $2,000,000. They are used in the manufacture of high grades of paper, basket ware, matting, hats, and cordage. The harvest takes place in the spring. Persistent exploitation is resulting in the rapid extermination of alfa grass, the more so because attempts to establish artificial plantations have so far been wholly unsuccessful.

DESERT REGION.

The oases of the Sahara, and particularly those of the depression known as the Oued Rirh, in the eastern part, are the only portion of the desert that is of much agricultural importance. There the presence of subterranean streams, carrying a considerable volume of water, has made it possible to plant thousands of date palms in groves of greater or less size.

Within the last three decades the sinking of a number of artesian wells in the Oued Rirh region has much increased the supply of water for irrigating purposes. Consequently, it has been possible to create new oases and to extend greatly the area in date palms. Two French companies have set out many thousands of palms of the best varieties, especially the celebrated Deglet Noor, and have introduced improved methods of cultivation and management. Dates have always been an important article of export from the Sahara to other parts of Africa. Recently a large export trade with Europe has been developed.

A considerable variety of fruits, vegetables, cereals, and forage crops is grown among the date palms in the oases. These, however, do not afford products for export to foreign countries, but serve merely to supply the wants of the local population. The area available is too small to allow these subordinate cultures to attain any considerable magnitude, even cereals and forage plants being grown in gardens rather than in fields.

Oranges are grown in the oases at the foot of the mountains that border the desert, but do not succeed farther south because of the occasionally severe winter frosts. Olives for oil and the large sorts used for pickling, almonds, several kinds of figs and grapes, pomegranates, apricots, and other fruits are produced. The apricots grown are of a native type and are remarkable for the large size the trees sometimes attain. The different kinds of fruit trees are not set out in separate orchards, but are mingled together. The same system, or lack of system, is observed in the way garden vegetables are grown. Of these the more common are onions, broad beans, carrots, cabbage, tomatoes, okra, eggplant, pumpkins, cucumbers, melons, and peppers. Alfalfa is grown in small, carefully tended patches, and is cut many times during the year. The cereals chiefly grown are wheat and barley in winter, and sorghum and Indian corn in summer. On the northern edge of the Sahara, where the slope is considerable and occasional heavy rains in winter cause a sheet of flood water to sweep down over the land, this is taken advantage of in producing crops of grain in the open desert bordering the oases. Ridges of mud are thrown up at intervals, and are arranged so as to catch and retain for a while the flood water.

PRINCIPAL CROPS IN DETAIL.

FRUIT CROPS.

GRAPES.

Wine grapes.—Grapes have long been an important product of Algeria, for even before the French occupation about fifty varieties were known to the natives. In Kabylia particularly, well-defined local varieties had been developed. Some of these are grown only in that country, apparently, while others occur under different names in other parts of the Mediterranean region. Until within the last three decades, grapes were grown chiefly for eating purposes, as the Mohammedan law forbids the use of wine. Since then, however, the planting of vineyards has made rapid progress among the colonists, and in 1900 nearly 350,000 acres, about one-tenth of the land owned by Europeans, was in vines. The estimated total value of Algerian vineyards is $114,000,000. Wine is now the most valuable product of the colony, the export amounting in 1899 to over 120,000,000 gallons. Most of the skill, energy, and capital of the French population is concentrated upon this crop. It has been computed that $6,650,000 is paid out annually in wages to the laborers in Algerian vineyards.

Fine wines and dessert wines form but a small part of the total yield, the Algerian product consisting chiefly of heavy-bodied and, in the case of red wines, deeply colored wines for blending purposes. These are being constantly improved in quality, and Algerian wines are now widely and favorably known in Europe—France, England, and Germany, especially, importing large quantities.

The varieties of wine grapes chiefly grown by European colonists are those of southern France. Carignane, from which red wine is made, is at present the favorite, and is being planted more extensively than any other variety. Other highly esteemed varieties that furnish red wine are Mourvèdre, Morastel, Aramon, Cinsault, and Ulliade (Oeillade). Carignane is notable for the rapidity with which it comes into bearing and for its large yields. At the same time it requires more care than some other varieties, and is subject to fungous diseases. Mourvèdre and Morastel, hardier varieties, but slower in developing and somewhat irregular in yield, are not as extensively planted as formerly. Cinsault and Ulliade are hardy varieties, and endure the trying conditions that prevail when the sirocco is blowing. The former, especially, is much grown. The latter is said to be very irregular in its yields. The variety known as "Petit Bouschet" is used for giving a deeper color to certain French wines made from other varieties.

White wines are made from the Clairette, Ugni Blanc, Semillon, and other varieties, while a native variety known as Feranah is highly esteemed by some vineyardists. All these, however, give rather light yields, so that the making of white wines from grapes having a colorless juice is now much practiced, the skins being removed before fermentation begins. Cinsault, Aramon, and Mourvèdre are especially used for this purpose. Excellent dessert wines are occasionally made from such varieties as Alicante and Muscat.

Vines are grown in nearly all parts of the colony, even in the extremely mountainous districts and in the oases of the Sahara; but the most extensive vineyards have been established in the great plains and valleys of the coast region, where the largest profits from the growing of wine grapes have been realized. Deep alluvial soils, containing a considerable amount of clay and of organic matter, are found to give the largest yields. These soils retain enough moisture during the summer to prevent much harm to the vines from the sirocco. The better qualities of wine are, however, commonly produced on hillside vineyards, at altitudes not exceeding 3,000 feet. Some districts that are otherwise perfectly adapted to vineyards suffer so heavily from hailstorms in spring as to make them unprofitable for grape culture.

The vines are planted to best advantage in squares or in a quincunx, i. e., in squares with one vine at each corner and one in the center. It is very important to arrange the vines so that the vineyard can be plowed in both directions. It is considered advisable, under Algerian conditions, when planting in squares, to set the vines 5, or, for some varieties, 6 feet apart each way. The vines are set out during the months of January, February, and March. Pruning is generally done in the latter part of the winter. The varieties most commonly grown by the colonists, such as Carignane, are trimmed back close to the stump, leaving a circle of 5 to 8 spurs. When trimmed long, the canes are trained on wire or are supported by forked sticks. Among the Kabyles, the vines are generally allowed to grow on trees. Close trimming is said to increase the ability of the vines to resist drought, which is an important matter in Algeria. Grafting is resorted to when it is desired to replace the varieties in a vineyard with better varieties, and to render it more productive, March and April being the best months for this operation. In Algeria vines generally begin to bear in their fourth year, although a full crop is not obtained until the sixth or seventh year.

Late in the winter, after trimming is completed and before the buds have begun to start, the vineyards are plowed, usually to a depth of 6 inches. This should be done when the soil is fairly dry. Occasionally the plow is followed by a subsoiler. Vines send their roots deep into the soil in Algeria, so that there is little danger of injuring them by this treatment. A hoe or pick is used to loosen the soil around the roots of the vines. In some vineyards, in order to cover the roots, a cross plowing is then given which, like all subsequent plowings, is shallower than the first. During the summer the vineyard is given as many cultivations with the hoe or the scarifier as are necessary to rid it of weeds and to preserve a loose mulch on the surface of the soil that will keep down evaporation. Bermuda grass is often a serious pest in Algerian vineyards.

Although in vineyards careful cultivation will partly take the place of irrigation, the yield can almost always be increased by the judicious application of water. Irrigation in winter, so as to store up water in the soil, is recommended for such regions as the Chéliff Valley, where the rainfall is small. The first irrigation in summer generally takes place when the grapes begin to color, and the second about two weeks before the vintage. About 2 acre-inches of water is used in flood irrigation, but only about 1½ acre-inches in furrow irrigation. It is desirable to follow each irrigation by a cultivation, in order to keep down weeds and prevent the surface of the soil from baking.

Nitrogenous fertilizers are needed in maintaining the wood growth of Algerian vineyards, and phosphoric acid is also often required to promote productiveness. Farm manure is much used and is applied at the rate of 12 to 18 tons per acre.

When wine making first began in the colony great difficulty was experienced in completing fermentation, and the quality of the wine was much impaired by the presence of unfermented sugar. This was due to the high sugar content of the Algerian grapes and to the high temperatures prevailing during fermentation. These difficulties have been largely overcome, however, by observing certain precautions. If the weather during the vintage is very hot, the grapes are gathered and put into the vats in the early morning while they are cool, and the temperature of the vats is kept down by causing cool water to circulate on the outside of them.

The fungous diseases, such as anthracnose, oïdium, and mildew, which attack vines in Algeria, have been more or less successfully kept in check by spraying. Not so, however, with phylloxera, which has wrought terrible havoc in the vineyards of Oran and Constantine departments since its first appearance in the colony in 1883. A very rigid inspection law has failed to put a complete stop to its ravages. The practice of flooding infected vineyards, which has given such happy results in southern France, can not be generally adopted in Algeria because of the scarcity of irrigating water. So far the vineyards of the central department, that of Algiers, have escaped damage from this destructive insect.

In the vineyards of western Algeria considerable losses have been sustained through the rise of salts in the soil. The effect of salt in the soil upon Algerian vineyards has been discussed by Dugast (see p. 44 of this report), who calls attention to the existence of occasional more resistant plants. In some districts the vines have been killed, while in less extreme cases the quality of the wine has been much impaired by taking up more or less of the salt contained in the soil. A French law forbids the sale of wine containing more than one part per thousand of sodium chlorid, but in some of the wine produced in Oran Department this percentage has been exceeded. It is considered safe to plant vines in any soil that is not too salty to permit a good growth of figs, pomegranates, alfalfa, or artichokes.

Table grapes.—Excellent table grapes are grown, some of which—the Cinsault, for example—are valuable also as wine grapes, while others, like the Golden Chasselas, are grown chiefly for the table. The latter is by far the most popular variety. It is an excellent grape, bearing shipment well. Grapes mature early enough for profitable exportation in the littoral zone of the coast region only. Near Algiers the Chasselas ripens in the first part of July and reaches the French markets in advance of home-grown grapes. Vines of this variety generally begin to yield freely in their fifth year. Reeds are usually planted as a wind-break, the same as in market gardens. An average crop from an acre is 3 tons of fruit. The first Algerian grapes that reach the Paris markets are said to bring as much as $26 per 100 pounds.

Table grapes grown elsewhere than along the coast ripen too late for export, but often find a good sale in local markets. The varieties peculiar to the colony are generally of inferior quality, although some of them are not without value. Those grown in Kabylia are nearly all pruned to long canes, and often ascend to the tops of tall trees. It is difficult to gather the grapes from such vines or to spray them when infected with fungous diseases.

Raisins are dried in small quantities by the Kabyles. Otherwise this industry has not developed in Algeria, although the climatic conditions would seem to be peculiarly favorable to raisin making.

OLIVES.

From the earliest times of which we have record the olive has been one of the most important products of northern Africa. The same varieties yield a higher percentage of oil in Algeria and Tunis than in southern Europe. The oil content varies greatly in different parts of the colony, but as high as 34 per cent has been obtained from olives grown in the oases of the Sahara. African oils have a higher margarin content and are more easily fixed at a temperature of 40° F. than oil made from European olives. The annual production of oil in Algeria is estimated at 13,200,000 gallons, the bulk of which is consumed in the colony. The export trade is as yet comparatively insignificant, amounting annually to only about $200,000. In fact, Algeria does not produce enough for home consumption, importing annually from 2,500,000 to 3,000,000 gallons of edible oils. The number of grafted olive trees in the colony is estimated at 4,500,000, the greater part of them being in Kabylia. Tunis, the olive-growing country par excellence of northern Africa, is said to contain some 15,000,000 grafted trees, covering about 500,000 acres. The olive is thoroughly at home in Algeria, especially in the Kabyle mountain district, where several local varieties exist, some of which are of considerable value.

Like some of the vines, some of the olive varieties are found only in the colony, while others, which have received local names in Algeria, are widely distributed in Mediterranean countries.

The olive grows wild in almost every part of Algeria, here and there forming actual forests, some of which were formerly of much greater extent than they are to-day. The fruits of these wild trees are worthless, but the stocks are much used for grafting with improved varieties. In Kabylia especially, the area in olive orchards is being rapidly extended by grafting wild trees.

The olive flourishes in a great variety of soils and is less sensitive than citrus fruits to cold and drought. Yet it has limitations, which must be considered when a new orchard is to be established. Well-drained soils, having a considerable slope, give the best results. The maximum oil production is said to be obtained from soils rich in lime. Sunny situations are to be preferred, although in districts subject to frosts in spring it is desirable that the trees should not be in a position where the first rays of the sun can strike them in the morning. A paying crop can not be expected in districts where temperatures as low as 25° F. or exceeding 105° F. are frequent.

In respect to elevation, olives will not thrive in Algeria at an altitude of much more than 3,000 feet, and appear to do best between 1,000 and 2,000 feet above sea level. In the immediate neighborhood of the sea the orchards suffer most from the ravages of certain insect enemies and of a bacterial disease. Olive orchards are particularly profitable in districts like the Chélif Valley, where they can be irrigated three or four times during the winter. If irrigation in summer is also possible, the yield can often be doubled. At each watering, from 1.5 to 2 acre-feet is applied.

Where an orchard is to be started with young trees, these are set out in most parts of Algeria to best advantage at intervals of 30 feet, in rows 50 feet apart. Sometimes the quincunx plan is adopted. On irrigated land, about 40 trees to the acre is the proper number. Planting is done during the winter, preferably in December or January. After six or eight years an orchard started with trees 5 feet high and 2 or 3 inches in diameter will generally pay expenses, and in fifteen years it will be in full bearing.

Other cultures are not permitted in the orchard, unless the water supply is ample and the soil is either naturally very fertile or is well manured. Cereals are often grown among the trees, but this tends to diminish the yield of fruit, and is generally discontinued after the trees begin to bear. On the other hand, where water is plentiful, the growing of broad beans and similar leguminous crops in olive orchards is a good practice.

Fertilizers, applied in alternate years when the trees are not bearing, largely increase the yields. A good tree, if furnished about 500 pounds of farm manure every other year, will yield 550 to 650 pounds of fruit every two years. The average yield from a tree 20 years old appears to be about 175 pounds, from 12 to 15 per cent of the weight being oil. The best method of keeping the soil of an olive orchard in first-class condition is to give it a good plowing as soon as the harvest is over. During the summer two or three cultivations are given, in order to keep the surface well mulched and thus reduce evaporation. The harvest begins in October, green olives, for pickling, being the first that are gathered.

By far the greater part of the oil crop of the colony is obtained from fruit grown by the natives, who themselves manufacture two-thirds of the oil produced and also supply with fruit the oil mills that are operated by Europeans. European colonists have not, so far, devoted as much attention to olive growing as the importance of the crop would warrant. In western Algeria, however, in districts infected with phylloxera, olives are often planted in vineyards, so as to take the place of the vines in case the latter should be destroyed.

Olive growing is the principal industry of Kabylia. Very little care is there given to the cultivation of orchards, this being generally limited to a single plowing in spring. The furrows are run horizontally along the hillside, so that as much rain water as possible can be retained in the soil. The trees are pruned with a hatchet while the fruit is being gathered. The whole family—men, women, and children—take part in the harvest, which is a sort of festival, like the vintage in European countries. Hired pickers are paid with a certain proportion of the fruit they gather. A woman can earn, during the two months of the picking season, olives enough to yield about 15 gallons of oil, worth perhaps $6.

Europeans who manufacture olive oil purchase the fresh fruit from native growers, paying from 40 cents to $1 per 100 pounds. The fruit is brought to the mills in baskets made of reeds or of olive twigs. In every Kabyle village there is a small oil mill, the miller being paid for his work with the product of the second pressing. The strong flavor of the oil made by the natives, which is very unpalatable to Europeans, is due to the fact that the fruit is not pressed while fresh, but is spread out for several months after gathering on a surface of hardened clay, where it is exposed to the sun and weather. The Kabyles use oil almost wholly in place of butter and lard, frying food in it and eating it on bread and "couscous."

Olives for pickling are grown in Algeria only in a small way, generally in the gardens of natives.

FIGS.

The fig ranks next to the olive in importance among the orchard crops of Algeria. Like the olive, it is most extensively grown in the mountain zone of the coast region, although common in every part of the colony. In Kabylia no less than two dozen varieties, some of them of excellent quality, are known. Figs, both fresh and dried, form a large part of the food of the Kabyles, who also export to Europe a considerable quantity of the dried product. The finest varieties for drying, such as are grown near Smyrna, are not, however, grown in Algeria, except in an experimental way. Figs are cultivated in the shade of date palms in the oases of the Sahara; but neither in yield nor in quality do the desert-grown figs compare with those of the mountains. Fig trees do not endure well the severe climate of the high plateau.

In the larger valleys of the coast region heavy yields can be obtained under irrigation. Some varieties grown in Algeria bear two crops a year; others, only one. In establishing a fig orchard, either nursery stock, budded from 2-year-old wood, or root shoots from good trees are used. Budding is generally done in February or March. Growth is rapid, amounting often to 5 feet during the first summer. The trees, when old enough for the orchard, are set out in winter, generally about 30 feet apart. The only pruning done consists in removing the dead wood and the shoots at the base of the trunk. The orchard is occasionally given a shallow plowing or cultivation. In most Algerian soils it is found that fertilizers containing phosphoric acid and potash, if applied in late winter, materially increase the yield of fig orchards.

In Kabylia, where the acreage in figs is constantly being increased, this tree bears well up to an altitude of 4,000 feet. More care is given by the Kabyles to fig than to olive orchards. The trees are sometimes reproduced by cuttings, but preferably by root shoots. Pruning is done during the winter. In January or February the first plowing is given, and is followed by several others during the spring. Several varieties grown in that district require to be caprified. In other words, in order to set fruit, their flowers must receive pollen from those of the wild fig, and this is carried to them by a small insect (Blastophaga) which lays its eggs in the young flower clusters of the wild fig, or caprifig. The first caprification usually takes place in June, and the operation is sometimes repeated three or four times during the summer. The method of the Kabyles is to thread together a few of the "male" figs or caprifigs and hang the chaplets thus made over the branches of the trees, the flowers of which are to be pollinated. Caprifigs sometimes sell for 6 cents a dozen among the natives. In fig orchards managed by Europeans the expense of caprification is estimated at about $5 per hundred trees.

In the mountains the harvest of figs for drying, although at its height in September, covers a period of about three months, as the fruit does not all ripen at once. As fast as the fruit matures it is gathered and placed in shallow trays. These are spread out on the ground when the sun is shining, but are piled together in the evening and placed under shelter when it rains. The fruit is turned over from time to time until it is dry. Figs that are kept for home use or for shipment to other parts of the colony are split down the middle and pressed in a mortar into a compact mass. Those intended for export are packed at the seaports into crates holding 70 or 80 pounds, made of leafstalks of the dwarf palm.

CITRUS FRUITS.

Only a comparatively small portion of the total area of Algeria is suitable for citrus fruits. Even oranges can be grown successfully only in the coast region, up to an elevation of 1,700 feet or thereabouts, and in the northern oases of the eastern part of the Sahara, notably at Biskra. In the oases, however, they are not very satisfactory in yield or quality. The best orange-growing district is that around Blida, in the Mitidja Valley at the base of the Atlas Range. Here has been developed an excellent type of early-ripening, sweet orange, known as the "Blida," the harvesting of which begins in October. The Malta blood orange thrives both in the coast region and in the oases. Brazil, Portugal, Jaffa, and other races are also grown in the colony. The natives grow oranges mostly from seeds, so that the quality of the fruit they produce is generally very inferior; yet some of the native varieties, notably in Kabylia and in the mountain ravines near Blida, are said to possess considerable merit.

The expense of starting an orange grove in Algeria is sometimes lessened by growing truck crops in the young orchard for the first six years. This practice, however, is not recommended by the best authorities. A row of cypress trees is commonly planted as a windbreak around orange groves. The average profit from an acre of oranges is said to be only about $45 annually. The bitter orange (bigarade) is very hardy in the colony and is much used as a stock upon which to graft less resistant varieties. From its flowers perfumery is manufactured.

Mandarins, which are extensively planted in Algeria, generally pay better than ordinary oranges. One authority estimates that an acre of these fruits gives an average net profit of $60 to $90. The harvest of mandarins at Blida begins in November. Lemons are less extensively planted, although they are quite hardy and yield well in the littoral zone.

For the irrigation of citrus fruits in the manner usually practiced in Algeria—by means of shallow basins around the base of each tree—

from 1.5 to 2 acre-inches of water is used at an application. If the soil is very permeable, as is the case in the Blida region, the orchard must be watered every week. Otherwise, an irrigation every two weeks suffices. As to cultivation, a plowing in March to a depth of 1 foot, a second plowing in May, and a cultivation in August are recommended.

DATES.[a]

Except in a single locality, where peculiar conditions exist, the date palm does not ripen its fruit freely in the coast region. Nor is the high plateau, with its cold winters, adapted to this tree. The true home of the palm is the desert region, particularly the low, eastern part. (See Pls. I and III.) In the oases of the Oued Rirh district the finest varieties of dates—notably the celebrated Deglet Noor—reach the acme of their development.

The environment in which the date flourishes is a peculiar one. It can not grow in the dry desert if the ground water is beyond the reach of its roots unless it is copiously irrigated. To ripen the fruit of the best varieties, frequent summer temperatures of 105° to 110° F., together with a very dry atmosphere and a very small rainfall, especially in the autumn, appear to be necessary. It is obvious that this combination of conditions is not to be met with everywhere. The area which possesses the needed climatic requirements is almost limitless, but an abundant supply of water for natural or artificial irrigation is of rare occurrence in the desert.

There are a great number of varieties of the date palm in the oases of Algeria—probably at least 150. These are usually easily distinguished by the character of the fruit, whether long or short, thick or thin, light or dark, with a large or small stone, etc. One of the commonest types is Rhars, an early-ripening soft, sweet date not suitable for exportation, but very popular among the inhabitants of the Sahara. Dates of this kind are either eaten fresh or, pressed into a compact mass, are stored and carried from place to place, usually in leather bags. The Deglet Noor is the date which is most extensively grown for the European trade. Put up in small wooden boxes, with the dates attached to the branch upon which they grew, this fruit bears shipment admirably, retaining without difficulty its shape and firm texture. It is one of the finest of table dates, not only because of its flavor but for the reason that it is clean and easily handled. The fine color and the transparency of the flesh add further to its attractiveness. During the last two decades the two French companies that are

[a] For a full discussion of this interesting subject by Mr. W. T. Swingle, see the Yearbook of the United States Department of Agriculture for 1900, p. 453, and Bulletin No. 53 of the Bureau of Plant Industry, 1904.

engaged in date growing in the Algerian Sahara have set out thousands of Deglet Noor trees. The natives also have planted them in large numbers. Of still another type are the dry dates which furnish a large part of the food of the population of the desert and are transported by caravans to every part of northern Africa. They are not sirupy like the Rhars type nor richly flavored like the Deglet Noor, but are a wholesome food and can be kept for indefinite periods. The best sorts are eaten either fresh or dry, while from the starchy flesh of inferior kinds flour is made and baked into a sort of bread.

In addition to dates, the natives of the Sahara obtain various other useful products from the palms. Trees of inferior value are made to yield "lagmi," or palm wine, a sweet juice which is obtained in abundance by cutting the bud at the summit of the stem. The wood of the palm is used for building houses, bridges, and dams, as well as for fuel. The leaves serve for thatching roofs, while from their fiber matting, baskets, hats, fans, and other articles are manufactured.

LESS IMPORTANT ORCHARD CROPS.

A great variety of other fruits characteristic of warm temperate and subtropical countries are grown with more or less success in Algeria, but their importance is not sufficient to warrant much more than an enumeration.

The peach is most at home in sheltered ravines of the mountain zone, where it makes a rapid growth and yields well. It is grafted upon *Prunus mirobalan* in deep, rich soils, and upon the almond in thinner, limy soils. The fruit is often of fine appearance, but generally lacks flavor.

The apricot is also grown most successfully in ravines and on sheltered slopes at low elevations in the mountain zone. In the oases of the northern part of the Sahara it becomes a large tree and yields heavily, but the fruit is poor in size and quality. Nevertheless, dried apricots are much in demand in the markets of the Sahara. The apricot in the coast region is sometimes grafted on the plum.

The almond is one of the fruit trees that is best adapted to the drier parts of Algeria. Two principal types are cultivated—the thin-shelled Princesse, which is exported in some quantity as an early fruit, and varieties with harder shell, which are generally dried.

The cherry is most at home in the mountain zone, doing well on a variety of soils. There are cherry orchards of considerable value in some parts of Algeria.

The plum thrives in rather deep soils, especially in the mountainous parts of the colony. The Reine Claude gives excellent results under irrigation at moderate elevations in eastern Algeria. The growing of prunes has not become an industry in the colony.

The pear grows vigorously in ravines and on shaded slopes in the mountain zone, especially in deep loamy and clayey soils. There are a number of native varieties of small value. Improved European varieties rarely give satisfactory results.

The apple is even less successful in Algeria, save in a few exceptional localities.

Among fruits characteristic of warmer parts of the world, the pomegranate should be mentioned. It is very hardy as to climate, but needs a moist soil in order to give the best results. Under irrigation good yields can be obtained. A number of types are grown in Algeria, the best sweet fruit being exported and bringing a good price. The better sorts are propagated by cuttings. The spiny, unimproved type of pomegranate is much used as a hedge plant.

The Indian fig, or prickly pear, is abundant in the coast region, where it is almost perfectly naturalized. It also occurs in some of the oases, but the high plateau region is generally too cold for it. There are several different races, some with yellow, some with red fruit. A white-fruited variety, of very limited cultivation, is said to be the finest of all. Indian figs are highly esteemed by the natives and by Spanish and Italian immigrants, but are rarely eaten by the French.

Japanese (kaki) persimmons do well in most parts of the coast region and promise to become one of the important fruit crops of the colony. The loquat is more sensitive to cold, but thrives in the littoral zone. In a few sheltered places along the coast bananas can be successfully grown, the "fig banana" being the type that yields best in Algeria. There is only a small area where the cultivation of such tropical fruits as the guava, avocado, cherimoya, and pineapple is possible.

In the Aurès Mountains walnuts flourish. Plantations of chestnuts, established some years ago by the forestry service, are now bearing abundant crops. The acclimatization of the pecan is being attempted by the botanical service of the colony.

TRUCK CROPS.

A great many garden vegetables are grown in Algeria, among which may be enumerated artichokes, asparagus, beans (broad, kidney, and string), beets, Brussels sprouts, cabbage, cardoon, carrots, cauliflower, celery, chick-peas, chicory, cucumbers, eggplant, garlic, lentils, lettuce, melons, onions, peas, peppers, sorrel, spinach, squash, strawberries, sweet potatoes, tomatoes, turnips, and watermelons. Most of these are grown chiefly for the local markets. In the littoral zone, however, the production in winter of early vegetables for export to Europe is an industry of considerable importance, some 20,000 tons being shipped out of the country every year. Artichokes, potatoes, peas, and string beans are the most important of these. The growing of early tomatoes for export is also becoming a profitable industry.

Near Algiers especially, market gardens abound. There the industry is chiefly in the hands of natives of the Balearic Islands, while in western Algeria the gardeners are generally Spanish, and in the eastern part of the colony Italians and Maltese. Neither the natives nor the French colonists have gone into the business of growing truck crops for export, although Arab and Kabyle families usually have small gardens in which they raise vegetables for their own use.

There are a number of factors which combine to limit gardens as a commercial enterprise to the neighborhood of the seashore. Nowhere else, except in the Sahara, are the winters sufficiently warm to allow Algerian vegetables to be put upon the markets of Europe early enough to insure a remunerative price. As it is, the competition of the Riviera, and other parts of the northern shore of the Mediterranean, has in recent years cut down by 40 or 50 per cent the prices formerly obtained. Facilities for rapid transportation by water, such as are obtainable near the coast, are essential to the success of this industry. An abundant supply of water for irrigation is indispensable. Finally, the large quantities of manure, sewage, etc., that are applied to the gardens can only be had in the large cities of the seaboard. At Tunis, Archimedean screws placed in the drains are said to be used for lifting sewage on to the fields.

Market gardens are generally irrigated by means of the noria. For the first irrigation of the season about 2 acre-inches of water are applied, while in each subsequent irrigation about 1.5 acre inches are used. Except in the case of artichokes, which will stand heavy flooding, the irrigation of truck crops demands considerable skill. The flow of the water should be gentle, and it should be allowed to stand at only a small depth on the fields.

By abundant watering and heavy manuring and fertilizing, crop is made to follow crop with hardly any intermission. From gardens thus managed the profits are very large. A high rent—often $75 or more an acre—is demanded for the best market-garden land in the vicinity of large cities. The gardener who leases the land usually lives upon it with his family. Each small plat into which the garden is divided is usually surrounded by a wind-break of reeds, either the living plants being set closely together to form a hedge or a fence being made of the dead stalks. Sorghum and Indian corn are also used for wind-breaks.

Globe artichokes are the truck crop that is most largely grown for export. "Gros vert de Laon" (Large Green of Laon) and "Violet précoce de Provence," or "Violet hatif" (Early Violet of Provence), are the most popular varieties for this purpose. Artichokes are harvested throughout the winter, from October until April, the same plant yielding several heads in succession. The average yield from an established field is about 30,000 marketable heads to the acre.

The consumption of potatoes in the colony being larger than the quantity produced, there is a considerable importation of this vegetable. Yet the production of early potatoes, especially of the Holland or Royal Kidney variety, for export to European markets, is an important phase of Algerian truck growing. The largest tubers are shipped to England, while the Paris markets prefer those of medium size. The best prices are obtained for potatoes marketed during Lent, especially just before Easter, when from $2 to $3.50 per 100 pounds is paid in Paris for Algerian potatoes.

Potatoes grown for consumption in the colony are sown in seed beds in January and February, and are set out about the end of April. Yields of 9,000 to 17,500 pounds per acre are obtained. The prices paid in Algerian markets for spring potatoes range from 50 to 85 cents per 100 pounds.

CEREALS.

The principal cereals of Algeria are wheat, barley, and oats, which are grown only as winter crops, and sorghum and Indian corn, which occupy the land in summer. Of these, wheat and barley are by far the most important. Algeria raises most of the grain needed for home consumption, importing only a relatively small quantity of soft wheat, used in bread making. The colony exports large quantities of wheat, barley, and oats. The area each year in cereal crops is estimated at 7,000,000 acres, which is about one-third of the entire cultivated area; hence much more land is in cereals than in all other crops combined. The mean annual production in the years 1890–1895 was 64,331,000 bushels, and the total value of the annual product of cereals averages $45,000,000.

While more or less grain is produced in every part of Algeria, the largest proportion is raised in the valleys of the coast region, notably in that of the Chéliff. Owing to the generally poor preparation of the land for cereals, the exhausted condition of much of the soil, and the fact that neither manuring nor rotation is generally practiced, the average yields are too low to make these crops as effective as they should be in contributing to the wealth of the colony. Much the greater part of the grain is grown by natives and gives yields averaging 30 per cent lower than those obtained by European colonists. In districts where improved methods of cultivation, notably in respect to deeper plowing, have been introduced by the colonists, yields much higher than the average are obtained. The country around Sidi bel Abbès, in extreme western Algeria, and Sétif, on the edge of the high plateau in the eastern part of the colony, is especially notable in this respect. The acreage in cereals that is in the hands of the natives, who depend for their crops entirely upon the rainfall and take no steps to conserve soil moisture, naturally varies much more from year to year than that farmed by Europeans.

WINTER CEREALS.

Wheat.—The average area in wheat during the ten years ended in 1893 was over 3,000,000 acres. Of this about three-fourths was owned and farmed by natives. The area in wheats of the hard or durum type, as compared with that in soft wheats, was as five to one. Less than 7 per cent of the area in wheat that is farmed by natives is devoted to soft wheats, while the European colonists grow hard and soft varieties in about equal proportion.

Algeria possesses excellent races of durum wheat, for which this part of Africa was famous even in Roman times.[a] Often several varieties are mixed together in one field, although the Arabs are generally acute in distinguishing the different types. Some of the most widely grown Algerian hard wheats have long, black beards. Some have short, others long heads. In some varieties the grain is short and thick, in others it is long and narrow. Types in which the grain is clear and amber colored are particularly valuable for making macaroni and semolina, considerable quantities of which are manufactured in the colony. Semolina forms the basis of "couscous," the national dish of the Arabs. Large quantities of Algerian hard wheats are also used at Marseille in the manufacture of macaroni and similar products, for which they are considered nearly, if not quite, equal to any in the world.

Authorities agree that the types of hard wheat already existing in the colony answer all requirements, and that it remains only to practice careful seed selection in order to improve the yield and to secure pure strains.

Several native races of soft wheats are also grown, including both bearded and beardless types. Soft wheats introduced from Europe have not, as a rule, proved a success. When grown near the coast they often fall a prey to rust, and are also liable to dry up without ripening when the hot weather begins in the spring. Recent experiments with the Richelle varieties, however, have indicated that this type is well adapted to Algerian conditions, giving good yields at several points.

Wheat, which is commonly broadcasted, is always sown in the fall, generally in November, after the rains have begun. In very dry years the soil is sometimes not in a condition for plowing in preparation for a crop of grain until well into the winter. This entails late sowing, which often greatly diminishes the yield obtained.

The harvest takes place in May or June, according to altitude, there being about four weeks' difference in time between the earliest and the latest localities in the colony. A native takes from three to five

[a] For descriptions and illustrations of the varieties of Algerian wheats, see C. S. Scofield, Bulletin No. 7, Bureau of Plant Industry, U. S. Department of Agriculture, 1902.

days to harvest an acre of wheat with a sickle, the implement that is still used in the greater part of Algeria. Recently, however, the combined reaper and binder has come into use in some places. Thrashing is done as soon as possible after the harvest and in a very primitive way. The sheaves are spread out on a floor of hardened clay, which is unsheltered from the air and sunshine. They are placed in concentric circles, with the heads turned inward. Horses, mules, or sometimes oxen, are then driven around on the floor, again and again, until the grain is beaten out. Sometimes the animals are hitched to a stone roller. Two men with three horses can thus thrash out 40 bushels of wheat a day, or if a roller is used, 70 bushels. About 5 cents a bushel is paid for thrashing wheat. The modern thrashing machines that are used in a few localities handle as much as 750 bushels in a day.

On the large estates wheat is cleaned by means of fans. Generally, however, a method is used which has been practiced for ages in the Mediterranean countries—that of pitching into the air the mixture of grain and chaff, the wind carrying away most of the latter. This can be done to advantage only on days when the wind is favorable. The straw is carefully saved and stacked, to be used as fodder, the stack being usually protected by a covering of dried mud mixed with short straw.

An ingenious contrivance for storing grain is in use among the Arabs. A piece of high ground having been selected, a hole 10 to 18 feet deep and 6 to 10 feet wide is dug, with a narrower opening. The interior is thoroughly dried by burning in it straw or brush, and is then lined with a layer of matting and straw about 6 inches deep. The carefully dried grain is packed closely into this cellar, the mouth of which is then covered with straw, matting, and finally with clay. Earth is then shoveled over the top to hide the whereabouts of the store. Grain can be kept for long periods without deterioration in this unique sort of granary. The Kabyles generally use earthenware jars for storing grain.

The average yield of wheat obtained by European colonists is about 15 bushels per acre, although under the most favorable conditions very much higher yields are sometimes had. The natives, on the other hand, are well satisfied with a yield of 8 or 9 bushels.

Wheat receives irrigation in only a few districts, notably in some of the large valleys of western Algeria. A marked increase in yield is the result. An irrigation in the early autumn at the rate of 3 or 4 acre-inches puts the land into good shape for plowing and sowing. The distribution of rainfall during the winter regulates subsequent irrigation, which does not exceed 2.5 acre-inches at each application.

Barley.—The area in barley averaged during the ten years ended in 1893 over 3,500,000 acres, 93 per cent of which was owned and cultivated by natives. Barley is even better adapted than wheat to native agriculture, being more drought resistant and requiring less preparation of the soil. The average yield for the entire colony is about 25 bushels per acre, but European colonists sometimes obtain 40 or 50 bushels. Barley forms a large part of the food of the native population and is also invaluable as forage, being almost the only grain that is fed to animals. Of the annual product of nearly 30,000,000 bushels, about one-eighth is exported. Much of this goes to northern France and to England, in which countries it is used in brewing. Algerian barleys are in high favor with European brewers, rather because of their cheapness than their quality. Improved races, like Chevalier, do not generally succeed in Algeria, being too liable to shatter; yet in some localities certain of the two-rowed European brewing barleys have given good yields. Naked varieties having an easily shelled grain are those generally grown by the natives to serve as food. They are very early and yield heavily.

Oats.—Compared with wheat and barley, oats are an unimportant crop in Algeria. The average annual acreage from 1884 to 1893 was only 114,000; i. e., less than 4 per cent of the area that was in wheat and less than 3 per cent of that in barley. Oats are grown almost exclusively by European colonists for export to Europe. Before the French conquest this cereal was practically unknown in Algeria. It is there considered by some authorities to be more resistant to drought and to salt in the soil than is either wheat or barley. It also requires less preparation of the soil and gives larger yields on newly cleared and poorly prepared land, being less likely to be choked by weeds. It can be sown up to the end of January—much later than wheat. The harvest takes place about the middle of May, and the average yield is 45 to 55 bushels per acre. Oats are said to be very susceptible in Algeria to the attacks of ergot and of rust, and for this reason the common winter oat is the only variety that can usually be grown at a profit.

SUMMER CEREALS.

Sorghum.—Two varieties of sorghum are grown, chiefly by the natives. These are white sorghum, the "bechna" of the Arabs, which is much used by the better class of Kabyles as a substitute for wheat flour in making "couscous" and bread; and black sorghum, or "dra," from the seeds of which the bread of the poorer natives is made. Black sorghum is also fed to animals; the leaves and stalks are a valuable resource at a season when green forage is scarce in Algeria.

If there is plenty of rain in April and May, and occasional showers in June, a good crop of sorghum can be made without irrigation. The heavier alluvial soils of the valley bottoms are considered best adapted to this crop, which is most grown in the mountain zone of the coast region. Sorghum is sown in April and ripens in August.

In good years 18 to 26 bushels of grain are obtained from an acre. During the ten years ended in 1893 the average area in sorghum was 75,000 acres.

Indian corn.—In the irrigated soils of the large valleys Indian corn is the most profitable summer cereal, but without a good water supply it is rarely a paying crop. For this reason, and because of the scarcity of manure, comparatively little is grown. The average area grown by natives during the ten years ended in 1893 was 20,000 acres. The variety known as "Quarantain" is esteemed for its earliness; "Caragua" for its large yields. Yields of 22 to 30 bushels per acre are obtained under irrigation, and the grain sells for about $1 per bushel. Algeria exports an insignificant quantity of this grain. Among the natives, especially in the Kabyle mountain districts, the roasted ears of maize are much esteemed as food, but with European colonists it is not in favor as a table vegetable.

FORAGE CROPS.

WILD FORAGE.

Two sorts of wild forage are to be distinguished—that of fallow fields and that of natural meadows.

Fallow-land forage.—After the removal of the winter crop of cereals wild plants of various sorts, including a great variety of Leguminosæ, spring up amid the stubble, especially when the autumn rains begin. This wild forage is generally most luxuriant during the first winter following the crop of grain. If the land is then left fallow for several years in succession a gradual deterioration of the wild forage, both in quality and in quantity, is observable. This can be prevented in large measure by occasional plowing. An application of farm manure at the rate of about 10 tons per acre will cause large yields of natural forage to be produced for two or three years, besides putting the land into excellent shape for two successive crops of cereals at the end of that period. Forage of this kind is generally pastured. If made into hay, it is usually fed on the farm, not being of a sort that is well adapted for baling and shipment.

In the oases of the Sahara, Bermuda grass, which the natives esteem as a forage plant, abounds. Almost every roadside and ditch bank is occupied by this grass. It is either grazed or is cut and fed green.

Forage of natural meadows and prairies.—The slopes of the hills and mountains of the coast region and the steppes of the high plateau, like the great plains of the Western States, are still covered in great part with a growth of grasses and other native plants, the value of which is enhanced by the presence of numerous species of vetch, clover, bur clover, and other Leguminosæ. In the high plateau region large flocks of sheep and goats are pastured upon the natural herbage of the range, generally obtaining no other food.

Two sorts of natural meadow are to be distinguished—such as occupies land that is dry during the summer and such as is moist throughout the year. The first type covers by far the greater area. As in California and in countries where most of the rain falls during the winter months, the herbage is parched and brown in summer. With the first autumn rains, however, a sudden transformation takes place. The grass turns green as if by magic, and innumerable flowering plants spring up to beautify the land.

During October, November, and December, in the coast region, cattle and other stock are turned out to graze upon this tender young growth. At its best, 5 acres will support 6 head of cattle. During the latter part of the winter and in the spring it is more profitable to keep animals off the natural meadows, allowing a hay crop to be made. The greater part of the hay of the colony is produced by the dry meadows of the coast region. This is the hay that is purchased for the cavalry service of the army, and it is exported in considerable quantity to France in years when the crop of that country is short.

Artificial treatment of these natural meadows is rarely attempted, yet in many cases occasional irrigations, plowings, and manurings would very largely increase the yields obtained. In some places it might be advantageous to seed to wild grasses and forage plants of better quality than those now occupying the land. Without treatment of any kind, however, natural meadows will last a long time in good soil—sometimes twenty years without serious deterioration.

Meadows that are moist and green throughout the year produce more abundant but coarser forage. A cutting of hay is sometimes taken in spring from such meadows, but during the rest of the year they are used as pastures. They are a valuable resource in summer, when most of the grass land is scorched and dry.

In the coast region, hay is cut between the middle of April and the middle of May, the date of harvest varying considerably in different years and at different altitudes. The scythe is generally used, a native workman receiving from 65 to 75 cents for cutting an acre. There are some localities, like the Mitidja Valley, near Algiers, where the nature of the ground permits the use of a mowing machine, which reduces the cost to about 30 cents an acre. The average yield of hay from an acre of natural meadow is a little more than 1 ton.

In the drier valleys, like the Chéliff, the hay can be gathered into double swaths by the horserake the day after it is cut. Two or three days later it can be stacked in ricks. The rick ordinarily contains from 2 to 2½ tons, and is generally covered over with a thatch composed of the coarse grass known as "dyss" (Ampelodesmos). In case it is not convenient to place the rick on high ground, care is taken to surround it with a trench to carry off the rain water. One end of the rick always faces the west, the direction from which come the heaviest rainstorms. Hay is taken out as required at the other end. In favorable seasons 2½ tons of hay can be cut, cured, and stacked at an expense of less than $5. Hay is usually baled at a cost of about 5 cents per bale of 110 pounds. Near the larger cities it is hauled at the rate of about 30 cents a mile for an ordinary wagonload.

The prices paid for green forage and for hay in Algeria are based upon those offered by the government, which purchases large supplies for the cavalry service of the army. Various stipulations are made as to the quality of the forage to be delivered, and as these rules are also followed by most private buyers it will be interesting to enumerate some of them. Hay is rejected if it consists of but one valuable species, if it has been mixed after cutting, and if it contains various coarse weeds, notably thistles and plants of the parsnip family, poisonous plants, grasses like foxtail with sharp-pointed beards that injure the mouths of animals, various salt-loving weeds, and coarse marsh plants. The hay must, of course, be well cured, perfectly dry, and reasonably free from dust. A veterinary surgeon is detailed to inspect the hay before it is purchased.

CULTIVATED FORAGE.

The area which is adapted to the cultivation of forage plants in Algeria in summer is limited by the scantiness of the water supply at that season. Only in the valleys of the coast region, where irrigation is practiced, can such crops be grown on an important scale. Hence, in the total production of forage in the colony, cultivated plants play a much less important part than wild vegetation.

LEGUMINOUS CROPS.

Alfalfa, or lucern.—In Algeria, as in the arid part of the United States, alfalfa is the most valuable cultivated forage plant for perennial meadows. It is grown extensively in the irrigated valleys of the coast region. In the high plateau region little alfalfa is cultivated, but in some of the oases of the desert region it is the most important forage crop. Often in the coast region and always in the Sahara, alfalfa is grown in small, carefully tended patches. (Pl. V, fig. 2.) Fall sowing is generally practiced, although in elevated regions like that around Sétif, where early frosts are likely to occur, it is sometimes advisable to sow in the spring. In that case, however, the seed must be put in as early as possible, as otherwise the young plants suffer from the dry, hot weather of the later spring months.

The seed is often put in in rows, thus permitting the frequent cultivation and weeding of the fields. Otherwise, weeds, especially Bermuda grass and chicory, choke out the alfalfa. If sown broadcast an occasional harrowing is necessary to keep down the weeds. In case the fields are infested with dodder, the worst enemy of alfalfa in Algeria, these methods are not efficacious and other means must be taken to get rid of the pest. When the drill is used, about 18 pounds of seed to the acre are sown, but if broadcasted, about 22 pounds. Occasionally alfalfa is put in—preferably in January or February—with oats or barley, the latter serving as a cover crop for the young alfalfa; but this practice is condemned by the best authorities. Well-kept alfalfa meadows last twelve years or longer in Algeria.

Alfalfa is generally cut with a scythe. A native laborer can cut a little more than an acre a day, and receives about 45 cents an acre for the work. When a mowing machine is used the cost of cutting an acre is about 25 cents. In the oases of the Sahara a sort of sickle, with a nearly straight blade having a serrated edge, is used in cutting alfalfa.

The alfalfa crop is irrigated in Algeria both by flooding and by the furrow method. The latter requires less water, but gives the best results only in rather light soils. Flooding is the preferable method if the irrigating water is decidedly saline. From 3 to 4 acre-feet are put on at each irrigation.

Under irrigation, with a watering given every week or so throughout the summer, seven or eight cuttings can be taken, yielding a total of 7 or 8 tons of hay per acre. In soils of the littoral zone that retain a fair amount of natural moisture throughout the summer, alfalfa can sometimes be grown without irrigation. Three cuttings, aggregating 3 or 4 tons of hay, besides a considerable amount of pasturage, can be obtained under such conditions.

Most of the alfalfa in the coast region of Algeria is derived from the "Lucerne de Provence," a race that is grown in southeastern France. This showed itself from its first introduction to be perfectly adapted to conditions in that part of the colony. On the other hand, seed of alfalfa brought from Poitou, in western France, considerably north of Provence, does not succeed nearly so well in Algeria. A native drought-resistant strain is grown without irrigation in the neighborhood of Sétif, in the eastern part of the high plateau region. This variety may prove valuable in parts of the Western States where water for irrigating is not available. Turkestan alfalfa is being tested in Algeria and gives indication of being well adapted to the drier parts of the colony, particularly where the soils are somewhat saline. A fair stand has been obtained near Algiers without irrigation. The alfalfa that is grown in the oases of the Sahara appears to be decidedly resistant to the presence in the soil and irrigating water of large amounts of salt. (Pl. IV, fig. 2.) At Rouïba, near Algiers, the writers saw trial patches of alfalfa grown from seed obtained from the United States, from Tougourt in the Algerian Sahara, and from Turkestan all grown without irrigation. That from the Sahara seemed to thrive better at Rouïba than the American sort. The leaflets are shorter, broader, and hairier than those of the American plants.[a] The Turkestan alfalfa seemed to be earlier in maturing its seed than either of the other sorts. Doctor Trabut, the Government Botanist, thinks it will grow with less water than other kinds of alfalfa, and that it may consequently prove valuable for the steppe or high plateau region of central Algeria. Although the stand grown from Turkestan seed was less than one year old and had received no irrigation whatever, it was in fairly good condition. It is, however, very liable to infection with a rust (*Pseudopeziza trifolia*). Doctor Trabut finds this very frequently the case with plants brought from extremely arid regions into the more humid climate of the coast region in Algeria.

At Tougourt, in the Algerian Sahara, alfalfa is grown in most of the gardens, generally in the shade of date palms, in small patches from which other plants are excluded. It is usually grown in plats about 20 feet long and 6 feet wide, with a low ridge of bare soil 4 feet or so wide between each plat. The top of the ridge is usually white with an efflorescence of salts. The seed is sown in the autumn in rows a foot or so apart, barley being generally sown with the alfalfa and harvested the following spring. Thenceforward the alfalfa grows alone, and the stand is usually allowed to occupy the ground 4 or 5 years. It is then plowed under, and other cultures—generally garden vegetables—take its place. By this system the roots of the alfalfa plants probably do not have time to grow down into those depths of the subsoil which are saturated with water from the almost constant irrigation given in these gardens.

Every week during the summer one or two irrigations are given the alfalfa, which is tended as carefully as any garden vegetable. With such frequent irrigation a great number of cuttings is possible, especially as the stems are cut whenever they reach a height of about 2 feet. One native grower stated to the writers that he obtained as many as 24 cuttings during the year, but this was doubtless an exaggeration. The stems are cut off very close to the ground by means of a curved iron knife with serrated edge. They are tied in small bunches, 7 or 8 inches in diameter, the ends of which are placed in running water to keep the alfalfa fresh and attractive looking until it is ready to be sold. In the market at Tougourt such a bunch sells for 1 cent. So far as we could learn, alfalfa is always fed green in these oases, and is

[a] At Yuma, Ariz., during the last two years, alfalfa from Turkestan, from the Algerian oases, and from Utah was grown side by side. No constant differences as to hairiness could be detected, but the leaflets of the Algerian seem to be generally broader than those of the Turkestan and Utah sorts. The Algerian sort seems also to grow faster and to promise larger yields than the others.

never made into hay. As it grows more or less throughout the winter, a sufficient supply of green forage can generally be obtained at all seasons.

The alfalfa grown at Tougourt is of fine quality, succulent, thin stemmed, almost perfectly smooth, and having large, thin leaves. These qualities are doubtless mainly due to its being more or less shaded by the date palms and to the frequent watering it receives; for, at the experiment station at Rouïba, alfalfa from Tougourt had wiry stems and was hairier even than the American alfalfa grown beside it.

The crust of salt that often covers the ditch banks and strips of bare soil between the plats of alfalfa is sufficient evidence that the soil of the oases is very saline. The water used in irrigating likewise has a high salt content. Yet there are reasons for believing that the amount of salt to which the plants are actually exposed during germination and while still very young is not so great as would at first appear to be the case. The soil is light and loamy, and hence easily drained. Especial attention is given to this matter by the Arabs, drainage ditches being dug in the gardens at frequent intervals. These end blindly, as there is no natural outlet for them. Nevertheless, they must have a considerable degree of efficiency, for the alfalfa that is nearest the ditches is always in decidedly better condition than that which is farther away. With this provision for drainage and the very frequent irrigations given, it is probable that a very considerable amount of salt is leached out of the uppermost layers of the readily permeable soil. The date palms that shade the ground do their part by keeping down evaporation and thus retarding the return of the salts to the surface. Finally, the oasis soils are very rich in gypsum (calcium sulphate). This, as is well known, neutralizes to a considerable degree the harmful effect of other salts in the soil.

At the small oasis of Kuda-Asli, a few miles from Tougourt, alfalfa was found growing in the open, unshaded by palms or other trees. Examination of the soil showed that the plants were making a fairly good growth, although the stand was thin, in the presence of 1.36 per cent of salts in the first foot of soil. A good growth occurred in the presence of 0.9 per cent in the first and 0.5 per cent in the second foot. Finally, an excellent stand had been obtained in soil that contained from 0.4 to 0.6 per cent of salts in the first and second feet. The water used for irrigating this field contained 460 parts of salt per 100,000. The soil is a sandy loam, and is so full of gypsum that at a depth of about 2 feet a veritable hardpan of this substance is encountered. The presence of this dense stratum would be expected to interfere seriously with drainage, to which the texture of the soil is otherwise well adapted. Consequently, notwithstanding the conditions mentioned in the preceding paragraph as tending to counteract to some extent the effect of the salt, it would seem to be beyond question that this alfalfa is a distinctly resistant race, and is able to endure more salt in the soil than the alfalfa ordinarily grown in the United States. A small quantity of seed, reported to have been harvested last year from this patch, was secured for trial in this country.

Horse beans (*Vicia faba*).—The horse bean is a form of the broad bean, having more numerous and smaller pods. It requires deep, strong soils, containing a considerable amount of lime. When grown as a forage crop it is sown, sometimes mixed with barley or oats and sometimes alone, in rows about 2 feet apart. When the pods begin to turn brown the beans are harvested, spread upon the ground to dry, and then thrashed. The coarse, black straw, mixed with other forage, is fed to animals. The seeds are a valuable feed for milch cows, but discretion must be used in feeding them. Horse beans yield about 10 tons of green forage and 22 to 28 bushels of seed per acre.

Sulla (*Hedysarum coronarium*).—This leguminous plant has been highly recommended for Algeria, but is generally found difficult to grow and uncertain in yield. It is a deep rooting plant with erect stems 2 or 3 feet high. In the green state it is said not to be relished by animals; but if cut before flowering and made into hay or ensilage it constitutes an excellent forage. It is, however, very difficult to cure without losing the leaves. A further objection is that, while occupying the land two years, only one cutting can be taken. A good stand is nevertheless very productive, the average yield being, according to one authority, 5½ tons of hay to the acre.

Fenugreek (*Trigonella fœnum-græcum*).—This plant is very useful as a green manure crop, especially on tobacco land, for which purpose it is recommended to be sown with horse beans. The forage is much relished by cattle, but is said to give a disagreeable flavor to beef. The aromatic seeds are considered stimulating and fattening when added to other forage.

Berseem (*Trifolium alexandrinum*).—Berseem promises to be a valuable forage crop under irrigation in parts of Algeria where the winters are mild. It is most likely to succeed near the coast and in the oases of the Sahara, especially as a green manure crop for orchards. A good stand has been obtained near Algiers by sowing as early as July, four cuttings having been taken before the end of May.

Vetches.—Vetches are sometimes grown alone, but their trailing habit makes them difficult to cut. They are best handled when sown with barley or oats, this mixture forming one of the most valuable winter forage crops of the colony. Winter vetch (*Vicia sativa*) is the species most used, the hairy vetch (*V. villosa*) not having proved a success. The seed is sown in October and November at the rate of 70 pounds of vetch and 25 to 35 pounds of oats or barley to the acre. Vetch seed is rather scarce and high priced. The crop is harvested in April or early in May, when the vetch is in blossom and the cereal in milk. It is ordinarily fed green, although this can be done with perfect safety only after allowing it to wilt for a few hours. The mixed hay furnished by vetch with barley or oats is far superior to that of the natural meadows. In seasons when the rainfall has been plentiful, yields amounting to 1½ or 2 tons per acre are obtained. The largest yields are given by land that has previously been manured at the rate of about 1,000 cubic feet of farm manure to the acre. In very wet springs hay of this kind is difficult to cure, the vetch having a tendency to rot and drop its leaves. This crop leaves the land in excellent shape to be put into grain the following winter.

The botanical service of the Algerian government has been experimenting for several years with a variety of leguminous plants that promise to be more or less useful as forage and green manure crops. For the latter purpose, especially in vineyards, lupines, horse beans, fenugreek, vetches, peas, and lentils are recommended.

TREE CROPS AS FORAGE.

In the coast region, especially in the mountain zone, a number of trees contribute to the supply of forage. The Kabyles, having little room for field crops, feed the leaves of various trees to their animals. The leafy twigs of the olive, removed in pruning, and the leaves of the elm are thus utilized. Dried fig leaves serve in winter as a substitute for hay. In the handsome ash of his mountains the Kabyle has a veritable overhead meadow, which yields him a constant supply of green forage. The most important of arboreal forage plants is, however, the carob.

Carob, or St. John's bread.—The pods of this small tree, which resemble those of the American honey locust in having their seeds surrounded by a sweetish pulp, are highly esteemed throughout the Mediterranean region as food for cattle. There are also improved varieties, which are used in some countries as human food. The carob flourishes throughout the coast region of Algeria. European colonists have not given it much attention, but, especially in mountainous districts, it is much valued by the natives, who not only plant orchards of carobs, but, with a little care, succeed in obtaining good yields from wild trees. From Bougie, the seaport of Kabylia, considerable quantities of the pods are exported to Europe.

The best results are obtained by top-grafting scions of improved races upon seedling trees. The pollen is borne upon separate individuals, so that care must be taken to have male trees in every plantation. The largest yields are obtained by following the Spanish practice of grafting a branch from a male tree upon the base of the trunk of a fruiting individual. The establishment of a plantation of carobs is therefore a somewhat troublesome undertaking. After six years the trees, as a rule, begin to bear fairly well. In fifteen or twenty years they are in full production, single trees of that age sometimes yielding 650 pounds of pods. In some races the pods are 10 inches long, their sugar content sometimes reaching 44 per cent.

The harvest takes place at the beginning of autumn. Poles are used to knock down the pods, which are spread out to dry in the shade. When thoroughly cured they are collected into stacks, which must be opened from time to time to prevent fermentation. Carobs after being crushed and mixed with coarser fodder constitute a very palatable and nourishing ration for live stock, especially for work animals.

Indian fig.—The Indian fig, or prickly pear, (*Opuntia ficus-indica* and *O. tuna*) is thoroughly at home in the coast region of Algeria, where it frequently attains the size of a small tree. Spineless varieties are a valuable resource for feeding live stock in summer, when green forage is generally scarce.

The Indian fig will grow in the stoniest, most sterile soils, and under such conditions will produce from 9 to 11 tons of green forage every two years. In good land still larger yields are obtained. This plant responds well to manuring and to a moderate amount of irrigation.

The feeding value of the large flattened joints of the stem is not great, about 65 per cent of their weight being water. For this very reason, however, they form an excellent ration, especially for milch cows, when mixed with dry feed, such as chopped straw, bran, oil cake, and the pods of the carob tree. A little salt is often added to the mixture. Grandeau, the well-known agronomist, speaks of the Indian fig as the "forage beet of warm regions." It is estimated that 75 pounds of the stems, together with an equal weight of straw, are equivalent in feeding value to 100 pounds of good hay. Hogs are extremely fond of the fruits.

MISCELLANEOUS CROPS.

TOBACCO.

Tobacco has long been cultivated in Algeria, where oriental types were grown by the natives before the French occupation. The first colonists introduced a considerable number of varieties, but only one of these, believed to be derived from Paraguay tobacco, is now extensively grown. The area annually planted to tobacco amounts at present to only 12,000 to 15,000 acres, most of which is in the Department of Algiers. The colony is said to produce each year from 11 to 13 million pounds of tobacco. This would mean an average yield per acre of 888 pounds, which is much higher than the average in most tobacco-growing countries. The yield from irrigated is said to be about double that from unirrigated land.

The quality of the product depends largely upon the locality. Some of the best Algerian tobacco is grown in the Kabyle mountain district, where the soils seem to be peculiarly well adapted to this crop. Much of the product of western Algeria is defective in combustibility, being grown in saline land, where it absorbs considerable salt. Soils containing more than 1 part per 1,000 of sodium chlorid are considered unsuitable for tobacco. Excessive irrigation also injures the quality, although increasing the yield, of much of the tobacco grown in that part of the colony. The finest tobacco is generally grown without irrigation. In the oases of the Sahara, snuff tobacco is cultivated by the natives.

The type of tobacco ordinarily grown in the colony has a wide, very compact flower cluster and crowded narrow leaves. Plants of this type are thought to suffer less from wind than broader leaved forms. For several years the botanical service of the colony has been carrying on experiments in crossing various high-grade foreign tobaccos with this Algerian type. It has been found that while most of the uncrossed foreign varieties are not well adapted to Algerian conditions, the crosses seem almost as much at home as the Algerian parent, and often retain the desirable qualities of the imported variety.

The best Algerian tobacco has an agreeable, sweet aroma, suggesting that of some Turkish varieties. It is especially suitable for cigarettes and smoking tobacco, very little being used in the manufacture of cigars.

FIBER PLANTS.

The production of vegetable fibers on a commercial scale is now limited to alfa grass and the dwarf palm, the latter yielding "vegetable horse hair." As neither of these plants is cultivated, they are discussed in this report under the head of "Forest products."

Flax, jute, hemp, sisal hemp, manila hemp, and ramie have all been tried from time to time, but the cultivation of none of these fiber plants has passed the experimental stage. The scarcity of water in summer is generally the most serious obstacle, but there are also other practical difficulties. The Algerian government is now offering a bounty to growers of flax and hemp. Cotton growing was an important industry during the American civil war, but has since been abandoned.

PERFUME PLANTS.

In the coast region, particularly in the littoral zone, the growing of plants used in the manufacture of perfumery is one of the most important of the minor agricultural industries.

The principal perfume plant of the colony is the rose geranium. It is propagated by cuttings, which are set out in December or January. Plantations, once established, continue to yield profitable crops for from four to eight years, those in heavier soils being the more lasting. Under irrigation three crops can be obtained each year, and the average total yield from an acre is said to be about 12 tons of leaves annually. The oil produced in one year by an acre of rose geranium is estimated to average about 25 pounds, but in rare cases is as high as 50 pounds. Some Algerian distilleries have an annual output of 2 tons of oil of geranium. In recent years the fall in price of this perfume has caused the acreage in rose geranium to be greatly reduced.

Among plants grown for the perfume obtained from their flowers are *Acacia farnesiana* and the bitter orange (bigarade). The latter yields orange-flower water and "Essence de Néroli." The leaves of *Eucalyptus globulus* are also used to some extent in making perfumery.

LIVE STOCK.

The live-stock industry is very largely in the hands of the Arabs. They raise practically all the sheep, goats, camels, horses, and donkeys, and much the greater number of the cattle of Algeria. The colonists usually buy from the natives the beef cattle which they fatten, and also their work animals. The natural forage of the country is, as has been previously stated, the principal resource of the raiser of live stock, cultivated forage plants playing an important part only in irrigated districts of the coast region. There the business of fattening cattle that have been raised on the wild forage of the hillsides and steppes has attained some importance.

The high plateau region, like many districts in the western part of the United States, is for the most part a "range," where animals are driven from place to place and pastured upon the natural herbage. Sheep and goats in vast numbers—about three-fifths of the total number in the colony—graze on the elevated plains. Cattle, however, are few. The flocks are the property of nomadic Arabs, Europeans having taken no part in the pastoral system of the steppe region, except in so far as to purchase the product. The conditions as to climate and food supply are often severe. In summer the herbage, except in moist depressions, is parched and brown, and water is very scarce, while the winters are rigorous. As yet, little has been done in the way of providing shelter and artificial sources of water for animals pastured on the high plateau.

Sheep and goats furnish the inhabitants of the high plateau region with almost everything they use, affording skins for their tents and vessels for holding water, wool and leather for their clothing, and meat and milk for their food. Goats are raised chiefly to supply the necessities of the natives, although their skins are exported in considerable quantity. Sheep, on the other hand, furnish a very important export trade in meat, hides, and wool. It is estimated that between 6 and 10 million sheep and 3½ million goats are annually pastured upon the elevated plains of Algeria.

CATTLE.

The greater number of the cattle raised in Algeria belong to a well-marked North African type—perhaps a subtype of the Spanish cattle—of which various races are distinguished. The best defined of these are the Guelma and the Moroccan races. They are rather small in size and of good shape, with rather long body, full flanks, large, well-formed chest, rather small belly, and erect, curved horns. In color they are usually dark, having black head and legs and dark gray, fawn-colored, or red back and flanks. They are hardy animals, habituated to the severe conditions under which they ordinarily live. Owing to the small amount of food obtainable during the long, dry summer they are small and slow in maturing, requiring usually six years to reach full development. In spring, when the natural pasturage is abundant, and at other seasons, if supplied with cultivated forage, they fatten rapidly. If given plenty of green forage and a small amount of grain, a steer can usually put on 400 pounds of meat without difficulty. When well treated, Algerian cattle make excellent work animals, but the cows are generally poor milkers.

Cattle are purchased from the Arabs for fattening, usually in the late summer or early autumn, and at a price of $9 to $13 per head. They are pastured during late autumn and winter on uncleared land or fallow grain fields. At the beginning of spring they are usually very thin, but fatten rapidly from that time on. After three months of spring pasturage they often weigh enough to be sent to the butcher. A large number go to the markets of the colony, but there is also a considerable export of live cattle. At Marseille, Algerian cattle sell on the hoof at the rate of $9.50 to $10.50 per 100 pounds. At this price there is a good profit in cattle fattened in the pasture, but not when fattened in the stable.

Improved European races of cattle are not generally adapted to the trying climatic conditions of Algeria; nor can they, like the native cattle, endure well the periods of scanty food supply that these conditions impose. Only in the restricted areas, where irrigation allows of the constant production of forage of good quality, is anything to be expected from the introduction of foreign breeds. In such localities crossing high-bred races with the hardy Algerian cattle may prove advantageous in increasing the milk and beef producing capabilities of the latter.

HORSES.

It is estimated that there are 210,000 horses in Algeria, four-fifths of which are the property of natives. Algerian horses belong to the African type, with an admixture of Arabian blood. In its most typical form the horse of Algeria is rather small and light, but is very hardy and capable of much work. The Arabs generally use horses to draw their plows.

The eastern part of the high plateau region is the center of horse breeding in Algeria. The Arabs of the Sahara obtain almost all their horses from that district. The industry of raising horses is, however, on the decline, the prices brought by good animals having fallen 100 per cent or more in the past ten or fifteen years. A mare of good pedigree and known for the excellence of her progeny can now be bought for about $150. The increasing popularity of the mule as a work animal, both among natives and Europeans, is partly responsible for this state of affairs.

DONKEYS.

There are some 275,000 donkeys in Algeria, almost all of which are the property of natives. In the coast region they have largely replaced the camel as a beast of burden, although the latter still retains its usefulness in the high plateau and desert regions. Wherever the use of wagons for transportation is precluded by the lack of good roads the donkey is employed.

MULES.

Of the 150,000 mules that existed in Algeria in 1900, less than one-fifth belonged to Europeans. The high plateau region, around Sétif and Constantine, produces the best mules of the colony. Mules are used by European farmers to draw their wagons and plows, and by the natives for riding and for carrying loads. A hardier and more robust animal is obtained if the donkey parent is of Algerian rather than of European origin.

CAMELS.

It is the one-humped Arabian camel, or dromedary, that is common in Algeria. The Mehari race of the dromedary is especially adapted to travel in the Sahara, making, without difficulty, marches of 70 miles a day for several successive days. Camels are, of course, well known for their endurance, getting along for considerable periods without food or water. They can carry for long distances loads weighing 300 pounds and more. Camels are raised and are used only by the Arabs. A good animal will sometimes bring $60. In agricultural work the camel is of practically no importance, except as a means of transportation.

SHEEP.

In is estimated that in ordinary years the flocks of the colony represent a total value of $28,500,000, which is almost wholly the property of natives.

Three principal races of native sheep are distinguished in Algeria—the Kabyle, or Berber, which is peculiar to the mountain region; the Barbary, a large-tailed race, which is most common in eastern Algeria; and, best of the three, the Arab, which is rapidly supplanting the others. The Arab race is that which is usually found in the large valleys and plains of the coast region and also in the high plateau region. The small, slender tail is a distinguishing mark of this race. The head is sometimes brown or black and sometimes white, the white-headed type being the finest of Algerian sheep. The short, dense, more or less curly, rather fine fleece of the Arab sheep is in marked contrast to the long, straight, coarse wool, resembling goat hair, with which the Kabyle sheep is covered. The best quality of wool is produced in the larger valleys of the coast region.

The colonists formerly purchased from the natives nearly all the sheep they fattened. There is a growing tendency, however, to raise sheep on the farms of the coast region. Sheep that are bred where they are fattened are found to give when only 14 months old from $6\frac{1}{2}$ to 9 pounds more meat than $2\frac{1}{2}$-year-old sheep that have been purchased from native shepherds.

The white-headed Arab type of Algerian sheep shows an approach to the Merino. Crossing with the latter race is found to give a superior animal, which produces not only more meat, but wool that is better in quality and about 50 per cent greater in quantity. Careful selection among the mixed native races can also be counted upon to enhance greatly the value of the meat and wool produced by Algerian flocks.

GOATS.

The natives usually pasture goats together with sheep and cattle, but this is from every point of view a bad practice. Except for their large milk production, goats are not held in much esteem among the European colonists. To the natives, however, their skins, hair, and meat are invaluable. The fact that they can pick up a living in places where cattle or even sheep can not obtain sufficient food is a strong point in their favor. Two races occur in Algeria—the Kabyle goat, with long hair and horns, and the hornless Arab race, which gives more milk.

FORESTRY.

GENERAL CONDITIONS.

According to official estimates there are about 8,000,000 acres of forest land in Algeria, of which about 60 per cent belongs to the coast region, or Tell. The term "forest land" is used, however, in its widest sense, land bearing a shrubby growth of lentisk, dwarf oak, olive, myrtle, dwarf palm, etc., such as occupies vast expanses in the coast region, being included. The steppes of the high plateau region, which are covered with coarse grasses and herbs, possess no forest in the strict sense of the word. Only here and there, in depressions, straggling shrubs and small trees of betoom (*Pistacia atlantica*) and of juniper are found. Yet considerable areas of this character are officially designated as "forest." In the desert region, except on the highest mountains, nothing resembling a forest occurs, the native vegetation being limited to scattered shrubs and coarse grasses, with an ephemeral growth of small herbs that spring up after the infrequent showers. The true natural forest is confined almost wholly to the mountains, especially those of the coast region and of the eastern part of the high plateau.

The forests of the colony are of various types, which owe their characteristics not only to natural conditions of climate and of soil, but also to the direct or indirect agency of man. In many localities only scattered old trees remain, the intervening spaces being occupied by brush or by a carpet of grass. Sometimes there is almost no vegetation except an occasional tree, and in such land active erosion takes place. This condition has probably been brought about for the most part by reckless exploitation or by fires which are often kindled by the natives in order to provide their flocks with the more abundant pasturage that springs up afterwards. The admission of flocks into the public forest reserves is frequently a cause of the rapid disappearance of the young trees, especially when goats are pastured among them. On the other hand, particularly at high elevations in the mountains, there are dense forests where the trees reproduce themselves freely; but this type is the exception rather than the rule.

The forests also differ in the diversity of species composing them. Sometimes large areas, especially at the higher elevations, are occupied almost solely by a single species. Sometimes while one kind of tree predominates, others are present in smaller numbers. Less often several species are mingled together in nearly equal proportion, forests of this type being most frequent in the littoral zone.

The composition of Algerian forests as to species depends upon climatic and soil conditions, and upon the altitude. Well-defined zones, each characterized by some one predominant species, succeed each other at different elevations in the mountains. From sea level up to about 2,500 feet, cork oak, olive, and Aleppo pine are the principal elements, the last being the most widely distributed tree in the colony. Here the forest is most apt to be mixed with a shrubby growth, made up of various species characteristic of the so-called "maquis" of the Mediterranean region.

From 2,500 to 4,000 feet, *Quercus ballota*, a kind of live oak, often predominates. The sweet acorns of this tree are much relished by the Kabyles, who make a practice of selecting and preserving such individual trees as bear the best nuts.

Between 3,500 and 6,000 feet, the handsome Zen oak (*Quercus lusitanica* var.) forms heavy forests of good-sized trees, usually 50 to 70 feet high. In one locality Zen oak covers an area of 100,000 acres.

Finally, at elevations of 4,000 to 6,000 feet, occur magnificent forests of Atlas cedar, a short-leaved variety of the cedar of Lebanon. The total area occupied by this tree approximates 90,000 acres. It usually forms an open forest, the trees being separated by expanses of grass land and low brush. Unfortunately, this superb tree shows very little tendency to reproduce itself. The Atlas cedar lives to a very great age. Individual trees of unusual size, distinguished, like some of the "big trees" of the Sierra Nevada, by particular names, are made the goals of pilgrimages by tourists.

Besides the species already enumerated, the following are noteworthy, either for their abundance or their economic value: Ash (*Fraxinus kabylica*), arbor vitæ (*Callitris quadrivalvis*), juniper (*Juniperus oxycedrus* and *J. phœnicea*), and fir (*Abies numidica*). The chestnut, almond, cherry, fig, and carob are all represented in the mountains of Algeria by wild forms.

Especially in the large valleys of the coast region, such as the Habra, Chéliff, and Mitidja, the planting of trees to furnish timber for construction and firewood, as well as for shade and protection against winds, has been extensively practiced. Species of Eucalyptus, notably *E. globulus* (blue gum) and *E. rostrata* (red gum), are most used. The latter has proved to be the better adapted to Algerian conditions, and is now rapidly replacing the blue gum. *Eucalyptus robustus* and, to a lesser degree, *E. occidentalis* are said to be the species that succeed best in saline soils. The colonists began in 1860 to plant Eucalyptus in large numbers, but when it became apparent that the value of the wood for building purposes had been overestimated, these trees somewhat declined in favor. Nowadays, however, their utility in other respects is generally appreciated.

A large part of the forest land of Algeria, including vast areas covered with brush and grasses, as well as much true forest, is owned by the government. A code of forest laws modeled upon those of France governs their administration. The penalties against starting forest fires are very severe, but are difficult to enforce, because of the mountainous character of much of the country, the frequent absence of facilities for travel, and the active or passive opposition of the Arab population, which is largely devoted to raising live stock. It has been necessary to open much of the public domain to flocks owned by the natives. Although regulations have been established which, if strictly enforced, would prevent serious damage from this cause, as a matter of fact the forests often suffer severely. But in some areas, where it has been possible to prevent grazing during longer or shorter periods, considerable reforestation has taken place.

Forest land belonging to the government, particularly such as bears a growth of cork oak or of alfa, is often leased for a nominal rental to companies or to individuals who exploit these products. Some of the most valuable forested areas are the private property either of Europeans or of natives.

FOREST PRODUCTS.

Following the loose application of the term "forest" that prevails in Algeria, there will be discussed under this head commercial products that are furnished not only by trees, but also by the grass known as alfa, and by the dwarf palm. As a justification for this arrangement, it should be stated that both of these plants occupy extensive areas which are officially designated as forest land, and that neither of them is ever cultivated.

FUEL.

Most of the trees—and many of the shrubs—native in Algeria supply the inhabitants with firewood and with charcoal, which, as in all Mediterranean countries, is much used for fuel. The expense of clearing land is often partly met by the sale of the firewood and charcoal obtained in the process. In some of the large valleys of the coast region, where there is little natural tree growth, plantations of eucalyptus are useful as a source of fuel.

TIMBER.

Most of the wood for construction used in Algeria is imported from northern Europe and from Austria, the natural resources of the colony in this respect having been little developed. Probably this is partly due to the scarcity of water and the consequent absence of large perennial streams, which render difficult and expensive the transportation of logs from the mountains. Artificial plantations have been of little value as a source of building timber, eucalyptus wood particularly being deficient in durability.

Some of the native timber trees promise well, and may some day come into extensive use. Live oak (*Quercus ballota*) and Zen oak (*Q. lusitanica*) furnish an exceedingly hard wood that is somewhat difficult to work. Wood of the Zen oak is particularly valuable for making brandy casks. The extremely durable wood of the Atlas cedar is excellent for railway ties, and is sometimes used in cabinetmaking, its pleasant odor enhancing its value for the latter purpose. Long immersion in water renders it almost indestructible. Arbor vitæ has a beautifully colored wood, variegated with numerous knots, and is highly esteemed by cabinetmakers.

CORK.

The total area occupied by the cork oak in Algeria is estimated at 1,025,000 acres, of which 725,000 acres are being exploited at the present time. About 60 per cent of the entire area belongs to the public domain. The total production of cork in 1899 amounted to 15,900 tons. It is estimated that if all the cork oak of the colony were in a productive state an annual revenue of from $2,000,000 to $4,000,000 could be derived from this source.

The cork oak ranges from sea level up to about 4,500 feet, the largest forests being found in the mountains of the coast region in northeastern Algeria, the western part of the colony being generally too dry for this tree. It avoids limestone, attaining its highest development on soils derived from the Numidian sandstone, where these soils are underlain by a subsoil heavy enough to retain considerable water.

The tree is usually of medium height and size, but its trunk sometimes reaches a circumference of more than 30 feet. The largest individuals are invariably hollow. The crooked trunk and irregular branching give this tree an unkempt, straggling appearance. The evergreen foliage resembles that of the live oak of the Southern States. The wood is of little value, the important products of this tree being cork and tan bark.

Well-managed forests of cork oak are kept free from undergrowth, thus diminishing the likelihood of loss from fire, to which they are peculiarly liable. The danger is greatest in September, when the sirocco is blowing. Fires are often wantonly kindled in the oak forests by malcontent natives and spread with terrible rapidity, frequently devastating vast areas. Only natural forests are exploited in Algeria, no attempt ever having been made to establish artificial plantations.

In bringing a forest of cork oak into condition for exploitation the first step is to remove the layer of old or "male" cork which forms under natural conditions. This operation, which requires considerable skill, is performed in the spring when the sap is beginning to rise. The subsequent yield depends largely upon the way in which this work of "demasclage" is done. It is advisable to put back into place the layer thus removed, fastening it around the trunk by means of wire and leaving it there for about two years; otherwise the trees are very liable to injury from dry, hot winds and from fire. Wrapping the trees in this way also prevents a second development of the worthless male cork.

The new cork which now begins to form is alone of commercial value. It is deposited at the rate of from 0.04 to 0.12 inch annually, and the first harvest is taken when the layer of cork has reached a thickness of about 1 inch. Thereafter the cork is removed every eight or ten years, the later crops yielding a better product than the earlier ones. The expense of each harvest from a single tree is about 2 cents.

Individual trees differ greatly in the rate at which cork is formed. As a rule, the best product is that which develops most slowly. Rapidly growing cork is more abundantly veined with loose tissue, which diminishes its value. The cork is sometimes seriously injured on the tree by the ravages of ants, which build galleries in it. The tree has also other insect enemies.

The cork, when cut, rolls up into tubes of the size of the trunk from which it was taken. It is first pressed out into sheets, then boiled, and finally the crust of bark is removed by scraping. Boiling increases the bulk by about one-fifth and renders the cork more elastic.

An acre of cork oak in full production yields a net annual revenue of about $2. The product from a single tree is worth from 4 to 10 cents a year after all expenses are deducted. Algerian cork sells at from 3½ to 10 cents per pound.

TAN BARK.

The forests of Algeria furnish a large amount of bark for tanning. The annual export of tan bark, chiefly to Great Britain and Italy, amounts to about $200,000. A considerable quantity is also consumed in the colony itself, the manufacture of leather being an important industry among the natives.

Most of this bark is furnished by several species of oak. The Kermes oak (*Quercus coccifera*) ranks first in production, the bark of the root being used. The forests of cork oak, especially those belonging to natives, also furnish a large quantity. The collection of the bark is generally done in such a way as to kill the tree, although if proper precautions were observed the forests could be exploited for tan bark without diminishing their production of cork. The bark of this oak yields about 19 per cent of tannin. A single tree will furnish several hundred pounds of bark, a ton of which sells for from $22.50 to $37.50.

Various tannin-producing plants, such as Australian species of acacia, which furnish the wattle bark of commerce, canaigre, and the Valonia oak, have been recommended for cultivation in Algeria, but none of these has yet become of practical importance. In Tunis experiments are being made by the government in the cultivation of the Sicilian sumac (*Rhus coriaria*), the powdered leaves of which are a valuable material for tanning.

ALFA.

The Arabs use the word "halfa" in much the same way as the term "bunch grass" is used in the western United States to designate any coarse, rush-like grass that grows in tufts. The "alfa" of the French colonists signifies, however, only the species known in Spain as "esparto" (*Stipa tenacissima*). The tough, fibrous leaves of this grass are used in manufacturing paper, basket ware, hats, cordage, etc. It is a long-lived plant, having strong, much branched rootstocks, which give it a good hold upon the soil. The young plant forms a dense tuft, which later takes the form of a hollow circle, as the stems in the center die out. This in turn becomes broken up into separate tufts, each of which is the starting point of a new circle. The leaves are like those of many other so-called "steppe" grasses, being flat and green during the rainy period, but turning yellowish white and rolling up into quills when the dry season sets in. They average from 20 to 30 inches in length, and end in long, sharp points. The leaves last about two years. The older ones are often infested with fungi, which usually attack first the point of the leaf.

Alfa grass covers large areas in Spain and in northern Africa. In Algeria it is most characteristic of the high plateau region, where it often occupies, almost alone, enormous expanses of the undulating plains, forming the so-called "sea of alfa." It is not, however, confined to the high plateau, and even reaches the seashore in extreme western Algeria. It ascends in the mountains to a maximum elevation of 6,000 feet. Where the average annual rainfall exceeds 20 inches a year alfa does not flourish. It prefers a dry, sandy soil, and will not endure the presence of any considerable amount of salt. In moist depressions, where the soil is clayey, other species take its place.

It is difficult to obtain an accurate estimate of the total area occupied in Algeria by this grass. Some authorities give 12,500,000 acres in the high plateau region alone, but this is doubtless an exaggeration. The alfa land of the colony belongs partly to the government and partly to individuals or private companies. The government concedes the right of exploitation for the modest sum of about 1 cent per acre. The holders of concessions, in their turn, usually sublet their rights to a contractor.

A stand of alfa in its natural condition is less valuable than one from which the leaves are regularly harvested. In the former case there are many more or less worthless old leaves mixed with the young leaves. When the exploitation of a stand is begun it is customary to burn it over so as to destroy the coarse old leaves. Thereafter, if the crop is harvested every season, only small, fine leaves, much stronger and more uniform in length than the older ones, are obtained. By firing a tract repeatedly for several successive years "white alfa," with extremely fine, flexible, light-colored leaves, is produced. Long-continued exploitation of a stand, without allowing it any rest, greatly weakens the plants. In fact, alfa has in this way been virtually exterminated in some of the more accessible areas.

As attempts to form artificial plantations of alfa have not so far proved successful, there is danger of the total annihilation of this industry, which, after stock raising, is the mainstay of the population of the high plateau region. To prevent this consummation, a closed season of four months has been established by law. Alfa can not be legally harvested or purchased from gatherers in the high plateau region during the months of March, April, May, and June. In the coast region the closed season extends from the middle of January to the middle of May.

The contractor who undertakes to harvest alfa puts up a barn on the tract and secures Spanish or Arab laborers, whom he provides with food and water, to gather the leaves. Alfa harvesters sometimes come long distances with their families, attracted by the high prices paid for this work. A good laborer can gather, in a day, 650 to 900 pounds of green leaves, for which he is paid nowadays at the rate of about 18 cents per 100 pounds.

The gathering of alfa is still done exactly as classical writers described the process in the times of the Romans. The harvester starts out early in the morning and selects a spot where there is plenty of the grass. Fastened to his left hand by a leather thong is a stick about 16 inches long. With his right hand he seizes a cluster of the tough leaves, rolls them obliquely around the stick, and gives a strong pull with both hands. This breaks off most of the blades at the point where they join the sheaths, although some of the sheaths generally come up with the blades and must be broken off by a second pull. The leaves are packed as fast as they are gathered into baskets, which are then carried to the barn. The green alfa sent in by each harvester is weighed and is then stacked in ricks. When dry it is sorted to remove any sheaths and branches that may still be attached to the leaves. It is baled under a hydraulic press and the bales are secured with hoops. The product is then ready for transportation to the nearest seaport.

Algeria now exports annually nearly 80,000 tons of alfa, which is approximately 35 per cent of the entire output of alfa-producing countries. The total value of the export from Algeria is nearly $1,500,000 a year. England is the largest purchaser, taking, indeed, nearly 90 per cent of the entire world's supply of alfa. France and Belgium also import considerable quantities.

More than 90 per cent of the total amount of alfa produced is used in the manufacture of superior grades of paper. Paper made from the leaves of alfa is strong, transparent, of a silky texture, and very light in proportion to its thickness. It is preferred to any other for printing costly books and engravings.

The best grades of alfa, however, are used in making basket ware, hats, and matting, bringing a price almost twice as great as is paid for that used in paper manufacture. The finest baskets are made from the "white alfa." Rope, brooms, and other articles are also manufactured from the leaves of this grass.

DWARF PALM.

The leaves of the dwarf palm (*Chamærops hystrix*) are much used by the Arabs for thatching their huts, making crates in which fruit is packed, etc.; but the only product of this plant which enters largely into commerce is the fiber, which constitutes about 40 per cent of the weight of the fresh leaves. Under the name of "vegetable hair" this fiber is exported in considerable quantity. It is used for stuffing mattresses and upholstered furniture. A cheap grade of rope, selling for about 80 cents per 100 pounds, is also made from it. The dwarf palm, like alfa, is never cultivated, only the natural growth being exploited. While alfa is preeminently a plant of the high plateau the dwarf palm belongs to the coast region, where it formerly covered vast expanses. Although still abundant, this plant is rapidly disappearing as more and more land is brought into cultivation. Commercial exploitation has helped to accelerate its destruction, there being numerous factories in Algeria for separating the fiber.

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FIG. 1.—SALT LAND, NEAR RELIZANE, IN THE COAST REGION OF ALGERIA.
This land, formerly cultivated, is now covered with a growth of salt-loving weeds.

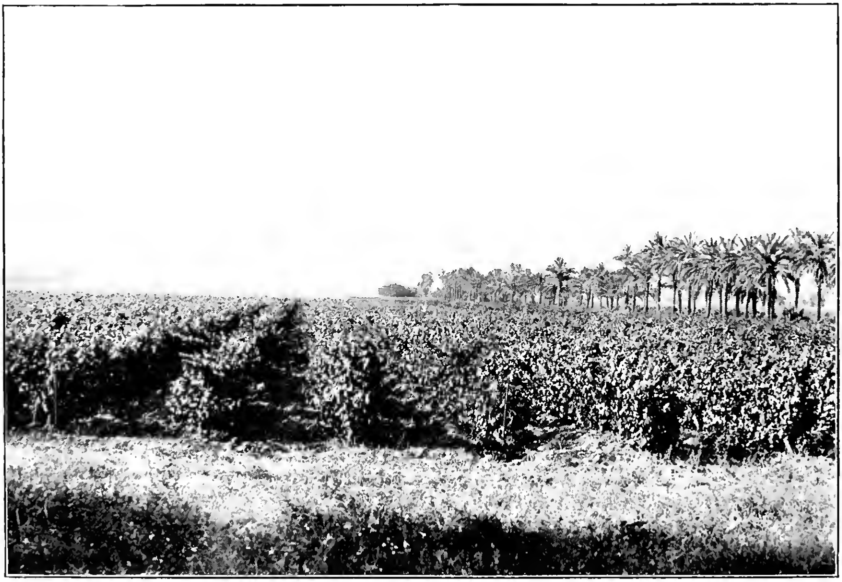

FIG. 2.—VINEYARD OF WINE GRAPES IN THE MITIDJA PLAIN, NEAR ALGIERS.

FIG. 1.—GARDEN OF THE KAID AT TOUGOURT, SHOWING CABBAGE, PEPPERS, AND OTHER VEGETABLES GROWN IN THE SHADE OF THE PALMS.

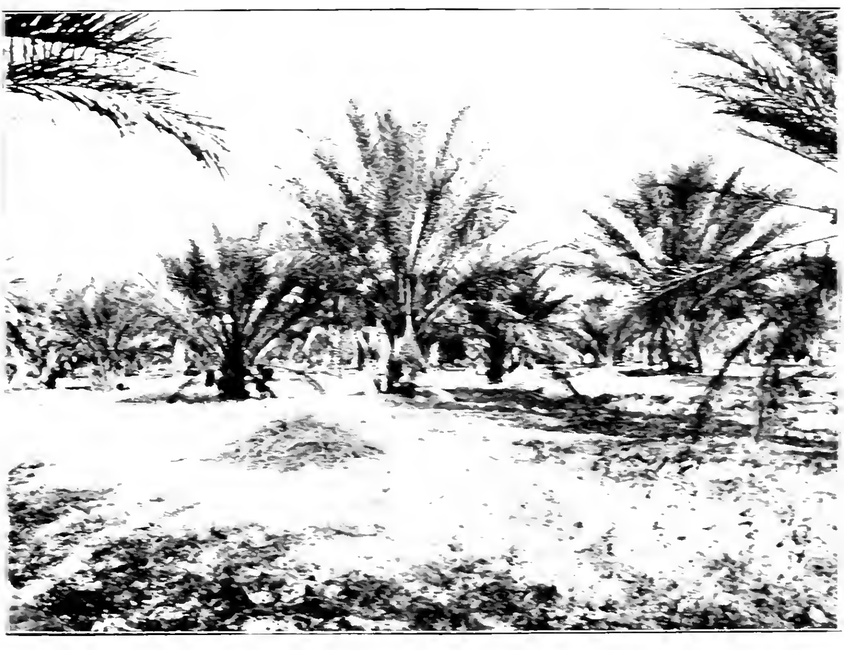

FIG. 2.—DATE PALMS PLANTED IN VERY SALTY LAND BY A FRENCH COMPANY AT OURLANA, IN THE SAHARA.

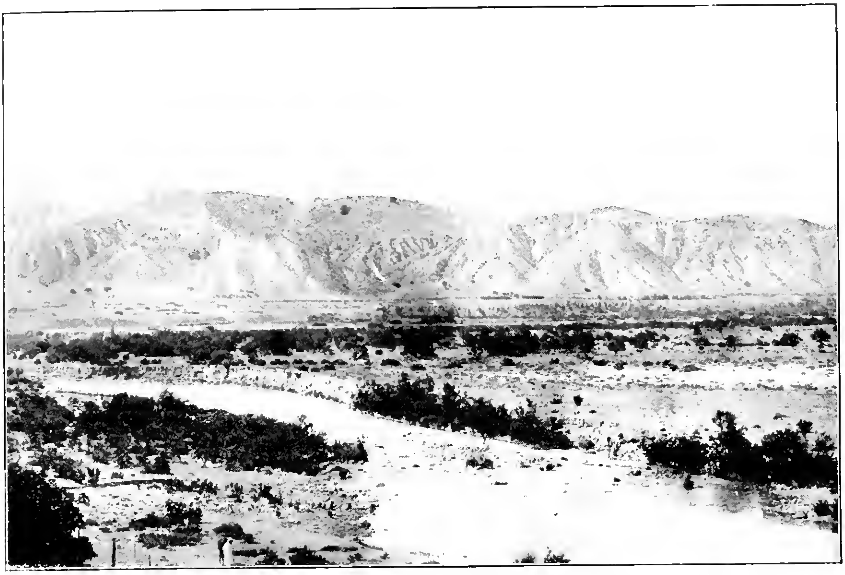

FIG. 1.—VALLEY OF THE HABRA BELOW THE RESERVOIR DAM, NEAR PERRÉGAUX, SHOWING WIDTH OF FLOOD PLAIN AND SMALL SIZE OF THE STREAM IN SUMMER.

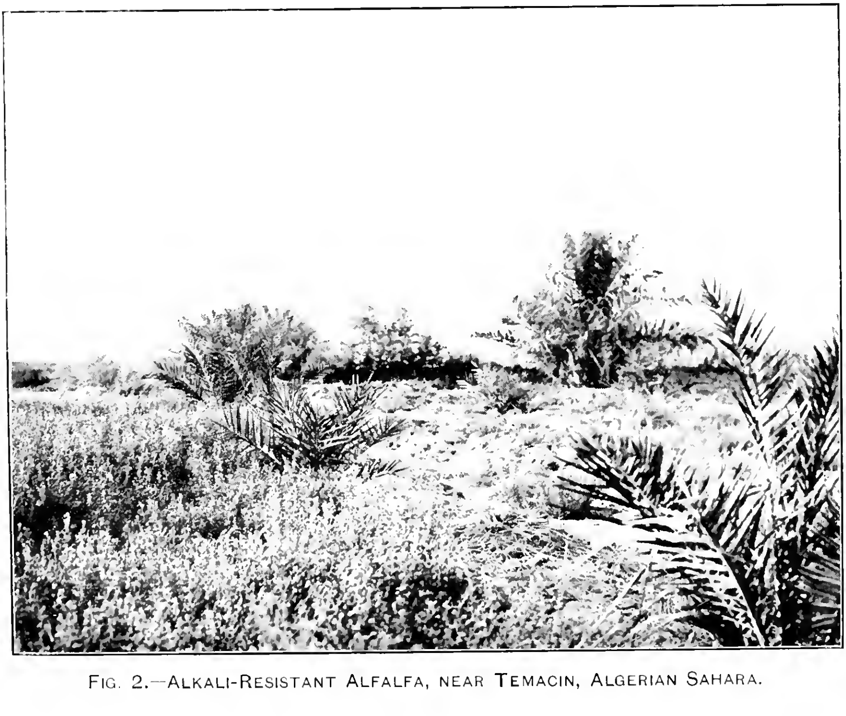

FIG. 2.—ALKALI-RESISTANT ALFALFA, NEAR TEMACIN, ALGERIAN SAHARA.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 81.

B. T. GALLOWAY, *Chief of Bureau.*

EVOLUTION OF CELLULAR STRUCTURES.

BY

O. F. COOK AND WALTER T. SWINGLE.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED AUGUST 4, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY — BULLETIN NO. 81.

B. T. GALLOWAY, *Chief of Bureau.*

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B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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[a] Detailed to Seed and Plant Introduction and Distribution.
[b] Detailed to Bureau of Chemistry.
[c] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 31, 1905.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 81 of the series of this Bureau, the accompanying technical paper entitled "Evolution of Cellular Structures."

This paper was prepared by Messrs. O. F. Cook and Walter T. Swingle, and has been submitted by the Pathologist and Physiologist with a view to its publication.

The accompanying plate is necessary to a complete understanding of the text of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Ever since the epoch-making discovery of Charles Darwin there has been a steadily increasing influence of the theory of evolution on the scientific study and practical utilization of the plants and animals on which agriculture is based. The present paper marks a step in the further working out of the doctrine of descent, inasmuch as it embodies results of an association of the data won in two very different fields of investigation; one making the cell its object of study, the other occupied with the species. The results herewith presented open new views as to the nature of higher animals and plants which can not fail to stimulate research and which promise to have great economic significance in the determination of the actual and latent capacities of the organisms utilized by man.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., May 8, 1905.

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EVOLUTION OF CELLULAR STRUCTURES.

INTRODUCTION.

The value of a new point of view lies in the fact that it permits new relations to be perceived. By means of the kinetic theory of evolution it has become possible to understand that organic development has been carried forward through gradual improvement of the methods of descent rather than by environmental causes. Instead of there being a law of heredity which tends to keep the individuals of a species uniform, or exactly alike, the tendency, especially among higher plants and animals, is to maintain, inside the species, a diversity of form and structure, most conspicuously manifested in the phenomenon of sex.

This intraspecific diversity is neither accidental nor incidental, but of great physiological and evolutionary importance. The interweaving of distinct lines of descent is necessary to sustain the strength and vital efficiency of the individual organisms, and to continue the evolutionary progress by which the species adapts itself to changing environments or enters new ones. Interbreeding is as indispensable for the species as for the individual, or even more so, for seedless plants continue their individual existences after the coherence of the specific group has been lost.

Normal and long-sustained evolutionary progress is not accomplished on single or narrow lines of descent, but is possible only for large companies of interbreeding individuals; that is to say, for species. It is thus no mere accident, but a fundamental necessity, which brings about the association of organic individuals into species and determines what might be called the specific constitution of living matter. Species are sexual phenomena; they have come where they are only through symbasis; that is, as groups of interbreeding individuals, traveling together along the evolutionary pathway.

This interpretation of familiar biological facts is supplemented and confirmed by the study of the processes of cell conjugation, which are the means of symbasic interbreeding. Among simple organisms conjugation is a periodical incident in the multiplication of equal and independent cells. Higher stages of organization were reached by the production within the same species of many kinds of cells and the building of these into large colonies or compound individuals. There was, however, a very early limit to the structures which could be built of the primitive, simple type of cells, as illustrated by the filament of the lower alga, the vegetative mycelium of the fungus, and the thallus of the liverwort. The plant series would have culminated, apparently, with the leafy axis of the moss if the basis of organization had not been changed from the primary or simple type of cells to the double or sexual type.

In undifferentiated unicellular or equal-celled (isocytic) organisms the successive generations of cells may be thought of as joined into a network by an occasional conjugation. The cells at the knots of the network are, as we know, double, being formed from the association of two nuclei and the accompanying protoplasms. They are often strikingly different from the remainder of the cellular fabric of descent, and have been given special names, such as oospore, zygospore, and resting spore. In the first or lowest category of sexual organisms only one cell in each generation is double; there is only one large bead at each node of the genealogical network. (See Pl. I.) A second type of organic structure was initiated when an organism attained the art of forming two or more of these double cells by division.[a] It is of such double cells that all the higher plants and animals are built. The new type of organization was not merely supplementary to the old; it was a new biological invention, giving rise to a new category of vitality, which not only outstripped the old type of structural organization, but even caused it to be abandoned and eliminated as a worse than useless impediment.

Organisms which were farthest ahead on the primitive basis have fallen far behind since the new course of development was opened. In such groups as the liverworts, mosses, and ferns the diversity of the two types of organic structure is strikingly obvious, and has received extensive study for years past under the name of "alternation of generations." Ample homologies have been found in the highest groups of plants to show that the so-called alteration of generations was everywhere in ancestral condition, and that all have followed essentially the same history in having abandoned the simple type of cell for the double as the basis of structural development.

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[a] The terminology followed in this paper presupposes for convenience the existence of the cellular type of organization common to most animals and plants. The conclusions here reached apply with equal force, however, to organisms such as the Infusoria among the protozoa, the Siphonocladiaceæ among the algæ, and the Saprolegniales and Mucorales among the fungi, in all of which groups considerable structural differentiation is attained without any division of the organism into cells. Such forms as Caulerpa and Acetabularia among the Siphonocladiaceæ reach a considerable size and even show a well-marked differentiation into the analogue of stem and leaf, rhizome and root, without the enormously expanded thallus being divided up into cells at all, although very numerous nuclei arise by subdivision and are scattered throughout the cytoplasm. These nuclei could be double, in which case such plants would be directly homologous to the double-celled organisms described in the following pages.

That these converging data pointed to something of fundamental evolutionary significance has been confidently believed since the publication a decade ago of Strasburger's epoch-making essay entitled "The Periodic Reduction of the Number of the Chromosomes in the Life-History of Living Organisms,"[a] but a new evolutionary standpoint was required before the larger import of the facts could be perceived. The reduction of chromosomes is indeed a striking and unique phenomenon in the life history of organisms, and it naturally became the focus of interest in the rapidly developing science of cytology. A new point of view was the more necessary, however, because of an unfortunate choice of terms which has undoubtedly tended to prevent the perception of the true relations of the facts, as it now interferes with a correct description of them. We refer to the characterization of the higher, double-celled, spore-bearing "generation" as "asexual." Appreciating the primitive character of such structures as the prothallus in ferns, Strasburger asserted that a new "asexual generation" had been intercalated into the life history of organisms. It is now perceived that for cytological purposes this is not the whole truth, and that for evolutionary purposes it is not true at all. The new "generation" was not merely intercalated into the *life history* of the organism; it was intercalated into the *sexual process*. It is, therefore, not asexual, but sexual, and in a higher degree than the so-called sexual generation. The latter bears, it is true, the cells which conjugate, but the former is produced *during the actual process of conjugation.* Organic perfection has been attained, not through the development of an "asexual generation," but by the lengthening out of the sexual process itself; not by abandoning or avoiding sexuality, but directly by means of it.

Among the lower plants the single cell formed by conjugation accomplishes in a brief space of time all the cytological processes which in the higher plants come between fertilization and chromosome reduction. Sexual fusion is immediate and complete, and takes place during a brief period of interruption of the growth and subdivision of vegetative cells. If the vegetative fern prothallus is to be termed sexual because it produces antheridia and archegonia, the sporophyte is sexual to the second degree, for it is built of conjugating cells, containing, until synapsis and the subsequent reducing divisions, a double number of chromosomes, the parental chromatin elements being still unfused. However important chromosome reduction may be, it is, after all, only a corollary or sequel of the *doubling conjugation.* It was not the reducing division, but *the long postponement of the reduction division*, which permitted higher types of organisms to be developed by means of double, sexual cells.

A special evolutionary significance was ascribed to the chromosome

[a] Strasburger, Edward, Annals of Botany, 1894, 8: 281–316.

reduction because cytology was approached from the standpoint of the somatic tissues of the higher plants and animals. This current interpretation reverses, however, the historical course of events. The reducing division was not an expedient incidental to the adoption of a process of sexual reproduction by organisms previously sexless. *It was not the reduction to fewer chromosomes, but the retention of the double number, that constituted the important step in sexual reproduction and made possible the evolution of complex higher organisms.* It is, therefore, not the reducing division, but the doubling conjugation, which should constitute the datum point or base line for tracing cytological homologies.

THE ELIMINATION OF THE SIMPLE-CELLED PHASE.

Chromosome reduction brought about by synapsis, or the fusion of the chromatin elements, followed by two special nuclear divisions, is not, historically speaking, the beginning of the sexual process, but the end of it. Chromosome reduction stands in no special causal relation to the subsequent conjugation. The number of cell generations formed between synapsis and conjugation differs greatly in the various natural groups, and merely shows how far the organism still adheres to its old simple-celled life history. Fecundation and synapsis, as the beginning and the end of the sexual process, would seem to be directly comparable in all organisms which have developed a double-celled sexual phase.

From the physiological standpoint, it may be an advantage to dispense with the simple-celled phase and thus shorten the period between the chromosome reduction which marks the end of one conjugation and the cell fusion which begins another. Synapsis relieves organic fatigue by means of new nuclear configurations, and has been thought of as a stimulant of vital activity or energy of growth, the benefit of which can be secured for the new double-celled structure by very prompt conjugation, as occurs in all the higher plants and animals. This consideration would help to explain the organic inferiority of such a group as the ferns, which, although they have developed a double-celled phase, continue to waste the energy derived from synapsis on a worse than useless simple-celled structure.

In all animals above protozoa this reduction of the simple-celled phase has gone so far as to result in its complete elimination, for the two peculiar nuclear divisions which occur in rapid succession immediately after synapsis constitute an essential part of chromatin reduction. That these phenomena noted are indissociably connected stages in the process of chromosome reduction has been emphasized recently by Farmer and Moore,[a] who propose the convenient term maiosis to

[a] Farmer, J. B., and Moore, J. E. S. On the Maiotic Phase (Reduction Divisions) in Animals and Plants, in Quarterly Journal of Microscopical Science, n. s., No. 192 (vol. 48, No. 4), Feb., 1905, pp. 489–557, pl. 34.

include synapsis and the subsequent heterotype and homotype nuclear divisions.[a]

ALTERNATION OF STRUCTURAL TYPES.

"Alternation of generations" is an expression borrowed from zoology; its application to the archegoniate plants has introduced endless complexities, and can be justified, after all, only by false analogies. Alternation of generations was discovered by Chamisso in a species of Salpa, a marine animal belonging to the Tunicates; but here, as well as in the traditional zoological example of the Aphides, or plant lice, the phenomena have entirely different evolutionary significance from the so-called antithetic alternation of generations in the archegoniate. Generations or individual life cycles of Salpa and of plant lice, which were originally alike, have become different, so that now parthenogenetic generations alternate with sexual generations. To make the archegoniate plants a parallel instance, it would be necessary to assume that what is now called the sporophyte was originally another thallus, or something that corresponded to one, which later on became modified into the sporophytic "generation." To state the case in this way may seem quite superfluous, since nobody has made such a suggestion. Strasburger and others have repeatedly declared that the so-called asexual generation had been intercalated—that is, added anew—and not substituted for something else. This, however, makes it only the more obvious that the sporophyte is a generation only in a very loose and inaccurate sense, and not because it corresponds to or takes the place of any other generation. The simple fact is that, instead of forming merely one oospore as the result of fertilization, the archegoniates have come to form a whole sporophyte or double-celled structure by the multiplication and progressive sterilization of potentially sporogenous tissue, as Bower has shown.[b]

Bower's generalization is, however, only a half truth, since the sterilization, or, better, the arrest of spore formation of some of the cells, is conditioned on the possibility of continued subdivision and growth of the fertilized egg, and this can occur only when there is a definite

[a] To recognize, however, as Farmer and Moore do, these two cell generations as a distinct "maiotic phase" in the life history of Metaphyta and Metazoa does not seem warranted, since chromosome reduction is apparently a mechanical necessity resulting from sexual conjugation and is consequently brought about in a practically identical manner in all symbasic organisms, from the lowest to the highest. Maiosis is rather a connecting link at the node in the network of descent than a distinct phase subject to expansion or contraction as organisms mount in the scale of evolutionary progress. On the other hand it is clear that the two peculiar cell generations occurring during maiosis can not properly be classed with the double-celled phase that usually precedes or with the simple-celled phase that usually follows, but constitute a transition stage marking the end of one generation and the beginning of another.

[b] Bower, F. O. A Theory of the Strobilus in Archegoniate Plants. Annals of Botany, 8:343–365. 1894.

postponement of some stage of sexual fusion, for if the final stage is once reached and the chromatin fuses, no further growth is possible, and a new generation is inaugurated automatically. When sexual fusion is immediate and complete, i. e., when nuclear fusion follows close on cell conjugation and is in turn at once succeeded by chromatic fusion, no development of the oospore can occur; it simply breaks up into four spores. Such was once the fate of the eggs of all organisms, and such is still their fate in the lower plants. All development of the fertilized egg other than a simple splitting into four spores is due to an arrest of the process of sexual fusion which permits its expansion into a mass of double cells, such as constitute the bodies of higher animals and plants.[a] It is, however, clear that the effect of such an arrest in the process of sexual conjugation and consequent intercalation of a double-celled phase in the life history of the organism is to lengthen the life cycle; it lessens the number of generations instead of making more of them.

Notwithstanding half a century of endeavor, botanists and zoologists have not yet found in the higher animals any definite homologue of the so-called antithetic alternation of generations discovered by Hofmeister[b] in the archegoniate plants. The whole idea of alternating generations must, however, be abandoned and emphasis placed instead on the expansion of the oospore or fecundated egg into a double-celled phase that comes to occupy a larger and larger part of the life cycle as organisms mount higher in the scale of evolutionary progress. It then becomes evident that in higher animals (Metazoa) the expansion of this phase has gone so far that the simple-celled stage has been completely suppressed, and in consequence their life history is as free from alternating phases as that of the lower plants, though for a very different reason. The lower groups show no expansion of the fertilized egg. The higher animals consist of nothing else.[c]

[a] It is clear that the expansion of the fertilized egg could occur in siphonaceous algæ and fungi without any cross walls forming between the nuclei as they arise by subdivision. The mature thallus of an Acetabularia is obviously the enormously expanded syngamete and may or may not contain double nuclei. On the other hand, the Infusoria may be found to consist of one double cell, the successive cell generations not adhering to form a tissue.

[b] Hofmeister, W., Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen. Leipzig. 1851.

[c] This fact is obscured, but not negated, by the splitting up during chromosome reduction of the egg and sperm mother cells of animals into four gametes, which are simple cells, but which are no longer capable of further development unless they conjugate. As previously noted (p. 13, footnote *a*), these two cell generations occurring during chromosome reduction constitute a transition stage between the old and the new generations and can not properly be classed with the simple-celled phase.

The occurrence of alternating phases in the life history of an organism indicates that it is in an unstable evolutionary condition, since it has not yet attained the

That there are two unicellular stages in the life history of an organism should not be allowed to introduce any confusing technicalities. For genealogical purposes the spore is quite as much the descendant of the antherozoid and the egg cell as it would be if the other tissues of the sporophyte had not been intercalated. From chromosome reduction to chromosome reduction, from spore to spore, or from egg to egg is one generation, and not two. The prothallus is no more mysterious than any other piece of ancient history. The ferns were originally liverworts, the capsules of which had the good fortune to get roots into the ground and keep on growing, but they have not yet learned to dispense with their first vain attempt at building a structure on a simple-celled basis.

SEXUALITY A MECHANISM OF EVOLUTION.

Stress has also been laid upon this supposed alternation of "sexual" and "asexual" generations in the belief that a clew was here to be gained regarding the nature of sex and of attendant "mechanisms of heredity." But since only one generation is really involved instead of two, and since the phase of existence which has been termed asexual is in reality the more strongly sexual, it is not surprising that these expectations have not been realized. Sexuality facilitates interbreeding and makes it the more effective by distributing new variations throughout the species; it is, in short, a mechanism of diversification and of evolution, a fundamental and universal fact which stands squarely in the way of the alleged law of heredity under which organisms would breed true and be exactly alike. This notion of a uniform and unchanging heredity,[a] or of any natural tendency to such a condition of organic

most effective type of organization. The persistence of a clearly two-phased condition in the vascular cryptogams and of a reduced alternation of phases, even in the highest algæ and flowering plants, is a proof of the extreme slowness of the evolutionary progress of the plant kingdom. Animals seem to have passed through the diphase period of their existence before the dawn of geologic history, and appear in the oldest fossil-bearing strata, not only as completely double-celled organisms but highly differentiated ones at that. Not only are there no traces of the two-phased progenitors which must have gone before the lowest known fossil organisms, but up to now zoologists have not realized the need of postulating such forms at all, and have been content to derive the higher animals from merely simpler but always completely double-celled ancestors, which, of course, are not primitive. It seems not improbable that the completely double-celled condition has been reached independently by different groups of higher animals, just as it has been approximated, though not attained, by the Fucaceæ and the phanerogams among plants. The animal kingdom does not contain, so far as is now known, a single species that shows alternating phases in its life history; it has no counterparts of all that wealth of forms which in the plant kingdom bridge the interval from the protophytes to the flowering plants.

[a] "The modifications introduced into palingenesis by kenogenesis are vitiations, strange, meaningless additions to the original, true course of evolution."—*Haeckel, Evolution of Man, vol. 11, p. 460, note 9.*

stagnation, can well be relegated to the limbo of hypotheses which have not proved useful. Heredity is not a mechanism or a force; it is merely another name for the property of organic continuity or succession. There is no more heredity in an organism at one stage of its life history than at another.

Sexual and other diversities inside specific lines are not useless morphological complexities or mere failures in the execution of a fundamental plan of complete uniformity. Diversity, interbreeding, and evolution are physiological factors of the highest importance in maintaining vital efficiency.

Morphologically speaking, sexuality is a specialization of the internal diversity of the species, and among plants, at least, it has been attained independently in a large number of unrelated natural groups. There are grades of sexual differentiation just as there are of organic structures. Moss plants and fern prothalli may be sexually differentiated and the differentiation may occur farther back in the spore itself, or even in the sporophyte or double-celled phase, as in the flowering plants and the higher animals. Thus in the same species there may be two sexualities, one in the simple-celled stage and another in the double, and these may have no homology or causal connection, except as they both serve the same purpose of promoting more efficient symbasis. Indeed, the sexuality of the highest types of organization is not merely double, but threefold; the individual has sex, as a whole; the double cells of which the body is composed are a part of a sexual process, and the simple cells which it produces for the initiation of a new generation are sexually differentiated.

TWO TYPES OF DOUBLE-CELLED STRUCTURES.

That organisms are everywhere associated in species is not because of some undiscovered principle or mechanism of heredity; it is simply because the interweaving of the lines of individual descent is being maintained, without which the specific association would be dissolved into indefinite radial divergence and degeneration, as among the varieties of bananas and other plants long propagated from cuttings. Many explanations have been conjectured for the supposed absence of sexual reproduction among the higher groups of fungi. From the standpoint of a symbasic evolution, however, it becomes evident that the existence of true, coherent species among these fungi is a sufficient evidence of interbreeding, and hence of sexuality. There is in many groups a deficiency of specialized sexual organs, but these are rendered unnecessary by abundant opportunities for direct conjugation among the mycelial filaments.

That the cells of the more complex reproductive tissues of the higher fungi are known to have two nuclei, while in the younger mycelium there is only one, might also have been accepted as proving that conjugation had taken place. This does not mean, of course, that cross-fertilization is indispensable for spore production among the fungi, but their habits of growth certainly give many opportunities for conjugations between mycelia of different descent, by which the existence of compact and well-defined species can be maintained, although the peculiar structure of fungous tissues permits extreme variability of the size and external form of the fruiting bodies.

In structural complexity, size, longevity, and other measures of organic efficiency the binucleate fungi have an intermediate position in the plant series. Their wide distribution and extensive differentiation into species, families, and orders are evidences of ample opportunities in time and environment, so that it is not unfair to explain their evolutionary limitations by reference to their peculiar type of organic structure.

Sexual reproduction is accomplished through conjugation or fusion of cells, a process which may be divided into three stages: (1) Plasmapsis, the fusion of the cytoplasm or unspecialized protoplasm; (2) karyapsis,[a] the fusion of the nuclei or nuclear protoplasm; (3) synapsis, the fusion of the chromatin. The binucleate cells of the fungi may be said to have passed the stage of plasmapsis, but karyapsis, or true fecundation, like that of the higher plants and animals, has not taken place.

For the form of sexuality which produces the binucleate cell structures of the higher fungi the name *apaylogamy* is proposed, in allusion to the fact that the two nuclei have not yet associated. The higher stage, where the nuclei fuse but the chromosomes remain apart, may be called *paragamy*, which implies that the union is still incomplete, but that a more intimate relation has been established. These two double-celled conditions may be further contrasted with *haplogamy*, the primitive method of undeferred combination of the sexual cells, nuclei, and chromatin.

To the "asexual generation," which is not asexual and not a generation, the term *paragamic phase* may be applied among the higher plants and animals, the tissues of which are composed of cells with a

[a] The etymology of these terms will be obvious to all students of biology, *plasma* and *karyon* being the familiar Greek renderings of protoplasm and nucleus, respectively. The other element, *ἅψις*, signifies a binding or tying together and also a mesh or network, a meaning especially appropriate in view of the reticular structure of living matter.

The series might be completed more logically by using the distinctive word *mitapsis* as a substitute for synapsis, which in its etymology is scarcely more than a Greek equivalent for the general term conjugation. Mitapsis is derived from *μίτος*, a thread, and alludes to the threadlike condition assumed by the chromatin during the process of chromatic fusion.

double number of chromosomes. The binucleate structures of the fungi may be referred to as the *apaylogamic phase*. The so-called "sexual generation" may be called the *haplogamic phase* in both cases. These new terms might not be necessary if words were used for descriptive purposes only, but in the present instance they have general implications too important to be disregarded.

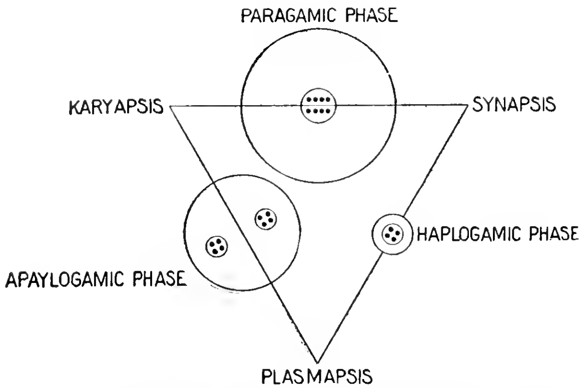


FIG. 1.—Diagram showing the different types of cell structures and their position in the life history of organisms.

Haplogamic structures are built between synapsis and plasmapsis, apaylogamic between plasmapsis and karyapsis, paragamic between karyapsis and synapsis. Between the three critical points of cytological activity there are three intervals, in which the organism can pause to gain additional size or numbers by vegetative division of cells. The relations between the cell structures and the nuclear processes are illustrated by the accompanying diagram (fig. 1).

No organisms have, however, structures built in all the three phases. The relative importance of each phase in the life histories of the different natural groups can also be illustrated by simple diagrams, as shown in figure 2.

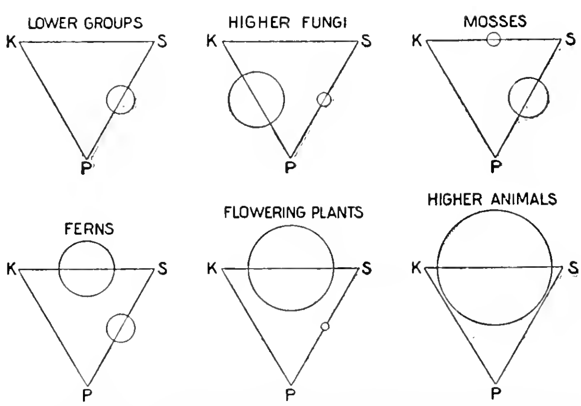


FIG. 2.—Diagram showing the relative importance of the paragamic, apaylogamic, and haplogamic phases in the life history of various groups of organisms.

The relative importance of the different phases in the life history of the various groups of organisms can be represented in another way, as is shown on Plate I. The diagrams on this plate show in addition a network of descent in its simplest form, composed of successive generations linked together at the first stage of conjugation. The generations themselves are seen to be composed of alternating simple and double celled phases in organisms of intermediate evolutionary rank, and finally the double-celled phase is shown to be an expansion of the fertilized egg, which constitutes an increasingly large part of the life history as organisms mount higher in the scale of evolutionary progress.

It is thus easy to understand why the two types of double-celled structures have very unequal possibilities of organization. Two nuclei are evidently better than one, but their association is too slight, apparently, to gain much of the vital stimulus consequent upon the more effective method of conjugation followed by the higher plants, where the chromosomes of two fused nuclei lie in juxtaposition in the new nucleus. The higher organisms have not merely double cells, but, what seems to be vastly more important, compound nuclei, a more advanced and energized stage of the sexual process, which enables them to maintain for exceedingly long periods of time the power of growth and subdivision.[a]

The intercalation of the double-celled structure does not change the order of nuclear events in cross-fertilization, but it may be said to change fundamentally their chronological and physiological relations. The true historical sequence of conjugation is plasmapsis, karyapsis, and synapsis, but the apparent and practical sequence in the higher plants and animals becomes synapsis, plasmapsis, and karyapsis, the synapsis which ends one conjugation being followed closely by the plasmapsis which begins another. The suspension of nuclear changes for vegetative growth no longer occurs between synapsis and plasmapsis, but between karyapsis and synapsis, the double-celled, paragamic structure being built, as already stated, on a new and highly sexual plane, that is, out of cells in a state of prolonged sexual union.

If, as may be supposed, the benefit of synapsis lies in the making of new associations of the ancestral chromatin elements, it is obvious that the bringing of two such newly energized nuclei together would produce a condition which, for want of other words, might be called a multiple vital tension. The double-celled type of structure involves, therefore, not merely a transfer of emphasis to a new part of the life-cycle, but a new and improved sexual process, which raises the biological equation to a higher power. From this standpoint it is obvious that the morphological diversities of sex have a fundamentally important and truly physiological function in building up and maintaining the efficiency of the complex organization of the higher plants and animals. It is as illogical to ascribe the internal diversity of

[a]As noted before, some organisms, such as Caulerpa and Acetabularia, show a considerable degree of evolutionary progress, and have not as a matter of fact attained the cellular type of organization at all; they may, however, be found to have double nuclei and to be very striking examples of the expansion of the fertilized egg.

species to external environmental causes as to arbitrary mechanisms of heredity.

The extent to which the static concept of a normally unchanging heredity has obscured evolutionary thought and investigation could not be better shown, perhaps, than by the fact that, notwithstanding the great multiplicity of terms which have been proposed for all the imagined kinds of variations, no name has been suggested for this normal and necessary intraspecific diversity. The deficiency may be made good by the use of the word *heterism* for the whole group of phenomena, ranging from mere individual diversity to the highest specializations of heterism, exemplified by sexes, castes, and polymorphic conditions. It is true that the members of a species look alike when compared with those of other species, and there may be no harm in ascribing this likeness to heredity, but there is nothing to show that this heredity of general resemblance has anything to do with evolution except as an incidental result. Evolution does not take place between species, but inside of them; it is not an *inter*specific phenomenon, but *intra*specific. Its principal factors are heterism and symbasis, not heredity and environment, as believed by the selectionists, nor heredity and segregation, as supposed by the mutationists.

HEREDITY IN RETICULAR DESCENT.

The greater efficiency of the double nuclei is, however, only one more evidence of the importance of sex as a means of diversity and of bringing diverse protoplasms together. The nuclear network of chromatin which controls the activities of the cell corresponds to the network of descent through which the cell has come into existence. Symbasis, or diversity of descent with normal interbreeding, is the foundation of the strength and vitality of the organism, because it increases the efficiency of the nuclei of the component cells.

Inbreeding or defective fertilization, on the other hand, would cause nuclear deterioration, as so strikingly shown by Maupas in the so-called senile degeneration of ciliate Infusoria induced by keeping them too long without cross-fertilization. This phenomenon is, indeed, closely parallel to senile degeneration, but there is, nevertheless, an important difference. In true senile degeneration the vigor of the cells is declining because of the absence or long postponement of conjugation. In monobasic degeneration, conjugation may take place, but is not effective because of insufficient diversity of descent. Monobasis is the antithesis of symbasis; it means descent without cross-fertilization, on single or very narrow lines. The inevitable result is degeneration, with a rapidity proportional to the closeness of the inbreeding and the complexity of the organisms.

This intimate relation between organic descent and organic structure enables us to understand the phenomena of organic succession without resorting to abstract principles or to hypothetical mechanisms of heredity. The network of descent is, as it were, a map showing the alternative routes of the developing organism, and permitting normally any combination of ancestral characters, as may well result from the endlessly varying arrangements into which the ancestral chromatin elements may fall at the time of synapsis or chromatic fusion. Twins developed from the same ovum would have the same arrangement of chromatin, which accords with their close similarity of form, but otherwise there is unlimited diversity, even among the simultaneous offspring of the same parents. It would seem, therefore, that instead of a mechanism of heredity inside the reproductive cells there is an automatic device for insuring diversity. The higher the organization the more complex the descent, and the greater the variety of nuclear configurations and the resulting individual diversity.

Nevertheless, inheritance is not governed merely by chance, nor limited even to the infinity of nuclear networks to be made by the combinations possible among the ancestral chromatin elements. With the greater vitality of interbred organisms is associated also a stronger heredity or prepotency of the wild or more broadly symbasic types when such are crossed with inbred domesticated varieties. New variations, too, appear to have the same effect as diversity of descent in lending greater vigor and prepotency. Even mutations, or degenerative variations induced by inbreeding, are prepotent on their own plane of symbasis—that is, when crossed only with their own inbred relatives—though they are promptly obliterated or "swamped" when brought into contact with the broadly symbasic wild type, the prepotency of the diverse descent being far greater than that attaching to the inbred variation. It is the prepotency of variations which renders evolution truly kinetic; for the methods of organic descent are such as to bring about a spontaneous change of type. The environment often influences the direction of this vital motion, but is in no proper sense an actuating cause.[a]

Cells are the units of organization, but species, as groups of interbreeding individuals, are the units of evolution. The causes of evolution are not revealed by hypothetical subdivisions of cells into character units or determinate elements, but by ascertaining the methods of descent through which interbreeding maintains organic strength and evolutionary progress. Cells divide themselves, as we know, into other cells, and species into other species, but it is only as cells and as species that their vital, organic, evolutionary activities are accomplished. *Individuals* vary and mutate, but only *species* evolve. To classify the various stages and functions of organisms under general and abstract terms may be desirable, but for evolutionary purposes it

[a] Cook, O. F. Natural Selection in Kinetic Evolution, Science, n. s., 19: 549. 1904.

is the network of descent which represents the concrete, significant fact, and it is this which can be resolved, if necessary, into its component lines, polygons, or nodes, to furnish units for the calculation of quantitative effects of inheritance, as in Galton's Law of Ancestral Resemblances and Filial Regression, under conditions of normal symbasic descent, or in Mendel's Laws of Disjunction, in hybrids of abnormally inbred varieties.

The recognition of the double character of the cells of the higher plants and animals permits many other phenomena of inheritance to be understood, though it seems to take us farther than ever from the hope of a merely mechanical explanation of the nature of heredity itself. If conjugation were concluded immediately, the well-known phenomena of sterile hybrids would be impossible, the sterility which puts an end to their existence being due, as now known, to the failure to perform synapsis or chromatin fusion. On the other hand, it may be that crosses between narrowly inbred varieties sometimes have the power of passing by the period of synapsis without a true fusion of the parental chromatin, perhaps in a manner corresponding to that in which Thalictrum produces seeds parthenogenetically, by avoiding chromosome reduction. The germ-cells might have a preponderance of chromatin from one parent or the other, or might even be quite unmixed, as claimed for Mendelian hybrids. It is obvious, however, that to explain Mendelism in this manner is to admit the essential abnormality of the phenomenon.

SUMMARY.

It has been held self-evident that there can be nothing in evolution except heredity and environment, and it was a simple deduction from such an aphorism that differences must all be due to environment, since "heredity would, if nothing interfered, keep the descendants perfectly true to the physical characters of their progenitors." Such heredity, however, is a pure figment of the scientific imagination; it is a hypothesis which lends us no aid in understanding the facts of organic succession. A stereotyped heredity could make nothing new; the interbreeding of diverse individuals and the prepotency of new variations are the constructive factors, not heredity and environment.

Symbasis is the method, interbreeding the means, and sexuality the mechanism whereby organic evolution has been accomplished; these are the concrete and efficient causes of the vital motion of species. The association of organisms into species of similar individuals is not brought about by a predetermining hereditary mechanism, but by symbasic interbreeding. The highest organization has not been attained in "asexual generations," but in structures completely and essentially sexual, built wholly of conjugating cells. There has been no evolution away from sexuality. Long-continued violations of the law of symbasis bring only degeneration.

This interpretation of evolutionary facts opens the way to an adequate physiological explanation of the significance of sex, and affords also a working theory of the chief cytological complications that have arisen as a consequence of sex—complications that have hitherto rendered obscure the nature of the cell-bodies of higher animals and plants.

The external diversity of organic nature and the internal diversity of cells and of reproductive processes take on new and unexpected significance. Both are shown to be consequences of sexual specialization, without which no evolutionary advance beyond simple-cell colonies has been possible. More than this, gradations in the perfections of the higher double-celled structure are correlated with definite stages of evolutionary progress, so that from the structure of an organism its kind of sexuality can be deduced. Evolution becomes, in the new view, a physiological rather than a morphological process, since the methods of descent affect the quality and efficiency of the organism even more promptly and fundamentally than they do its external form.

PLATE.

EXPLANATION OF PLATE.

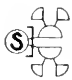
The circles (○), eights (8), and thetas (θ) represent in each case the nucleus or nuclei belonging to a cell, and the succession of cell generations is shown by a string of nuclei either simple, in pairs (apaylogamic double cells), or fused (paragamic double cells). The half circles (◠ ◡) and quadrants (◸ ◹) represent the two cell generations formed during chromosome reduction. The brackets [ ] represent a cell at the period or periods when the organism is reduced to a unicellular condition. All the signs for nuclei could be supposed to be inclosed by a cell wall, which has been omitted for the sake of clearness. For the same reason only the cell lineage leading directly up to the formation of the gametes has been shown, and no account has been taken of the enormous multiplication of cells which occurs not only to build up the bodies of animals and plants but also to form many gametes. Only a few of the numerous cell generations which make up the organisms in question are shown.

EXPLANATION OF SIGNS.

P Plasmapsis—fusion of the cytoplasm, or unspecialized protoplasm.

K Karyapsis—fusion of the nuclei, or nuclear protoplasm.

Ⓢ Synapsis—fusion of the chromatin elements.


Heterotypic and homotypic divisions following synapsis.

OOOO Nuclei of haplogamic phase—structures composed of simple cells having nuclei and chromatin elements completely fused.

8888 Nuclei of apaylogamic phase—structures composed of double cells, each having two unfused nuclei.

θθθ Nuclei of paragamic phase—structures composed of double cells having single nuclei containing unfused chromosomes.

[ ] Cell, at periods where the organism is reduced to a single cell.


The expanded egg.

EXPLANATION OF FIGURES.

FIG. 1.—Lower organism, such as Sphaeroplea, having only simple-celled (haplogamic) tissues. The fertilized egg undergoes no development beyond merely splitting up into four spores when it germinates.

FIG. 2.—Higher fungus, such as Agaricus or Puccinia, showing alternation of simple-celled and double-celled phases, the latter apaylogamic, i. e., with two unfused parental nuclei in each cell. The fertilized egg has expanded into a mass of apaylogamic tissue.

FIG. 3.—Moss, showing alternation of a long simple-celled and a short double-celled phase, the latter paragamic, i. e., with parental nuclei fused but with their chromosomes still distinct and unfused. The fertilized egg has expanded slightly into a mass of paragamic tissue.

FIG. 4.—Fern, showing alternating phases as in moss (figure 3), but with a short simple-celled phase and a long double-celled phase, the paragamic phase having developed at the expense of the haplogamic. The fertilized egg has expanded very much into a mass of paragamic tissue.

FIG. 5.—Flowering plant (phanerogam), showing alternation of a very short simple-celled phase with a very long double-celled phase, the paragamic phase having developed greatly at the expense of the haplogamic. The egg mother-cell develops only one cell (macrospore). The fertilized egg expands into a large mass of paragamic tissue in which the greatly reduced haplogamic phase develops in a semiparasitic manner, it having no free existence.

FIG. 6.—Higher animal, having only double-celled tissues, the haplogamic phase having been completely suppressed by the greatly expanded paragamic phase. The egg mother-cell develops only one egg. The fertilized egg has expanded into a large mass of tissue.

O

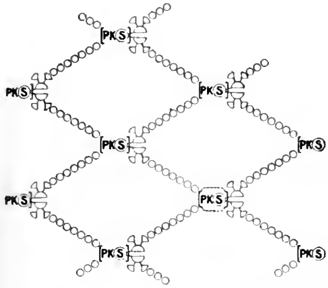


FIG. I.—LOWER ORGANISM.

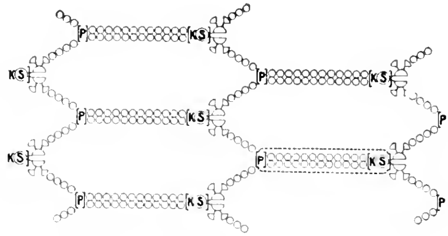


FIG. 2. HIGHER FUNGUS.

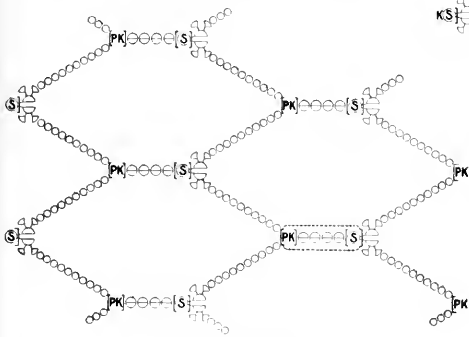


FIG. 3.—MOSS.

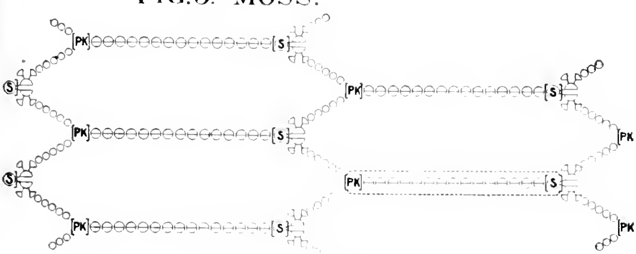


FIG. 4.—FERN.

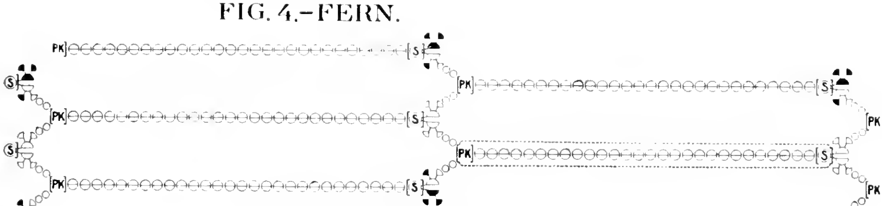


FIG. 5.—FLOWERING PLANT.

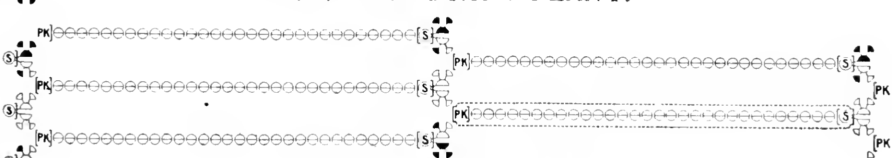


FIG. 6.—HIGHER ANIMAL.

DIAGRAM ILLUSTRATING THE NETWORK OF DESCENT, SUCCESSION OF GENERATIONS, ALTERNATING PHASES, AND EXPANSION OF THE FERTILIZED EGG.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 82.

B. T. GALLOWAY, *Chief of Bureau.*

GRASS LANDS OF THE SOUTH ALASKA COAST.

BY

C. V. PIPER,
Agrostologist in Charge of Forage Plant Introduction.

GRASS AND FORAGE PLANT INVESTIGATIONS.

Issued August 22, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Government Printing Office, Washington, D. C.

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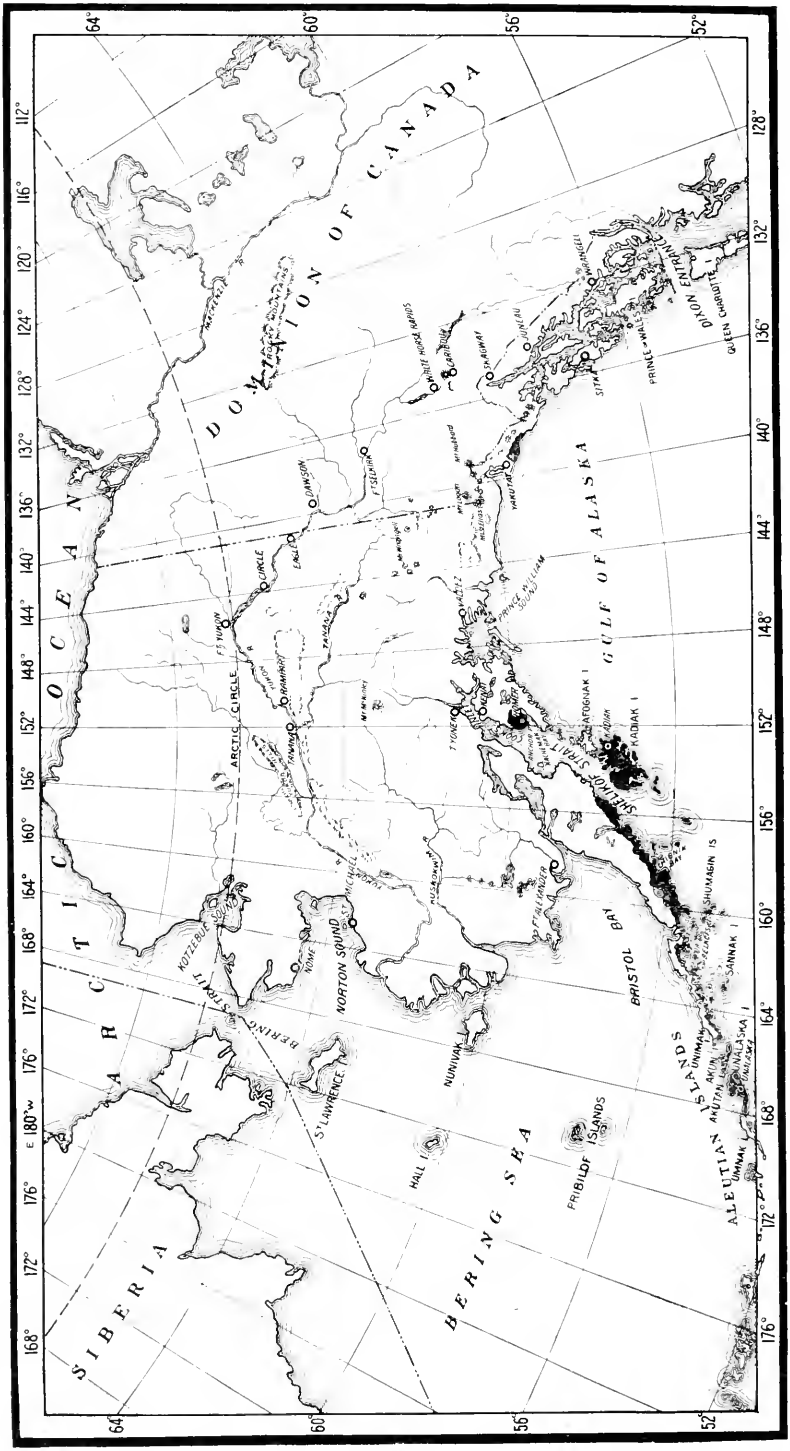

MAP OF ALASKA.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 82.

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1905.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., May 19, 1905.

SIR: I have the honor to transmit herewith a paper entitled "Grass Lands of the South Alaska Coast," and to recommend that it be published as Bulletin No. 82 of the series of this Bureau.

This paper was prepared by Mr. C. V. Piper, Agrostologist in Charge of Introduction of Grasses and Forage Plants, Grass and Forage Plant Investigations, and has been submitted by the Agrostologist with a view to publication.

The four plates accompanying the paper are necessary to a proper understanding of the text.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

Since the discovery of gold in Alaska in 1897 continuous calls for information concerning the agricultural possibilities of the Alaska Peninsula have come to the Department of Agriculture. Much valuable information on this topic has been secured by the Office of Experiment Stations largely through the Alaska experiment stations at Sitka, Kenai, and Copper Center in charge of Prof. C. C. Georgeson, but as the work of these experiment stations was necessarily largely local in character, and as it was highly desirable to study conditions in sections remote from the stations, the Office of Experiment Stations requested the Bureau of Plant Industry to send some one to explore as large an area of the Alaskan country as might be feasible. Accordingly Prof. C. V. Piper, of the Office of Grass and Forage Plant Investigations, was detailed to make this exploration under the joint auspices of the Office of Experiment Stations and the Bureau of Plant Industry. The summer of 1904 was spent in this work. The area explored is shown in black on the map constituting Plate I. Many interesting facts relating to agricultural possibilities in the region covered were recorded, and Professor Piper discusses them in the following pages in detail.

For further information concerning the results of this exploration the reader is referred to the Annual Report of the Office of Experiment Stations for the year 1904.

W. J. Spillman, *Agrostologist.*

Office of Grass and Forage Plant Investigations,
Washington, D. C., April 14, 1905.

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II. Fig. 1.—A view of the flat lands lying at the head of Woman's Bay, Kadiak Island, Alaska. Fig. 2.—Mowing beach rye on Kadiak Island, Alaska 38

III. Bluetop (*Calamagrostis langsdorfii*), 6 feet high, on Kadiak Island, Alaska, July, 1904 38

IV. Fig. 1.—A view of Kadiak, Alaska, November 7, 1903. Fig. 2.—A different view of Kadiak, March 26, 1904 38

GRASS LANDS OF THE SOUTH ALASKA COAST.

INTRODUCTION.

A glance at the accompanying map of Alaska (Pl. I) will show that the coast line beginning at Dixon Entrance, in longitude 132°, latitude 54° 30′, and extending to Unalaska, in longitude 166° and latitude 54°, is nearly in the form of a semicircle, or, rather, of a half ellipse, the east and west diameter of which would be about 2,000 miles and the north and south diameter about half this distance. Near the northernmost part of this coast line are two large inlets, the eastern one Prince William Sound, the western one Cook Inlet. It will be further noticed that islands are very numerous on the coast and that the coast line is much indented by narrow inlets or fiords, a fact better shown on larger maps. The principal places mentioned in this paper are likewise indicated on the map. Officially, the region from Mount Saint Elias eastward is known as southeastern Alaska, that west of this peak as southwestern Alaska. From an agricultural standpoint, however, there is a much better and very marked dividing line. From Cook Inlet eastward practically all of the lands lying near the coast are densely timbered up to an altitude of 2,000 to 3,000 feet. From Cook Inlet westward, excepting Afognak Island and a small portion of Kadiak Island, the lands are devoid of timber, and are for the most part grass covered.

The total area of the coast grass lands is about 10,000 square miles, nearly all of which lies between Cook Inlet and Unalaska, a distance of about 700 miles. At least one-half of this land would seem capable, in time at least, of profitable utilization. From various causes it has remained until now practically unused.

South Alaska is a mountainous country, a great range of snow-capped peaks on the mainland paralleling the entire coast. Eastward from Cook Inlet great numbers of glaciers arise in the higher mountains, and many of these rivers of ice extend downward to the sea. Westward from Cook Inlet no glaciers reach the sea, although many of the mountain peaks are from 5,000 to 8,000 feet high. This striking difference apparently depends on a much smaller annual rainfall and snowfall.

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In general the lands are hilly, sometimes rising abruptly from the seashore, but seldom too steep to afford a luxuriant grass covering. More often, however, the hills near the coast are low and rounded, with intervening valleys. In places there are wide areas contiguous to the coast of from 100 to 1,000 feet elevation and comparatively level. Most of the smaller islands, too, have comparatively gentle slopes, and either are under 1,000 feet elevation or have but few hills reaching above that height. The coast line everywhere is indented by numerous bays or inlets, into many of which rivers flow. At the heads of these bays there are, as a rule, considerable areas of flat or nearly flat lands. Such locations naturally afford the most advantageous sites for agricultural settlements, especially as these flat lands are exceedingly well grassed, and with little preliminary labor can be prepared for mowing.

Where the land is level it is very likely to be wet and covered with a growth of peat moss. Under such circumstances it supports but a scanty vegetation. Even on the hillsides this peat moss may become established, and where it does so the grasses quickly become less luxuriant. The decay of this moss and of other vegetation results in the formation of a humous soil, very retentive of moisture. So deep does this humus become that the real soil is often entirely concealed. Where it is possible to destroy this moss by burning, the result is always a heavy crop of grass or other plants. Most of the land that lies at less than 1,000 feet elevation is covered by a most luxuriant growth of native grasses. Over large areas these grasses are frequently 6 feet high, thus furnishing a large quantity of fodder. On the remaining areas, lying at higher elevations or on exposed slopes, the grasses are too short to cut for hay, but furnish splendid grazing.

That grass in Alaska is exceedingly abundant and fairly nutritious and that cattle will thrive upon it are facts beyond question. But these facts in themselves are not sufficient to enable a prospective settler thinking of engaging in stock raising to determine whether or not such a venture would be likely to prove profitable. The mere abundance of grass of fair quality is not sufficient to insure success in stock raising in an isolated region like that under consideration.

The following statements regarding the Alaska grass lands and the factors that have a bearing on their profitable utilization are based on as complete a survey as one season's work would permit, together with the facts previously recorded by reliable authorities. A detailed report of the conditions actually observed will appear in the Annual Report of the Office of Experiment Stations for 1904. The present bulletin designs rather to cite these facts in their bearing upon the south Alaska grass lands as a desirable field for stock raising.

THE LOCATION OF THE GRASS LANDS.

The accompanying map (Pl. I) indicates the general location of the southern Alaska areas which are covered with grasses. These areas differ considerably in detail and are here discussed separately.

KADIAK ISLAND.

Kadiak Island, which lies off the mouth of Cook Inlet, is about 100 miles long by 50 miles wide. It is mountainous in character, the hills rising more or less gently from near the seashore to heights of 1,000 to 3,000 feet. At the end of July, 1904, there was still considerable snow at 2,000 feet (Pl. IV), but this is said to be quite unusual. This island, like most of the Alaska coast, is much cut into by long, narrow bays, into most of which flow streams. The flat lands lying at the deltas of these streams are, as a rule, very heavily covered with grasses (Pl. II). The slopes also, up to an altitude of 1,500 feet, are well grassed, except where there are thickets of alder or willow; but these slopes are usually too steep to utilize otherwise than by grazing. The total area of these hillside lands is much greater than that of the approximately level stretches, in the proportion of at least 20 to 1.

On the hillsides the principal grass is bluetop (*Calamagrostis langsdorfii*), which often covers large areas in a pure growth. This was exceedingly fine on hillsides burned over in March, by which means the old straw and moss were destroyed, thus permitting better drainage and making the soil warmer. In such places this grass is often 6 feet high. On the contrary, if the hills are burned over in June the fire is likely to kill the grass roots as well as the moss, with the result that fireweed usually takes possession of the ground.

Other grasses than bluetop on the hillsides are relatively unimportant, though sometimes considerable areas of Siberian fescue occur, and on the higher slopes are a number of low grasses of forage value.

On the flat lands before mentioned the tall beach sedge (*Carex cryptocarpa*) forms a broad fringe along the shores of the bays and sloughs, especially on lands which are occasionally covered by tide water. Back of this sedge, beach rye (*Elymus mollis*) forms a more or less broad zone, often mixed with patches of a coarse bluegrass (*Poa glumaris*). In the still drier portions bluetop occupies the ground almost exclusively. The three plants mentioned furnish the great bulk of forage on Kadiak Island, and indeed on most parts of the Alaskan coast, but the bluetop is more abundant than all of the other grasses combined.

Bluetop has slender stems and thin leaves, thus curing very readily and making a sweet and palatable hay. Beach rye, on the contrary, has thick stems and thick leaves, in consequence of which it cures slowly. Beach sedge has a three-sided, solid, pithy stem, and is therefore very difficult to dry. All three of these plants grow so luxuriantly that they often yield 3 tons of hay or more per acre.

Of forage plants other than grasses the lupine and fireweed, hereafter described, are both abundant. In a green state they are readily eaten by sheep, but cattle prefer the grasses.

In portions of the island which have been more or less closely grazed for some years it was noticeable that the taller wild grasses had largely disappeared, being replaced principally by bluegrass (*Poa pratensis*) and wild barley (*Hordeum boreale*). Cattle seem to be much more fond of the former than of the latter grass, although in parts of northern Europe the wild barley is considered a most excellent grass.

All of Kadiak Island, except a small portion in the extreme northeast, is practically timberless, as are most of the adjacent islands. In the valleys, however, there is usually a small number of cottonwoods and willows, and on wet slopes scrub willows and alders form dense thickets. Afognak Island, however, which lies northeast of Kadiak, is quite densely covered with spruce.

ALASKA PENINSULA AND ADJACENT ISLANDS.

The whole region to the west of Kadiak Island might briefly be described as similar to that island, but entirely devoid of timber, the shrubs being more scrubby and the grasses less luxuriant. The peninsula itself is very mountainous, and for considerable stretches along the coast the hills rise abruptly from the water's edge. In the bays and inlets, however, there are frequently considerable areas of comparatively level lands well grassed, though seldom as luxuriantly covered as those before mentioned. The islands lying off the coast are comparatively low, and some of them are said to be exceedingly well adapted to stock raising. Such areas as were examined indicate that in general there is a greater variety of forage grasses than to the eastward, but most of them are smaller in size.

At the present time there is a mail steamer plying once a month between Valdez and Unalaska. This boat carries the mail, and stops at such points as business demands. The population of this entire region is exceedingly sparse, and many of the outlying islands would probably have to be reached by means of sailing craft.

UNALASKA AND THE NEIGHBORING ISLANDS.

Unalaska and the neighboring islands differ on the whole comparatively little from Kadiak Island, though the vegetation as a rule is decidedly less luxuriant. The grasses are much the same in kind, although differing in their relative abundance. Some difficulty would be experienced on these islands in finding sufficient tall grass to furnish winter fodder in case large quantities were necessary, though in some of the more sheltered valleys small areas were observed where the grasses were very tall. There is quite a herd of cattle at Unalaska which, according to local reports, receive but very slight attention during the winter, only a small quantity of feed being cut for them. The principal advantage of Unalaska and the neighboring islands would seem to lie in the fact that they are on the line of travel of the vessels going to the Yukon and to Nome. If sufficient numbers of cattle were raised on these islands, doubtless little difficulty would be experienced in finding a market for them at the above-mentioned points. Indeed, a Seattle company, which purposes, among other things, to engage in cattle raising primarily for these northern markets, has already begun operations on Akun Island.

KENAI PENINSULA.

Kenai is the name given to the large peninsula lying between Cook Inlet and the Gulf of Alaska. That portion of it on the east side of Cook Inlet and north of Kachemak Bay, comprising an area 100 miles long by 20 to 30 miles wide, is an extensive plateau. Its southern portion, on Kachemak Bay, lies 500 to 1,000 feet or more above the sea level. It slopes mainly to the westward, so that that part from Anchor Point northward is but 100 to 200 feet above the sea level. Most of this land is timbered with spruce, but there are considerable areas of grass near Anchor Point, near Homer, and on the north side of Kachemak Bay.

At Homer there is an extensive sand spit, about 4 miles in length and from one-fourth to 1 mile across, which supports a good growth of several grasses and sedges. Beach rye is the most important and most abundant, but red fescue, bluegrass, and seashore grass furnish considerable grazing. At the base of the spit the land rises gradually to the high plateau above, the scattered timber giving the appearance of mountain parks. The open portions of this land support a luxuriant growth of bluetop, often 6 feet tall. At a rough estimate the open grass lands in this vicinity comprise about 2,000 acres.

The site of a proposed Finnish colony is on the north side of Kachemak Bay, not far from its head. From the colony site to the head of the bay are extensive tide flats, which are mainly covered with sedges about 2 feet high. The marshy nature of these lands, together with the coarse nature of the forage, makes them of but limited value. Undoubtedly they can be much improved by diking.

The grass lands of the colony site proper consist of about 500 acres of excellent land, covered with a luxuriant growth of bluetop. These lands lie close to the seashore and less than 100 feet above it. Back of these lands are hills 500 to 1,500 feet high, the plateau on the top of which consists in part of extensive grass areas. Much of this grass is bluetop, often 6 feet high. Other areas are pure growths of Siberian fescue. Interspersed with these are several other good grasses, but none of them in great quantity. These plateau grass lands are apparently very extensive. To render them accessible will, however, require the building of roads or trails up to the easiest slopes. At Anchor Point there is but little grass land near the seashore, but on the plateau behind are considerable areas much like those just described. The plateau at this point is, however, much lower.

An important circumstance in relation to all of the grass lands of this region lies in the fact that they are underlaid with coal, which is exposed for miles in the bluffs along the coast. In view of this fact it is doubtful if title to the land can be gained by homesteading it.

At Kenai there are no naturally grassed lands, except the sand dunes along the beach and the marshes lying inside of them. The dunes are covered principally with beach rye and bighead sedge (*Carex macrocephala*). In the brackish marshes red fescue and seashore grass are plentiful. Here also is found poison parsnip (*Cicuta douglasii*) in small marshes, and there is a record of some native cows having been killed by it several years ago.

THE YAKUTAT PLAINS.

The only extensive areas of grass lands known in southeastern Alaska are those lying in the river valleys near the coast south of Yakutat. Inasmuch as these lands have been several times referred to in reports, and as they are now in part accessible owing to the building of the Yakutat and Southern Railway, a careful examination was made of them. The above-mentioned railway has been built primarily to reach the several rich salmon streams flowing into the ocean south of Yakutat, it being impracticable to fish them by approach from the ocean. This railway is projected to be built to the Alsek River, a distance of 45 miles. At present it is built only to the Setuck River, 10 miles from Yakutat.

Practically the whole of this region is an old glacial moraine, composed of fine gravel, which slopes very gently to the seashore. The land close to the seashore is somewhat higher than that lying behind, and is heavily timbered. Owing to this strip of higher land most of the streams flow parallel to the coast for some distance near their debouchments. It is along the valleys of these streams that the grass lands lie, but owing to the flatness of the land and the slight elevation above the sea level they are very ill-drained, notwithstanding the gravelly nature of the soil.

Traveling along these rivers in a canoe one receives the impression that the grass is tall and rank on these flat lands. This, in fact, is the case on a very narrow strip just along the river banks, where there is a fine growth of bluetop (*Calamagrostis langsdorfii*) and sedge (*Carex sitchensis* Presc.). This strip of tall grass is, however, nearly always confined to the immediate banks of the rivers. The great mass of the land is covered with a thin layer of bog moss, which supports but a scant vegetation of grass and sedges less than a foot high.

It is a conservative statement to say that fully 80 per cent of these Yakutat grass lands are thus scantily grassed. Apart from this scant amount of grass, which practically precludes the cutting of winter forage, another serious difficulty presents itself in the fact that poison parsnip (*Cicuta douglasii*) occurs quite plentifully over all the land that is the least boggy, which, as before stated, is 80 per cent of the area. Thus, even if these meadows were used only for grazing, great care would need to be exercised in the spring, when grass is scanty and the sweet but very poisonous tubers of this plant are frequently forced to the surface by the frost.

While the above statements are true concerning the Yakutat meadows as a whole, there are small areas which are exceptional. For example, along the lower Ankow River occurs a narrow strip of several hundred acres well grassed with silver-top (*Deschampsia cæspitosa*) and beach rye (*Elymus mollis*) and free from Cicuta. Care would need to be exercised in utilizing even this, as the surrounding boggy lands bear an abundance of poison parsnip.

Again, the strip of land lying just within the ocean dunes is often well grassed with beach rye and red fescue (*Festuca rubra*).

A particularly good area of arable land lies along the railway where it reaches the Setuck River. This consists of 3 or 4 square miles of gravelly, well-drained, level land, at present looking much like a worn-out meadow. It is apparently very well adapted to such cultivated grasses as smooth brome-grass and tall meadow oat-grass. It will undoubtedly grow all sorts of hardy vegetables. The present grass covering is rather scanty, but it is probable that this can be greatly increased by cultivation. This particular piece of land is well worthy of the attention of homesteaders.

It is within the bounds of possibility that the larger part of the Yakutat plain can be drained and made into fine meadow lands. In its present state, however, this land is not adapted to stock raising, with the exception of such small areas as above noted.

IMPORTANT FACTORS RELATING TO THE AGRICULTURAL VALUE OF THE GRASS LANDS.

In determining whether or not the grass lands previously described offer a desirable field for settlement, a number of factors that bear more or less directly upon the problem need consideration. These factors may be discussed in the following sequence:

(1) The abundance and permanence of the feeds available.
(2) The possibility of raising forage on cultivated lands.
(3) The known facts in regard to live-stock raising.
(4) The available markets.
(5) Transportation facilities and freight rates.
(6) The desirability of south Alaska as a home.
(7) The choice of a location

THE ABUNDANCE AND PERMANENCE OF NATIVE FODDER PLANTS.

Live-stock husbandry in Alaska will have to depend primarily upon the native plants, supplemented in time, perhaps, by such additional ones as experiments shall indicate may compete with the native plants, or which upon cultivated land will yield heavily enough to be profitable. The most important and abundant of the native forage plants are as follows:

Bluetop.—Bluetop (*Calamagrostis langsdorfii*) is by far the most plentiful tall grass in Alaska, growing along the whole coast. On Kadiak Island and the Kenai Peninsula it is especially abundant, often being 6 feet high and very dense (Pl. III). It grows with special luxuriance on hillsides that have been burned over early in the spring. This burning destroys the moss, and thus makes the soil better drained and warmer. Bluetop also flourishes on the level boggy lands, but prefers a well-drained soil. Owing to its thin stems and leaves it cures very readily, and is therefore the usual hay grass of Alaska. It is often called redtop, but this name should be restricted to the true redtop, a very different grass.

There are no accurate data bearing on the point as to how well this grass will withstand continued cutting, but the general belief is that it rapidly becomes thinner in stand. It is noticeable about villages where cows are kept that the bluetop is scarce, being replaced by other grasses, especially bluegrass and wild barley. The area of bluetop is so great, however, that in many places it would be quite practicable to manage so as not to cut the same plats two years in succession, which practice would probably maintain the density of the stand.

Beach rye.—Along all the quiet shores and inlets of Alaska, wherever there is low land near the beach, there is a strip of beach rye (*Elymus mollis*) occurring just above high-tide level. Sometimes this strip is only a few feet wide, but on the low level lands near the heads of fiords there are often large areas of it 3 to 5 feet high (Pl. II, fig. 2). One patch of it examined had been cut the year previous, and on this the stand was scarcely half as dense as on neighboring pieces which had not been cut. This observation accords with the experience of others.

Where sand dunes occur on the coast, as at Kenai and near Yakutat, beach rye is an important sand binder. In such locations it is often very different in appearance from that found in other situations, the heads being short and thick. This is the result of infestation by a parasitic worm.

Bluegrass.—The true Kentucky bluegrass (*Poa pratensis*) is common all along the Alaska coast, where it thrives to perfection. It shows a tendency to occupy the ground where closely grazed, and cattle exhibit a marked preference for it. Several closely allied species also occur, and it is an important fact that they persist and increase where other grasses disappear, which seems to insure the permanence of pasturage of a high quality.

Silver-top.—The very nutritious grasses known as silver-top (*Deschampsia cæspitosa* and *D. bottnica*) occur in some abundance, especially in gravelly soils, whether on the hillsides or near the seashore. Owing to their stems being nearly leafless they yield but little hay, but the numerous fine basal leaves furnish most excellent forage.

Siberian fescue.—Siberian fescue (*Festuca altaica*) makes large tussocks, especially in gravelly soil and in open timber up to 1,000 feet elevation. In such locations it often makes a nearly pure growth It seems to be fully as nutritious as the well-known sheep fescue, but is a much larger grass.

Sedges.—Two tall species of sedge, *Carex cryptocarpa* and *C. sitchensis*, in places make dense stands 3 feet high or more, especially in wet soil; in the case of the former, more especially in tidal marshes. Considerable quantities of this sedge were cut for hay near Kadiak, and it is said to furnish excellent feed. These sedges are both quite smooth and soft, unlike most others.

Alaska lupine.—The blue-flowered plant known as Alaska lupine (*Lupinus unalaschensis*) is quite tall, often 3 feet high, and sometimes occupies large areas almost to the exclusion of other plants. It is thick leaved and rather fleshy, and is the only leguminous plant that is really abundant in Alaska. Sheep eat it readily. Should it prove palatable as well as nutritious to cattle the problem of a good winter ration for milch cows would be considerably simplified. Experiments with it as silage, both pure and mixed with grass, are much to be desired.

With the exception of this plant the only legumes of forage value in the grass regions are two species of wild pea, both of which, unfortunately, are rather scarce.

Fireweed.—The well-known plant called fireweed (*Epilobium angustifolium*) often occupies the ground to the exclusion of others, especially where the land has been burned over in summer and the grass roots thus destroyed. Sheep seem fond of it. It is possible that this plant may prove profitable as silage, at least when mixed with grasses, but no tests with this end in view seem to have been made. Its great abundance at times makes such a test desirable.

There are three possible ways of preserving the above-mentioned plants for winter feed. The more easily dried—as bluetop and bluegrass—may be made into hay. Continued sunshiny weather on the Alaska coast is not to be depended upon, so that haymaking is accomplished only with much uncertainty. Where one needs but a small amount of fodder, little difficulty is experienced in selecting the few necessary sunshiny days. Where, on the contrary, one needs great quantities of winter feed, haymaking is impracticable. Resort in such cases must be had either to brown hay or to silage. Brown hay is simply half-cured hay, made by stacking the grass green or half dry—really a compromise between hay and silage. Sometimes salt is scattered over the layers while it is being stacked. It is more or less used in all countries where haymaking is difficult. While analyses show it to contain practically as much nutriment as hay or silage, cattle are not eager for it, and it can be considered only an emergency feed.

Unquestionably when large quantities of winter forage are needed for stock, silage must be depended upon, and undoubtedly, all things considered, it will be the most satisfactory feed. Practically the only Alaska forage plant thus far used as silage is beach rye, and the experiences with this plant of Prof. C. C. Georgeson, special agent in charge of the Alaska Agricultural Experiment Stations, and of others who have grown it, show it to be both palatable and nutritious. In all probability other Alaskan grasses, and perhaps other plants, will be found to be quite as satisfactory.

Where timber is available silos may be constructed of logs, like the one at the Sitka Experiment Station. This silo has the advantage of enabling a man to utilize his own labor. On the other hand, the material for stave silos can be secured at very reasonable prices, and this doubtless is the best silo to use in the timberless regions.

FOOD VALUE OF NATIVE ALASKAN GRASSES.

Chemical analyses have been made of the principal Alaskan grasses, and while these can be properly interpreted only in connection with digestion experiments, their comparison with the analyses of standard grasses furnishes some measure of their value.

Analyses of Alaskan grasses (air-dried samples taken when in flower).

Species	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calamagrostis langsdorfii (Bluetop)	7.18	4.58	1.03	40.37	42.94	3.90
Carex cryptocarpa (Sedge)	5.85	10.32	2.12	45.34	25.72	10.65
Elymus mollis (Beach rye)	11.92	12.71	2.26	35.29	30.31	7.51
Phleum pratense (Timothy)	8.59	8.94	2.14	45.69	30.06	4.58
Poa pratensis (Bluegrass)	8.11	8.94	2.04	41.45	34.24	5.22
Deschampsia bottnica (Silver-top)	8.75	7.44	2.07	47.05	31.54	4.15
Calamagrostis aleutica	8.33	10.00	1.37	37.89	38.89	4.52

Analyses of standard grasses for comparison.

Species.	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Poa pratensis (Bluegrass)	17.44	10.80	3.45	46.10	22.09	7.35
Agrostis alba (Redtop)	14.30	8.48	2.84	46.77	21.71	5.90
Phleum pratense (Timothy)	15.01	6.01	3.01	41.90	29.59	4.48
Dactylis glomerata (Orchard grass)	14.30	7.34	2.28	47.08	23.58	5.42
Deschampsia cæspitosa (Silver-top)	14.30	9.04	1.06	37.20	29.03	9.37
Calamagrostis canadensis (Bluejoint)	6.87	11.19	3.45	35.82	37.18	5.49

The analyses of the Alaskan grasses were all made by the Bureau of Chemistry of the Department of Argiculture, and with the exception of the first three, from material collected in 1904, were originally published in Bulletin No. 48, Office of Experiment Stations. The other analyses have been compiled from various authorities.

CULTIVABLE FORAGE CROPS.

The experiences of a number of individual investigators, as well as the tests made at the Sitka and Kenai experiment stations, throw a good deal of light on the possibility of growing fodder plants and forage crops on cultivated land. Much more testing is necessary, however, before some of the conclusions which at present seem probable can be considered demonstrated.

In the way of grasses the tests made at Sitka by Professor Georgeson on muck soils showed tall meadow oat-grass to be the most promising. Tall fescue, bluegrass, meadow foxtail, and redtop did fairly well, while orchard grass, timothy, and Italian rye-grass were not promising. From observations on a number of these and other grasses introduced by chance, some rather definite conclusions may be drawn. Timothy is more or less abundantly introduced at various places on the coast, but does not as a rule thrive very well, being often inferior in size to the native mountain timothy. It is altogether probable, however, that a variety of timothy suited to the conditions might readily be secured by selection, as chance specimens of the plant seen were very fine. The success of such a selection, however, will largely depend on the possibility of growing seed in Alaska.

Among other useful grasses that have become accidentally introduced and show marked adaptability to the conditions are redtop, rough-stalk meadow grass, bluegrass, and fowl meadow grass.

White clover thrives everywhere along the coast and is an aggressive plant. Red clover and alsike are not promising and alfalfa does not thrive.

In the way of cereals, the earliest varieties of oats and barley will mature for two or possibly three out of five seasons. Of course, such a crop is not entirely lost if the grain fails to mature, as it can be utilized as hay or silage. On this account it will probably be wisest to grow the crop mixed with field peas, as such a mixture will make excellent silage, whereas oats alone could only be preserved as hay, a difficult thing to do so late in the season. It is to be clearly understood that under present conditions it is unnecessary to plant any cultivated ground in such crops as grass, or perhaps even legumes. The above facts are of value simply as indicating what well-known forage plants will thrive, thus to some extent showing the future agricultural possibilities of Alaska.

SILAGE ALONE AS A RATION FOR MILCH COWS.

The writer has been unable to find any published data on results obtained by feeding milch cows nothing but grass silage. Presumably the best of results would not thus be obtained.

In order to obtain some light on the subject, Dr. James Withycombe, director of the Oregon Experiment Station, was requested to conduct such a test. The results of his experiment are reported as follows:

The silage test was made on a nonbreeding Jersey cow which freshened in February, 1902. In January, 1904, this cow was fed largely on silage, with a moderate amount of mill feed and light ration of hay as a preliminary preparation. From February 1 to April 30 she was fed wholly on corn silage and a light ration of ground oats daily. She consumed during the ninety days' feeding 3,785 pounds of corn silage and 270 pounds of the oat chop. The following table shows variation in weight and her production:

Date.	Weight.	Milk.	Average test.	Fat.	Date.	Weight.	Milk.	Average test.	Fat.
	Lbs.	*Lbs.*	*P. ct.*	*Lbs.*		*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*
December 1	955	196	5.8	11.36	March 1	925	195	5.8	11.31
January 1	945	199	5.9	11.74	April 1	890	221	5.5	12.15
February 1	905	178	5.7	10.15	April 30	860			

The cow was in good condition at the close of the experiment, which indicates that silage may with safety constitute a large portion of the ration of a dairy cow.

This experiment was undertaken at the suggestion of the Government agrostologist to determine in a measure if it were practicable to winter cattle in Alaska on grass silage.

The 3 pounds of ground oats were fed daily for the purpose of bringing the corn silage up to a protein standard equaling that of mixed-grass silage.

Protein percentage of feed consumed.

Ground oats	11.56
Corn silage	1.58
Protein percentage of grass silage (approximately)	2.72

Average amount of total protein consumed daily in 42 pounds of corn silage and 3 pounds of ground oats, 1.01 pounds. Approximate amount of protein contained in 40 pounds of grass silage, 1.08 pounds.

It will thus be seen that this test indicates that cattle can be successfully wintered on grass silage and that dairy cows may be expected to yield a reasonable amount of milk when fed exclusively on this feed.

ALASKAN EXPERIENCE IN STOCK RAISING.

Hogs.—A few hogs were seen at various Alaska villages. They are fed refuse, and graze on various succulent plants when obtainable. They are very fond of wild rice, the bulb of a lilylike plant (*Fritillaria kamtschatica*), which, however, is not very abundant. Unfortunately these animals are prone to feed on fish offal and other sea refuse, and as a consequence their flesh has a disagreeable flavor. Unquestionably there is too little feed adapted to hogs to make their raising profitable in Alaska.

Goats.—Angora goats have been tested by the Alaska Commercial Company at Kadiak and by Rev. C. P. Coe at Wood Island. According to Mr. Washburn, formerly resident superintendent of the Alaska Commercial Company at Kadiak, the company had a few years ago about 50 head of these animals on Ukamak Island, near Kadiak, which were entirely self-sustaining, increasing about 60 per cent each year. The mohair is said to have been good, both in quantity and quality.

Rev. C. P. Coe, of Wood Island, has several head of Angora goats which have passed the last two winters with but little care. This year his herd has shown very satisfactory increase, and no difficulty is anticipated in wintering the kids. A large part of their feed is derived from willows and other browse, and where this is abundant the animals need but little feed in winter. Owing to their tractability and the ease with which they are kept, especially where browse is abundant, Angora goats should prove most useful animals both for the natives and for whites.

Sheep husbandry.—Two definite attempts have been made to establish sheep raising in south Alaska, though small numbers have been kept at various points for short periods. The first attempt was made by the Alaska Commercial Company, which in 1883 imported a band of about 300 sheep from California. Unfortunately no accurate record of this experiment is available, and the accounts of various persons differ considerably. Many of the sheep died the first winter, according to some reports from lack of shelter, according to others from scab. The remainder were kept on a small island near Kadiak, where the only shelter was a small grove of spruce, but in winter they were usually transferred to new grazing grounds where they could feed on the tall, dry grass. In very severe weather they were sometimes sheltered and fed hay. These sheep are said to have yielded about 5 pounds of excellent wool per head each year, and the annual increase is reported to have been about 60 per cent of the adult animals. No particular care was given them, and the last were slaughtered about six years ago. The venture, even excluding the loss of the first winter, seems not to have been profitable.

The only sheep now in Alaska are on the ranch of the Frye-Bruhn Company, near Kadiak, who have about 80 head. These sheep are the remnant of 9,000 which were shipped in from Oregon in 1902 and 1903, the remainder having perished. At first sight it would seem that this appalling loss of more than 98 per cent was conclusive evidence that sheep raising in Alaska is not likely to prove profitable. Inquiry into the causes of the mortality do not bear out this conclusion necessarily. About 500 of the sheep were drowned in March, 1903, by being caught at the head of a narrow cove by the incoming tide. One hundred and fifty head were lost by becoming frightened and jumping over cliffs. The rest of those that died succumbed to scab, which broke out in January, 1903. Owing to lack of shelter it was then impossible to treat them by dipping, as that would practically have been equivalent to killing them. The result was that all but 80 died of the disease. Thus all the mortality was due to causes entirely preventable. It was interesting to learn that several head of these sheep which ran wild survived the winter without care, and the writer was informed by trustworthy witnesses of other cases of this kind. In the light of present knowledge it is difficult to say whether sheep can be profitably raised in southwestern Alaska.

In regard to the two attempts which have been made, it is noteworthy that in both instances the animals were shipped from a comparatively warm and dry climate to one cool and notably wet; furthermore, that none of them perished from any cause directly connected with the Alaska conditions.

There are, however, some further difficulties in connection with sheep raising in Alaska which need careful consideration. It is the general opinion in Kadiak that in an ordinary winter sheep can not safely be left without care after the beginning of January. Indeed, many would place the time a month or six weeks earlier. New grass never appears before May 15, and often not until June 1. Therefore, under the best of conditions, sheep will need four and a half months of feeding and shelter. The superintendent of the Frye-Bruhn ranch, after one winter's experience, thinks that feed and shelter should be given for a longer period than that mentioned.

Another serious difficulty lies in the lateness of the lambing season. It is generally agreed that lambing should not take place before June 1. The lambs will need shelter and feed by December 1 or earlier, unless one takes serious chances of losing many.

Whether sheep raising could be made profitable at present under such conditions remains to be demonstrated. The mere fact that sheep in small numbers have wintered without care is no proof that successful sheep husbandry can thus be carried on, nor even that one or two months' feeding will suffice. The risks involved in such a procedure are too great to warrant a careful stock raiser in taking any chances.

Destructive wild animals are no menace to sheep raising on the islands. Eagles may destroy a few lambs, but these birds are easily exterminated. Kadiak bears are too scarce and too easily destroyed to merit consideration. On the mainland, however, both wolves and brown bears may prove troublesome.

In the light of present knowledge one is safe in saying that sheep can be raised on the Alaska coast if adults are given five months' feed and shelter and the lambs a month more—this with the ordinary sheep of the western ranges. With more hardy breeds better adapted to the conditions the outlook for success would be better. It need hardly be said that extreme caution should be taken to import only perfectly healthy animals. The great mortality caused by scab and the great danger of such a disease as foot-rot in a damp climate demand that extreme care be taken not to introduce these diseases.

Cattle.—Cattle have been raised at nearly all the Alaskan coast settlements ever since the Russian occupation. Some of the original stock, according to local tradition, is still represented in the band of cattle at Nannilchuck. These are small animals, but said to be very hardy. Nearly all of the cattle kept near the villages are milch cows, mostly grades, but a number of Holsteins and Jerseys were seen. When owned by whites the animals are given shelter and feed for about five months. When they belong to the natives they are forced to exist through the winter with little or no care, eking out an existence by feeding on browse and seaweeds. No accurate data could be gathered concerning the amount and character of the milk yield, but it was universally said that the milk is most excellent in summer, and good in winter when the animals are properly fed. It is unfortunate that no accurate records could be obtained as to the winter yield of cows fed only on native hay or silage.

Several herds of beef cattle have been successfully maintained in the neighborhood of Kadiak. The experience of the Alaska Commercial Company is thus summarized by Mr. Washburn, the former superintendent at Kadiak:

> We have bred stock on the islands of Kadiak, Ukamak, and on Long Island. On Long Island we have about 40 head of cattle. These cattle are fed from two to six weeks each winter. The remainder of the time they have been able to get their own subsistence. During occasional winters we have carried our stock through with no feeding. We have had very good increase from them, and should say that the percentage of calves raised from the breeding cows is about 75. The cattle on this island have not been housed except during the short period when we were obliged to feed them.
>
> On Ukamak Island we have a herd of about 20 head, which are entirely self-sustaining. We have not found it necessary either to feed or shelter these cattle during the winter season, and the increase has been fully as good as that of the herd on Long Island.
>
> On Kadiak Island we have not kept any stock cattle, but only a herd of dairy cows and some working horses. These we have, of course, fed regularly during the winter season for about five months. We are able to cure sufficient hay on a lot we have leveled, and we have used the only mowing machine in western Alaska. We have obtained very good results from feeding the Alaska hay to both cows and horses, and find that they require no more grain when fed this hay than when we feed hay imported from California.

The Frye-Bruhn Company, of Seattle, began operations near Kadiak in July, 1903, importing about 200 head of beef cattle, mostly Herefords. Owing to unpreparedness and inexperience, about 140 head of this number were lost during the first year. Most of these were killed by falling over cliffs. Owing to the fact that the earliest grass appears on the steep southerly slopes, the cattle crowded in such places; in some instances the sod, loosened by the frost, gave way and precipitated them over the cliffs. In other cases the cattle used their horns when crowded, the wounded ones losing their foothold in endeavoring to escape. As precautions, more care is taken in selecting the early feeding grounds and the cattle have been dehorned.

The common experience of cattle owners in Alaska has been that the animals fatten readily on the grass in the spring, and remain in good condition without care until late in the autumn. Some Herefords slaughtered at Kadiak in July furnished beef of remarkably fine quality.

From the experience had at the Kenai Experiment Station, oxen keep in good working condition all winter on no other feed than native grass hay and silage, and the limited experience of others has given similar results. It is not probable, however, that animals will remain fat on such feeds alone.

Nothing has been done up to the present time in the way of introducing breeds that are likely to be especially adapted to the peculiar conditions. It is highly probable, as has been pointed out by Professor Georgeson, that long-haired hardy breeds like the Galloway or the West Highland cattle will prove much more successful than breeds adapted primarily to a drier and warmer climate.

POPULATION AND AVAILABLE MARKETS.

No very accurate data are available as to the present population of the Alaska coast towns and villages, which furnish the only markets close to the grass lands. The population of the principal towns along the coast is approximately as follows: Sitka, 1,500; Valdez, 1,000; Seward, 500; Kadiak, 50; Unalaska and Dutch Harbor, 600. The total population from Valdez to Unalaska, inclusive, is about 8,000, of whom less than one-half are whites. From Valdez to Sitka, excluding the former, the population is perhaps 4,000, about half of them white. Thus the coast of Alaska from Sitka to Unalaska provides a market population at present of not more than 6,000 people, as no market for meat or dairy products can be expected so far as the natives are concerned.

No account is here taken of the towns lying along the interior channels in southeastern Alaska, whose populations aggregate perhaps 8,000 whites, though a portion of this market could perhaps be reached.

Skagway and Valdez are the principal south Alaskan points which supply the interior, and consequently are of especial importance in considering markets.

A considerable market for beef and dairy products could perhaps be established by shipping from Unalaska to the population of the Nome district and the lower Yukon. Unalaska is on the line of transportation from Puget Sound to Nome and the Yukon River, though at present few of the vessels stop there.

Thus the present available markets in Alaska for live-stock products are very limited. The supply for these markets at the present time is shipped from Puget Sound.

It is evident, however, that it is possible to raise in Alaska far more produce of this kind than the local markets can consume. The only other markets that can possibly be reached are those furnished by the cities of British Columbia and of the State of Washington. Freight rates are at present, and perhaps will be for some time to come, such that dairy products and wool are the only articles that could profitably be shipped to such distant ports.

No predictions can here be ventured concerning the future development of south Alaska. The present resources are mainly furs, fisheries, and mines. The fur industry is becoming less and less important. The fisheries are already highly developed, but are capable of considerable increase. The mines undoubtedly will become more and more important. It is probable, too, that the extensive explorations now carried on in prospecting for oil will result in the development of another important industry.

FREIGHTS AND TRANSPORTATION.

At the present time both freight and passenger rates to and between Alaskan ports may be considered moderate. The great bulk of the freight traffic is northward, a condition that is not unlikely to continue. Any permanent increase in the traffic to and from Alaskan ports will naturally be accompanied by a corresponding lowering of rates. The transportation companies doing business in south Alaska seem to be quite as liberal as conditions will permit, and so far as expressed sentiment goes their general policy will be the wise one of encouraging as far as possible any industry that promises to add to the sum total of the traffic.

DESIRABILITY OF SOUTH ALASKA AS A HOME.

Climate.—The south Alaska coast lies in the same latitude as northern Labrador, the north of Scotland, and the south of Sweden, but none of these regions is very similar to it. In fact, south Alaska has several peculiarities which render close comparison with any other region difficult. In general, the climate is a moist one, accompanied by no great extremes in temperature. The thermometer very seldom reaches zero in winter, nor does it exceed 75° F. in summer.

The following tables give the more important meteorological data as compiled from various published reports, localities in Sweden, Canada, and the State of Washington being included for comparison:

Monthly and annual mean temperatures at points in Alaska and elsewhere.

Station	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Sitka [a]	31.1	32.9	35.6	40.8	47.0	52.4	55.4	55.9	51.5	44.9	38.1	33.3	43.3
Sitka [b]	34.2	33.0	37.2	41.9	46.9	51.6	54.4	56.6	52.3	45.7	39.8	36.0	44.5
Kadiak	30.0	28.2	32.6	36.3	43.2	49.5	54.7	55.2	50.0	42.3	34.7	30.5	40.6
Unalaska [a]	30.0	31.9	30.4	35.6	40.9	46.3	50.6	51.9	45.5	37.6	33.6	30.1	38.7
Unalaska [b]	33.5	30.5	32.6	35.2	40.4	45.9	49.6	50.3	46.0	40.4	34.6	32.8	39.3
Port Angeles, Wash	34.7	36.7	41.7	45.6	50.6	54.0	56.6	56.8	52.7	47.7	42.4	38.2	46.1
Ottawa, Canada	11.9	12.2	17.6	41.5	63.6	66.9	70.4	68.7	57.7	43.1	34.5	17.8	42.1
Stockholm, Sweden	33.5	29.5	33.8	39.5	52.5	57.0	59.1	59.3	53.6	40.6	35.6	27.3	43.4

[a] From records kept by the Russian Government.
[b] From records of the United States Signal Service

Average precipitation at points in Alaska.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Total precipitation, May 1 to Sept. 30.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Sitka	7.95	8.02	7.78	5.03	3.89	3.87	4.14	6.67	10.94	12.96	10.77	8.52	90.54	29.51
Kadiak	6.56	3.70	4.86	4.01	5.92	4.91	3.38	4.97	7.26	8.09	6.56	7.94	68.16	26.44
Unalaska	13.81	7.68	6.48	7.51	4.49	4.26	2.78	3.40	8.64	11.98	9.30	11.81	92.14	23.57

In comparing the data for Sitka, Kadiak, and Unalaska it will be noted that the average mean temperature of Sitka is a little higher than that of Kadiak, which in turn is higher than that of Unalaska. It will also be noted that Sitka and Unalaska have about the same rainfall—considerably greater than that of Kadiak.

A matter of more practical consequence than either the copious rainfall or the comparatively high mean temperature is the rather low total of effective temperatures during the months from May to September, inclusive. By effective temperature is meant that above 43° F., at which plant growth practically begins. These totals, as compiled by Evans,[a] are as follows:

Sitka	1,479.1
Kadiak	1,152.1
Unalaska	624.5
Port Angeles, Wash	1,671.0
Ottawa, Canada	5,424.7
Scotland	1,692.7
Stockholm, Sweden	2,701.9

The difference in totals between Sitka and Kadiak is very striking, but not so much as that between Kadiak and Unalaska. Undoubtedly this effective temperature factor is the principal cause of the sharp demarcation between the timbered and the timberless regions on the Alaska coast.

Garden products.—This same factor—the low total of effective temperatures—limits also the variety of garden products that can be grown, but along the whole coast a considerable variety of vegetables is successfully raised, such as potatoes, turnips, cabbage, cauliflower, Brussels sprouts, kale, lettuce, peas, radishes, and rhubarb. Red currants and red raspberries grow wild on Cook Inlet, and these hardy varieties will thrive at most places along the coast—at Sitka even the ordinary garden varieties ripening. In southeastern Alaska salmon berries, cranberries, and huckleberries grow wild in abundance.

[a] Bulletin No. 48, Office of Experiment Stations, U. S. Department of Agriculture.

Fuel.—In the timbered region a supply of fuel is easily obtainable, while in the timberless country a rather scant quantity is secured from scrubby willows and alders and from beach drift. Coal of an inferior quality, but still fairly satisfactory for domestic use, is abundant along Cook Inlet. At present none of this is mined, but considerable quantities are gathered from exposed ledges, or from drift on the beaches. Most of the coal used along the Alaska Peninsula, however, is at present shipped from Puget Sound. In some localities the paraffin residue from oil seepage is utilized as fuel.

CHOICE OF A LOCATION.

In general, Kadiak and the neighobring islands and the Cook Inlet country are the most favorable places for live-stock raising on account of a great luxuriance of grasses and contiguity to timber. The Cook Inlet region enjoys the reputation of being the garden spot of the Alaska coast, apparently producing finer vegetables than elsewhere, though lying farther north than the Alaska Peninsula and most of the territory described in these pages. The accessible grass lands here are, however, comparatively limited.

On the other hand, Unalaska and the neighboring islands, while possessing less abundant grass and perhaps a less favorable climate, can perhaps reach markets in the Nome region and on the lower Yukon. At Yakutat, while the grass is not overabundant, the location is more favorable for shipments southward.

The prime requisite of any Alaska location is a sufficiently large available supply of winter forage. Of summer range there is an abundance nearly everywhere, but the utilization of this is definitely limited by the number of cattle one can safely winter. The all-important point is therefore to have a sufficient acreage of land from which hay or silage can be secured. By selecting locations on the flat lands that so commonly occur at the heads of the narrow fiords one can easily control for all practical purposes great areas of grazing lands.

The writer can not refrain from quoting here the following opinion of a widely traveled man from California, who for three years has been engaged in placer mining on the beach on the west side of Kadiak Island and who is seriously considering taking up a homestead and bringing his family to Alaska:

> In all my travels I have never found a place where one can live so well or so cheaply as I have done for the past three years. I can raise all sorts of hardy vegetables and berries, besides the wild ones, and have unlimited grass to keep cattle and sheep. Fish of the choicest sorts—salmon, halibut, cod, and many others—are very abundant, and the stream flowing by my cabin door swarms with trout. In the way of big game there are bears. Of small game

ducks and geese are plentiful in the spring and fall, and fresh gull eggs may be had for the gathering. To add to all this, if ready money is not available, I can always make good wages at least by washing out gold on the beach.

Surely there is here a combination of resources that makes failure well-nigh impossible.

LAND LAWS APPLYING TO ALASKA.

The following report regarding the methods by which title may be secured to agricultural lands in Alaska was prepared in the office of the Commissioner of the General Land Office, through the courtesy of the Secretary of the Interior. It refers solely to acquiring title to agricultural lands and not to the town-site or mineral laws, or to mission claims under section 27 of the act of June 6, 1900 (31 Stat. L., 330):

Section 1 of the act of Congress approved May 14, 1898 (30 Stat. L., 409), extending the homestead laws to Alaska, may be summarized as follows:

First. Extending the homestead laws and the rights incident thereto to the district of Alaska.

Second. Extending to such district the right to enter surveyed lands under provisions of law relating to the acquisition of title through soldiers' additional homestead rights.

Third. Granting the right to enter unsurveyed lands in said district under provisions of law relating to the acquisition of title through soldiers' additional homestead rights.

Fourth. Prohibiting the location in said district of any indemnity, deficiency, or lieu lands pertaining to any land grant whatsoever orginating outside of said district.

Fifth. Limiting each entry under this section to 80 rods along the shore of any navigable water, and reserving along such shore a space at least 80 rods between all such claims, and prohibiting the entry or disposal of the shore (meaning land lying between high and low water mark) of any navigable waters within said district.

Sixth. Limiting each homestead in said district, whether soldiers' additional or otherwise, to 80 acres in extent.

This section was amended by the act of March 3, 1903 (32 Stat. L., 1028), the provisions of which may be stated as follows:

The amendatory act does not specifically reenact that portion of the act of 1898 which granted the right to enter *unsurveyed* lands in the district of Alaska under the provisions of law relating to the acquisition of title through soldiers' additional rights, but it is provided thereby "that no more than one hundred and sixty acres shall be entered in any single body by such scrip, lieu selection, or soldiers' additional homestead right," which seems to negative any intention to modify or repeal the existing law with regard to the exercise of such rights in the district of Alaska further than to limit the amount which may be entered in a single body to 160 acres. Further, that portion of the amendatory act which provides that "no indemnity, deficiency, or lieu-land selections pertaining to any land grant outside of the district of Alaska shall be made, and no land scrip or land warrant of any kind whatsoever shall be located within or exercised upon any lands in said district, except as now provided by law," seems to recognize that there are such outstanding rights; but, unless soldiers' additional homestead rights are thereby considered as scrip rights, this Department is not advised as to any other law permitting the exercise of any such rights in the district of Alaska. Soldiers' additional homestead applications, under sections 2306 and 2307, Revised Statutes, are received as heretofore, but not more than 160 acres can be taken in a single body.

The act of 1898 is amended so as to increase the amount of land which may be entered as a homestead in the district of Alaska to 320 acres, and in providing therefor grants such rights to "any person who is qualified under existing laws to make homestead entry of the public lands of the United States who has settled upon, or who shall hereafter settle upon, any of the public lands of the United States situated in the district of Alaska, whether surveyed or unsurveyed." If a person be qualified, therefore, to make homestead entry under existing laws, he may enter not to exceed 320 acres, upon which he may have settled, in the district of Alaska, and without regard to the amount he might be authorized to make homestead entry of elsewhere; but the right to locate a soldier's additional homestead right in the district of Alaska, without settlement, is not thereby changed. Only 160 acres or less may be commuted.

No entry of any kind in the district of Alaska can, however, be allowed for land extending more than 160 rods along the shore of any navigable water, which is twice the extent originally permitted by the act of 1898, and along such shore a space of at least 80 rods is reserved between all claims, being the same as originally provided in the act of 1898.

HOMESTEADS.

The homestead laws secure to qualified persons the right to settle upon, enter, and acquire title to not exceeding 320 acres of public land, by establishing and maintaining residence thereon and improving and cultivating the land for the continuous period of five years.

A homestead entryman must be the head of a family or a person who has arrived at the age of 21 years, and a citizen of the United States, or one who has filed his declaration of intention to become such, as required by the naturalization laws, to which section 5 of the act of March 3, 1891 (26 Stat. L., 1095), attaches the conditions that he must not be the proprietor of more than 160 acres of land in any State or Territory, and that since August 30, 1890, he has not acquired title to, nor is now claiming under any of the agricultural public-land laws, an amount of land which, together with the land now applied for, will exceed in the aggregate 320 acres.

Where a wife has been divorced from her husband or deserted, so that she is dependent upon her own resources for support, she can make homestead entry as the head of a family or as a femme sole.

Where an unmarried woman settles upon a tract of public land, improves the same, establishes and maintains a bona fide residence thereon with the intention of appropriating the same for a home under the homestead law, and thereafter marries before making entry of said land, or before making application to enter said land, she does not, on account of her marriage, forfeit her right to make entry and receive patent for the land: *Provided*, That she does not abandon her residence on said land and is otherwise qualified to make homestead entry: *And provided further*, That the man whom she marries is not, at the time of their marriage, claiming a separate tract of land under the homestead law. (Act June 6, 1900, 31 Stat. L., 683.)

APPLICATION FOR A HOMESTEAD FOR SURVEYED LAND.

To obtain a homestead the party should select and personally examine the land and be satisfied of its character and true description.

He must file an application, stating his true name, residence, and post-office address, and describing the land he desires to enter, and make affidavit that he is not the proprietor of more than 160 acres of land in any State or Territory; that he is a citizen of the United States, or that he has filed his declaration of intention to become such, and that he is the head of a family, or over 21 years of age, as the case may be; that his application is honestly and in good faith made for the purpose of actual settlement and cultivation, and not for the benefit of any other person, persons, or corporation, and that he will faithfully and honestly endeavor to comply with all the requirements of law as to settlement, residence, and cultivation necessary to acquire title to the land applied for; that he is not acting as agent of any person, corporation, or syndicate in making such entry, nor in collusion with any person, corporation, or syndicate to give them the benefit of the land entered, or any part thereof, or the timber thereon; that he does not apply to enter the same for the purpose of speculation, but in good faith to obtain a home for himself, and that he has not, directly or indirectly, made, and will not make, any agreement or contract in any manner with any person or persons, corporation, or syndicate whatsoever, by which the title which he might acquire from the Government of the United States should inure, in whole or in part, to the benefit of any person except himself; and, further, that since August 30, 1890, he has not acquired title to nor is he claiming under any of the agricultural public-land laws an amount of land which, together with the land he is seeking to enter, will exceed in the aggregate 320 acres, and that he has not theretofore had the benefit of the homestead laws, and must pay the legal fee and that part of the commissions which is payable when entry is made, and furnish the usual nonmineral affidavit.

On compliance by the party with the foregoing requirements the receiver will issue his receipt for the fee and that part of the commissions paid, a duplicate of which he will deliver to the party. The matter will then be entered in the records of the district office and reported to the General Land Office.

The applicant must in every case state in his application his place of actual residence and his post-office address, in order that notices of proceedings relative to his entry may be sent him. The register and receiver will note the post-office address on their tract books.

INCEPTIVE RIGHTS OF HOMESTEAD SETTLERS.

An inceptive right is vested in the settler by the proceedings hereinbefore described. He must, within six months after making his entry, establish his actual residence in a house upon the land, and must reside upon and cultivate the land continuously in accordance with law for the term of five years. Occasional visits to the land once in six months or oftener do not constitute residence. The homestead party must actually inhabit the land and make it the home of himself and family, as well as improve and cultivate it.

At the expiration of five years, or within two years thereafter, he may make proof of his compliance with law by residence, improvement, and cultivation for the full period required, and must show that the land has not been alienated except as provided in section 2288, Revised Statutes (sec. 2291, Rev. Stat.), as amended by section 3 of the act of March 3, 1891 (26 Stat. L., 1095).

The period of continuous residence and cultivation begins to run at the date of actual settlement in case the entry at the district land office is made within the prescribed period (three months) thereafter or before the intervention of a valid adverse claim. If the settlement is on unsurveyed land, the latter period runs from the filing of plat in the district land office. (Act May 14, 1880, 21 Stat. L., 140.)

HOMESTEAD SETTLERS ON UNSURVEYED LANDS.

A homestead settler on unsurveyed public land not yet open to entry must make entry within three months after the filing of the township plat of survey in the district land office. (Act May 14, 1880, 21 Stat. L., 140.)

CULTIVATION IN GRAZING DISTRICTS.

In grazing districts stock raising and dairy production are so nearly akin to agricultural pursuits as to justify the issue of patent upon proof of permanent settlement and the use of the land for such purposes.

Proofs can only be made by the homestead claimant in person, and can not be made by an agent, attorney, assignee, or other person, except that in case of the death of the entryman proof can be made by the statutory successor to the homestead right in the manner provided by law.

Sections 2291 and 2292, Revised Statutes, provide for obtaining title to lands entered by a homestead settler by his heirs. The act of June 8, 1880 (21 Stat. L., 166), provides for homestead claimants who become insane.

HOMESTEAD CLAIMS NOT LIABLE FOR DEBT AND NOT SALABLE.

No lands acquired under the provisions of the homestead laws are liable for the satisfaction of any debt contracted prior to the issue of the patent. (Sec. 2296, Rev. Stat.)

The sale of a homestead claim by the settler to another party before becoming entitled to a patent vests no title or equities in the purchaser as against the United States. In making final proof the settler is by law required to swear that no part of the land has been alienated except for church, cemetery, or school purposes or the right of way for railroads, canals, or ditches for irrigation or drainage across it. (Sec. 2288, Rev. Stat., as amended by sec. 3 of the act of March 3, 1891, 26 Stat. L., 1095.)

SOLDIERS AND SAILORS' HOMESTEAD RIGHTS.

Any officer, soldier, seaman, or marine who served for not less than ninety days in the Army or Navy of the United States during the rebellion, and who was honorably discharged and has remained loyal to the Government, and who makes a homestead entry of 320 acres or less on any land subject to such entry, is entitled under section 2305 of the Revised Statutes to have the term of his service in the Army or Navy, not exceeding four years, deducted from the period of five years' residence required under the homestead laws.

If the party was discharged from service on account of wounds or disabilities incurred in the line of duty the whole term of enlistment, not exceeding four years, is to be deducted from the homestead period of five years; but no patent can issue to any homestead settler who has not resided upon, improved, and cultivated his homestead for a period of at least one year after he commenced his improvements. (Sec. 2305, Rev. Stat.)

Similar provisions are made in the acts of June 16, 1898 (30 Stat. L., 473), and March 1, 1901 (31 Stat. L., 847), for the benefit of like persons who served in the late war with Spain or during the suppression of the insurrection in the Philippines.

A party applying to make entry under the provisions of section 2304 must file with the register and receiver a certified copy of his certificate of discharge, showing when he enlisted and when he was discharged; or the affidavit of two respectable, disinterested witnesses corroborative of the allegations contained in the prescribed affidavit (Form 4-065) on these points, or, if neither can be procured, his own affidavit to that effect.

The widow or, in case of her death or remarriage, the guardian of minor children may complete a filing made by the soldier or sailor as above, and patent will issue accordingly.

SOLDIERS' ADDITIONAL HOMESTEAD ENTRY.

Any officer, soldier, sailor, or marine who served for not less than ninety days in the Army or Navy of the United States during said wars, who had, prior to June 22, 1874, the date of the approval of the Revised Statutes, made a homestead entry of less than 160 acres, may enter an additional quantity of land, adjacent to his former entry or elsewhere, sufficient to make, with the previous entry, 160 acres. (Rev. Stat., 2306.) This right was extended by section 2307, Revised Statutes, to the widow, if unmarried; otherwise to the minor orphan children by proper guardian. If there be no widow, unmarried, and no minor orphan children, the right is held to be an asset of the soldier-entryman's estate, to be disposed of by his personal representative as other personal property. (29 L. D., 510 and 658.) An assignment by the heirs will be accepted if accompanied by a certificate of the proper court showing that no administration has ever been had on the soldier's estate and that they are all the heirs entitled to the right. The right was formerly regarded as a personal one and not transferable, but under authority of the decision of the Supreme Court of the United States in the case of Webster *v.* Luther (163 U. S., 331), it is now held to be assignable without restriction, and residence and cultivation are not required in its exercise, either by the original beneficiary or by his assignee, whether the original entry was perfected or abandoned (24 L. D., 502).

It was formerly the practice, on proof of military service and original entry, under section 2306, Revised Statutes, to issue a certificate in the name of the soldier-entryman, showing his additional right and its area, but the practice was discontinued by circular of February 13, 1883 (1 L. D., 654), and it is held that there is no statutory authority for the same and that the soldier can obtain the right for himself and sell it to another without certification (23 L. D., 152).

By the act of March 3, 1893 (27 Stat. L., 593), provision is made that where soldiers' additional homestead entries have been made or initiated upon a certificate of the Commissioner of the General Land Office of the right to make such entry, and the certificate of right is found to be erroneous or invalid for any cause, the party in interest thereunder on making proof of his purchase may, if there is no adverse claimant, perfect his title by payment of the Government price for the land, but no person may acquire more than 160 acres through the location of any such certificate.

By the act of August 18, 1894 (28 Stat. L., 397), all certificates regularly issued are declared to be valid, notwithstanding any attempted sale or transfer, and holders thereof desiring to exercise a right of entry in their own names must file such certificates in the General Land Office, together with satisfactory proof of ownership and of bona fide purchase for value. If, upon examination, the proof so filed is satisfactory, an additional certificate will be attached to the original authorizing the location thereof, or entry of land therewith, in the name of the assignee or his assigns. (Circular of October 16, 1894; 19 L. D., 302.)

Existing homestead laws, while recognizing settlement upon unsurveyed public lands, do not authorize the entry or the patenting thereof until the public surveys have been regularly extended over them. This section as amended, however, in terms authorizes the entry of unsurveyed lands in Alaska, and makes provision for a private survey for the purpose of patenting the claim, if the public surveys have not been extended thereto at the time it is desired to submit proof, as is hereinafter referred to.

In executing surveys for homestead applications the instructions now prevailing will be followed, and the limit of 160 rods as to frontage will be measured along the meandered line of said frontage.

The form of the tract sought to be entered, if upon unsurveyed land, is prescribed in the act as follows:

> If any of the land * * * is unsurveyed, then the land * * * must be in rectangular form, not more than a mile in length, and located upon the north and south lines run according to the true meridian.

That is, the boundary lines of each entry must be run in cardinal directions, true north-and-south and east-and-west lines by reference to a true meridian (not magnetic), with the exception of the meander lines on meanderable streams and navigable waters forming a part of the boundary lines of the entry. Thus a frontage meander line, and other meander lines which form part of the boundary of a claim, will be run according to the directions in the Manual of Surveying Instructions issued by this Office, but other boundary lines will be run in true east-and-west and north-and-south directions, thus forming rectangles, except at intersections with meander lines.

In other respects the rules previously adopted to govern surveys of claims under the act of May 14, 1898, will continue to be followed, of course taking into consideration the limitations as to area of claims.

Every person who is qualified under existing laws to make a homestead entry of the public lands of the United States who settles or has settled upon any of the unsurveyed public lands of the United States in the district of Alaska with the intention of taking the same under the homestead law shall, within ninety days from date of settlement or prior to the intervention of an adverse claim, file the record of his location for record in the recording district in which the land is situated, as provided by sections 13 to 16 of the act of June 6, 1900 (31 Stat. L., 326 to 328).

Said record shall contain the name of the settler, the date of settlement, and such description of the land settled on, by reference to some natural object or permanent monument as will identify the same.

If at the expiration of the time required under sections 2291 and 2292, Revised Statutes, and as modified by section 2305, Revised Statutes, or at such date as the settler desires to commute under section 2301, Revised Statutes, the public surveys have not been extended over the land located, the locator may secure a patent for the land located by procuring, at his own expense, a survey of the land, which must be made by a deputy surveyor who has been duly appointed by the surveyor-general, in accordance with section 10 of the act of May 14, 1898 (30 Stat L., 409), and the provisions of the act of March 3, 1903, as herein set forth.

When the survey, either public or private, as herein provided for is approved by the surveyor-general under authority of this Office, the same rules should be followed as heretofore established governing the location of soldiers' additional homestead rights, in addition to which the settler must furnish the required proof of residence and cultivation.

The office of the surveyor-general of Alaska is located at Sitka.

Section 10 of said act of May 14, 1898, also provides that all affidavits, testimony, proofs, and other papers provided for by this act and by said act of March 3, 1891, or by any departmental or Executive regulation thereunder, by depositions or otherwise, under commission from the register and receiver of the land office, which may have been or may hereafter be taken and sworn to anywhere in the United States, before any court, judge, or other officer authorized by law to administer an oath, shall be admitted in evidence as if taken before the register and receiver of the proper local land office. And thereafter such proof, together with a certified copy of the field notes and plat of the survey of the claim, shall be filed in the office of the surveyor-general of the district of Alaska, and if such survey and plat shall be approved by him, certified copies thereof, together with the claimant's application, shall be filed in the United States land office in the land district in which the claim is situated, whereupon, at the expense of claimant, the register of such land office shall cause notice of such application to be published for at least sixty days in a newspaper of general circulation publshed nearest the claim within the district of Alaska, and the applicant shall at the time of filing such field notes, plat, and application to purchase in the land office aforesaid, cause a copy of such plat, together with the application to purchase, to be posted upon the claim, and such plat and application shall be kept posted in a conspicuous place on such claim continuously for at least sixty days, and during such period of posting and publication, or within thirty days thereafter, any person, corporation, or association having or asserting any adverse interest in, or claim to, the tract of land or any part thereof sought to be purchased, may file in the land office where such application is pending, under oath, an adverse claim setting forth the nature and extent thereof, and such adverse claimant shall, within sixty days after the filing of such adverse claim, begin action to quiet title in a court of competent jurisdiction within the district of Alaska, and thereafter no patent shall issue for such claim until the final adjudication of the rights of the parties, and such patent shall then be issued in conformity with the final decree of the court.

When a settler desires to commute, the survey and homestead application must cover his entire claim, but only 160 acres, or less, thereof may be commuted, in which event the entry will stand intact as to the portion not commuted, subject to future compliance with the requirements of law within the statutory period of seven years.

Entrymen who commute will be required to pay, in addition to the price of $1.25 per acre, the same fees and commissions as in final homesteads.

Whenever a settler or other claimant desires to make entry or submit final proof, he should address the register and receiver of the United States land office at Juneau, Alaska.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Map of Alaska, showing the approximate location of the grass-land areas in black.

PLATE II. Fig. 1.—View of the level lands at the head of Womans Bay, Kadiak Island. Similar areas occur at the heads of most of the inlets. Fig. 2.—Mowing beach rye on the Frye-Bruhn ranch.

PLATE III. Bluetop (*Calamagrostis langsdorfii*) on Kadiak Island, 6 feet high, July, 1904. The hillsides in the background were burned over during the preceding spring, and are covered with an equally luxuriant stand of the same grass.

PLATE IV. Fig. 1.—A view of Kadiak, November 7, 1903. A light fall of new snow covers the low mountains in the background. Fig. 2.—Another view of Kadiak, March 26, 1904. The small snowfall of this region is made very clear by these two pictures.

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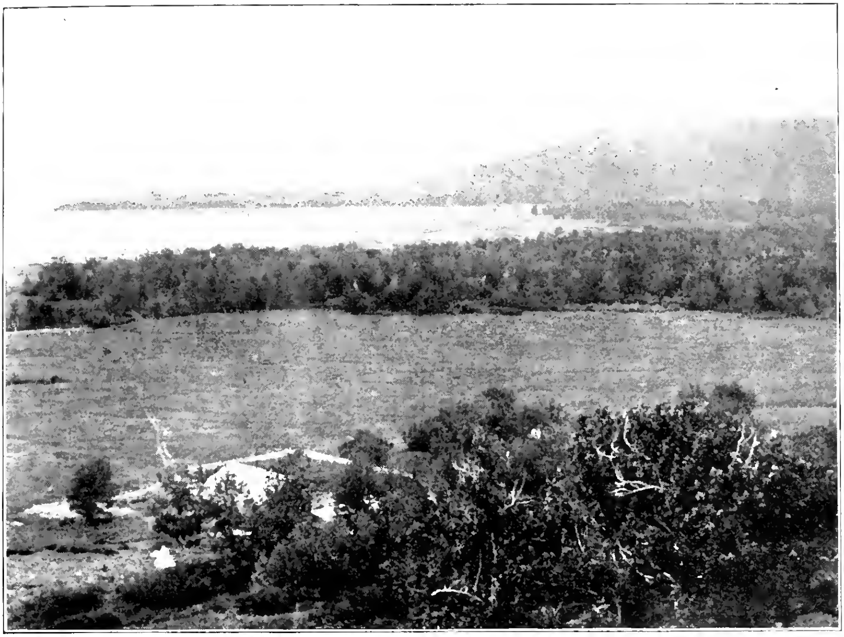
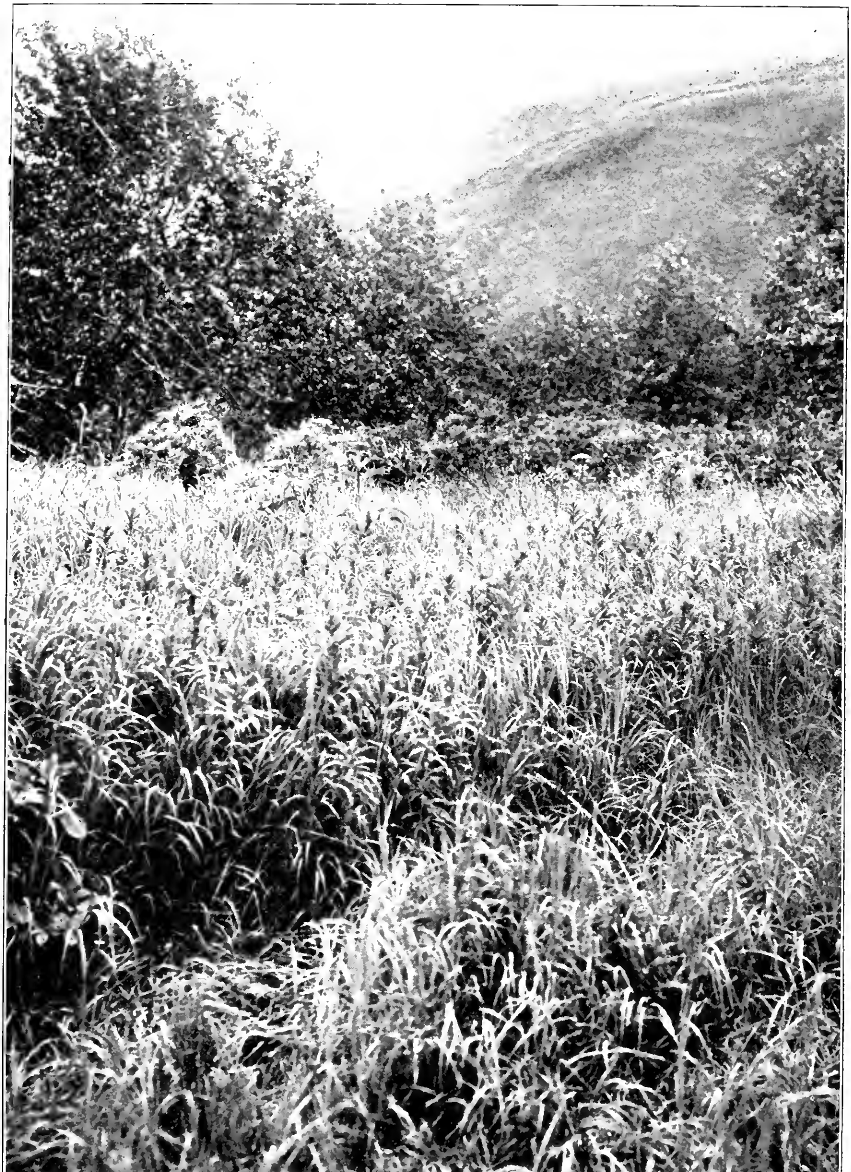


FIG. 1.—A VIEW OF THE FLAT LANDS LYING AT THE HEAD OF WOMAN'S BAY, KADIAK ISLAND, ALASKA.

FIG. 2.—MOWING BEACH RYE ON KADIAK ISLAND, ALASKA.



BLUETOP (CALAMAGROSTIS LANGSDORFII) SIX FEET HIGH, ON KADIAK ISLAND, ALASKA, JULY, 1904.

The grass on the hillside in the background was just as luxuriant.

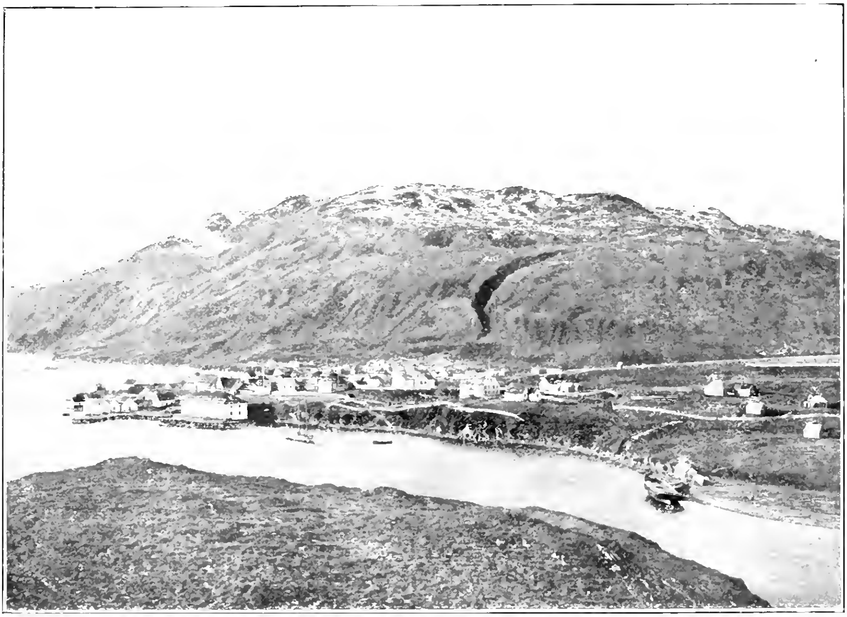


FIG. 1.—A VIEW OF KADIAK, ALASKA, NOVEMBER 7, 1903.

FIG. 2.—A DIFFERENT VIEW OF KADIAK, MARCH 26, 1904.

The small snowfall of this region is made very clear by these two pictures.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 83.

B. T. GALLOWAY, *Chief of Bureau.*

THE VITALITY OF BURIED SEEDS.

BY

J. W. T. DUVEL,

ASSISTANT IN THE SEED LABORATORY.

ISSUED AUGUST 4, 1905.

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GOVERNMENT PRINTING OFFICE.
1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Government Printing Office, Washington, D. C.

No. 1. The Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.
2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.
3. Macaroni Wheats. 1901. Price, 20 cents.
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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 83.

B. T. GALLOWAY, *Chief of Bureau.*

THE VITALITY OF BURIED SEEDS.

BY

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ASSISTANT IN THE SEED LABORATORY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 29, 1905.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 83 of the series of this Bureau, the accompanying technical paper entitled "The Vitality of Buried Seeds."

The experiments discussed were undertaken in order to determine the length of time that seeds of different species of plants will retain their vitality when buried at various depths. Seeds of both cultivated and wild plants were used, but special attention was given to weed seeds in order to ascertain what weeds can be eradicated by deep plowing and how long the soil must remain undisturbed before the vitality of the seeds will be entirely destroyed. The results of the first year's experiments show that the noxious character of weeds is closely associated with the length of time the seeds will remain viable in the soil, and that many weeds can be eradicated by plowing. Much additional information is given, showing the relative resistance of the seeds of cultivated plants and of those commonly designated as weeds, and the influence upon the preservation of vitality of the depth of burial, of hard seed coats, and of hulled as compared with unhulled seed.

This paper was prepared by J. W. T. Duvel, Assistant in the Seed Laboratory, and has been submitted with a view to publication.

The accompanying illustrations are necessary for a complete understanding of the paper.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE VITALITY OF BURIED SEEDS.

INTRODUCTION.

The preservation of the vitality of seeds when buried in the soil and the awakening of metabolic activity in such seeds on being exposed to conditions favorable to their germination are equally as important to the practical farmer as to the scientist. The intelligent farmer in order to combat noxious plants successfully should know how much time must elapse after heavy crops of weeds of various sorts are turned under before the ground can be plowed again with safety. He should also know what plants he can hope to eradicate in this way, for with many of our worst weeds this method would result only in failure. In fact, the reason why the majority of our most persistent weeds are so difficult to eradicate is because their seeds are capable of retaining their vitality for a number of years when buried in the soil. It thus becomes important to know how different species of seeds behave when buried under similar conditions, and how seeds of the same species behave when buried under different conditions.

KINDS OF SEEDS BURIED.

So much has already been written on the germination of seeds that have remained dormant in the soil for a number of years, in some cases even for centuries, that it seemed desirable to determine with some degree of accuracy the length of time that certain seeds will retain their vitality when buried in the soil under known conditions. Accordingly, in the autumn of 1902, 112 different samples of seeds were selected for these experiments, as follows:

TABLE I.—*List of seeds selected for the experiments.*

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Poaceæ (grass family):		
16173	*Agropyron repens* (L.) Beauv. (couch grass)	100	31
16174	*Avena fatua* L. (wild oat)	71	9
16175	*Avena sativa* L. (oats)	24	8
16176	*Bromus secalinus* L. (cheat, chess)	34	36
16177	*Bromus racemosus* L. (upright chess, smooth brome-grass)	33	37
16178	*Chaetochloa verticillata* (L.) Scribn. (foxtail)	108	66
16179	*Chaetochloa glauca* (L.) Scribn. (yellow foxtail)	46	33
16180	*Chaetochloa viridis* (L.) Scribn. (green foxtail)	5	67
16181	*Eleusine indica* (L.) Gaertn. (wire-grass, crab-grass)	26	72
16182	*Elymus virginicus* L. (Virginia wild rye)	77	15
16183	*Elymus canadensis* L. (nodding wild rye)	74	13
16184	*Elymus triticoides* Buckl. (wild wheat)	69	14

TABLE I.—*List of seeds selected for the experiments*—Continued.

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Poaceæ (grass family)—Continued.		
16185	*Festuca elatior* L. (meadow fescue)	38	35
16186	*Hordeum sativum* Jessen. (barley)	23	12
16187	*Panicum virgatum* L. (tall, smooth panicum)	70	32
16188	*Phalaris arundinacea* L. (reed canary grass)	93	34
16189	*Phleum pratense* L. (timothy)	112	68
16190	*Poa pratensis* L. (Kentucky bluegrass)	75	73
16191	*Secale cereale* L. (rye)	25	11
16192	*Sporobolus airoides* Torr. (hair-grass drop-seed)	12	69
16193	*Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed)	63	71
16194	*Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed—hulled seed)	13	70
16195	*Triticum aestivum* L. (wheat)	22	10
16196	*Zea mays* L. (corn—Boone County white)	14	1
16197	*Zea mays* L. (sweet corn—early Concord)	15	2
	Cyperaceæ (sedge family):		
16198	*Cyperus esculentus* L. (yellow nut-grass)	7	74
	Liliaceæ (lily family):		
16199	*Allium cepa* L. (onion)	27	39
	Convallariaceæ (lily-of-the-valley family):		
16200	*Asparagus officinalis* L. (asparagus)	32	16
	Moraceæ (mulberry family):		
16201	*Cannabis sativa* L. (hemp)	4	17
	Urticaceæ (nettle family):		
16202	*Boehmeria nivea* Gaud. (ramie)	2	75
	Polygonaceæ (buckwheat family):		
16203	*Fagopyrum fagopyrum* (L.) Karst. (buckwheat)	21	18
16204	*Polygonum pennsylvanicum* L. (Pennsylvania persicaria, smartweed)	9	40
16205	*Polygonum persicaria* L. (lady's-thumb, smartweed)	10	78
16206	*Polygonum scandens* L. (climbing false buckwheat)	11	41
16207	*Rumex salicifolius* Weinm. (willow-leaved dock)	107	76
16208	*Rumex crispus* L. (curled dock), not cleaned	103	39
16209	*Rumex obtusifolius* L. (broad-leaved dock, bitter dock)	102	77
	Chenopodiaceæ (goosefoot family):		
16210	*Axyris amaranthoides* L. (Russian pigweed)	1	81
16211	*Beta vulgaris* L. (sugar beet)	72	19
16212	*Chenopodium album* L. (lamb's quarters, white goosefoot)	96	79
16213	*Chenopodium hybridum* L. (maple-leaved goosefoot)	62	80
	Amaranthaceæ (amaranth family):		
16214	*Amaranthus retroflexus* (rough pigweed)	83	82
	Phytolaccaceæ (pokeweed family):		
16215	*Phytolacca americana* L. (poke, pigeon berry)	104	42
	Portulacaceæ (purslane family):		
16216	*Portulaca oleracea* L. (purslane, pussley)	86	83
	Silenaceæ (pink family):		
16217	*Agrostemma githago* L. (corn cockle)	16	43
16218	*Alsine media* L. (common chickweed)	110	84
16219	*Vaccaria vaccaria* (L.) Britton (cowherb)	55	44
	Brassicaceæ (mustard family):		
16220	*Brassica nigra* (L.) Koch (black mustard)	67	87
16221	*Brassica oleracea* L. (cabbage)	17	45
16222	*Brassica campestris* L. (turnip)	40	88
16223	*Bursa bursa-pastoris* (L.) Britton (shepherd's purse)	3	89
16224	*Erysimum cheiranthoides* L. (wormseed, treacle mustard)	58	47
16225	*Neslia paniculata* (L.) Desv. (ball mustard)	85	46
16226	*Sisymbrium altissimum* L. (tall sisymbrium)	78	86
16227	*Thlaspi arvense* L. (field penny cress)	60	85
	Rosaceæ (rose family):		
16228	*Potentilla monspeliensis* L. (rough cinquefoil)	73	90
	Caesalpiniaceæ (senna family):		
16229	*Cassia marylandica* L. (wild senna, American senna)	52	48
	Fabaceæ (pea family):		
16230	*Lespedeza frutescens* (L.) Britton (wand-like bush clover)	43	52
16231	*Medicago sativa* L. (alfalfa, lucern)	59	49
16232	*Phaseolus vulgaris* L. (bean)	20	4
16233	*Pisum sativum* L. (pea)	19	5
16234	*Robinia pseudacacia* L. (locust tree, false acacia)	37	51
16235	*Trifolium hybridum* L. (alsike clover)	50	93
16236	*Trifolium pratense* L. (red clover)	49	50
16237	*Trifolium pratense* L. (red clover) harvest of 1900	54	91
16238	*Trifolium pratense* L. (red clover) hard seed from No. 16237	68	92
16239	*Trifolium repens* L. (white clover)	41	94
16240	*Vigna catjang* Walp. (Iron cowpea)	42	3
	Linaceæ (flax family):		
16241	*Linum usitatissimum* L. (flax, linseed)	30	53
	Anacardiaceæ (sumac family):		
16242	*Rhus glabra* L. (scarlet sumac)	47	20
	Malvaceæ (mallow family):		
16243	*Abutilon abutilon* (L.) Rusby. (velvet leaf)	111	54
16244	*Gossypium hirsutum* L. (cotton)	18	6
16245	*Hibiscus militaris* Cav. (halberd-leaved rose mallow)	31	55

TABLE I.—*List of seeds selected for the experiments*—Continued.

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Hypericaceæ (St. John's wort family):		
16246	*Ascyrum hypericoides* L. (St. Andrew's cross)	44	95
	Onagraceæ (evening primrose family):		
16247	*Onagra biennis* (L.) Scop. (common evening primrose)	8	96
	Apiaceæ (carrot family):		
16248	*Apium graveolens* L. (celery)	94	57
16249	*Pastinaca sativa* L. (parsnip, wild)	95	56
	Oleaceæ (olive family):		
16250	*Fraxinus americana* L. (white ash)	105	21
	Convolvulaceæ (morning-glory family):		
16251	*Convolvulus sepium* L. (hedge bindweed, great bindweed)	56	23
16252	*Ipomœa lacunosa* L. (small-flowered white morning-glory)	81	22
	Cuscutaceæ (dodder family):		
16253	*Cuscuta polygonorum* Engelm. (smartweed dodder)	63	98
16254	*Cuscuta epilinum* Weihe. (flax dodder)	82	97
	Verbenaceæ (vervain family):		
16255	*Verbena hastata* L. (blue vervain)	66	100
16256	*Verbena urticifolia* L. (white vervain, nettle-leaved vervain)	79	99
	Solanaceæ (potato family):		
16257	*Capsicum annuum* L. (red pepper)	39	59
16258	*Datura tatula* L. (purple stramonium, jimson weed)	106	61
16259	*Lycopersicon lycopersicon* (L.) Karst. (tomato)	45	60
16260	*Nicotiana tabacum* L. (tobacco)	99	101
16261	*Solanum nigrum* L. (black nightshade, garden nightshade)	61	58
	Scrophulariaceæ (figwort family):		
16262	*Verbascum thapsus* L. (great mullen)	76	102
	Plantaginaceæ (plantain family):		
16263	*Plantago lanceolata* L. (ribwort, ribgrass, buckhorn)	88	105
16264	*Plantago major* L. (common plantain)	91	103
16265	*Plantago rugelii* Dec. (Rugel's plantain, broad plantain)	65	104
	Cucurbitaceæ (gourd family):		
16266	*Citrullus citrullus* (L.) Karst. (watermelon)	6	26
16267	*Cucumis melo* L. (muskmelon)	26	25
16268	*Cucumis sativus* L. (cucumber)	18	24
	Cichoriaceæ (chicory family):		
16269	*Lactuca scariola* L. (prickly lettuce)	98	107
16270	*Lactuca sativa* L. (lettuce)	28	62
16271	*Taraxacum erythrospermum* Andrz. (red-seeded dandelion)	90	106
	Ambrosiaceæ (ragweed family):		
16272	*Ambrosia artemisiæfolia* L. (ragweed)	87	63
16273	*Ambrosia trifida* L. (great ragweed)	53	28
16274	*Xanthium pennsylvanicum* Wallr. (Pennsylvania clotbur, cocklebur)	51	27
	Asteraceæ (aster family):		
16275	*Arctium lappa* L. (burdock, clotbur)	101	112
16276	*Bidens frondosa* L. (black beggar ticks)	84	64
16277	*Carduus arvensis* (L.) Robs. (Canada thistle)	80	111
16278	*Chrysanthemum leucanthemum* L. (whiteweed, oxeye daisy)	92	110
16279	*Grindelia squarrosa* (Pursh.) Dunal. (broad-leaved gum plant)	89	108
16280	*Helianthus annuus* L. (common sunflower, wild)	97	29
16281	*Helianthus annuus* L. (common sunflower, cultivated)	29	7
16282	*Onopordon acanthium* L. (cotton thistle, scotch thistle)	109	65
16283	*Rudbeckia hirta* L. (black-eyed Susan)	57	109
	Pinaceæ (pine family):		
16284	*Pinus virginiana* Mill. (scrub pine, Jersey pine)	36	30

HOW THE SEEDS WERE BURIED.

The foregoing list represents 109 species, 84 genera, and 34 families of plants. Carefully counted seeds of these samples were mixed with dry clay soil and packed in well-baked earthen pots (the common flowerpot used in greenhouses). The filled pots were covered with inverted clay saucers in order to prevent the seeds from being destroyed or becoming mixed with other seeds which might have been in the soil with which the pots were covered. By burying the seeds mixed with earth in porous clay pots of this character they were subjected to conditions almost identical with those which would exist if the seeds were buried either accidentally or by natural causes. The porous clay pots admitted of the free circulation of air and water.

The pots containing these seeds were buried at three different depths. Eight complete sets were buried from 6 to 8 inches below the surface, being covered approximately the same as would result from deep plowing. Twelve complete sets were covered to a depth varying from 18 to 22 inches, sufficiently deep in this latitude to be reasonably secure from the action of frost. Twelve more complete sets were buried at a depth varying from 36 to 42 inches where the conditions were nearly uniform, so far as the three factors which regulate the germination of seeds are concerned, namely, heat, moisture, and air (oxygen). Figure 1 shows the arrangement of the pots, which were of 6-inch, 4-inch, and 2-inch sizes, to accommodate the different kinds of seed.

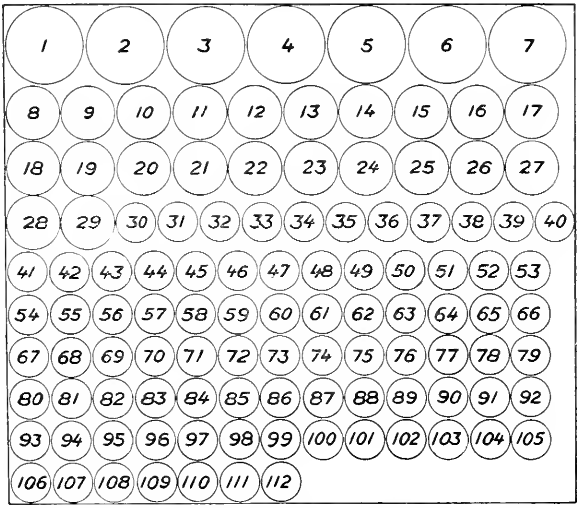


FIG. 1.—Diagram showing order in which seeds were buried.

These seeds were buried December 19 to 23, 1902, in a heavy clay soil on the Arlington Experimental Farm of the United States Department of Agriculture. With the exception of two of the duplicate samples of red clover, the seeds were of the harvest of 1902.

In each case a definite number of seeds was taken. Of the larger kinds, such as beans, peas, corn, etc., 100 seeds were used, but for the majority of the samples 200 seeds were taken. The seeds selected were for the most part of plants with which the greater number of the farmers throughout the United States are more or less familiar, either as plants of economic importance or as weeds.

In all 32 complete sets, representing 3,584 pots, were buried. One set from each of the three different depths is to be taken up as the conditions warrant and will be tested for vitality. The results of these tests are to be compared with the germination of seeds from the original bulk samples designated throughout this report as "controls."

The control samples are being stored in cloth bags in a dry room on the second floor of the Seed Laboratory. The first complete series of three sets was taken up in November, 1903, eleven months after they had been buried. The results of the first year's experiment are given in the following pages.

GERMINATION TESTS.

In making the germination tests of the buried seeds the contents of the pots, the mixture of seed and soil, were spread on sand in ordinary greenhouse flats. Along with these, in the same flats, were control samples taken from the original bulk lot of seeds, as previously mentioned. In addition, another complete set of control samples was tested in the germinating chambers of the Seed Laboratory. The temperatures given in the tables are those best suited for the germination of the different seeds.

For convenience the results of the germination tests have been divided into three groups, as follows:

A. Seeds in which the control samples, as well as those that were buried, gave only negative results when tested in the greenhouse.

B. Seeds which had either decayed or germinated and afterwards decayed while they were buried.

C. Seeds which had not completely lost their vitality while buried.

The first group, i. e., those in which both the control samples and those which had been buried failed to germinate when planted in flats in the greenhouse, consists of the following species:

1. *Axyris amaranthoides* L. (Russian pigweed).
2. *Boehmeria nivea* Guad. (ramie).
3. *Bursa bursa-pastoris* (L.) Britton (shepherd's purse).
4. *Cannabis sativa* L. (hemp).
5. *Chaetochloa viridis* (L.) Scribn. (green foxtail).
6. *Citrullus citrullus* (L.) Karst. (watermelon).
7. *Cyperus esculentus* L. (yellow nut-grass).
8. *Onagra biennis* (L.) Scop. (evening primrose).
9. *Polygonum pennsylvanicum* L. (Pennsylvania smartweed, persicaria).
10. *Polygonum persicaria* L. (lady's-thumb, smartweed).
11. *Polygonum scandens* L. (climbing false buckwheat).
12. *Sporobolus airoides* Torr. (hair-grass drop-seed).
13. *Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed—hulled seed).

In this series the hemp should be discarded, as repeated tests failed to show any seeds from the bulk samples capable of germination. The control samples of the other seeds when tested in the germinating chambers germinated nearly as well and in some cases even better than the chamber tests which were made at the time the seeds were buried. Undoubtedly some of these seeds had decayed while buried in the soil; in fact, the watermelon seeds, *Axyris amaranthoides*, and *Sporobolus airoides* were marked "mostly decayed" when taken up. Generally speaking, the results show that the failure to germinate was not in the seeds, but that the conditions in the greenhouse were at fault, and until other tests are made these results can not be discussed with any degree of satisfaction. On the other hand, it is certain that some of the smaller seeds failed to germinate because they were covered too deeply when sown in the flats in the greenhouse.

Polygonum scandens possibly should be classified in Table III, inasmuch as some of the seeds which were buried at depths of from 18 to 22 inches and from 36 to 42 inches showed a few sprouts at the time the seeds were taken up, but after being transferred to the greenhouse no seedlings were developed. However, the failure in the germination of the control sample of *Polygonum scandens* throws it into the first group (A) with the other two species of the same genus, i. e., *Polygonum pennsylvanicum* and *P. persicaria*.

The result of the tests of the buried seed of *Sporobolus cryptandrus*, as given in this group, should be compared with the germination of the unhulled seed as given in Table III, No. 64. The control samples of both the hulled and the unhulled seed which were sown in the greenhouse failed to germinate, but all three samples of the unhulled seed that had been buried gave some germination when tested in the greenhouse.

TABLE II.—*Results of tests of seeds which had either decayed or germinated and afterwards decayed while buried.*

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests.			Greenhouse tests in sand.			
							Depth of burial.		
			Temperature.	Original sample.	Control.	Control.	6-8 inches.	18-22 inches.	36-42 inches.
			°C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
14	16196	Zea mays (Boone County white corn)	20-30	99.5	99	....	....	....	....
15	16197	Zea mays (sweet corn)	20-30	98.5	98.5	....	....	....	....
16	16217	Agrostemma githago	20-30	99	98.5	....	....	....	....
17	16221	Brassica oleracea	20	85.5	82	....	....	....	....
18	16244	Gossypium hirsutum	20-30	77.5	72	....	....	....	....
19	16233	Pisum sativum	20-30	99	98	....	....	....	....
20	16232	Phaseolus vulgaris	20-30	97.5	98.5	....	....	....	(a)
21	16203	Fagopyrum fagopyrum	20-30	100	98.5	....	(b)	(c)	....
22	16195	Triticum aestivum	20	99	96.5	....	(d)	....	(a)
23	16186	Hordeum sativum	20	100	98	....	(d)	(d)	(d)
24	16175	Avena sativa	20-30	70.5	91.5	95.5	0	0	0
25	16191	Secale cereale	20	100	98.5	88	0	0	0
26	16267	Cucumis melo	20-30	96.5	97	88	0	0	0
27	16199	Allium cepa	20-30	94.25	88	70.5	0	0	0
28	16270	Lactuca sativa	20-30	100	98.5	91	0	0	0
29	16281	Helianthus annuus (cult.)	20-30	97	96.5	13	0	0	0
30	16241	Linum usitatissimum	20-30	93.5	95	83.5	0	0	0
31	16245	Hibiscus militaris	20-30	98.25	92	94	0	0	0
32	16200	Asparagus officinalis	20-30	80	[e] 69	74	[f] 0	[f] 0	[f] 0
33	16177	Bromus racemosus	20-30	100	98.5	92.5	[a] 0	0	[a] 0
34	16176	Bromus secalinus	20-30	88.5	77	95.5	0	0	0
35	16181	Eleusine indica	35	78.25	91.5	75	0	0	0
36	16284	Pinus virginiana	20-30	18	6.5	13.5	0	0	0
37	16234	Robinia pseudacacia	20-30	14	[g] 11.5	3.5	0	0	0

[a] Many had germinated and afterwards decayed.
[b] Approximately 10 per cent had germinated, the remainder had decayed.
[c] An occasional old sprout was found.
[d] Approximately all had germinated and afterwards decayed.
[e] Clipped, 87 per cent; not clipped, 51 per cent.
[f] Practically all had sprouted; the sprouts from seeds buried at the 36-42-inch depth were found matted in the bottom of the pot.
[g] Clipped.

The corn, sweet corn, corn cockle, cabbage, cotton, peas, beans, buckwheat, wheat, and barley—the first ten samples given in the foregoing table—were all so unmistakably decayed when the seeds were taken up that the contents of the pots were thrown away, no greenhouse tests being made. The first six of these samples showed no trace of any remains of old sprouts: apparently all of the seeds had decayed before germination had taken place. If germination took place it must have been comparatively soon after burial, thus giving ample time for all of the old sprouts to decay beyond identification. This, however, seems hardly probable, considering that the seeds were buried during the latter part of December, 1902; moreover, the beans, buckwheat, and barley from some or all of the different depths showed clearly the remains of well-developed radicles.

The beans which were buried at depths of from 6 to 8 and from 18 to 22 inches had decayed, while many of those buried at a depth of from 36 to 42 inches had germinated and afterwards decayed. The buckwheat from the 6 to 8 inch depth showed that approximately 10 per cent had germinated, while at 18 to 22 inches there were only the remains of an occasional old sprout, and at 36 to 42 inches all of the seed had decayed. In the wheat the greater number of the grains that were buried from 6 to 8 and from 36 to 42 inches had germinated and then decayed, while those which were buried at a depth of from 18 to 22 inches showed only decayed seed. Approximately all of the barley at the three different depths had germinated and afterwards decayed.

The last fourteen species given in this table were marked "decayed" when the seeds were taken up, but as the conditions were not so clearly indicated as in those first mentioned, germination tests were made in the greenhouse.

The results of the germination tests show that none of the pots contained any viable seeds. Of this latter group only the pots containing the *Asparagus officinalis* and *Bromus racemosus* (Nos. 32 and 33) showed remains of old sprouts. The seeds in the other pots apparently had all decayed without any germination during the time they were buried. The germination of the asparagus seed had been almost perfect. The pot buried at the greatest depth contained only a mass of sprouts, many of which were still partially alive. The *Bromus racemosus* showed that germination had taken place only in the pots buried at 6 to 8 and 36 to 42 inches, while those buried at the depth of 18 to 22 inches had all decayed before germinating.

It is interesting to note in this connection the behavior of the two species of Bromus—*Bromus secalinus* (cheat or chess) and *B. racemosus* (upright chess). The seeds of both of these species had completely lost their vitality within the eleven months in the soil, while the control samples gave a germination of 95.5 and 92.5 per cent.

respectively. These differences are more clearly shown in Plate I, A and B.

The results above stated, while perhaps not altogether conclusive, inasmuch as they represent only single tests of 200 seeds in each case, show that seeds of these two plants will not remain viable for long periods when buried in the soil.

This is particularly interesting in the case of the common cheat or chess, which is frequently a pernicious weed in the grain fields of the United States. The generally accepted opinion is that the grains of cheat will live in the soil for a number of years, the seeds germinating when conditions are most favorable, the resulting plants then crowding out the wheat. Some people even hold that in "off seasons" wheat turns to cheat, but fortunately such erroneous ideas are fast disappearing.

The results of these experiments show that cheat, whenever found growing in grain fields or elsewhere, has come from seed recently sown and has not been lying dormant in the soil. With but few exceptions the unexpected appearance of cheat comes either from seeds that have been sown unintentionally mixed with wheat or other grains so that they passed unobserved, or from seeds that have been scattered with stable manure.

Dr. Beal[a] has also shown that buried seeds of *Bromus secalinus* do not retain their vitality for a long period of years. In Beal's experiments the first test was at the expiration of five years, but not a single grain of cheat responded to the germination test at that time.

Table II includes the majority of our more commonly cultivated plants of the field or garden, all of which failed to show any seeds capable of germination after having been buried in the soil for approximately one year. This statement will hold good for the majority of our cultivated plants. There are, however, a number of exceptions. Many of these will be found in Table III, some showing that vitality was remarkably well preserved. Of these celery, parsnip, and tobacco (numbers 94, 95, and 99, respectively) should be mentioned in particular. The highest germination in each case was 64 per cent for the celery from the 18 to 22 inch depth, 63 per cent for the parsnip from the 36 to 42 inch depth, and 70 per cent for the tobacco from the 18 to 22 inch depth.

[a] Bulletin No. 5, Michigan Agricultural College, 1884.

TABLE III.—*Results of tests of seeds that had not completely lost their vitality while buried.*

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests.			Greenhouse tests in sand.			
			Temperature.	Original sample.	Control.	Control.	Depth of burial. 6–8 inches.	18–22 inches.	36–42 inches.
			° C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
38	16185	Festuca elatior	20–30	97	83	86	0.5	0.0	[a]0.0
39	16257	Capsicum annuum	20–30	96	97	80	.0	.0	.5
40	16222	Brassica campestris	20	90.25	86	18.5	.0	.0	[b].5
41	16239	Trifolium repens	20	84.75	42.75	86	.0	[b]1	.0
42	16240	Vigna catjang	20–30	82.5	59.5	70	.0	1	.0
43	16230	Lespedeza frutescens	20	15	[c]1	2.5	.0	.0	1
44	16246	Ascyrum hypericoides	30	1.5	.0	.0	1	.0	.5
45	16259	Lycopersicon lycopersicon	20–30	99.25	72.5	88	.5	1	.5
46	16179	Chaetochloa glauca	20–30	55.75	37.5	18	1	1	1
47	16242	Rhus glabra	20–35	.0	.0	.0	.0	.0	2
48	16268	Cucumis sativa	20–30	100	98.5	62	.0	1	3
49	16236	Trifolium pratense	20	89.75	73	85.5	2	4	4
50	16235	Trifolium hybridum	20	91.75	84	73	2	4	4.5
51	16274	Xanthium pennsylvanicum	30	50	....	.0	.0	.0	.5
52	16229	Cassia marylandica	30	14.5	[d]98	20	3	3	5
53	16273	Ambrosia trifida	20–30	29	52.5	48	.0	[b]2	6
54	16237	Trifolium pratense (10964)	20	67.75	....	70	4.5	[b]5	6
55	16219	Vaccaria vaccaria	20–35	[e]6.5	88	68	.0	[b]4	7
56	16251	Convolvulus sepium	20–30	4	2	24	2	4	7
57	16283	Rudbeckia hirta	30	65.5	78.5	74.5	6.5	6.5	7
58	16224	Erysimum cheiranthoides	20–35	52.5	42	14.5	2	[b]5	[b]8
59	16231	Medicago sativa	20	84.5	64.5	97	[b]2	[b]9	[b]9
60	16227	Thlaspi arvense	20–30	57.25	54.5	.5	[b]11	8	11.5
61	16261	Solanum nigrum	20–30	97.75	91	12	9.5	10.5	12.5
62	16213	Chenopodium hybridum	20–30	61	18.5	10.5	7.5	9.5	13
63	16253	Cuscuta polygonorum	20–30	12	8.5	55.5	11.5	10.5	13
64	16193	Sporobolus cryptandrus	30	2.25	3	.0	.5	1.5	13.5
65	16265	Plantago rugelii	20–30	3.75	5.5	67.5	12	12	13.5
66	16255	Verbena hastata	20–30	9	.5	....	11.5	13	14
67	16220	Brassica nigra	20	1.5	13.25	34	10	[b]14	[b]14
68	16238	Trifolium pratense (hard)	20	13.75	9.25	18	[b]10.5	15.5	14.5
69	16184	Elymus triticoides	20–30	84	75	85	1.5	[b]3.5	[b]15.5
70	16187	Panicum virgatum	20–30	30.5	36.5	22	7	17	16
71	16174	Avena fatua	20–30	70.5	91.5	93.5	[b]9	[b]8	18
72	16211	Beta vulgaris	20–30	153	....	90.5	7	19.5	20
73	16228	Potentilla monspeliensis	20–30	41	83	73.5	[b]9.5	16	21.5
74	16183	Elymus canadensis	20–30	93.5	95.5	81	.0	[b]7	[b]22
75	16190	Poa pratensis	20–30	90.75	87	59	16	22	24.5
76	16262	Verbascum thapsus	20–30	82.5	98	72.5	7	7.5	25.5
77	16182	Elymus virginicus	20–35	65.25	44	83	[a]2	[b]13.5	[b]25.5
78	16226	Sisymbrium altissimum	20	88.25	86.25	76	[b]10.5	17.5	26
79	16256	Verbena urticifolia	30	1.5	.0	56.5	23.5	24.5	26.5
80	16277	Carduus arvensis	20–30	56.75	68	5	24	22.5	28.5
81	16252	Ipomoea lacunosa	20–35	98.5	[f]88	88	20	25	33
82	16254	Cuscuta epilinum	20–30	.0	.0	.5	15.5	23.5	34
83	16214	Amaranthus retroflexus	20–30	94.75	91	61	18	22	35
84	16276	Bidens frondosa	20–30	75	52.5	25	29	33	36
85	16225	Neslia paniculata	20–35	96	97	68	23	24.5	38.5
86	16216	Portulaca oleracea	35	83.75	91.5	16	39	38.5	30.5
87	16272	Ambrosia artemisiaefolia	20–30	58.5	42.5	30.5	32	37	41
88	16263	Plantago lanceolata	30	82.5	78	67.5	41	41	41
89	16279	Grindelia squarrosa	20–30	25.75	41	87.5	30.5	36	42
90	16271	Taraxacum erythrospermum	20–30	85.75	87.5	85.5	35.5	41.5	45.5
91	16264	Plantago major	20–30	24	78	.0	39.5	43.5	46.5
92	16278	Chrysanthemum leucanthemum	20–30	96.25	91	85.75	[b]21	[b]33	[b]49.5
93	16188	Phalaris arundinacea	20–35	69.25	8	78	45	46.5	56.5
94	16248	Apium graveolens	20–30	88	83.5	72.5	48.5	64	60
95	16249	Pastinaca sativa	20–30	55.5	67	78.5	29	51	63
96	16212	Chenopodium album	20–30	67.25	58	33.5	32	63.5	64.5
97	16280	Helianthus annuus (wild)	20–30	100	97	86	43.5	64	66.5
98	16269	Lactuca scariola	20	.25	11.5	83	63.5	69	69.5
99	16260	Nicotiana tabacum	20–30	89.25	84.25	89.25	46.5	70	55
100	16173	Agropyron repens	20–30	80.24	84	23.5	20.5	[b]73	66.5
101	16275	Arctium lappa	20–30	99.75	96	88.5	42.5	63.5	73
102	16209	Rumex obtusifolius	20–30	97.5	95.5	80	73	72.5	79.5
103	16208	Rumex crispus	20–30	80.75	83.5	91	67.5	79.5	79
104	16215	Phytolacca americana	20–30	40.5	[d]88.5	84.5	7.5	66.5	80.5
105	16250	Fraxinus americanus	20–30	49.5	2	26	.0	.0	84
106	16258	Datura tatula	20–30	99	[d]54	88	[b]86	84	86.5
107	16207	Rumex salicifolius	20–30	98.25	96.5	2.5	88.5	85.5	70.5
108	16178	Chaetochloa verticillata	20–30	92.75	94.5	88.5	[b]58	71	90
109	16282	Onopordon acanthium	20–30	95.5	31	.0	86	93	90.5

TABLE III.—*Results of tests of seeds that had not completely lost their vitality while buried*—Continued.

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests. Temperature.	Chamber tests. Original sample.	Chamber tests. Control.	Greenhouse tests in sand. Control.	Greenhouse tests in sand. Depth of burial. 6–8 inches.	Greenhouse tests in sand. Depth of burial. 18–22 inches.	Greenhouse tests in sand. Depth of burial. 36–42 inches.
			° C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
110	16218	Alsine media	20–30	97	98.5	93	90.5	96.5	92.5
111g	16243	Abutilon abutilon							
112g	16189	Phleum pratense							
		Average percentage of germination		63.2	57.5	53.2	20.5	26.5	31

a Many had germinated and afterwards decayed.

b Fresh sprouts found when samples were taken up. These sprouted seeds were not thrown away, but were transplanted with the remainder of the sample and tested in sand in greenhouse, consequently those which produced seedlings are included in the percentages of germination given in the table. These fresh sprouts were found as follows:

Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.
	Inches.			*Inches.*			*Inches.*			*Inches.*	
39	36–42	1	59	36–42	1	71	18–22	Many.	92	18–22	Many.
53	18–22	3	60	6– 8	1	73	6– 8	4	92	36–42	Many.
54	18–22	1	67	18–22	2	71	18–22	Few.	100	18–22	1
55	18–22	1	67	36–42	2	74	36–42	Many.	106	6– 8	2
58	18–22	10	68	6– 8	1	77	18–22	10	108	6– 8	Many.
58	36–42	5	69	18–22	Few.	77	36–42	5			
59	6– 8	4	69	36–42	Many.	78	6– 8	1			
59	18–22	2	71	6– 8	Many.	92	6– 8	Many.			

c Clipped seed germinated, 59 per cent.

d Clipped.

e Germinated, 84 per cent at 20° C.

f Clipped seed germinated, 100 per cent.

g Tests interrupted.

In Table III the names of the seeds are arranged in the order of their vitality as determined by the germination tests made in the greenhouse. The list of seeds tested begins with *Festuca elatior* (meadow fescue), which showed only one viable seed, that being from the 18 to 22 inch depth, and ends with *Alsine media* (common chickweed), in which nearly all of the seeds retained their power of germination throughout the entire period that they remained in the soil. The germination of the latter, when sown in the greenhouse, was almost perfect. (See Pl. II, fig. 1.)

In many instances some of the seeds had germinated while they were buried. In most cases the seeds which had germinated afterwards decayed. In the larger seeds this could usually be determined without much difficulty, but with many of the smaller seeds no such observations could be made. However, it is more than probable that many of the smaller seeds which showed a low germination when transplanted in the greenhouse had germinated and afterwards decayed before being dug up, but this could not be satisfactorily determined by a hurried field examination. Many of the pots also contained fresh sprouts at the time the seeds were taken up. The number of fresh sprouts in each case is indicated in a footnote to Table III.

Unlike Table II, Table III includes names of but very few of our cultivated plants. The majority belong to that class of plants commonly known as weeds. These results show that but a limited number of our cultivated plants produce seeds which can retain their vitality for any length of time when buried in soil. On the other hand, the seeds of the plants which are commonly known as weeds are of strong vitality, and many of them deteriorated but very little with the treatment given. This, of course, is what we would expect. By natural selection the wild plants which survive are just those from seeds which are capable of living in the soil for a period of time more or less extended, and ultimately this factor becomes hereditary. With most of the cultivated plants the seeds are gathered and carefully saved from year to year, resulting in the loss of these inherited characteristics.

The mere fact that certain seeds retain their power of germination for a period of years when buried in the soil brands the plants which they produce as weeds. The length of time that such seeds can remain in the soil and still retain their power of germination largely determines their noxiousness. In other words, it may well be said that the pernicious character of weeds is directly proportional to the length of time the seeds will remain viable when buried in the soil. For this reason bad weeds are difficult to eradicate once the seeds are allowed to mature. (See Pl. II.)

RELATION OF DEPTH OF BURIAL TO VITALITY.

Table III shows that many of the seeds were better preserved the deeper they were buried. This is probably best explained by the difference in the three factors which govern germination, viz. *heat*, *moisture*, and *oxygen*. At the greatest depth the amount of moisture is always more uniform, the supply of air is greatly lowered, and the temperature is much reduced. The temperature decreases very rapidly as we go below the surface of the soil, and at 3½ feet is comparatively uniform throughout the year. Experiments conducted at McGill College, Montreal, Canada, by C. H. McLeod show that at a depth of 40 inches below the surface of the soil the minimum and maximum temperatures through the year were approximately 35° and 60° F., respectively.[a]

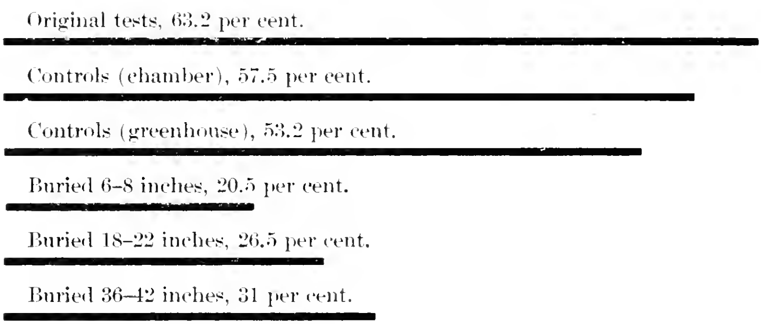
The greater number of seeds germinate best when subjected to daily alternations in temperature. These alternations do not take place at a depth of 3 feet below the surface; consequently there is a better

[a] Trans. Roy. Soc., Canada, Ser. 2, Vol. 7, Sec. III, pp. 13–16, 1901.

preservation of vitality at that depth as a result of the more dormant condition of the seeds. (See Pl. III and the diagram below.)

As was anticipated, most of the seeds which were stored in the Seed Laboratory preserved their vitality much better than those that were buried. But there are a number of cases in which the seeds were preserved practically as well in the soil as in the laboratory, the deterioration being very small in either case. However, with but few exceptions, an ample number of seeds remained germinable at the termination of the first year to produce plants in sufficient number to keep the up-to-date farmer busy for a good share of the summer in suppressing them. The average percentages of germination of all samples, including the original test and both controls, are best shown in the following diagram:

Average germination of controls and buried seeds.



HARD SEEDS.

An interesting point in these first results is in the behavior of the Trifoliums and closely related genera, including Lespedeza and Medicago. Generally speaking, these seeds are considered to be able to withstand very critical treatment, but the results of the first year's experiments show that the seeds of all of these deteriorated very greatly while in the soil.

The white clover, No. 41, germinated only 1 per cent, and showed one fresh sprout when taken up from the 18 to 22 inch depth and nothing from the shallower or deeper trenches. The red clover did but little better; No. 49, a sample of the harvest of 1902, germinated 2, 4, and 4 per cent for the three different depths of 6 to 8, 18 to 22, and 36 to 42 inches, respectively. Another sample of red clover, No. 54, germinated 4.5, 5, and 6 per cent, respectively, for the three different depths. A third sample of red clover, No. 68, germinated 10.5, 15.5, and 14.5 per cent, respectively, from the three depths. The last two samples were of Oregon-grown seed of the harvest of 1900. The original sample of this seed, No. 54, contained 51.5 per cent of hard seed. No. 68 includes only the hard seed selected from the Oregon clover by soaking in water for 18 and then for 20 hours a portion of the original bulk sample, using only the remaining hard seed.

These results, while unsatisfactory, show clearly that it is the hard seeds in the clovers which remain over in the soil for some considerable time. The alsike clover, No. 50, behaved practically the same as the sample of red clover first mentioned. The Lespedeza, or bush clover, No. 43, gave results very similar to the white clover. The alfalfa, No. 59, gave a germination of only 2, 9, and 9 per cent, respectively, for the three different depths. But in all cases a few fresh sprouts were present when the seeds were taken up, showing that the seeds were germinating and afterwards decaying.

SEEDS OF CULTIVATED VERSUS WILD PLANTS.

A number of interesting cases showing the greater hardiness of the seeds of wild plants over those of like or closely related cultivated forms were recorded. In *Helianthus annuus* (Nos. 6 and 97) the seeds from the cultivated plant—our common sunflower of the garden—all decayed, while the seeds of the wild sunflower retained their vitality and germinated 43.5, 64, and 66.5 per cent, respectively, for the three different depths. Similarly with *Lactuca sativa* and *Lactuca scariola*, Nos. 5 and 98, respectively, the common garden lettuce seed had all decayed, while the seed of the prickly lettuce, possibly the parent of our cos varieties, germinated 63.5, 69, and 69.5 per cent, respectively, for the three different depths. Another striking example is in *Avena sativa*, No. 1, and *Avena fatua*, No. 71, the latter germinating 9, 8, and 18 per cent, respectively, for the three different depths, besides showing many fresh sprouts in the two shallower depths at the time the seeds were taken up.

Furthermore, it is not uncommon to find wide variations in different species of the same genus, even where all forms are wild, e. g., Elymus, Chaetochloa, Chenopodium, Cuscuta, Plantago, etc. But in the cases above mentioned of the cultivated and the closely related wild forms the ability of the seeds to withstand such treatment as being buried in the soil has been lost by long cultivation of the plants and the careful preservation of the seeds under artificial conditions or storage, while seeds from the wild forms can survive when buried in the soil, for it is the plants from just such seeds that have survived.

SUMMARY.

The length of time that seeds will retain their vitality when buried in the soil is of much importance in the extermination of weeds.

The seeds of many of our pernicious weeds can be destroyed by deep plowing, if the soil is left undisturbed for some time.

Seeds of the cultivated plants, with but few exceptions, lose their vitality when buried in the soil.

Seeds of the plants commonly designated as weeds retain their vitality remarkably well when buried in the soil.

In general, the pernicious character of weeds is directly proportional to the length of time the seeds will remain viable when buried in the soil.

The deeper seeds are buried, the better is vitality preserved.

Hard seeds of the same species retain their vitality much better than those with softer seed coats.

Unhulled seed, especially of the grasses, is more resistant than hulled seed, and the vitality is always better preserved.

Seeds of plants from the same genus often retain their vitality in a very different degree.

Vitality is best preserved, even in weed seeds, when the seeds are carefully harvested and stored in a dry and comparatively cool place.

PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—*Bromus racemosus*, smooth brome grass. Fig. 2.—*Bromus secalinus*, cheat or chess. The two divisions at the right of each figure show the vigorous growth made by the check samples. In the three divisions at the left, A, B, and C, were planted the seeds which had been buried at depths of 6 to 8 inches, 18 to 22 inches, and 36 to 42 inches, respectively. The vitality of the seeds of these two species, which are considered as noxious weeds in the grain fields of the United States, was destroyed at the expiration of eleven months.

PLATE II. Fig. 1.—*Alsine media*, common chickweed. Fig. 2.—*Rumex crispus*, curled dock. Fig. 3.—*Datura tatula*, jimson weed. Seedlings from weed seeds which did not lose their vitality by burial for eleven months, as shown in the three divisions at the left of each flat, the germination being practically the same as in the case of the two check samples shown at the right of each flat.

PLATE III. Fig. 1.—*Elymus canadensis*, nodding wild rye. A, buried 6 to 8 inches—all killed; B, buried 18 to 22 inches—only one seedling shows in the figure, but the total germination was 7 per cent, as given in the table; C, buried 36 to 42 inches—germinated 22 per cent; the two check samples at the right made vigorous growth, germinating 81 per cent. Fig. 2.—*Fraxinus americanus*, white ash. A, buried 6 to 8 inches, and B, buried 18 to 22 inches—all killed; C, buried 36 to 42 inches—germinated 84 per cent; the check samples germinated 26 per cent, but the seedlings had "damped off" before the photograph was taken. Fig. 3.—*Phytolacca americana*, poke. A, buried 6 to 8 inches—germinated 7.5 per cent; B, buried 18 to 22 inches—germinated 60.5 per cent; C, buried 36 to 42 inches—germinated 80.5 per cent; the two check samples germinated 84.5 per cent.

The illustrations show that in many cases the vitality of seeds is better preserved at a depth of 36 to 42 inches than at shallower depths.

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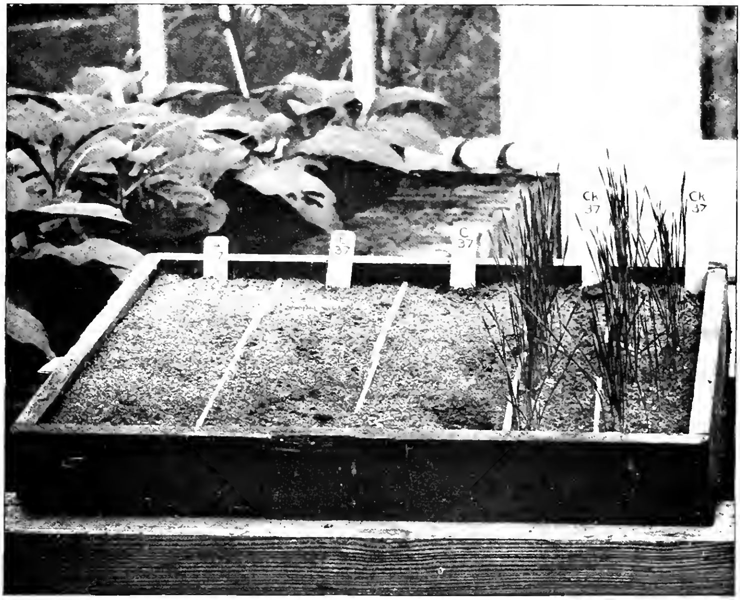

FIG. 1.—BROMUS RACEMOSUS (SMOOTH BROME-GRASS).

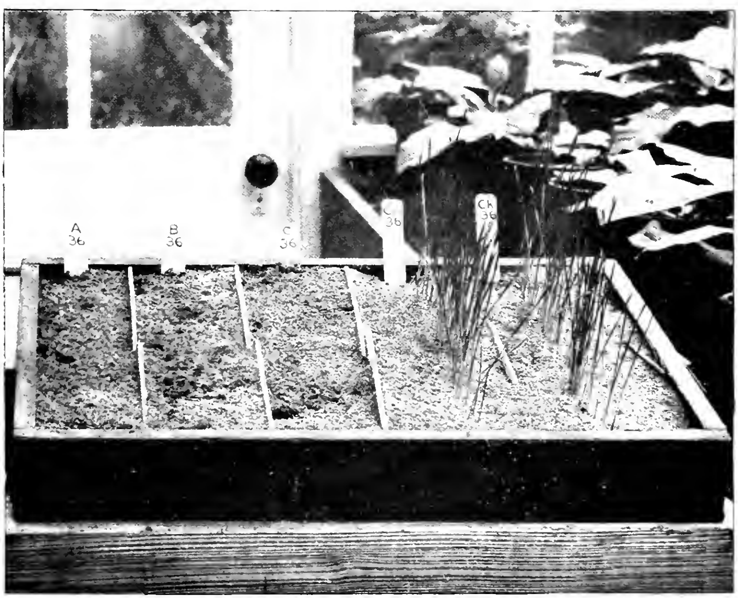

FIG. 2.—BROMUS SECALINUS (CHEAT, OR CHESS).

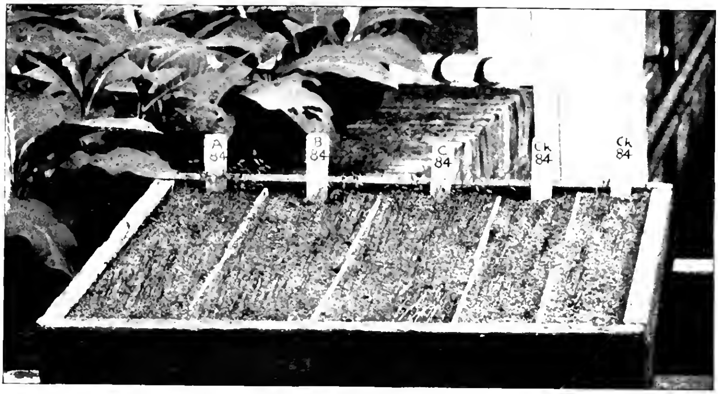

FIG. 1.—ALSINE MEDIA (COMMON CHICKWEED).

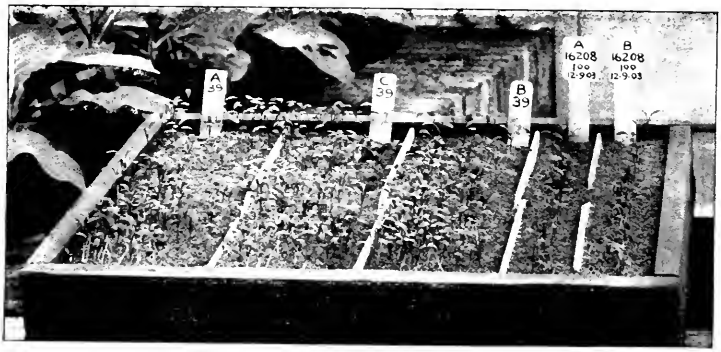

FIG. 2.—RUMEX CRISPUS (CURLED DOCK).

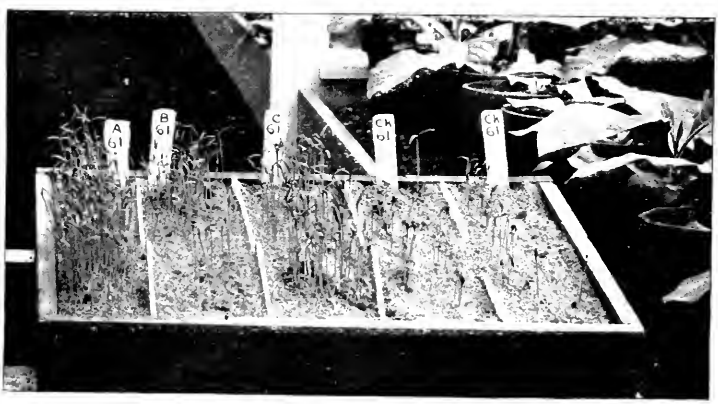

FIG. 3.—DATURA TATULA (JIMSON WEED).

FIG. 1.—ELYMUS CANADENSIS (NODDING WILD RYE).

FIG. 2.—FRAXINUS AMERICANA (WHITE ASH).

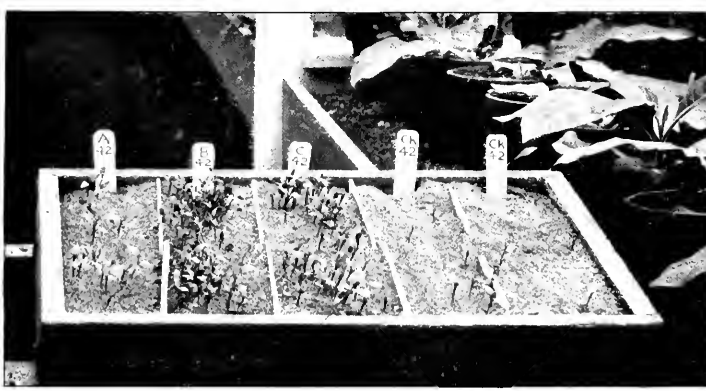

FIG. 3.—PHYTOLACCA AMERICANA (POKE).

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 84.

B. T. GALLOWAY, *Chief of Bureau.*

THE SEEDS OF THE BLUEGRASSES.

I. THE GERMINATION, GROWING, HANDLING, AND ADULTERATION OF BLUEGRASS SEEDS.

By EDGAR BROWN, *Botanist in Charge of Seed Laboratory.*

II. DESCRIPTIONS OF THE SEEDS OF THE COMMERCIAL BLUEGRASSES AND THEIR IMPURITIES.

By F. H. HILLMAN, *Assistant Botanist, Seed Laboratory.*

ISSUED NOVEMBER 14, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory; and Dry Land Agriculture and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 84.

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 15, 1905.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 84 of the series of this Bureau the accompanying technical paper entitled "The Seeds of the Bluegrasses."

This paper was prepared by Mr. Edgar Brown, Botanist in Charge of the Seed Laboratory, and Mr. F. H. Hillman, Assistant Botanist, Seed Laboratory, and has been submitted with a view to publication.

The bluegrasses are among the most important forage plants in many sections of the United States and Europe, and large quantities of seed are harvested annually for use in this country and for exportation.

The process of cleaning the seed of the bluegrasses for market is such that many of the distinguishing characters are lost, and separate descriptions are necessary for the hand-picked and commercial seed of the same species.

The seeds of the different commercial species are so nearly alike in general appearance that at present none but the trained observer can distinguish between them. This similarity of appearance has encouraged the use of the cheaper and less desirable species, especially Canada bluegrass, for the adulteration of or substitution for the more expensive species.

The descriptions and illustrations herewith given of the bluegrasses and of their impurities will be of great value in furnishing seedsmen the necessary information to enable them to distinguish the different species.

The accompanying illustrations are necessary for a complete understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE SEEDS OF THE BLUEGRASSES.

I. THE GERMINATION, GROWING, HANDLING, AND ADULTERATION OF BLUEGRASS SEEDS.

By Edgar Brown,

Botanist in Charge of Seed Laboratory.

DESCRIPTION OF COMMERCIAL AND HAND-GATHERED SEEDS.

Great difficulty is experienced in distinguishing the seeds of the species of Poa. It is especially important to be able to recognize them, as the species vary greatly in value and the seed of one species is frequently substituted for that of another.

The descriptions of the seeds of Poa already published have been largely those of complete or hand-gathered specimens. But the seeds of some kinds as they appear on the market are more or less broken and have lost many of their distinguishing characters. The process of cleaning often rubs off the web at the base of the seed and the hairs along the sides and breaks the tip. On this account descriptions based on specimens of perfect seeds are not to be relied upon in identifying certain commercial Poas.

The mutilation of seeds during the process of cleaning is especially marked in home-grown seed of Kentucky bluegrass (*Poa pratensis*). Even the hand-gathered seed of rough-stalked meadow grass (*Poa trivialis*) is frequently so much injured about the slender apex as to increase greatly the difficulty of distinguishing it from that of Kentucky bluegrass. On the other hand, the commercial seeds of wood meadow grass (*Poa nemoralis*) and fowl meadow grass (*Poa triflora*) retain much of the pubescence on the glume, often the web, and are usually not broken on the tip.

It is important that descriptions and illustrations to be used in practical seed testing be taken from the commercial as well as hand-gathered seed and be comparative in character. Those given in this paper have been prepared from both hand-gathered and commercial seed. The term seed is here used in its popular sense.

GRADES AND QUALITY OF COMMERCIAL SEEDS.

The seeds of all species except Kentucky bluegrass are known to the American trade in only one grade. This is the so-called "fancy" grade, which is based on relative cleanness and on the bright appearance of the seed. The quality of different samples passing under this grade name is not necessarily uniform, but among the more careful dealers a purity standard of from 80 to 90 per cent is usually maintained.

The seeds of Kentucky bluegrass and of Canada bluegrass raised in this country are usually much cleaner and freer from foreign seeds than the European-grown seeds of rough-stalked meadow grass, wood meadow grass, and fowl meadow grass.

Kentucky bluegrass seed is commonly offered in two grades—"fancy," and "extra-clean" or "extra-cleaned." The latter names are a survival of the time when the seed was hand cleaned and the "extra-clean" was the best seed on the market. With the advent of improved machinery the "fancy" grade was established and it is now the only grade generally accepted by the intelligent purchaser. The "extra-clean" still on the market belies its name, since it consists of the chaff or cleanings from the fancy seed, and consequently contains only light seed. Samples of "extra-cleaned" as offered usually contain less than 10 per cent of seed.

In some cases the growers find a sale for the rough or uncleaned seed after it has been passed through a feed cutter. In this condition it has very much the appearance of fine-cut straw with a large percentage of chaff, and can be scattered over pastures and other areas, seeding them as effectually as could be done by the use of fancy recleaned seed. If well cured, the germinating quality of such seed is excellent, and the mass contains from 60 to 70 per cent of pure seed. Except for foreign trade the percentage of germination has little to do with the price and grade of bluegrass seed.

Aside from adulterated samples the purity of "fancy" seed of all species of bluegrass is usually good. Of the 2,887 samples of Kentucky bluegrass tested by the Zurich Seed Control Station from 1876 to 1903 the average purity was 86.3 per cent. Of the 69 samples tested in the Seed Laboratory of the Department of Agriculture during the past year the average purity was 75.02 per cent.

ADULTERATION.

The seed of Canada bluegrass (*Poa compressa*) is the only kind used as an adulterant of Kentucky bluegrass in this country. During the year 1904 649,451 pounds of Canada bluegrass seed were imported from Canada, practically none of which is being sold under its true name. Among the samples of seed sold for Kentucky bluegrass and sent to the Seed Laboratory for examination a large number have contained from 30 to 50 per cent of Canada bluegrass seed and several have been entirely composed of the Canada seed.

It is significant in this connection that the price of Canada bluegrass seed varies with that of Kentucky bluegrass seed, being usually about one-half that of the latter. This adulteration is not merely a simple fraud by which the farmer pays for what he does not get, but the difference in the resulting pasture or hay crop is very important. Canada bluegrass, while having many good qualities in common with other species of Poa, is by no means a pasture grass, for which purpose Kentucky bluegrass is unexcelled.

The seed of wood meadow grass (*Poa nemoralis*) is sometimes adulterated with other species of Poa, and samples have been offered under this name that contain no wood meadow grass seed. One sample tested in the Seed Laboratory contained 59.4 per cent of *Poa pratensis* and 23 per cent of *Poa compressa*, the remainder being chaff and dirt. Samples of fowl meadow grass (*Poa triflora*) have been examined which consisted largely of various common grass and clover seeds combined with an abundance of weed seeds. These samples contained small quantities of Kentucky and Canada bluegrass seeds, much chaff and dirt, and some of them no seeds of fowl meadow grass.

The seed of Kentucky bluegrass is used to adulterate that of the higher priced *Poa trivialis*, pure seed of the latter species usually being hard to obtain. Some of the German authorities say that it is necessary for every farmer to save his own seed of this grass in order to be sure that it is pure. Hunter[a] says:

> Previously to 1883 good and genuine seed of this species (*Poa trivialis*) could not be obtained in this country [England]. Seed of the *Poa pratensis* was commonly supplied for it. It is now less difficult to procure genuine seed, but large quantities of seed of *Poa pratensis* (which usually costs about one-third the price) are prepared to resemble and are sold for *Poa trivialis*, and it is only by careful microscopic examination that the nature of the seed can be determined

WEIGHT PER BUSHEL.

The standard weight of a bushel of bluegrass seed of any grade is 14 pounds. The actual weight, however, varies from 6 to 8 pounds in the case of "extra cleaned" to 27 pounds or more for especially good samples of fancy recleaned seed. In the bluegrass region of Kentucky it is the usual practice to sell the seed fresh from the strippers or cured in the chaff by the bushel of 14 pounds, but it is always weighed, not measured. The cleaned seed is always sold by the pound. As the weight per bushel of bluegrass seed depends directly on its purity, it is customary in quoting the price of "fancy" seed to accompany it with a statement as to the weight per bushel.

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[a] Treatise on Permanent Pasture Grasses, James Hunter. Chester, England, 1901.

The foreign trade is much more critical than the domestic trade, and the seed exported usually weighs from 22 to 24 pounds per bushel, while the domestic trade is content with seed weighing from 18 to 20 pounds. The heavier seed costs more per pound than the lighter seed, since there is more labor in its preparation, but it is cheaper for the purchaser.

GERMINATION.

The germination of commercial bluegrass seed is often poor. At the Zurich Seed Control Station the average percentage from 3,069 samples of Kentucky bluegrass seed tested from 1876 to 1904 was 65 per cent, while 908 samples of *Poa trivialis* tested showed an average of 72 per cent. The quality of Kentucky bluegrass seed as respects germination appears, however, to be improving. Last year's tests at the Zurich station gave an average of 68 per cent, while a few years ago 50 per cent was considered fair or satisfactory. Only the best seed goes to Europe, and consequently the percentage of germination of that offered in this country is low. As carefully cured seed will germinate from 80 to 90 per cent, the cause for the poor quality of commercial seed is doubtless to be found in the way it is harvested and cured.[a] The usual process is to pile the freshly stripped seed in ricks, either outdoors or in barns. This mass heats quickly if not stirred often during the first few days. One pile left without stirring reached a temperature of 140° F. in sixteen hours, killing all the seed.

GROWING AND HANDLING.

With the exception of our native western species, more or less seed of all the commercial Poas is gathered in Europe, where they are found wild. The harvesting is done by hand from the natural meadows, woods, or other uncultivated areas. The seed is cleaned by hand and carried to market in small quantities and collected by dealers who supply the trade. The United States furnishes Europe with Kentucky bluegrass seed, and Europe furnishes the seed of rough-stalked meadow grass and wood meadow grass, as well as of the other commercial species of Poa used in this country.

Poa pratensis (Kentucky bluegrass).—The bulk of the Kentucky bluegrass seed comes from a limited area known as the bluegrass region of Kentucky. The counties of Bourbon, Scott, Fayette, Clark, and Woodford furnish most of it, although there is a small quantity saved in Shelby County. Some is harvested in southwestern Illinois, and there is another area on the border between Missouri and Iowa where a considerable amount of seed is saved. The seed is gathered from the natural woodland pastures as well as from those where it has

[a] See Bulletin No. 19, Bureau of Plant Industry, "Kentucky Bluegrass Seed: Harvesting, Curing, and Cleaning."

been sown. It is customary to graze cattle on it nearly the entire year, as they do not materially injure the crop of seed if they are kept out for two or three weeks immediately before gathering. The seed is harvested by pulling the heads off with a stripper, the grass not being cut for hay. The cleaning is a rather difficult process, as it is necessary to rub the heads thoroughly in order to separate the seed from the web at the base. The last of the chaff and dirt which is blown out during the cleaning process is sold as "extra-cleaned" seed.

Poa compressa (Canada bluegrass).—The seed of Canada bluegrass is mostly produced in the Province of Ontario, along the north shore of the eastern half of Lake Erie. The soil is a heavy clay on limestone. In this section Canada bluegrass is not sown, but appears as a volunteer in any fields that are not kept under cultivation, making a thick growth and crowding out other grasses and weeds. It is nearly always found in wheat fields when the wheat crop is a partial failure. In this case the seed, ripening as it does at the same time as the wheat, is thrashed with it and screened out in cleaning. Where the seed is harvested alone the grass is cut with a mowing machine and cured the same as ordinary hay, and afterwards thrashed with a clover huller or grain separator. The hay is bright green, even when not cut until after the seed is ripe, and is well liked by some farmers as feed, while it is considered hard and of little value by others. A good crop is from 200 to 300 pounds of clean seed per acre. There has been some demand for this seed in the Southeastern States under the name of Virginia bluegrass. The seed is easily cleaned, as it is comparatively free from wool at the base and does not require rubbing, as does Kentucky bluegrass seed. No special machinery is used except rather long sieves to insure sufficient screening.

Poa trivialis (rough-stalked meadow grass).—The wholesale trade in the seed of rough-stalked meadow grass is largely confined to the city of Hamburg, Germany. The seed is collected in the neighborhood of that city and in the marshes of the Elbe. Seed of good quality is also supplied from Denmark, where in one locality this grass is grown especially for seed, and it is said to yield as much as 400 pounds to the acre. The seed is stripped or the grass is cut and the seed allowed to after-ripen, when it is cleaned by hand.

Poa nemoralis (wood meadow grass).—The seed of wood meadow grass is gathered by hand in the woods of Germany, and cleaned in the same manner as is the seed of *Poa trivialis*.

Poa triflora (fowl meadow grass).—Though widely distributed throughout the northern portion of the United States, this species is chiefly a natural meadow grass of lowlands, and is usually so mixed with sedges and other grasses that seed collection on a commercial scale has not thus far been undertaken in this country. The seed of this species on the market comes from Europe and is very poor.

Prof. L. R. Jones, of the Vermont Agricultural Experiment Station, reports the seed production from a nearly pure stand of this grass as amounting to 6 bushels of 19 pounds each per acre. A small plat yielded seed at the rate of over 7 bushels per acre. The seed is produced abundantly and ripens evenly. In Vermont it is harvested in the latter part of July. The name fowl meadow grass is often applied to another lowland grass, *Panicularia nervata*.

Poa arachnifera (Texas bluegrass).—The seed of Texas bluegrass is gathered by hand in northern Texas. It is cleaned by rubbing between the hands, and, owing to the long, woolly hairs at the base of the seed, it is never "fancy clean." The best seed is produced on rich, black, waxy soil, and is ripe about May 1 to 15. Only a small quantity is gathered each year, and consequently it is high priced and can not be considered as a commercial seed at the present time.

Poa annua (annual bluegrass).—The seed of the annual bluegrass is not on the market in this country, though the plant is common about dwellings, especially in the South and East, and ripens its seed throughout the summer. The seeds do not ripen evenly, the upper ones falling before the lower flowers have opened. The seed is gathered and used to some extent in Europe.

Poa alpina (alpine meadow grass).—Alpine meadow grass is best known in Switzerland, where the seed ripens from the end of June to the middle of July. The viviparous form can be propagated by scattering the buds during the hot weather.

Poa sudetica.—The seed of *Poa sudetica*, which is a European grass, is rare in the market, but is occasionally quoted by French and by German firms. It is sometimes mixed to some extent with the seeds of the meadow grasses, particularly water meadow grass (*Panicularia americana*).

In addition to the foregoing, other species of Poa occur in the western and northwestern United States, where they contribute to the native forage of the stock ranges. The seeds of these species, however, are not found in commerce.

II. DESCRIPTIONS OF THE SEEDS OF THE COMMERCIAL BLUEGRASSES AND THEIR IMPURITIES.

By F. H. Hillman,

Assistant Botanist, Seed Laboratory.

THE BLUEGRASSES.

The "seeds" of the species of Poa, or the bluegrasses, are the ripened florets or individual parts of the smaller clusters, or spikelets, of the general floral system of the plant. The number of florets in each spikelet varies from two to nine in the different kinds of Poa commonly found in commerce. There is some variation in the number of florets in the spikelets of each species. The florets separate readily at maturity, and well-cleaned samples of seed contain few whole or partial spikelets.

A complete, mature spikelet embraces, besides its several florets, a pair of chaffy scales, termed empty glumes, between which the florets, or at least the lower ones, rest. The empty glumes, while somewhat

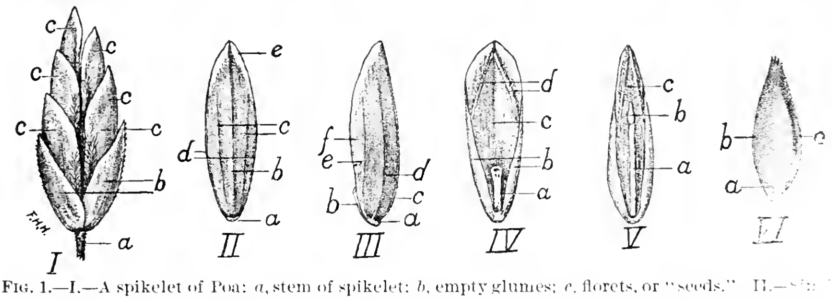

Fig. 1.—I.—A spikelet of Poa: *a*, stem of spikelet; *b*, empty glumes; *c*, florets, or "seeds." II.—Single floret, back view: *a*, callus; *b*, keel; *c*, intermediate veins; *d*, marginal veins; *e*, hyaline part of glume. III.—Single floret, side view: *a*, callus; *b*, rachilla segment; *c*, keel; *d*, intermediate vein; *e*, marginal vein; *f*, margin of glume. IV.—Single floret, front view: *a*, rachilla segment; *b*, marginal fold; *c*, palea; *d*, keels of palea. V.—Terminal floret, front view: *a*, rachilla segment; *b*, aborted floret; *c*, palea. VI.—Caryopsis, or grain: *a*, location of embryo; *b*, keeled face; *c*, grooved face.

dissimilar, are keeled, acute, and one or three veined. The keel of each is usually hispid-ciliate above the middle. A portion of the stem of the spikelet often remains attached to the base of the empty glumes when these are found in commercial samples.

Each mature, well-developed floret or seed consists of a caryopsis, commonly called grain, two inclosing scales which, together with the empty glumes, constitute the chaff, and a slender appendage, the rachilla segment. (Fig. 1.)

The caryopsis corresponds to an individual grain in wheat, rye, and barley, and consists almost entirely of the seed proper, to which is added only the thin wall of the seed vessel. This is intimately blended with the seed coat, the two forming the covering of the true seed. The caryopsis is spindle-shaped and often broadest between the middle and the base. It is often bluntly keeled along one face and more or less evidently grooved along the opposite face. In the commercial bluegrass seeds the grain is amber-colored or dull wine-colored and semitranslucent. The surface is finely granular and dull. The kernel of the seed forms that part of the grain within the seed and seed-vessel walls. It consists of the embryo and endosperm, the latter forming the greater part. The embryo is situated at the basal extremity of the grain and is evident externally as a small ridge, often within a slight depression, on the keeled face. The grain adheres along its grooved face to the palea in some species in which free grains are not common in well-cleaned commercial seed.

The two chaffy scales of the floret differ chiefly in size, form, relative position, venation, and texture. The larger one, called the flowering glume or simply the glume, incloses the edges of the other, termed palea. The grain rests between the glume and palea, its keeled face lying against the glume. The rachilla segment is at the base of the palea and opposite the glume. It is one of the articulating sections of the rachilla, or axis of the spikelet.

The characters by which the different kinds of bluegrass seeds are distinguished one from another are afforded by the glume, palea, and rachilla segment, and involve size, form, color, veins of the glume, form and texture of the apex of the glume, and the pubescence.

The glume is stiffish and more or less pointed at the ends. Its base is marked by the presence of a small, somewhat knob-like appendage, the callus. The latter bears the scar of attachment of the floret and, in certain species, a more or less pronounced tuft of webby hairs. The back of the glume is more or less keeled along its longitudinal center. Besides the fold forming the keel, the edges of the glume are infolded along the marginal veins. The marginal folds often are most pronounced within and sometimes are confined to the lower half of the glume, in which event the upper margins usually diverge and become spreading or flaring at the apex. The keel is strongly arched lengthwise in some species and in others is nearly straight. Five veins traverse the glume longitudinally; one occupies the keel, two are at the marginal folds and are termed the marginal veins, while the other two are situated midway between the keel and marginal veins and are called intermediate or, by some authors, lateral veins. The intermediate veins exhibit considerable variation in distinctness in the different species. The vein occupying the keel extends to the apex. The apex and often the upper part of the lateral margins of the glume in most species are thin and translucent, or hyaline. The extent of the hyaline portion of the apex has much to do with the form of the latter and is variable in the different species.

The palea is commonly more delicate in texture than the glume, being partially hyaline. It usually is shorter than the glume, but in some species equals or exceeds it in length. The difference in length usually is most evident in the lower florets of the spikelet. Two veins traverse the palea lengthwise and nearly meet at its apex. The margins of the palea are more or less acutely infolded along these veins, which are called the keels of the palea. The keels are mostly covered by the glume in some species, while in others they are almost wholly exposed. There is some variation in this respect, however, among seeds of the same species. The apex of the palea is often notched.

The rachilla segment is nearly cylindrical and usually somewhat curved. It is slightly expanded at the apex, which is obliquely truncate, its terminal surface constituting the scar of attachment to the succeeding floret. Different florets in the same spikelet in certain species exhibit a marked variation in the length of the rachilla segment, which is shortest in the lower florets and conspicuously longer in the terminal one, where it usually bears an aborted floret as a small, pointed appendage.

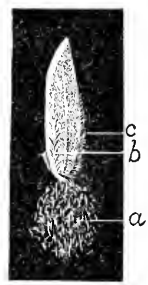

Fig. 2. — Unrubbed Kentucky bluegrass seed (*Poa pratensis*): *a*, web; *b*, pubescence of marginal vein; *c*, pubescence of keel.

The surface of the florets of different species of Poa is subject to considerable variation. Some florets are smooth, or glabrous; others bear numerous minute, stiffish hairs, rendering the surface rough, or scabrous; and some have a fine, appressed pubescence covering a part of the surface. Most of the species have a more or less silky pubescence on the keel and marginal veins below the middle or somewhat higher on the keel. The intermediate veins are more rarely pubescent. The keels of the palea are usually fringed with minute hairs, or are hispid-ciliate, but in some species they are silky pubescent. The basal web is wholly wanting in some species and in others varies from a few fibers to a copious tuft. It readily separates from the floret in most species. The rachilla segment is usually smooth, but in some species it is appressed pubescent. The presence of the hairs on the marginal veins often necessitates that care be used in examining the rachilla segment with respect to pubescence. (Fig. 2.)

The color of mature seeds varies from very light brown to dark brown. Sterile seeds are usually lighter or straw colored. Immature seeds are more or less tinged with green; some are purplish. In certain species the glume is tinged with golden yellow near the apex. The aborted terminal floret and all the hairs are white. The rachilla segment is lighter colored than the glume or palea.

Poorly cleaned samples are apt to contain many sterile florets. These are slender, sometimes shrunken, and usually lighter colored than the grain-bearing florets, which are comparatively plump and often dark colored, owing to the color of the grain appearing through the thin palea. (Fig. 3.)

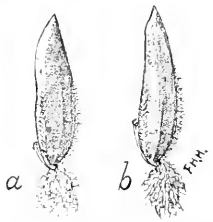

FIG. 3.—Seeds of Kentucky bluegrass (*Poa pratensis*): *a*, grain bearing; *b*, sterile.

The recognition of the several species of Poa, when the identity is questionable, requires the use of a good lens and a knowledge of the principal distinguishing characters. A sample under examination should be spread thinly on a sheet of paper, or, better still, on a black surface. With a good light and means for turning the seeds over while under the lens, they can easily be examined with reference to size, color, distinctness of veins, character of pubescence, the condition of the margins of the glume, etc. Exposing the different sides of the florets to the light while under examination is often absolutely essential in determining the nature of the veins and pubescence.

KEY TO THE SEEDS OF THE MORE COMMON SPECIES OF POA AS FOUND ON HERBARIUM SPECIMENS.

Basal web present.
- Web very persistent and conspicuous .... *P. arachnifera.*
- Web easily removed, small; keel of the glume pubescent.
  - Intermediate veins distinct.
    - Intermediate veins sharply defined as narrow ridges; glume margins narrow, not easily seen from the side; marginal veins usually smooth. *P. trivialis.*
    - Intermediate veins usually not sharply defined; glume margins broader, easily seen from the side in fertile florets; marginal veins pubescent. *P. pratensis.*
  - Intermediate veins indistinct.
    - Rachilla segment smooth or nearly so; florets 2–2½ mm. long.
      - Florets usually broader above than below the middle; apex usually flaring; rachilla segment smooth .... *P. compressa.*
      - Florets not evidently broader above than below the middle; apex usually golden yellow; rachilla segment sometimes rough .... *P. triflora.*
    - Rachilla segment usually pubescent.
      - Florets 2½–3 mm. long, usually not yellow at the apex. ..... *P. nemoralis.*

Basal web not present.
- Florets strongly pubescent.
  - Intermediate veins distinct; palea keels prominent, often arched forward. *P. annua.*
  - Intermediate veins indistinct; palea keels not arched............... *P. alpina.*
- Florets not pubescent .... *P. sudetica.*

KEY TO COMMERCIAL BLUEGRASS SEEDS AFTER PREPARATION FOR MARKET.

Seeds *4–6 mm. long;* web longer than glume, forming a woolly tuft *and causing the seeds to cling in bunches in the sample* .... *P. arachnifera.*

Seeds 2–2¾ mm. long, usually rubbed free from hairs and disconnected in the sample, *often more or less torn at the apex;* commonest commercial kinds.

Intermediate veins distinct; seeds contracted at the apex *and not wider above than below the middle;* hyaline margin of apex seldom present in rubbed seed. *P. pratensis.*

Intermediate veins very indistinct; seeds broader above than below the middle; hyaline margin of apex usually evident *and flaring* .... *P. compressa.*

Seeds 2–3 mm. long, chiefly unrubbed; disconnected or clinging somewhat in the sample; usually not torn at the apex; smooth or the pubescence on the veins and the web more or less evident.

Intermediate veins indistinct.

Rachilla segment usually pubescent; long, sterile rachilla segments conspicuously common; *intermediate veins scarcely evident;* keel and marginal veins pubescent; apex of seed often flaring; seed 2½–3 mm. long .... *P. nemoralis.*

Rachilla segment smooth; intermediate veins but slightly evident; keel and marginal veins pubescent; apex of seed sometimes flaring; *seed 2–2½ mm. long.* *P. triflora.*

Intermediate veins very distinct.

Rachilla segment smooth and slender; keel pubescent, marginal veins usually smooth; apex of seed acute and compressed; *seeds often distinctly curved as viewed from the side* .... *P. trivialis.*

COMPARISON OF THE PRINCIPAL DISTINGUISHING CHARACTERS OF BLUEGRASS SEEDS.

Species.	Florets.		Glume.						Palea.	Rachilla segment.	Aborted floret.
	Number in the spikelet.	Length.	General form.	Apex.	Intermediate veins.	Silky pubescence.	Basal web.	Color.			
		mm.									
P. pratensis.	3–5	$2-2\frac{3}{4}$	Lanceolate or ovate-lanceolate.	Acute, mostly torn in commercial seed.	Distinct; not sharply defined, slender ridges; smooth.	On keel and marginal veins; absent in commercial seed.	Well developed; absent in commercial seed.	From light brown to dark brown, often purplish.	Equal to or somewhat shorter than the glume; keels hispid-ciliate and more or less exposed.	$\frac{1}{6}$ to $\frac{1}{2}$ the length of glume; smooth.	Minute.
P. compressa.	3–9	$2-2\frac{1}{2}$	Oblong-obovate or lanceolate.	Usually obtuse; torn or flaring in commercial seed.	Indistinct or apparently wanting; smooth.	Same as in *P. pratensis.*	Slight; absent in commercial seed.	Straw-colored or light brown, sometimes purplish.	Same as in *P. pratensis.*	$\frac{1}{5}$ to $\frac{1}{2}$ the length of glume; smooth.	Minute.
P. trivialis.	2 or 3	$2-2\frac{1}{2}$	Narrowly lanceolate, often curved.	Acute; usually hyaline-edged and entire; distinctly keeled.	Sharply defined as slender ridges; smooth.	On keel; marginal veins smooth; often present in commercial seed.	Slight; usually absent in commercial seed.	Light brown, sometimes purplish.	Same as in *P. pratensis.*	Very slender, $\frac{1}{4}$ to $\frac{1}{2}$ the length of glume; smooth.	Minute.
P. nemoralis.	2 or 3	$2\frac{1}{2}-3$	Lanceolate or ovate-lanceolate.	Obtuse or acute; hyaline and often flaring.	Indistinct; smooth.	On keel and marginal veins; present in commercial seed.	Same as in *P. trivialis.*	Light brown, sometimes yellowish at the apex.	Same as in *P. pratensis.*	Slender, $\frac{1}{4}$ to $\frac{3}{4}$ the length of glume; pubescent; long, sterile segments abundant.	Often as long as the rachilla segment.
P. triflora.	2–4	$2-2\frac{1}{2}$	Same as in *P. nemoralis.*	Acute or slightly flaring; hyaline.	Same as in *P. nemoralis.*	Same as in *P. nemoralis.*	Same as in *P. trivialis.*	Light brown, usually yellowish at the apex.	Same as in *P. pratensis.*	Slender, $\frac{1}{4}$ to $\frac{1}{2}$ the length of glume; smooth or rough.	Often long.

P. arachnifera.	4 or 5	4–6	Narrowly lanceolate.	Acuminate; hyaline-edged; not flaring.	Usually distinct as narrow ridges; smooth.	Same as in *P. nemoralis.*	Very copious; persistent; present in commercial seed.	Straw-colored or light brown.	Shorter than glume; keels hispid-ciliate.	$\frac{1}{3}$ to $\frac{1}{2}$ the length of glume; smooth.	Minute.
P. annua.	3–5	$1\frac{1}{2}$–3	Robust; ovate-lanceolate.	Acute or broadly flaring and hyaline.	Distinct; more or less pubescent.	On all the veins or only on keel and marginal veins; often on surface between the veins at base.	None.	From light brown to dark brown.	Equal to or shorter than glume; keels prominent, arched, pubescent.	Stout, $\frac{1}{4}$ to $\frac{1}{3}$ the length of glume.	Minute.
P. alpina.	3–6	$2\frac{1}{2}$–$3\frac{1}{2}$	Obovate or ovate-lanceolate.	Acute or flaring, hyaline.	Indistinct or evident below the middle; smooth or pubescent.	On keel and marginal veins and on surface between the veins at base.	None.	Light brown; sometimes purplish and yellowish.	Equal to or shorter than glume; keels exposed, slightly pubescent and hispid-ciliate.	From minute to $\frac{1}{5}$ the length of floret; smooth.	Minute.
P. sudetica.	2 or 3	3–4	Lanceolate or ovate-lanceolate.	Acute or acuminate; keeled and merely hyaline-edged.	Distinct for nearly or quite their full length; scabrous.	None; veins and often the general surface scabrous.	None.	Light brown to dark brown, sometimes purplish.	Equal to or exceeding the glume, often separated from it at the apex.	$\frac{1}{5}$ to $\frac{1}{2}$ the length of floret; the sterile segment tapering.	Minute or sometimes conspicuous.

DESCRIPTIONS OF SPECIES.

Poa pratensis L.

KENTUCKY BLUEGRASS, JUNE GRASS.

Spikelets 3–5 flowered; florets 2–2¾ mm., rarely 3 mm., long, lanceolate or fusiform as viewed from the back, lanceolate or ovate-lanceolate as viewed from the side, mostly acute or the terminal floret sometimes acuminate at the apex, glabrous between the veins, varying from light brown to dark brown, sometimes tinged with purple, sterile florets lighter; glume usually sharply keeled quite to the apex and often strongly arched, particularly at the base; its marginal folds comparatively broad, extending from the base nearly or quite to the apex, becoming hyaline-edged above the middle in the lower florets, usually not expanded or flaring at the apex, the edges nearly meeting in sterile florets, separated and usually distended forward in fertile lower florets, often scarcely covering the palea keels of fertile terminal florets, the hyaline edge more or less torn away and the margins jagged at the apex in rubbed commercial seed; intermediate veins distinct and glabrous; keel and marginal veins silky pubescent below the middle or somewhat higher on the keel; basal web well developed; pubescence and web wanting, except occasional traces of the former, in well-rubbed commercial seed; palea nearly or quite as long as the glume, its keels finely hispid-ciliate and usually covered for the greater part of their length by the margins of the glume; rachilla segment slender, glabrous, varying from about one-sixth of the length of the glume in the lower florets to one-half its length in the terminal one; aborted floret of the sterile rachilla segment minute; grain 1½ mm. long, somewhat keeled and grooved, often broadest below the middle, reddish brown or darker about the embryo, and semitranslucent. (Fig. 4.)

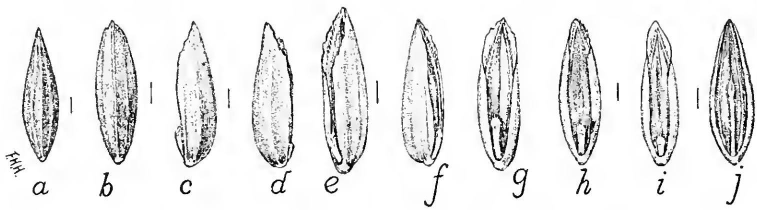

FIG. 4.—Different forms of commercial seeds of Kentucky bluegrass (*Poa pratensis*): *a* and *b*, back views; *c–f*, side views; *g–j*, front views; *j*, a terminal floret.

Commercial Kentucky bluegrass seed is mostly free from the silky and webby hairs present in hand-gathered samples, owing to the rubbing process to which it is subjected before being marketed. The severe rubbing results in more or less injury to the thin margins of the glume, particularly at the apex, which is usually found to be more or less torn when examined with a lens. Seeds of a well-rubbed sample do not tend to cling in small bunches as do those which are unrubbed or hand-gathered. Well-developed seeds are rather robust and have the glume margins well separated and evidently distended forward. Sterile seeds, or such as have the grain wanting or poorly developed, are generally lighter colored, slenderer, and more compressed, while the glume margins more nearly meet and are but slightly or scarcely distended. Such are much lighter in weight than well-developed seeds and consequently are mostly blown out with other chaff in well-cleaned seed.

Kentucky bluegrass seed is most readily confounded with that of Canada bluegrass (*Poa compressa*) and rough-stalked meadow grass (*Poa trivialis*). Owing to the difference in cost, *Poa compressa* is sometimes mixed with or substituted for Kentucky bluegrass, while the latter is sometimes similarly employed with respect to *Poa trivialis*.

The characteristic differences between Kentucky bluegrass seed and that of Canada bluegrass, as exhibited by the bulk samples and by individual seeds under the lens, may be compared as follows:

Kentucky bluegrass (*Poa pratensis*).	Canada bluegrass (*Poa compressa*).
The usual, well-cleaned bulk samples are brown in color.	Average samples lighter colored than those of Kentucky bluegrass.
Individual, well-matured seeds exhibit the same brown color of the bulk sample.	The lighter color of individual seeds affords the principal character for the preliminary recognition of these seeds in mixtures.
Nearly all the seeds taper from the center to both ends and are not broader at the apex than at the base.	Most of the seeds are broader at the apex than at the base, often distinctly broader at the apex than at the middle.
The apex of commercial seeds is usually torn, obtusely pointed, keeled, and scarcely hyaline.	Apex of commercial seeds often torn, mostly expanded or flaring, often but slightly keeled.
The intermediate veins are almost invariably distinct.	The intermediate veins are very indistinct or apparently wanting.

A number of the samples of Kentucky bluegrass seed examined contained seed of the Canada bluegrass. As the latter seed found in commerce usually contains the prickles or even the seeds of Canada thistle (*Carduus arvensis*), these are often found in samples of Kentucky bluegrass seed containing the Canada bluegrass seed. Their presence indicates the admixture, since the Canada thistle does not grow in the seed-producing localities of Kentucky, while it is abundant in Canada, where the Canada bluegrass is produced. Samples of pure Kentucky bluegrass seed are apt to contain the prickles of horse nettle (*Solanum carolinense*), sometimes wrongly called bull thistle, a prickly plant common in the bluegrass region of Kentucky. These prickles are similar to those of the Canada thistle, but may be distinguished, as shown hereafter in this paper in describing the impurities of the bluegrass seeds. The fact that Canada bluegrass only begins to flower at the time Kentucky bluegrass is ripe precludes the possibility of the mixture of the two kinds of seed owing to the fact of growth together. Such mixture can occur only after the seed is gathered, through accident or intent.

Poa compressa L.

CANADA BLUEGRASS, FLAT-STEMMED BLUEGRASS.

Spikelets 3–9 flowered; florets 2–2½ mm. long, oblong-obovate or the terminal one lanceolate as viewed from the back, somewhat narrowly oblong as viewed from the side, obtuse or the terminal one acute, smooth between the veins, straw colored or light brown; glume somewhat arched, especially at the base, and strongly keeled at the back, the keel often less pronounced at the apex than at the base; margins infolded from the base for about three-fourths the length of the floret in the lower florets and nearly to the apex in the upper ones, hyaline-edged above the middle, often broadly so at the apex, which is more or less flaring in the lower florets, the thin apex often torn and jagged in commercial seed; intermediate veins very indistinct or not evident, glabrous; keel and marginal veins silky pubescent below the middle; basal web present, slight; palea nearly or quite equaling the glume, finely hispid-ciliate on the keels, which are usually more or less exposed above the middle, sometimes from the base; rachilla segment glabrous, varying from about one-fifth the length of the glume in the lower florets to one-half its length in the terminal one; aborted floret of the sterile rachilla segment minute; grain 1–1½ mm. long, keeled and slightly grooved, semitranslucent. (Fig. 5.)

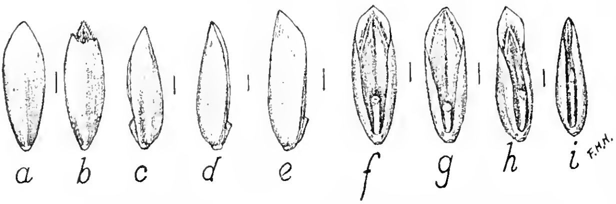

FIG. 5.—Commercial seeds of Canada bluegrass (*Poa compressa*): *a* and *b*, back views; *c–e*, side views; *f–i*, front views of florets; *i*, a terminal floret.

The seed of Canada bluegrass is the cheapest of the bluegrass seeds, and is therefore not adulterated with other Poas, although it is itself used as an adulterant to a considerable extent.

Pure samples of Canada bluegrass seed almost always contain the prickles and sometimes the seeds of Canada thistle (*Carduus arvensis*); therefore, the occurrence of these prickles with other kinds indicates the use of this species as an adulterant. Their occurrence with seed of *Poa trivialis* without evidence of the presence of Canada bluegrass seed is noted under the discussion of *P. trivialis*.

Poa trivialis L.

ROUGH-STALKED MEADOW GRASS.

Spikelets 2 or 3 flowered; florets 2–2½ mm., rarely 3 mm., long, narrowly lanceolate or the fertile terminal one ovate-lanceolate as viewed from the back, usually lanceolate and curved as viewed from the side, laterally compressed as compared with other species, straw colored or light brown and sometimes purplish, sharply keeled, the keel somewhat arched; margins of the glume scarcely or but slightly distended, narrowly and rather sharply infolded nearly or quite to the apex, which is hyaline-edged, very acute and rarely expanded; intermediate veins very distinct as narrow and sharply defined ridges; keel slightly pubescent below the middle, or rarely smooth; marginal veins smooth or sometimes pubescent, basal web present; palea nearly equal to the glume, its keels smooth or finely hispid-ciliate near the apex and mostly covered by the margins of the glume except in the larger terminal florets; rachilla segment very slender, glabrous, varying from one-fourth to one-half the length of the glume; grain 1–1½ mm. long, keeled and grooved, semitranslucent, reddish brown. (Fig. 6.)

Rough-stalked meadow grass is chiefly hand gathered; consequently the commercial seed is apt to bear more or less of the web as well as the silky pubescence on the keel. In many samples, however, both are rubbed away.

This seed resembles that of *Poa pratensis* and that of *Poa compressa* so closely that both are employed as adulterants, the former apparently to considerable extent, since it has frequently been found to constitute a considerable part of samples of so-called rough-stalked meadow grass. One sample examined marked "*Poa trivialis*" from Europe consisted almost wholly of *Poa compressa*. Several samples from Europe contained prickles of Canada thistle, but no seeds of Canada bluegrass were found.

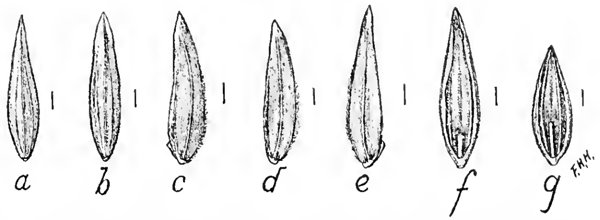

Fig. 6.—Seeds of rough-stalked meadow grass (*Poa trivialis*): *a* and *b*, back views; *c–e*, side views; *f* and *g*, front views; *g*, a terminal floret.

The principal distinguishing characters of the three species may be compared as follows:

Rough-stalked meadow grass (*Poa trivialis*).	Kentucky bluegrass (*Poa pratensis*).	Canada bluegrass (*Poa compressa*).
Commercial seeds are usually pubescent on the keel vein, usually smooth on the marginal veins and bear more or less of the webby hairs, consequently cling together in masses.	Commercial seeds rarely pubescent on the veins and the webby hairs wanting; consequently mobile in bulk, not clinging in masses; unrubbed seed pubescent on the marginal and keel veins.	
As viewed from the side, the seeds are somewhat curved, much narrower than the others, the glume margins usually only slightly evident.	Seeds mostly straight as viewed from the side, glume margins often strongly distended.	Seeds straight, the glume margins somewhat evident from the side.
Apex of the glume usually uninjured, strongly keeled, acute, slightly hyaline-margined, often curved.	Apex of the glume more or less torn in commercial seed; keeled, sharply pointed, hyaline-edged and not curved in unrubbed seed.	Apex of the glume often torn, otherwise somewhat keeled, obtusely pointed, broader than the base, hyaline-edged.
Intermediate veins sharply defined as narrow ridges.	Intermediate veins distinct as rather coarse ridges.	Intermediate veins indistinct or apparently wanting.
Rachilla segment very slender and less variable in length than in *P. pratensis* or *P. compressa*.	Rachilla segment coarser than in *P. trivialis* and often very short.	

Poa nemoralis L.

WOOD MEADOW GRASS.

Spikelets 2 or 3 flowered; florets $2\frac{1}{2}$–3 mm. long, lanceolate or ovate-lanceolate, mostly acute at the apex, light brown, sometimes yellowish tinged near the apex; glume rather broadly keeled and somewhat arched at the back; margins of the glume narrowly infolded quite to the apex or hyaline-edged and often flaring above the middle; intermediate veins very indistinct; keel and marginal veins silky pubescent below the middle; basal web slight; surface between the veins glabrous; palea nearly equal to the glume, evidently shorter in florets having a flaring apex, its keels hispid-ciliate and usually covered by the margins of the glume; rachilla segment varying from one-fourth to three-fourths of the length of the glume, the sterile rachilla segment very uniformly much longer than the others, more or less appressed pubescent, the pubescence somewhat variable and sometimes nearly wanting; aborted floret of the sterile rachilla segment often one-half as long as the segment; grain $1\frac{1}{2}$ mm. long, rather slender, semitranslucent. (Fig. 7.)

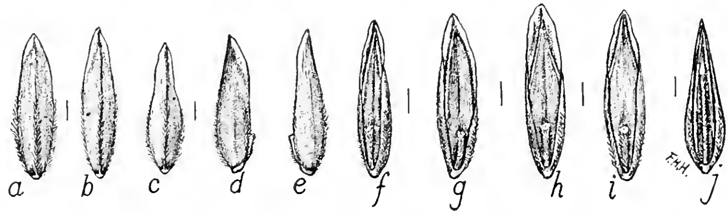

FIG. 7.—Seeds of wood meadow grass (*Poa nemoralis*): *a–c*, back views; *d* and *e*, side views; *f–j*, front views; *j*, a terminal floret.

Commercial wood meadow grass seed is not rubbed in preparation for market, and therefore possesses much of its rather persistent and prominent silky pubescence, and the thin tips of the florets are mostly uninjured. The pubescence of the rachilla segment is persistent and present in most of the seeds of all pure samples of this species. It affords the most marked characteristic by which the seeds of *P. nemoralis* may be distinguished from those of other commercial species of Poa. The conspicuously longer rachilla segments of the terminal florets are noticeably abundant in samples of this species, since these florets constitute from one-third to one-half of all the seed. The abundance of the long rachilla segments is helpful in distinguishing these seeds from those of other Poas.

Commercial seed of *P. nemoralis* is apt to be very much adulterated with other species of Poa. Of a number of samples examined less than half were true to name. One was nearly pure Canada bluegrass seed, and the rest consisted in part of one or all of the following species: *P. pratensis*, *P. compressa*, and *P. trivialis*.

The following comparison of characters should render it comparatively easy to distinguish the seeds of *P. nemoralis* from those of the other species.

<table>
<tr><th>Wood meadow grass (Poa nemoralis).</th><th>Kentucky bluegrass (Poa pratensis); Rough-stalked meadow grass (Poa trivialis).</th><th>Canada bluegrass (Poa compressa).</th></tr>
<tr><td>Silky pubescence of the veins mostly present and prominent.</td><td colspan="2">Silky pubescence of the veins wanting or but slight.</td></tr>
<tr><td>Apex of the glume slenderly pointed or narrowly flaring.</td><td>Apex of the glume acute.</td><td>Apex of the glume broadly flaring.</td></tr>
<tr><td>Intermediate veins indistinct.</td><td>Intermediate veins distinct.</td><td>Intermediate veins indistinct.</td></tr>
<tr><td>Rachilla segment pubescent, often more than half the length of the glume.</td><td colspan="2">Rachilla segment smooth, not exceeding half the length of the glume.</td></tr>
</table>

Poa triflora Ehrh. (**P. flava** L., **P. serotina** Ehrh.).

FOWL MEADOW GRASS, FALSE REDTOP.

Spikelets 2–4 flowered; florets 2–2½ mm. long, lanceolate or ovate-lanceolate as viewed from the back, broadly keeled and strongly arched at the back, light brown and usually strongly tinged with yellow above the middle, sometimes purplish, margins of the glume narrowly infolded below the middle or quite to the apex, which is hyaline-edged, expanded but scarcely flaring; intermediate veins indistinct; keel and marginal veins silky pubescent below the middle; basal web slight; palea nearly or quite equal to the glume, finely hispid-ciliate on the keels, which are mainly covered by the glume margins in the lower florets; rachilla segment slender, glabrous or sometimes slightly scabrous, from one-fourth to one-half or two-thirds the length of the glume; aborted floret of the sterile rachilla segment often prominent and nearly as long as the rachilla segment; grain 1 mm. long, comparatively robust and smooth, scarcely keeled or grooved, semitranslucent. (Fig. 8.)

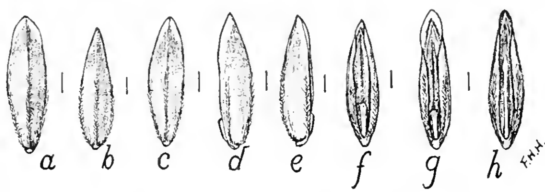

Fig. 8.—Seeds of fowl meadow grass (*Poa triflora*): *a–c*, back views; *d* and *e*, side views; *f–h*, front views; *h*, a terminal floret.

Most, if not all, of the seed of *P. triflora* on the market appears to be of foreign production. The samples examined have proved to be the worst found among the bluegrasses. It is probable that a better grade of seed could be secured from the natural meadows in this country where this species often constitutes the principal grass. The seeds of *P. triflora* are very similar to those of Canada bluegrass and wood meadow grass.

The principal distinguishing characters of the three kinds are as follows:

FOWL MEADOW GRASS (*Poa triflora*).	CANADA BLUEGRASS (*Poa compressa*).	WOOD MEADOW GRASS (*Poa nemoralis*).
Seeds 2–2½ mm. long.	Seeds 2–2½ mm. long.	Seeds 2½–3 mm. long.
Seeds mostly narrower at the apex than at the center.	Seeds mostly broader at the apex than at the center or base.	Seeds narrower or not broader at the apex than at the center.
Seeds usually yellowish at the apex.	Seeds not yellowish at the apex.	Seeds sometimes yellowish at the apex.
Intermediate veins usually evident but indistinct.	Intermediate veins indistinct or more commonly not evident.	Intermediate veins indistinct.
Pubescence of the veins and the web often present in commercial seed.	Pubescence of the veins and the web mostly absent in commercial seed.	Pubescence of the veins usually present in commercial seed.
Rachilla segment mostly smooth, sometimes slightly rough, often two-thirds the length of the glume.	Rachilla segment smooth, not exceeding one-half of the length of the glume.	Rachilla segment pubescent or sometimes only rough, often three-fourths the length of the glume.

The name fowl meadow grass is often applied, both by seedsmen and by writers upon grasses, to *Panicularia nervata*.

Poa arachnifera Torr.

TEXAS BLUEGRASS.

Spikelets 4 or 5 flowered; florets 4–6 mm. long, narrowly lanceolate, acuminate, straw colored or light brown; glume strongly keeled quite to the apex and somewhat arched; margins narrowly infolded below and becoming broadly hyaline above the middle, not widely flaring at the apex; marginal and keel veins strongly pubes-

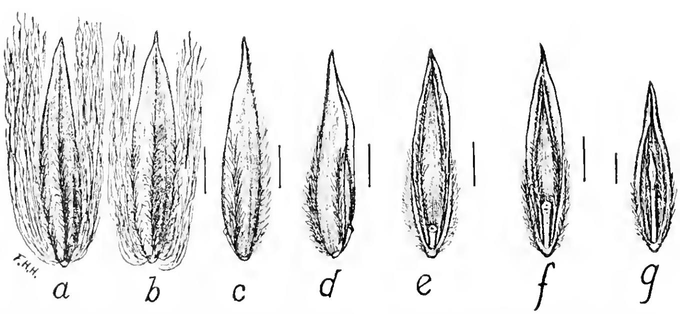

FIG. 9.—Seeds of Texas bluegrass (*Poa arachnifera*): *a* and *b*, back views, seeds showing the long hairs of the web; *c* and *d*, side views; *e–g*, front views; *g*, a terminal floret.

cent with long, silky hairs; basal web copious, often twice as long as the floret, very persistent; surface between the veins glabrous, the keel hispid-ciliate above the middle; palea from three-fourths to four-fifths the length of the glume, its keels more or less exposed, silky pubescent to the middle and hispid-ciliate at the apex; rachilla segment varying from about one-sixth to one-third the length of the glume, glabrous; aborted floret of the sterile rachilla segment minute; grain slender, 1½–3 mm. long, oblong-fusiform, nearly opaque, distinctly grooved and keeled. (Fig. 9.)

Texas bluegrass seed in commerce is unrubbed, and as the silky pubescence and web are very persistent they are always present. The hairs are so long and copious that the seeds cling in loosely matted, woolly bunches, and thus are easily distinguished from all the other commercial Poas. (Fig. 10.)

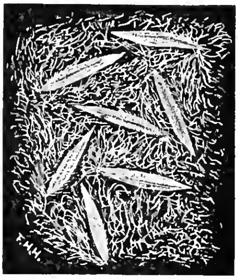

FIG. 10.—A cluster of Texas bluegrass seeds matted by the webby fibers.

Poa annua L.

ANNUAL MEADOW GRASS.

Spikelets 3–5 flowered; florets 1½–3 mm. long, ovate or ovate-lanceolate and relatively robust, strongly keeled and arched at the back, more or less densely pubescent, light brown or dark brown and often purplish or yellowish; margins of the glume very narrowly infolded below the middle, thin and broadly hyaline above the middle in the lower florets, flaring, gaping, or infolded at the apex; intermediate veins usually distinct as narrow ridges extending from the base to the margin of the apex, glabrous or pubescent; marginal veins and keel densely soft-pubescent below the middle; surface between the veins sometimes more or less pubescent at the base; web wanting; palea somewhat shorter than the glume, except in the terminal floret; keels of the palea coarse and prominent, mostly exposed, usually arched forward and exposed to side view in florets having a well-developed grain, often contracted toward the rachilla segment at the base, silky pubescent from near the base nearly to the apex; rachilla segment glabrous, from one-fourth to one-third the length of the glume, aborted floret of the sterile rachilla segment minute; grain 1–1½ mm. long, robust, distinctly granular, keeled and grooved, slightly translucent. (Fig. 11.)

The seed of *Poa annua* is not in the trade and is not apt to become mixed with the commercial bluegrass seeds. It may be readily distinguished from the common commercial species of Poa by its abundant

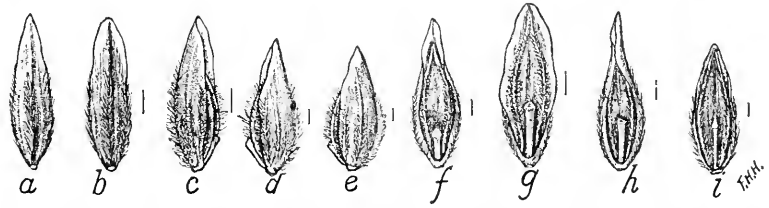

FIG. 11.—Seeds of annual meadow grass (*Poa annua*): *a* and *b*, back views; *c–e*, side views; *f–i*, front views; *i*, a terminal floret.

pubescence, arched and silky pubescent keels of the palea, and robust form. The seed most closely resembles that of *Poa alpina*, from which it is distinguished in individual seeds by its distinct intermediate veins and prominent, arched, and silky pubescent but not hispid-ciliate palea keels.

Poa alpina L.

ALPINE MEADOW GRASS.

Spikelets 3–6 flowered; florets 2½–3½ mm. long, ovate-lanceolate or obovate, the uppermost lanceolate, broadly keeled, arched, acute, or obtuse, light brown, sometimes purplish, and often yellowish tinged at the apex; margins narrowly infolded below the middle and becoming broadly hyaline at the apex; intermediate veins indistinct or evident only below the middle; keel and marginal veins silky pubescent below the middle or higher on the keel, which is hispid at the apex; surface between the marginal veins and keel appressed pubescent at the base; web wanting; palea nearly or quite equal to the glume, its keels not arched as in *Poa annua*, slightly silky pubescent below the middle and hispid-ciliate above; rachilla segment glabrous, varying from no longer than wide to one-third the length of the glume; aborted floret of the sterile rachilla segment minute; grain 1½ mm. long, keeled and grooved, semitranslucent, dark reddish brown, granular. (Fig. 12.)

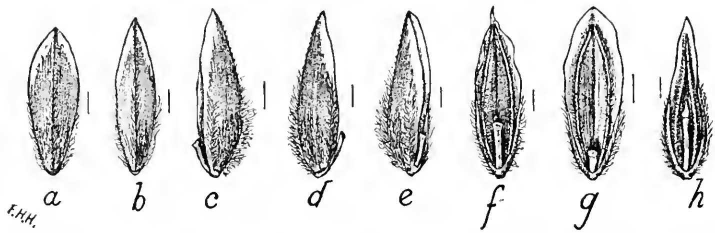

Fig. 12.—Seeds of alpine meadow grass (*Poa alpina*): *a* and *b*, back views; *c–e*, side views; *f–h*, front views; *h*, a terminal floret.

The seed of *Poa alpina* is not on the market and is not likely to be found in commercial seeds. Individual seeds of *P. alpina* closely resemble those of *P. annua*, but are to be distinguished by the indistinct intermediate veins of the glume, the variable rachilla segment, and especially by the keels of the palea, which are slenderer, not arched, less pubescent, and strictly hispid-ciliate above. The plant is alpine and occurs in the northern part of the United States as far west as Colorado, in Canada and Alaska, and in Europe and Asia.

Poa sudetica Haenke.

Spikelets 2 or 3 flowered; florets 3–4 mm. long, lanceolate or ovate-lanceolate; apex acute or acuminate; glume somewhat arched and strongly keeled at the back, light brown or dark brown, sometimes tinged with purple; margins of the glume narrowly infolded below the middle, narrowly hyaline-edged above the middle and not flaring at the apex; all the veins distinct, never silky pubescent, usually hispid;

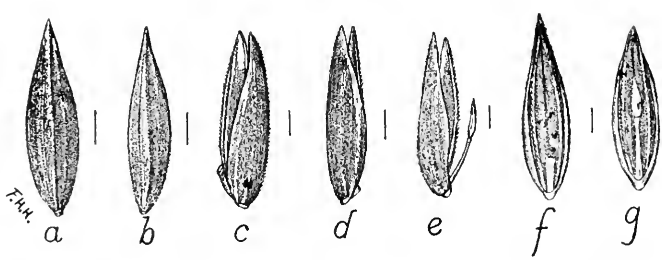

Fig. 13.—Seeds of *Poa sudetica*: *a* and *b*, back views; *c–e*, side views; *f* and *g*, front views; *g*, a terminal floret.

general surface scabrous or sometimes glabrous; web not present; palea equaling or somewhat exceeding the glume and often separated from it at the apex in florets having a well-developed grain; keels of the palea hispid-ciliate, mostly exposed and more or less evident from the side; rachilla segment varying from one-fifth to one-third or even one-half the length of the glume, glabrous or scabrous, sterile rachilla segment tapering to the apex, the aborted floret usually minute, but sometimes conspicuous and nearly equal to the rachilla segment; grain about 2 mm. long, robust, light brown, slightly keeled and grooved, semitranslucent. (Fig. 13.)

This is a European species not found in the American market.

Panicularia spp.

Owing to the fact that *Panicularia nervata* is sometimes sold as fowl meadow grass, a description of its seed is presented. A description of the closely allied *P. americana*, which is often associated with *P. nervata*, is added as an aid in comparing the two species.

Panicularia nervata (Willd.) Kuntze.

NERVED MANNA GRASS, SOMETIMES CALLED FOWL MEADOW GRASS.

Florets 1–1½ mm. long, robust, ovate (obovate with reference to the plant), light brown, purplish and sometimes greenish when immature; glume rounded at the back, prominently seven-veined, its margins somewhat infolded at the base and not flaring at the apex, which is sometimes narrowly hyaline; surface smooth, except the veins, which are sometimes scabrous; palea equal to or sometimes longer than the glume, broad, the keels exposed, prominent and nearly meeting at the rounded and sometimes slightly notched apex, usually scabrous above the middle; rachilla segment one-fifth to one-fourth the length of the glume, subcylindrical and scarcely expanded at the apex, the terminal one somewhat longer than the others and tipped by a minute, aborted floret; grain loosely held by the stiffish glume and palea, obovate, slightly flattened, ¾–1 mm. long, smooth, somewhat polished, very dark brown or black, sometimes slightly translucent. (Fig. 14.)

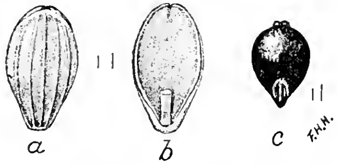

FIG. 14.—Seeds of nerved manna grass (*Panicularia nervata*): *a* and *b*, back and front views; *c*, grain.

Panicularia americana (Torr.) MacM.

REED MEADOW GRASS, WATER MEADOW GRASS, TALL MANNA GRASS.

Florets 3–3½ mm. long, elliptical-oblong as viewed from the front or back, somewhat spindle-shaped as viewed from the side, obtuse at the apex, brown, or purplish before complete maturity; glume rounded at the back, distinctly seven-veined, its margins narrowly infolded at the base and not flaring at the apex; surface smooth between the scabrous veins; palea equal to the glume, concave, its keels exposed, nearly meeting at the apex, very finely hispid-ciliate; rachilla segment one-fifth to one-fourth the length of the glume, subcylindrical, somewhat expanded at the apex, that of the terminal floret slightly longer and tipped by a minute, aborted floret; grain broadly oblong, 1½–2 mm. long, somewhat flattened, very dark brown, slightly translucent, smooth, and somewhat polished when fully developed. (Fig. 15.)

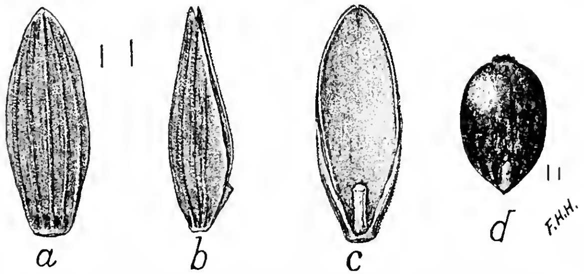

FIG. 15.—Seeds of water meadow grass (*Panicularia americana*): *a*, *b*, and *c*, back, side, and front views of seeds; *d*, grain.

WEED SEEDS COMMONLY FOUND WITH COMMERCIAL BLUEGRASS SEEDS.

The following weed seeds are those most frequently found with the various kinds of bluegrass seed.

Bursa bursa-pastoris (L.) Britton.

SHEPHERD'S-PURSE.

Seeds $\frac{2}{3}$–1 mm. long, oval-oblong, one extremity often pointed by the whitish tissue of the scar, flattened with rounded edges; faces similar and usually presenting two shallow grooves; color yellowish or reddish brown, usually darker near the scar; surface nearly smooth; endosperm absent; embryo curved upon itself, the cotyledons incumbent; seeds developing a coat of transparent mucilage when placed in water. (Fig. 16.)

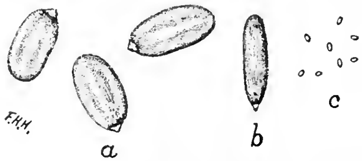

FIG. 16.—Seeds of shepherd's-purse (*Bursa bursa-pastoris*): *a*, side view; *b*, edge view; *c*, natural size of seeds.

Seldom found abundantly, but occurring frequently in all of the commercial bluegrass seeds.

Lepidium virginicum L.

PEPPERGRASS.

Seeds $1\frac{1}{2}$ mm. long, much flattened, ovate with one edge straight and thicker than the other, the curved edge narrowly margined, the margin usually hyaline and broadest at the broad end of the seed; faces similar, each nearly crossed lengthwise by a curved groove; scar at the small extremity, marked by a small, whitish tissue; surface smooth, dull, and reddish yellow; endosperm wanting; embryo curved upon itself, the cotyledons accumbent; seeds developing a copious coat of transparent mucilage when placed in water. (Fig. 17.)

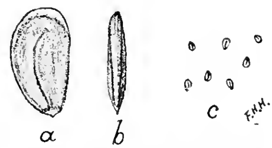

FIG. 17.—Seeds of peppergrass (*Lepidium virginicum*): *a*, side view; *b*, edge view; *c*, natural size of seeds.

Frequently found in home-grown seed and sometimes very abundant, especially in poorly cleaned seed.

Cerastium vulgatum L.

MOUSE-EAR CHICKWEED.

Seeds about $\frac{1}{2}$ mm. long, flattened but not thin, rounded or triangular, the broad edge rounded, the narrow edge notched; surface roughened by small tubercles or very short ridges, dull, and reddish-brown; embryo cylindrical, curved about the endosperm, its extremities nearly meeting at the notch in the seed coat. (Fig. 18.)

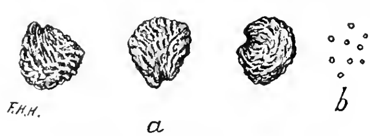

FIG. 18.—Seeds of mouse-ear chickweed (*Cerastium vulgatum*): *a*, side views; *b*, natural size of seeds.

Found frequently; sometimes abundant in poorly cleaned seed.

Alsine media L.

COMMON CHICKWEED.

Seeds circular-ovate, about 1 mm. in diameter with little variation in size, flattened with plane faces and flattened edges; scar in a small notch in the edge; surface dull, slightly tubercled, the tubercles in rows on the edges and in more or less evidently concentric rows on the similar faces; color brown, or reddish in immature seeds; embryo cylindrical, curved about the endosperm, its extremities nearly meeting at the scar. (Fig. 19, *a*.)

Alsine media is very common in the United States, but is so low-growing that the American method of seed stripping prevents the occurrence of its seeds in abundance in commercial bluegrass seeds. Its seeds are common in European bluegrass seeds, particularly those of rough-stalked meadow grass.

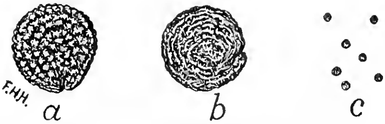

FIG. 19.—Seeds of chickweeds: *a*, *Alsine media*; *b*, *A. graminea*; *c*, natural size of seeds.

Alsine graminea (L.) Britton.

Seeds similar to those of *Alsine media*, except in form and surface markings; usually circular or oval; faces and edges somewhat rounded, finely roughened by short, interlacing ridges which are arranged more or less concentrically on the faces and parallel on the edges; surface dull; color grayish-brown, immature seeds reddish. (Fig. 19, *b*.)

Not found in American seed; frequent, although not abundant, in European seed.

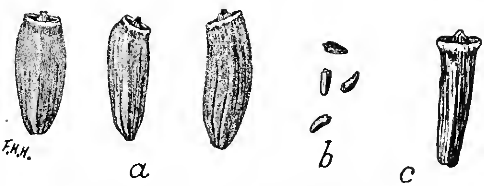

FIG. 20.—Seeds of Canada thistle (*Carduus arvensis*): *a*, well-matured seeds; *b*, natural size of seeds; *c*, a shriveled seed.

Carduus arvensis (L.) Robs.

CANADA THISTLE.

Seeds (akenes) 2–3 mm. long, oblong-lanceolate, flattened with obtuse edges, slightly ridged along each face, straight or curved edgewise, sometimes facewise; apex truncate, often obliquely so, concave with a ring-like border; corolla scar represented by a central, conical projection; surface dull and mostly smooth, sometimes with several narrow, longitudinal grooves; color brown, the apical margin usually lighter and sometimes yellowish. (Fig. 20.)

Prickles of Canada thistle and horse nettle (*Solanum carolinense*) often occur in certain bluegrass seeds. While the presence of the former is significant with respect to adulteration, the two kinds are apt to be confounded.

The prickles of Canada thistle are 2–6 mm. long, very slender, yellowish, usually expanded and laterally flattened at the base, which consists of a portion of the leaf tissue and is darker colored than the rest of the prickle, somewhat rounded or angular in form and jagged-edged. (Fig. 21, *c* and *d*).

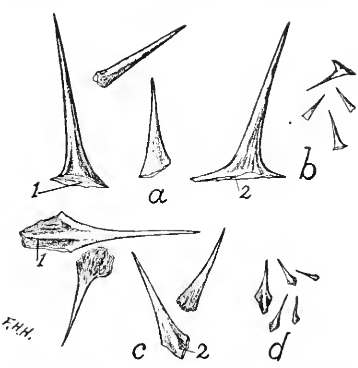

FIG. 21.—Prickles often found with bluegrass seed: *a* and *b*, horse nettle (*Solanum carolinense*) enlarged and natural size; *c* and *d*, Canada thistle (*Carduus arvensis*) enlarged and natural size; 1 and 2, characteristic forms of the bases of the two kinds of prickles.

The prickles of horse nettle (*Solanum carolinense*) are coarser, 4–8 mm. in length, light yellow in color, usually not darker at the base. They are produced on the stems and the coarse midribs of the leaves, and on breaking off have a transversely flattened scar. They occur frequently in samples of Kentucky-grown *Poa pratensis* and are easily mistaken for those of Canada thistle. (Fig. 21, *a* and *b*.)

Matured seeds, shriveled seeds, and prickles from the leaves and stems of Canada thistle are frequently found in Canada bluegrass seed. The presence of the prickles in the more expensive kinds of bluegrass seed indicates the probable use of Canada bluegrass seed as an adulterant. These prickles have been found, however, in rough-stalked meadow grass seed in which no trace of Canada bluegrass seed appeared. Owing to the troublesome nature of Canada thistle, care should be taken not to introduce its seeds with those of the bluegrasses.

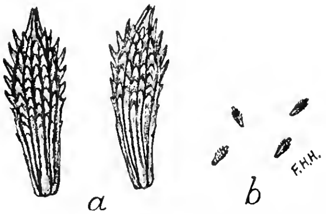

Fig. 22.—Seeds of dandelion (*Taraxacum taraxacum*): *a*, side views; *b*, natural size of seeds.

Taraxacum taraxacum (L.) Karst.

DANDELION.

Seeds (akenes) 3–4 mm. long, including the persistent base of the beak, which forms the pointed apex of the seed, lance-shaped or broadly so, straight or curved, flattened or slightly four-angled with similar faces, barbed in the upper, broader half; teeth directed toward the apex, prominent on the edges and arranged in about five rows on each face, which has two slender grooves with three rows of teeth between them; surface dull; color light brown or dark brown. (Fig. 22.)

Occurring occasionally in both American and European seed, these seeds have appeared most frequently in Kentucky bluegrass and rough-stalked meadow grass seeds.

Matricaria inodora L.

SCENTLESS CAMOMILE.

Seeds (akenes) 1⅓–2 mm. long, slender or robust, oblong with obtuse extremities, tapering somewhat from the truncate apex to the base, slightly flattened; faces dissimilar, one having three prominent, longitudinal ribs joined at the apex, the lateral ribs and a partial one joined to them at the apex appearing on the opposite face, which also presents two small cavities separated by the partial ridge; surface between the ridges transversely roughened, dark brown or black and darker than the brown or yellowish ridges. (Fig. 23.)

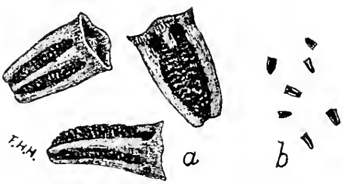

Fig. 23.—Seeds of scentless camomile (*Matricaria inodora*): *a*, back, front, and edge views; *b*, natural size of seeds.

Found only in foreign-grown seed, chiefly in rough-stalked meadow grass and wood meadow grass seeds.

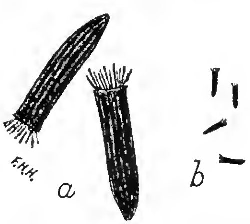

Fig. 24.—Seeds of hawkweed (*Hieracium* sp.): *a*, side views; *b*, natural size of seeds.

Hieracium sp.

HAWKWEED.

Seeds (akenes) 1–3 mm. long, cylindrical, pointed at the base; apex truncate, bearing a small tuft of short, whitish, marginal bristles (the remnants of the pappus bristles); surface lightly ten-ridged lengthwise; color brown or black, reddish in immature seeds. (Fig. 24.)

Found most frequently in wood meadow grass seed. The seeds of several species of hawkweed, occurring in both America and Europe, are practically indistinguishable. Specific determinations can not be made by examination with a lens. The troublesome character of orange hawkweed (*Hieracium aurantiacum*), whose seeds are 1¼–1¾ mm. long, justifies care in the use of seed containing seeds of any species of hawkweed.

Anthemis cotula L.

DOG FENNEL, MAYWEED.

Seeds (akenes) cylindrical, broadly club-shaped, 1½–2 mm. long, straight or curved; surface dull and usually roughened by many small tubercles more or less distinctly arranged in ten rows, indistinctly few-tubercled or nearly smooth, but commonly more or less evidently ten-ribbed; base tipped by the rounded, whitish scar; apex rounded or slightly pointed; color varying from light to dark brown. (Fig. 25.)

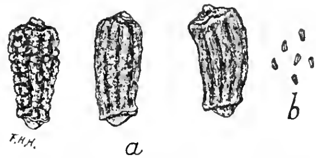

Fig. 25.—Seeds of dog fennel (*Anthemis cotula*): *a*, side views; *b*, natural size of seeds.

Found occasionally, but never abundantly, in both American and European bluegrass seed.

Chenopodium album L.

LAMB'S-QUARTERS, PIGWEED.

Seeds nearly circular, lens-shaped, with blunt edges, 1–1⅓ mm. in diameter, occurring in commercial seeds as free seeds or as fruits, the seeds proper being invested by the thin pericarp; free seeds jet black, smooth or nearly so, and highly polished; scar occupying a curved groove extending from the center to the edge of one face and usually evident as a light-colored line; fruits only slightly larger than the seeds, mostly gray or black and dull; pericarp wall often broken away, exposing the shining black surface of the seed; again, this wall and the seed coat are often broken, exposing the yellowish or whitish embryo and endosperm; embryo cylindrical, occupying the border of the seed and surrounding the endosperm, its extremities almost meeting, the tip of the caulicle occupying an extension of the seed coat at the edge beside the scar. (Fig. 26.)

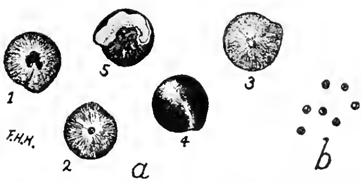

Fig. 26.—Seeds of lamb's-quarters (*Chenopodium album*): *a*, various forms of seeds; *b*, natural size of seeds.

Found chiefly in Kentucky bluegrass and Canada bluegrass seeds, but not frequently and never abundantly.

Plantago lanceolata L.

RIB-GRASS, BUCKHORN, ENGLISH PLANTAIN.

Seeds oval-oblong, 1¾–3 mm. long, flattened, one face convex, the other having a deep groove and rounded, infolded edges which scarcely meet at one end; surface smooth or slightly uneven, shining in fresh seed, brown or somewhat amber-colored; scar situated at the center of the grooved face; embryo straight, in the center of the endosperm, usually evident through the somewhat transparent endosperm and seed coat. When placed in water the seeds develop a coat of transparent mucilage. (Fig. 27.)

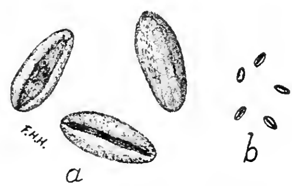

Fig. 27.—Seeds of rib-grass (*Plantago lanceolata*): *a*, front and back views of seeds; *b*, natural size of seeds.

Small seeds are found to some extent in both American and European seed; more commonly in Kentucky bluegrass than in Canada bluegrass seed.

Rumex crispus L.

CURLED DOCK.

Seeds (akenes) $1\frac{1}{2}$–$2\frac{1}{2}$ mm. long, triangular with equal faces and broadly ovate-lanceolate; color dark reddish brown; surface smooth, polished; apex acute; base obtuse, contracted, and narrowly truncate at the scar; edges narrowly margined; faces longitudinally concave in poorly developed seeds; true seed coat thin; embryo cylindrical, resting in the center of one face of the endosperm; caulicle pointing to the base of the akene. (Fig. 28.)

FIG. 28.—Seeds of curled dock (*Rumex crispus*): *a*, broad and narrow forms; *b*, natural size of seeds.

Found occasionally, especially in Kentucky bluegrass and in Canada bluegrass seeds; small, imperfectly developed seed more commonly found than large, heavy seed. Their sharply three-angled, beechnut-like form distinguishes them from other impurities, except one or two other kinds of dock. The docks are destructive weeds, and care should be taken to prevent the sowing of their seeds.

Rumex acetosella L.

SHEEP'S SORREL, SORREL.

Seeds (fruits) acutely oval, three-angled, with equal faces, 1–$1\frac{1}{2}$ mm. long; represented in commercial seed by the seed-like akene only or by the akene covered by the thin, closely fitting perianth segments, which are six in number, three broad ones covering the sides of the akene and three small ones covering the angles at the base; covered by the perianth, the seeds are finely roughened, dull, and reddish brown; venation of the three broad segments evident; small segments at the basal angles often broken away; akenes but slightly smaller than when covered by the perianth, bluntly three-angled; surface smooth, somewhat polished, reddish brown or wine colored, often semitranslucent; angles dark at the apex; internal structure essentially the same as in *Rumex crispus*. (Fig. 29.)

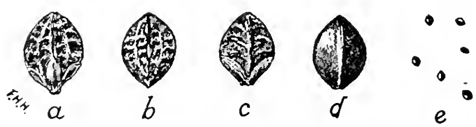

FIG. 29.—Seeds of sorrel (*Rumex acetosella*): *a*, *b*, and *c*, seed enveloped by the perianth; *d*, seed with perianth removed; *e*, natural size of seeds.

One of the commonest impurities in commercial seed, found in all seed of the cultivated bluegrasses.

Veronica arvensis L.

CORN SPEEDWELL.

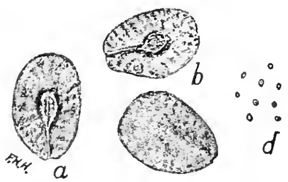

FIG. 30.—Seeds of corn speedwell (*Veronica arvensis*): *a* and *b*, front views, *c*, back view, *d*, natural size of seeds.

Seeds $\frac{1}{2}$–$\frac{3}{4}$ mm. long, flattened and thin, more or less regularly oval, plane or sometimes curved facewise; center of the inner face marked by the relatively large, raised chalaza, which is united by a narrow ridge (the raphe) to the scar on the edge of the smaller extremity of the seed; external face slightly ridged longitudinally, indicating the position of the embryo, which is surrounded by the endosperm; surface dull, finely roughened by somewhat radially-disposed ridges, and reddish yellow. (Fig. 30.)

Found in bluegrass seed of various species, especially common in seed of Kentucky bluegrass. The relatively prominent chalaza and the radially uneven surface distinguish them from the seed of the closely allied *Veronica peregrina*, which sometimes occurs in commercial seed.

Juncus tenuis Willd.

SLENDER RUSH.

Seeds very minute, about ⅓ mm. long, broadly spindle-shaped, the extremities usually slightly curved; surface (as seen under a lens) nearly smooth; color reddish yellow, darker at the extremities, which sometimes bear a small white tissue. (Fig. 31.)

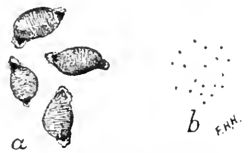

FIG. 31.—Seeds of slender rush (*Juncus tenuis*): *a*, seeds enlarged; *b*, natural size of seeds.

Often quite abundant in poorly cleaned Kentucky bluegrass seed, sometimes clinging in bunches of several seeds each.

Juncoides campestre (L.) Kuntze.

FIELD RUSH.

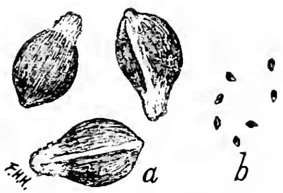

FIG. 32.—Seeds of field rush (*Juncoides campestre*): *a*, different views; *b*, natural size of seeds.

Seeds 1¼–1½ mm. long, oval, not flattened, the extremities unequally pointed, the basal extremity turned slightly to one side and consisting of soft white or yellowish tissue; a narrow and often indistinctly defined whitish ridge extends from the base to the apex; body of the seed wine-colored and semitranslucent or grayish. (Fig. 32.)

Found frequently in the seed of wood meadow grass and of the *Poa sudetica* of European origin.

Juncoides albida DC

WOOD RUSH.

Seeds 1–1¼ mm. long, narrowly oval, not flattened; base without an appendage of soft tissue; apex more acutely pointed than the base; a distinct brown or reddish brown ridge joins the base and apex; body of the seed reddish brown or wine-colored, often semitranslucent. (Fig. 33.)

Found in various species of European-grown bluegrass seed. The usually smaller size, absence of the basal appendage, and more distinct and constant reddish-brown lateral ridge serve to distinguish these from the seeds of *Juncoides campestre*.

FIG. 33.—Seeds of wood rush (*Juncoides albida*): *a*, different views; *b*, natural size of seeds.

Carex cephalophora Muhl.

OVAL-HEADED SEDGE.

Seeds (akenes) 1½–2 mm. long, lens-shaped and broadly ovate, contracted at the base and tipped at the apex by a conical appendage (the base of the style); surface smooth and dull; color varying from light to dark brown; apical appendage often broken away in seeds found in commercial samples; perigynium broadly ovate-lanceolate, plano-convex, the tapering extremity usually rough-edged and notched at the apex; surface sometimes slightly grooved or ridged lengthwise, otherwise smooth; color varying from light brown to greenish or dark brown. (Fig. 34.)

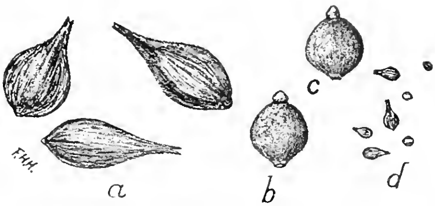

Fig. 34.—Seeds of sedge (*Carex cephalophora*): *a*, seeds inclosed by the perigynium; *b* and *c*, seeds with perigynium removed; *d*, natural size of seeds.

Seeds of sedge (Carex) are found in both American and European bluegrass seed. Owing to the wide area of their production, the seeds of various species of Carex occur in commercial bluegrass seed. The seeds of Carex are fruits (akenes) and occur free or inclosed within a sac-like covering (the perigynium). *Carex cephalophora* is the species most commonly found in Kentucky bluegrass seed.

ERGOT OCCASIONALLY FOUND IN COMMERCIAL BLUEGRASS SEED.

Claviceps purpurea (Fr.) Tul.

ERGOT.

This is a fungus growth affecting the grain (caryopsis) of many grasses. It is very common in the seed of redtop and other species of Agrostis, and occasionally occurs in bluegrass seed. The grain of the seed becomes elongated, extending beyond the glume and palea, attains about twice the length of the glume, and is club-shaped, straight, or, more commonly, somewhat curved. It is black, dull, and somewhat grooved lengthwise. (Fig. 35.)

Fig. 35.—Ergot (*Claviceps purpurea*) of Kentucky bluegrass: *a*, enlarged; *b*, natural size.

O

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 85.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRINCIPLES OF MUSHROOM GROWING AND MUSHROOM SPAWN MAKING.

BY

B. M. DUGGAR,

Professor of Botany in the University of Missouri, and Collaborator of the Bureau of Plant Industry.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

Issued November 15, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations; Botanical Investigations; Farm Management, including Grass and Forage Plant Investigations; Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory, and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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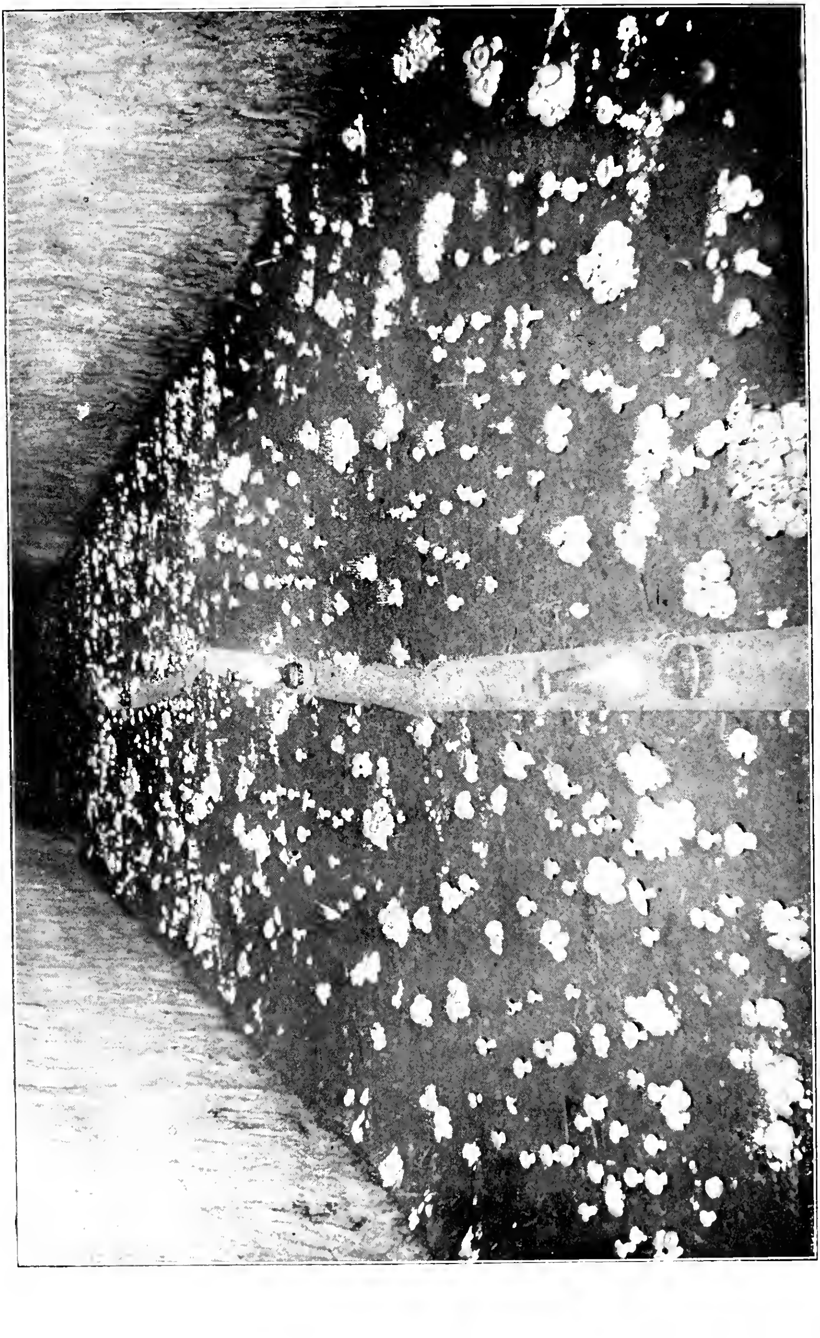

A FINE BED OF MUSHROOMS GROWN FROM SPAWN OF PURE-CULTURE ORIGIN.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 85.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRINCIPLES OF MUSHROOM GROWING AND MUSHROOM SPAWN MAKING.

BY

B. M. DUGGAR,

PROFESSOR OF BOTANY IN THE UNIVERSITY OF MISSOURI, AND COLLABORATOR OF THE BUREAU OF PLANT INDUSTRY.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED NOVEMBER 15, 1905.

WASHINGTON:

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1905.

BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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[a] Detailed to Seed and Plant Introduction and Distribution.
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[c] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., August 21, 1905.

SIR: I have the honor to transmit herewith a paper entitled "The Principles of Mushroom Growing and Mushroom Spawn Making," and to recommend that it be published as Bulletin No. 85 of the series of this Bureau.

This paper was prepared by Dr. B. M. Duggar, Professor of Botany in the University of Missouri and Collaborator with the Office of Vegetable Pathological and Physiological Investigations of this Bureau. Under the direction of the Pathologist and Physiologist, Doctor Duggar has been engaged for several years in the investigation of mushroom culture in all of its phases, and great advances have been made, especially in the production of purer and better spawns.

The accompanying illustrations are necessary to a complete understanding of the text of this bulletin.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

The bulletin submitted herewith presents the results of the work up to the present time on the problems of mushroom culture and spawn making. The first publication on the subject from the standpoint of pure culture was Bulletin No. 16 of the Bureau of Plant Industry. This was followed by a Farmers' Bulletin (No. 204) on mushroom culture, presenting the results of our work for the use of the practical grower. As an outcome of the work Doctor Duggar has already accomplished, spawn of pure-culture origin is now being produced on a very large scale by several growers and is giving excellent results. This method enables the grower to improve and maintain the most desirable varieties of mushrooms in the same manner as is possible with other plants propagated from cuttings or buds. Information which would enable a grower to accomplish this has not been up to this time available. The general method of securing pure cultures as here described will enable the experimenter to cultivate spawn of other edible species of mushrooms in case it should be found desirable to cultivate them. The methods described differ radically from any hitherto used. They are of more general application and give far better results.

For the past three years this work has been carried on in cooperation with the University of Missouri, Doctor Duggar having left the Department to accept the professorship of botany in that institution. We wish to express our appreciation of the facilities furnished by the university for continuing this work.

Albert F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., June 16, 1905.

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THE PRINCIPLES OF MUSHROOM GROWING AND MUSHROOM SPAWN MAKING

INTRODUCTION.

For a number of years there has been an increasing demand in the United States for information concerning mushroom growing. In the horticultural and agricultural press many individual practices have been presented; but in order to give rational encouragement to mushroom growing in favorable sections of this country it was recognized at the outset of the investigations undertaken by the writer that much experimental work would be required. Bearing upon the culture of *Agaricus campestris* [a] a number of physiological questions were demanding attention, for it was desirable to ascertain (1) the conditions of spore germination, in order that "virgin" spawn might be propagated and the principle of selection attempted; (2) the relation of this fungus to nutrients, or a determination of the substances or compounds which might best serve as food materials; and (3) the relation of the growing mycelium and of mushroom production to temperature, moisture, and other conditions of the environment. In the next place it would be necessary to determine the application of any physiological principles established to the practice of mushroom growing and mushroom spawn making.

In connection with a presentation of the results of the experimental work [b] it seems desirable to include also a more or less comprehensive account of the present status of mushroom growing at home and abroad.

---

[a] Throughout this paper the writer has employed the generic name *Agaricus* in the sense in which it is usually understood by those interested in the practical side of the work.

[b] During 1903–4 the writer was assisted in the experimental work by Mr. A. M. Ferguson, instructor in botany in the University of Texas, at that time special agent of the Department of Agriculture, and during 1904–5 similar assistance has been rendered by Mr. L. F. Childers, student assistant. Through the assistance thus given it has been possible to complete an unusual amount of experimental work, only a portion of which can be described in detail, although it has all been taken into consideration in the conclusions drawn.

It is not possible at this time to give more than a few brief suggestions concerning the possibility of cultivating other edible species than *Agaricus campestris*. The determination of the fundamental needs of diverse species will require study during a term of years.

GENERAL CONSIDERATIONS.

The propagation of *Agaricus campestris* does not seem to have been undertaken to any extent by the ancient Greeks or Romans. The occasional references to mushrooms in the classics are very general, as a rule, and do not suggest that artificial propagation was attempted. In the vicinity of Paris *Agaricus campestris* has been cultivated for several centuries, and the plants have certainly been sold on the open market quite as long.[a] It has not been possible to ascertain whether the methods now in vogue are essentially the same as those employed a few centuries ago. It is very probable, however, that the methods have been gradually improved. It would appear that the cultivation in caves is comparatively recent. The earliest records obtainable concerning the cultivation of mushrooms in the underground quarries indicate that this practice was not common previous to the nineteenth century.

Mushrooms are to-day extensively grown in England and France, and to a limited extent in Belgium, in Germany, and in many other countries. Paris remains, however, the center of commercial production. In the vicinity of that city the culture of mushrooms is now almost entirely confined to the underground limestone quarries or cement mines. The caves used for this purpose are termed "carrières" or "champignonières." These caves may consist of a labyrinth of galleries, or halls, ranging from 5 to 50 feet in width and from 5 to 30 feet in height. In some regions the earth is practically honeycombed by them, and the extent of the cave space used by the larger growers may be measured by miles. For the most part the ventilating system is perfect, every cave system possessing numerous air shafts, protected at the surface by wooden towers. Artificial partitions in the caves themselves enable the operator to control the ventilation. Until recent times the cultural methods have been more or less sacredly guarded by the growers, and even to-day it is not easy to get permission to make a casual visit to the champignonières. In many cases the work has been followed from generation to generation within the same family. There are at present, however, large corporations in control of some of the most famous caves.

[a] In a painting of the early seventeenth century (that of a Fishmonger's and Poulterer's Shop, by Jordaens and Van Utrecht, in the Gallery of Old Pictures, Brussels) *Agaricus campestris* and Boletus are shown on sale as a conspicuous part of a market scene.

In the United States fresh mushrooms have only recently been of any importance commercially, although florists and gardeners of English and French training have long been successful growers on a small scale. Nevertheless, during the past decade or so, the record of failures has been most conspicuous, and it is certain that of the many who attempted this work only a few, relatively, were uniformly successful.

The conditions under which mushrooms may be successfully grown are limited, and intelligent attention is therefore essential. It must be said, moreover, that the majority of failures may be directly traced to erroneous ideas as to the cultural requisites, or to a reckless disregard of conditions. The essential conditions will be subsequently defined in detail, but it may be stated here that failures are usually due to one or more of the following causes: (1) Poor spawn; (2) very poor manure; (3) unfavorable temperature; and (4) heavy watering during the early stages of growth.

Under suitable conditions mushrooms may be grown with assurance of success. Ordinarily they are grown only where the conditions may be controlled, and success should therefore be invariable.

MARKET CONDITIONS.

In the vicinity of Paris the mushroom industry has been remarkably developed during the past eight or ten years. The total product sold through the central market of Paris in 1898 was nearly 4,000,000 pounds; the quantity for 1900 is given as approximately 8,500,000 pounds, and for 1901 nearly 10,000,000 pounds. These figures show most convincingly the present status of the mushroom industry in France. It may be safely assumed that more than one-third of this quantity is consumed in a fresh state in and about the city. The growth of the canning industry during this period has also been remarkable. In 1898 about 1,800,000 pounds were preserved, while in 1901 the canned product amounted to nearly 6,200,000 pounds. During 1901 the approximate monthly production of mushrooms ranged from 651,000 pounds to 985,000 pounds, from which it is evident that these caves yield heavily throughout the year. In some instances growers are able to get a crop every four or five months.

It is extremely difficult to estimate the quantity of mushrooms grown in the United States. It is certain, however, that the production has increased very greatly, and particularly within the last four or five years. In the vicinity of several of our larger cities there are to-day individual growers who produce more than the total commercial output in the neighborhood of those cities ten years ago.

There is now a very good open market for fresh mushrooms in a few of the larger cities, although many large growers continue to sell entirely by contract or by special orders to hotels and restaurants. With such an enormous comparative consumption of the canned product, there is every reason to believe that fresh mushrooms can be sold in much greater quantity as soon as this product becomes a certain factor in the market. With canning factories to take the surplus product, growers could afford to accept a smaller margin of profit, and this would place mushrooms within reach of many who may not be able to purchase them at present average prices. *Agaricus campestris* and its varieties and allied species are perhaps the only fresh mushrooms commonly salable in the markets of American cities. Throughout practically the whole of Europe several other species are legitimate market products. The more delicate or fleshy forms of the latter are sold as fresh mushrooms; others are dried, and some of these, being tougher, are used only for soups, sauces, and gravies. Besides the various species of truffle and morel, any special mention of which will be omitted here, the French market to-day legalizes the sale of five or six other species of mushrooms.

GERMINATION STUDIES.

Review of earlier work.—In a small way the germination of the spores of Basidiomycetes has received attention from the earliest times. A complete historical review of the literature dealing with spore germination will be found in Bulletin No. 16 of the Bureau of Plant Industry. It will be seen that most of the early work furnishes only incidental references to spore germination. By far the most important contributions made by early workers to this particular subject were several papers by Hoffmann.[a] It is not to be expected that the method employed by him would yield accurate results. Nevertheless, the work of Hoffmann is comprehensive for that time. Brefeld,[b] in his extensive reports upon the Basidiomycetes, gives the results of germination studies with a large number of the fleshy fungi. More than 200 species were used in his various experiments, and successful germination is recorded for about 160 species.

In 1898 the writer became interested in some attempts to germinate the spores of certain Basidiomycetes. Subsequently the problem received incidental attention in connection with some general studies on the physiology of spore germination.[c] The work progressed only

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[a] Hoffmann, H. Ueber Pilzkeimungen. Botan. Zeitg., 19: 209–214, 217–219. 1859. Beiträge zur Entwickelungsgeschichte und Anatomie der Agaricineen. Botan. Zeitg., 18: 389–395, 397–404. 1860. Untersuchungen über die Keimung der Pilzsporen. Jahrb. f. wiss. Botanik, 2: 267–337. 1860.

[b] Brefeld, O. Botanische Untersuchungen über Schimmelpilze. Basidiomyceten, I, Bd. I, H. 3. 1877. Untersuch. a. d. Gesammtgebiete der Mykologie. Basidiomyceten, II, H. 7; III, H. 8. 1888–89.

[c] Duggar, B. M. Physiological Studies with Reference to the Germination of Certain Fungous Spores. Bot. Gaz., 31: 38–66.

far enough to suggest that an investigation of the factors influencing germination might yield studies of special interest. During 1900–1901 Dr. Margaret C. Ferguson undertook a systematic investigation of the relation of stimuli to germination in certain species. The results[a] have made it evident that the problems involved are not the well-known simple nutrient or physical factors. Miss Ferguson spent much time in experimenting with a great variety of nutrient media and special stimuli. Several thousand cultures were made. In the majority of these cultures *Agaricus campestris* was used, and it is shown that from the known ecological relationships of this fungus one could not possibly predicate the probable stimulus for germination. In fact, with no known nutrient medium or special chemical stimulus employed, was there anything more than erratic germination. Nevertheless, the work was finally very successful in the discovery that almost a perfect percentage of germination could be secured by the influence of the living hyphæ of *Agaricus campestris* upon the spores, as announced in the statement that "if a few spores are able to germinate under the cultural conditions, or if a bit of the mycelium of *Agaricus campestris* be introduced into the culture, the growth resulting will in either case cause or make possible the germination of nearly all the spores of the culture, provided, of course, that the other conditions are not such as to inhibit germination."

The stimulus would seem to be of enzymatic nature. No other mycelium tested produced a similar effect. This was a distinct advance in our knowledge of factors influencing germination. The stimulus, however, could only be looked upon as perhaps a substitution stimulus. It did not seem possible that it could obtain in nature, nor could it be looked upon as wholly satisfactory from a practical point of view.

Miss Ferguson's results offered encouragement; but, nevertheless, the problems with *Agaricus campestris* and related species were left open for further investigation. It should, perhaps, be emphasized that prior to 1902 no method had been published, so far as can be learned, whereby one might be able to obtain with uniformity the germination of *Agaricus campestris*. It is quite certain that Chevreul and others obtained at best only erratic results. Nevertheless, as early as 1893 Costantin and Matruchot[b] announced that a method had been developed by them whereby they were able to germinate the

[a] Ferguson, M. C. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and Other Basidiomycetous Fungi. Bulletin No. 16, Bureau of Plant Industry, U. S. Dept. Agriculture, pp. 1–43. 1902.

[b] Costantin and Matruchot. Nouveau procédé de culture du champignon de couche. Compt. Rend. de l'Acad. des Sci., 117 (2): 70–72. (Compare, also, Bul. Soc. de Biol., 2 December, 1893.)

spores and to grow in pure culture the mycelium of *Agaricus campestris*. Information concerning the details of the method employed was avoided in the reports of this announcement and in subsequent references to the process.[a] In the first announcement the method is stated as follows:

Method followed.—The spores are collected free from contaminations, and in order to preserve them in that condition are sown on a certain sterilized nutritive medium. We obtain in this manner a twisted mycelium which constitutes pure spawn. By repeated cultures on an identical substratum the spawn can be multiplied indefinitely, and is transferred at a proper time to sterilized manure, where it develops abundantly in several weeks. At that stage it possesses the characteristic appearance and odor of natural spawn. It can then be sown in a bed of ordinary manure, to which it adheres and where it grows and fruits normally.

In the later paper cited, writing of the recent improvements in mushroom culture, Costantin expresses himself as follows:

We have succeeded in manufacturing an artificial spawn obtained from the spore germinated on a medium free from contamination. It is then pure spawn. We can state further that it is virgin spawn.

In 1897 Répin[b] claimed to have independently arrived at results similar to those obtained by Costantin and Matruchot. Concerning his germination studies he says:

It is only recently that the study of this question has been renewed, independently and simultaneously by Costantin and Matruchot.

There is nothing unusual in the germination of the spores of Agaricus. Spores can be germinated on media such as used in bacteriology, on wet sand, or in moist air as well as on manure. Without doubt, germination is not produced with the same spontaneity and rapidity as in the case of the spores of lower fungi, which fact makes it necessary to promote the process by some artifices, but they are only sleight-of-hand tricks, variable according to the operators, and which are acquired after some unsuccessful attempts. The spores which should germinate (and these are always in the minority) begin by swelling. This very simple method makes it possible to obtain virgin spawn at pleasure. It is applied industrially in the manufacture of spawn of Agaricus from cultures which I have made.

So far as the writer has been able to ascertain, therefore, no description of the method employed by the above writers is to be found. The report of Miss Ferguson's work is accordingly the only available scientific record defining the conditions under which germination had been constantly obtained up to this time.

Experimental work.—The writer has been able to confirm Miss Ferguson's work repeatedly, and at the same time numerous series of experiments have been made to test further the possibility of influenc-

[a] Constantin, J. La culture du champignon de couche et ses récent perfectionnements. Extrait du Revue Scientifique. April, 1894.

[b] Répin, C. Le blanc vierge de semis pour la culture du champignon de couche. Revue Générale des Sciences. (September 15, 1897.)

ing germination by chemical stimuli. In distilled water, on the one hand, and in plant decoctions (such as decoctions of beans, sugar beets, mushrooms, potatoes, etc.) and in bouillon, on the other hand, there have been tested a large number of inorganic and organic salts, carbohydrates, nitrogenous compounds, and active enzymes.

The results of one series of experiments are tabulated in detail. In general, it has been found that dulcite, monobasic magnesium phosphate, magnesium phosphite, magnesium potassium ammonium phosphate, ammonium molybdate, magnesium lactophosphate, dibasic calcium phosphate, and other salts, especially phosphates, have in one medium or another been more or less effective as stimuli for germination. Unfortunately, none of the substances mentioned, apparently, are very strong stimuli; they are unable to cause invariable germination in all nutrient media. Moreover, in subsequent series, where the conditions have been the same, within experimental possibilities, wholly analogous results have not always been obtained. No account has been taken, however, of the particular variety of *Agaricus campestris* from which the spores were obtained, and it may be that this will influence the results.

It is to be noted from the following table that Miss Ferguson's method of employing living bits of mycelium was modified by the use of small pieces of the inner tissue of a young mushroom taken under sterile conditions. It was found that often a new growth of mycelium was developed from this tissue. Whenever this growth appeared, the influence upon spores in the drop culture was, as might be expected, the same as had been demonstrated for the living mycelium. Frequently a few spores germinated within from three to five days. The most interesting conclusion, however, which could be drawn from the cultures in which small bits of tissue were used was the following: Under favorable conditions a small piece of the inner growing tissue of a mushroom is capable of producing a mycelium with great readiness. This fact has been utilized, as shown in detail later, in the development of a new and effective method of securing pure cultures of fleshy fungi in general.

TABLE I.—*Extent of germination.*

No.	Media.	After 3 days.	After 5 days.
1	Distilled water	{a—5 spores {b—None	As before. Do.
2	Bouillon	None	None.
3	½ per cent KH_2PO_4	do	Do.
4	½ per cent KH_2PO_4 in bouillon	do	Do.
5	½ per cent K_2HPO_4	do	Do.
6	½ per cent K_2HPO_4 in bouillon	do	Do.
7	½ per cent Na_2HPO_4	do	Do.
8	½ per cent Na_2HPO_4 in bouillon	do	Do.
9	½ per cent $(NH_4)_2HPO_4$	do	Do.
10	½ per cent $(NH_4)_2HPO_4$ in bouillon.	do	Do.

TABLE I.—*Extent of germination*—Continued.

No.	Media.	After 3 days	After 5 days.
11	½ per cent $MgH_4(PO_4)_2$	10 spores	50 per cent.
12	½ per cent $MgH_4(PO_4)_2$ with bouillon.	*a*—1 spore *b*—None	3 per cent. None.
13	½ per cent $MgHPO_4$	None	Do. 1 per cent.
14	½ per cent $MgHPO_4$ in bouillon	*a*—10 spores	Germinated spores badly injured.
15	½ per cent $Mg(NH_4)PO_4$	None	None.
16	½ per cent $Mg(NH_4)PO_4$ in bouillon.	2 spores	As before; injured.
17	½ per cent $MgK(NH_4)PO_4$	Few spores	5 per cent.
18	½ per cent $MgK(NH_4)H_2(PO_4)_2$ in bouillon.	do	Do.
19	½ per cent $(NH_4)_2C_4H_4O_6$	*a*—None *b*—None	Few spores. 10 per cent.
20	½ per cent $(NH_4)_2C_4H_4O_6$ in bouillon.	10 spores	As before; injured.
21	½ per cent magnesium lactophosphate.	do	5-10 per cent.
22	½ per cent magnesium lactophosphate in bouillon.	do	2-5 per cent.
23	½ per cent $Ca_2H_2(PO_4)_2$	None	1-2 per cent.
24	½ per cent $Ca_2H_2(PO_4)_2$ in bouillon	10 spores	Injured.
25	½ per cent $KCHO_2$	None	1-2 per cent.
26	½ per cent $MgHPO_3$	10 spores	10-50 per cent.
27	½ per cent $MgHPO_3$ in bouillon	do	1 per cent.
28	½ per cent $MgK(NH_4)H_2(PO_4)_2$ in mushroom decoction.	do	1-2 per cent.
29	½ per cent KH_2PO_4 in mushroom decoction.	None	None.
30	½ per cent K_2HPO_4 in mushroom decoction.	do	Do.
31	½ per cent Na_2HPO_4 in mushroom decoction.	Few spores	Injured.
32	½ per cent $(NH_4)_2HPO_4$ in mushroom decoction.	1 or 2 spores	Few spores.
33	½ per cent $MgHPO_4$ in mushroom decoction.	Few spores	2-5 per cent.
34	do	10-50 per cent	10-20 per cent.
35	½ per cent $Mg(NH_4)PO_4$ in mushroom decoction.	Few spores	Contaminated.
36	¼ per cent $(NH_4)_2C_4H_4O_6$ in mushroom decoction.	2 per cent	Contaminated; 50 per cent, but injured.
37	½ per cent magnesium lactophosphate in mushroom decoction.	10 spores	3-5 per cent; injured.
38	½ per cent $Ca_2H_2(PO_4)_2$ in mushroom decoction.	5-8 per cent	10 per cent.
39	½ per cent $KCHO_2$ in mushroom decoction.	2-3 per cent	10-20 per cent.
40	½ per cent $MgHPO_3$ in mushroom decoction.	1-2 per cent	*a*—5 per cent. *b*—Contaminated
41	Decoction of mushrooms	*a*—2 per cent *b*—Very few spores	2 per cent. 1-2 per cent.
42	Living tissue of mushroom in mushroom decoction.	*a*—Few spores [a] *b*—None [b]	12 spores.
43	do	*a*—Few spores [a] *b*—None [b]	As before. None.

[a] In this cell the tissue developed a new growth.
[b] No growth from tissue introduced.

On account of the fact that magnesium phosphite and magnesium potassium ammonium phosphate had in most cases proved to be stimuli for germination, experiments were next made to determine the efficiency of these salts on various media, as indicated in the table on the following page.

Table II.—*Efficiency of salts on various media.*

Nature of compost.	Appearance after 25 days.	Nature of compost.	Appearance after 25 days.
Well-rotted stable manure.[a]	No growth.	Well-rotted cow manure.[b]	Good growth.
Do.[b]	Fine growth.	Peaty mold[a]	No growth.
Half-rotted stable manure.[a]	One, fair growth; one, good growth.	Do.[b]	Do.
Do.[b]	No growth.	Maryland peat[a]	Do.
Fresh stable manure[a]	One, good growth; one, slight growth.	Do.[b]	Do.
Do.[b]	One, good growth; one, fine growth.	Well-rotted Ginkgo leaf mold.[a]	Do.
Well-rotted cow manure.[a]	One, good growth; one, slight growth.	Do.[b]	Do.
		Cotton-seed motes[a]	One, no growth; one, fine growth.
		Do.[b]	Fine growth.

[a] Watered with concentrated solution of magnesium phosphite.
[b] Watered with strong solution of magnesium potassium ammonium phosphate.

Large test tubes were used in these experiments, and duplicate cultures were made in every instance. From these and from numerous other cultures it was ascertained that germination could not be obtained invariably, even on favorable media and under pure-culture conditions, by the use of these partial stimuli. Nevertheless, the percentage of failures has usually been small. By means of the stimulus given by magnesium phosphite it has also been possible to get growth from the spores in test-tube cultures with gray filter paper as the solid substratum and various plant decoctions and culture solutions as the nutrients. Details of these results, however, may be omitted.

In many cases it has been possible to obtain growth from the spores by the use of the stimulating salts which have been mentioned in connection with the germination studies. Where it is desired to make experiments along this line the writer has found it more practicable to use spores from a mushroom as young as possible. If one takes a mushroom just at the time that the veil is breaking, inoculations may be readily made from the spores and few contaminations will result. In this case, by means of a sterile needle, or scalpel, a few spores may be removed from the spore-bearing, or gill, surface and these may be transferred to the tubes in the same way as were bits of the fresh tissue. It is also possible to secure a spore print from a mushroom the gill surface of which has not been exposed to germs of the atmosphere. In the latter case it is desirable to remove stem and partial veil, peel off the incurved edges of the cap which have been in contact with the soil, and place the cap, gill surface downward, in a sterilized dish or on sterile paper. If this is then kept free from dust, a spore print may be obtained, which should not be contaminated by foreign germs. This print may then be used in making a large number of spore cultures.

Experiments were also made in which pots of unsterile composts and manures were inoculated, on the one hand, with spores, and, on the other hand, for control purposes, with spawn from pure cultures. The duration of the experiments was two months. Some of these pots were watered with a mineral nutrient solution including as one constituent magnesium phosphite, designated *X*, others with the same solution to which was also added a small quantity of dried blood, designated *Y*, and the remainder with pure water. The results are tabulated as follows:

TABLE III.—*Extent of growth of spores and spawn in pots.*

		Cattle manure, old.	Fresh stable manure and sand.	Stable manure.	Old stable manure and sand.	Old stable manure.	Fertilizer.
Spores	*a*	Good	None	Slight	None	None	*Y*.
	b	None	do	do	do	do	*Y*.
Spores	*a*	Good	Very good	do	do	do	*X*.
	b	Do.	do	do	do	do	*X*.
Spawn	*a*	Slight	Slight	None	do	do	*Y*.
	b	Do.	do	Slight	do	do	*Y*.
Spawn	*a*	None	None	Good	do	do	*X*.
	b	Do.	do	Slight	do	do	*X*.
Spawn	*a*	None	Slight	do	do	do	None.
	b	Do.	do	None	do	do	Do.

TISSUE CULTURES.

The suggestion which had presented itself of using bits of living tissue from a sporophore instead of spores seemed also, from general observations, to be of sufficient importance to warrant a thorough trial. During moist weather, or in a moist cellar where mushrooms are being grown, one will frequently find that an injury in a young mushroom is rapidly healed by a growth of hyphæ from the edges of the injured area. The same thing had been noted in the open in the case of puffballs. In many instances, moreover, pure cultures of fungi in other groups have been obtained by the use of small bits of a sclerotial mass of tissue. Accordingly, a young sporophore of *Agaricus campestris* was obtained, and after breaking it open longitudinally a number of pieces of tissue from within were carefully removed with a sterile scalpel to a sterile Petri dish. A number of cultures were then made by this tissue-culture method on a variety of nutrient media, such as bean pods, manure, leaf mold, etc. From this and from numerous other similar tests it was ascertained that when the mushrooms, from which the nocules of tissue are taken, are young and healthy, there is seldom an instance in which growth does not result. It was easily shown that failure to grow was generally due to the advanced age of the mushroom used, to an unfavorable medium, or to bacterial contamination.

The first successful pure cultures were made by this method during the early spring of 1902 from mushrooms grown indoors. During the following summer, or as other fleshy fungi appeared in the open, cultures were made from other forms in order to determine the general applicability of the method. The experiments were successful in most cases, although it was found almost impossible to obtain certain species of fungi in a condition young enough to be free from bacterial infestation. In general, the method seemed to commend itself strongly as a means of procuring pure cultures of desirable edible species, particularly of those species the spores of which could not be obtained pure or which could not be readily germinated.

During the two subsequent seasons this method has been employed with a great variety of fungi representing many natural orders. No systematic endeavor has been made to determine the limitations of the tissue-culture method as applied to Basidiomycetes, but, incidental to the general studies, cultures have been made from forms differing very widely, not only in relationship but also in texture and in habitat.

In all there is a record of 69 species having been tested upon one or another medium. In a few cases the cultures have invariably been contaminated, and it is to be supposed, perhaps, that the plants were collected in a condition too old for the purpose in hand. In only about ten forms has it seemed that there is no evident reason for the failure to develop mycelium. Of the remainder fully 40 have grown promptly on the media employed. The table following indicates the names of the species employed and the results obtained. It must be said, however, that cultures of a number of species were made of which no record was kept; among these, also, some grew and some failed.

Table IV.—*Results obtained from different species.*

Fungus.	Number of cultures.[a]	Substratum.	Result.
Agaricus arvensis	Few.	Beans, manure, leaves, etc	Rapid growth.
Agaricus augustus	1	Beans	Contaminated.
Agaricus campestris (various varieties).	∞	Beans, manure, leaves, etc	Rapid growth.
Agaricus fabaceus	∞	do	Do.
Agaricus fabaceus var	∞	do	Do.
Agaricus placomyces	1	Beans	Some growth.
Agaricus villaticus	Few.	Manure, leaves, etc	Rapid growth.
Amanita frostiana	1	Leaves	Contaminated.
Amanita muscaria	2	Beans	Do.
Amanita verna	2	do	Do.
Amanitopsis vaginata	2	do	Do.
Armillaria mellea	∞	Beans, leaves, dead wood, etc	Rapid growth.
Boletinus porosus	2	Beans	Slow growth.
Boletus fellens	2	do	No growth.
Boletus miniato-violaceus	1	do	Do.
Boletus peckii	2	do	Contaminated.
Bovistella ohiensis	Few.	Beans, leaves, etc	Rapid growth.
Calvatia craniiformis	Few.	do	Do.
Calvatia cyathiforme	∞	Beans, leaves, soil, etc	Do.
Calvatia rubro-flava	Few.	Beans, leaves, etc	Do.
Cantharellus cibarius	1	Beans	No growth.
Clavaria formosa	1	do	Do.

[a] ∞ indicates an indefinite number.

TABLE IV.—*Results obtained from different species*—Continued.

Fungus.	Number of cultures.	Substratum.	Result.
Clitocybe illudens	2	Beans	Some growth.
Clitocybe sp.?	2	do	Rapid growth.
Clitopilus prunulus	Few.	Beans, manure, etc	Some grew well.
Collybia platyphylla	1	Beans	No growth.
Collybia radicata	Few.	do	Good growth.
Collybia velutipes	1	do	Do.
Coprinus atramentarius	∞	Beans, leaves, manure, etc	Rapid growth.
Coprinus comatus	∞	Beans, manure, leaves, etc	Do.
Coprinus fimetarius	Few.	Beans, leaves	Do.
Coprinus micaceus	∞	Beans, leaves, manure, etc	Do.
Cortinarius armillatus	1	Beans	Contaminated.
Cortinarius castaneus	1	do	Do.
Cortinarius sp.?	Few.	Beans, leaves, manure	Good growth.
Daedalia quercina	Few.	Beans, leaves, manure, etc	Rapid growth.
Hydnum caput medusae	1	Beans	Good growth.
Hydnum coralloides	2	do	Do.
Hydnum erinaceum	2	do	Do.
Lactarius corrugis (?)	Few.	Beans and leaves	Slight growth, one.
Lactarius piperatus	∞	do	No growth.
Lactarius volemus	1	Acid beans	Some growth.
Do	∞	Beans	No growth.
Lepiota americana	1	do	Do.
Lepiota morgani	2	do	Some growth.
Lepiota procera	∞	Beans, leaves, etc	Rapid growth.
Lepiota rhacodes	Few.	do	Do.
Lycoperdon gemmatum	2	Beans	Good growth.
Lycoperdon wrightii	1	Sod	Do.
Morchella esculenta	2	Beans and leaves	Do.
Pluteus cervinus	Few.	do	Some growth.
Pleurotus ostreatus	∞	Beans, leaves, manure, etc	Rapid growth.
Pleurotus ulmarius	1	Beans	Do.
Pholiota adiposa	1	Beans and leaves	No growth.
Polyporus betulinus	1	Beans	Slow growth.
Polyporus intybaceus	1	do	Do.
Polyporus sulphureus	2	Beans and leaves	Rapid growth.
Polystictus cinnabarinus	2	do	Good growth.
Russula adusta	1	Beans	No growth.
Russula emetica	∞	Beans, etc	Often contaminated but some grew.
Russula sp	Few.	Beans	No growth.
Russula sordida	1	do	Do.
Russula virescens	Few.	do	Do.
Secotium acuminatum	2	do	Slow growth.
Strobilomyces strobilaceus	1	do	No growth.
Stropharia sp.	1	do	Contaminated.
Tremella mycetophila	1	do	No growth.
Tricholoma personatum	1	Beans and manure	Good growth.
Tricholoma russula	2	Beans and leaves	Do.

It is not to be understood that the failures recorded in the foregoing table indicate that these species will not grow. The evidence is that they did not grow upon the media used, and it is very probable that most of these could be propagated in culture by this method if a systematic attempt were made to determine what substrata are desirable. The writer believes that this statement holds true particularly in the case of certain species of Boletus. No attempt was made to cultivate Boleti in any other way than upon bean pods. A few mycelial threads were developed in such cases, but these failed to grow upon the bean, apparently dying before even the nutrients in the fragment of tissue were exhausted.

It is interesting to note that many of the fungi which have given good growth have not hitherto been grown in pure culture. According-

[a] Costantin et Matruchot. Sur la production du mycelium des champignon supérieurs. Extrait Compt. Rend. d. Séances de la Soc. de Biologie. January,

ing to Costantin and Matruchot,[a] Van Tieghem (1876) produced the mycelium of Coprinus in pure culture. Later, Brefeld [a] accomplished the same result with many species of Coprinus, and also with *Armillaria mellea.* Costantin has also published a number of brief papers, or announcements, of successful cultures upon artificial media of the mycelium of several fleshy fungi. Besides *Agaricus campestris*, he has grown the mycelium of *Amanita rubescens*, *Armillaria mellea*, *Collybia velutipes*, *Lepiota procera*, *Marasmius oreades*, *Tricholoma nudum*, *Pleurotus ostreatus*, *Pholiota aegerita*, *Coprinus comatus*, *Polyporus tuberaster*, *P. frondosus*, *Hydnum coralloides*, *Morchella esculenta*, and perhaps a few others. He has also grown to maturity sporophores of *Agaricus campestris*, *Coprinus comatus*, and *Tricholoma nudum*. Unfortunately, Costantin seldom indicates the substratum upon which his cultures were made. Falck [b] reports having produced in culture the sporophores of *Collybia velutipes*, *Phlebia merismoides*, *Hypholoma fasciculare*, *Chalymotta campanulata*, and *Coprinus ephemerus* in his studies upon the connection of oidial stages with perfect forms of the Basidiomycetes. In the work of the writer so far no special attempt has been made to obtain the sporophores of the fungi cultivated except in the case of *Agaricus campestris.* Nevertheless, the following species have fruited in pure culture upon the media indicated:

	Medium.
Agaricus campestris	Manure.
Agaricus fabaceus	Manure.
Agaricus amygdalinus	Manure.
Armillaria mellea	Beans.
Bovistella ohiensis	Soil.
Calvatia cyathiforme	Soil.
Calvatia rubro-flava	Soil.
Cortinarius sp	Soil.
Coprinus comatus	Leaves.
Coprinus fimetarius	Leaves.
Coprinus solstitialis (?)	Leaves, etc.
Daedalia quercina	Leaves, etc.
Hydnum coralloides	Beans.
Lycoperdon wrightii	Soil.
Pleurotus ostreatus	Beans and manure.
Pleurotus ulmarius	Manure.

In some instances the sporophores have been minute, owing to the small quantity of the culture medium.

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[a] Brefeld, O. Unters. aus d. Gesammtgebiete d. Mykologie, S. 9, 10.

[b] Falck, R. Die Cultur der Oidien und die Rückführung in die höhere Fruchtform bei den Basidiomyceten. Cohn's Beiträge zur Biologie der Pflanzen, 8: 307–346 (Pls. 12–17).

From the standpoint of obtaining pure cultures, the tissue-culture method is capable of very general application. Three considerations render it particularly important, as follows: (1) When a suitable culture medium is at hand, a pure culture may be obtained almost invariably from a young, healthy plant. (2) Cultures may be made from fungi the spores of which have never been brought to germination. (3) Pure cultures are made by direct inoculation; that is, dilution cultures are rendered wholly superfluous. In the case of *Agaricus campestris* and other Basidiomycetes, in which the gill-bearing surface is protected until the spores are produced, it is possible, with the precautions previously mentioned, to obtain the spores pure, or practically pure, and at the same time in considerable quantity. This is not possible with the great majority of fleshy fungi, which are truly gymnocarpous. Again, members of the genus Coprinus are deliquescent, and here it is impracticable to secure spores by the spore-print method. In the Lycoperdaceæ and other Gasteromycetes it has been found that bacteria are frequently present in the tissues by the time the spores are formed, and, even if the spores could be germinated, direct cultures would perhaps be seldom possible. By the tissue method it is only necessary that the plant shall be so young that the cells of the tissue are capable of growth and that there are no foreign organisms present in the tissue. In this connection it may be stated that in the Phallineæ, Hymenogastrineæ, and Lycoperdineæ no representative has been germinated, while in the Plectobasidineæ germination is known only in the case of *Sphaerobolus stellatus and Pisolithus crassipes.*

When the natural conditions of germination shall have been more definitely ascertained, direct spore-culture methods should in practice, perhaps, replace the pure tissue-culture methods in making virgin spawn. This would render unnecessary a tedious portion of the work, and the process of spawn making would be thereby made less expensive.

A discussion of the respective practical merits of the spore and tissue methods would not be complete without reference to the comparative vigor, or productive power, of the resulting mycelium. In the growth of the mycelium no difference could be detected. The writer has also grown mushrooms from spawn produced by both of these methods; but the results do not indicate that there is any advantage for the one over the other. It is believed, therefore, that the processes of basidial and spore formation are in this regard relatively unessential, or at least do not intensify whatever invigoration may, in general, result from mere sporophore production. It is to be expected, perhaps, that any and all cells of the sporophore may be invigorated by whatever is to be gained by the assemblage, or concentration, in the differentiated sporophore, of food products collected by a ramifying mycelium. According to the studies of Harper,[a] Maire,[b] and others, there is no sexual fusion in the case of the Basidiomycetes which have been studied. Two nuclei are present in the cells of the sporophore, but these are associated conjugate nuclei, and the fusion of these in the basidium is generally considered in no sense an act of fertilization, but rather a form of nuclear reduction. Maire states that the cells of the mycelium obtained by the germination of the basidiospore are uninucleate. It has not yet been ascertained when or how the binucleate condition arises.

NUTRITION.

Although *Agaricus campestris* has been cultivated for so long a time, it does not seem that it has previously been subjected to careful experimentation from the point of view of nutrition. The belief generally prevalent is that the most essential factor in the nutrition of the mushroom is the "ammonia" of the manure or compost. Again, it is claimed that organic waste products, such as those indicated, must undergo a process of fermentation, or "preparation," in order to furnish the necessary nutrients for the growing mycelium. This idea, as will be seen later, is merely based upon casual observations "in nature," and it is found wholly erroneous when tested for its fundamental worth by the elimination of other factors of the compost environment.

Growth on manure and other complex media.—Early in this investigation it was ascertained that the mycelium of *Agaricus campestris* in pure cultures would grow luxuriantly on fresh stable manure, and as a rule upon the same product in any stage of fermentation or decomposition. In some instances, undoubtedly, fresh manure may contain injurious compounds; somewhat oftener the same is true for the fermented product. In some instances it is desirable to dry or thoroughly air the fresh manure before use. Fresh manure from grass-fed animals is not to be recommended. The mycelium also grows luxuriantly on bean stems or pods, on half-rotted leaves of deciduous trees, on rich soil, on well-rotted sawdust, and on a variety of other substances. It does not grow readily upon peaty products.

Some of the more promising edible species were cultivated in various media in order to obtain an idea of the comparative value of these media in furnishing a nutrient to particular forms. It is not possible, of course, to base definite conclusions upon results obtained

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[a] Harper, R. A. Binucleate cells in certain Hymenomycetes. Bot. Gaz., 33: 1–25. 1902.

[b] Maire, R. Recherches cytologiques et taxonomiques sur les Basidiomycetes. Bul. Soc. Myc. de France, 18: 1–209. 1902.

from pure cultures, since the presence of particular foreign organisms in the substratum under natural conditions is perhaps quite as important a consideration as that of the specific nutrient value of the substratum. The following results are, however, suggestive:

1. Agaricus campestris.
   - Leaves—good growth throughout.
   - Soil—fair growth, with tendency to become threaded early.
   - Manure—good growth throughout.
   - Beans—good growth throughout.
   - Sugar beet—fair growth, spreading very slowly.
   - Potato—slight growth, spreading very slowly.
   - Corn meal—slight growth, spreading slowly, soon becoming brown.
2. Agaricus fabaceus.
   - Leaves—very good growth, rapidly filling tube.
   - Soil—good growth, but slower than the above.
   - Manure—good growth, but slower than the above.
   - Beans—very dense growth, soon filling whole tube.
   - Sugar beet—good growth; somewhat less rapid and abundant than the above.
3. Agaricus villaticus.
   - Practically the same as *Agaricus campestris.*
4. Agaricus fabaceus var.
   - Practically the same as *Agaricus fabaceus.*
5. Bovistella ohiensis.
   - Leaves—good growth throughout.
   - Soil—growth throughout, but sparse and threadlike.
   - Manure—good growth throughout.
   - Beans—good growth; appressed.
   - Sugar beet—very slight growth.
6. Calvatia cyathiforme.
   - Leaves—very good growth throughout.
   - Soil—good growth; quite as rapid as above.
   - Manure—practically no growth.
   - Beans—good growth, but spreads very slowly.
   - Sugar beet—slight growth.
7. Calvatia craniiformis.
   - Practically the same as above.
8. Calvatia rubro-flava.
   - Practically the same as in the other species of this genus, but spreads somewhat more slowly on soil.
9. Coprinus atramentarius.
   - Leaves—very good growth throughout.
   - Soil—slight growth.
   - Manure—fair growth, but very slow.
   - Beans—very good growth.
10. Coprinus comatus.
    - Leaves—very good growth throughout; rapid.
    - Soil—good growth.
    - Manure—very good growth throughout; rapid.
    - Beans—very good growth throughout; rapid.
    - Sugar beet—very slow growth.

11. Lepiota rhacodes.
    Leaves—very good growth.
    Soil—slight growth.
    Manure—slight growth.
    Beans—very good growth throughout.
    Sugar beet—very good growth throughout.
12. Morchella esculenta.
    Leaves—very good growth; mycelium never dense.
    Soil—very little growth.
    Manure—very slight growth.
    Beans—very good growth.
    Sugar beet—good growth, but slower than above.
13. Pleurotus ostreatus.
    Leaves—very good growth; rapid.
    Soil—fair growth.
    Manure—good growth.
    Beans—very good growth; rapid.
    Sugar beet—slight growth; very slow.
14. Pleurotus ulmarius.
    Practically the same as Pleurotus ostreatus.
15. Polyporus sulphureus.
    Leaves—fair growth; abundant, filling tube.
    Soil—fair growth.
    Manure—fair growth, but very slow.
    Beans—very good growth, rapidly filling tube.
    Sugar beet—fair growth; much lighter mycelium than the above, with prompt oidial development.
16. Tricholoma personatum.
    Leaves—very good growth throughout.
    Soil—very good growth throughout.
    Manure—growth slow, but eventually good.
    Beans—good growth throughout.

Plates II, III, and IV show some of the more important of these species.

Taking into consideration the variable quality of the stable manure which may be obtained at all seasons, the value of half-rotted deciduous leaves as a substratum for Basidiomycetes is worthy of special emphasis. The writer has found such material more readily sterilized than manure, and usually more prompt than the latter to give growth.

In order to test in pure cultures the probable effect of fertilizers as indicated by any marked increase in the rapidity of growth of the mycelium, experiments were made by adding a small quantity of ordinary nutrient salts to test tubes containing manure. A chlorid and a nitrate of the following salts were employed, viz, ammonium, calcium, magnesium, and potassium. In addition, dibasic potassium phosphate and also sodium chlorid, as well as control cultures, were used. Three tubes were employed with each of the compounds mentioned. There was no marked difference in the amount or rapidity of the growth noted, as found by comparing the averages of growth.

It seemed possible, however, that some slight advantage resulted from the calcium compounds, but there was no pronounced benefit in any tube. Further reference is made to the use of nutrient salts in mushroom growing in another chapter.

Growth on chemically known media.—In an attempt to determine somewhat more accurately the value of different compounds as nutrients, particularly carbohydrate and nitrogenous substances, several series of extensive tests have been made with *Agaricus campestris*, and also with *Agaricus fabaceus* and *Coprinus comatus*. These fungi do not grow readily in liquid media, and it has been difficult to obtain a wholly reliable and satisfactory substratum, one which would itself be practically pure, or well known, chemically, and at the same time effective for its purpose. After unsatisfactory attempts with various gelatinous solid media, with charcoal, etc., it was decided that the commercial gray filter paper had more to recommend it than any other substance suggested. Accordingly, all experiments were made in Erlenmeyer flasks of 150 c. c. capacity, and in each flask was placed about 6 grams of this paper wadded into pellets. The latter was moistened in each case with the nutrient solution used. The flasks were subsequently sterilized in the autoclave and then inoculated with a very minute fragment of straw with the fresh mycelium from a pure culture on manure.

Tabulation of special results.—In the following tables are given the results of two out of several series of experiments, which have been conducted in order to throw some light on the point just discussed. These tables include, also, many cultures on media of unknown composition.

TABLE V.—*Results of growth on media—First series of experiments.*

No.	Medium.	Extent of growth.
1a 1b	Dt. H_2O	Very slight. Do.
2a 2b	Solution A	Do. Do.
3a 3b	Solution A and cane sugar, 1½ per cent	Do. Do.
4a 4b	Cane sugar, 1½ per cent	Do. Do.
5a 5b	Solution A and lactose, 1½ per cent	Do. Do.
6a 6b	Lactose, 1½ per cent	Do. Do.
7a 7b	Solution A and glycerin, 1½ per cent	Do. Do.
8a 8b	Glycerin, 1½ per cent	Do. Do.
9a 9b	Solution A and starch paste, ½ per cent	Fair growth Do.
10a 10b	Starch paste, ½ per cent	Do. Do.
11a 11b	Solution A and starch, ½ per cent, and diastase, trace	Contaminated, discarded. Fair.
12a 12b	Starch, ½ per cent, and diastase, trace	Good. Do.
13a 13b	Solution A and dextrose, 1½ per cent	Very slight. Good.

TABLE V.—*Results of growth on media—First series of experiments*—Continued.

No.	Medium.	Extent of growth.
14a 14b	Dextrose, 1½ per cent	Slight. Do.
15a 15b	Solution A and mannite, 1½ per cent	Very slight.
16a 16b	Mannite, 1½ per cent	Lost.
17a 17b	Solution A and maltose, 1½ per cent	Contaminated with Aspergillus. Fair growth, yellowish in color.
18a 18b	Maltose, 1½ per cent	Fair. Do.
19a 19b	Solution A and potassium tartrate, ½ per cent	Slight. Do.
20a 20b	Potassium tartrate, ½ per cent	Do. Do.
21a 21b	Solution A and magnesium tartrate, ½ per cent	Do. Do.
22a 22b	Magnesium tartrate, ½ per cent	Do. Do.
23a 23b	Solution A and ammonium tartrate, ½ per cent	Do. Do.
24a 24b	Ammonium tartrate, ½ per cent	Do. Do.
25a 25b	Solution A and potassium lactate, ½ per cent	Do. Do.
26a 26b	Potassium lactate, ½ per cent	Do. Slight to fair.
27a 27b	Solution A and magnesium lactate, ½ per cent	Slight. Do.
28a 28b	Magnesium lactate, ½ per cent	Do. Do.
29a 29b	Solution A and ammonium lactate, ½ per cent	Fair to good. Do.
30a 30b	Ammonium lactate, ½ per cent	Slight. Do.
31a 31b	Solution A and calcium hippurate, ½ per cent	Very good. Do.
32a 32b	Calcium hippurate, ½ per cent	Slight. Do.
33a 33b	Solution A and asparagin, ½ per cent	Do. Do.
34a 34b	Asparagin, ½ per cent	Do. Do.
35a 35b	Solution A and peptone, ½ per cent	Good. Do.
36a 36b	Peptone, ½ per cent	Very slight. Do.
37a 37b	Solution A and casein, ½ per cent	Very good. Do.
38a 38b	Casein, ½ per cent	Do. Do.
39a 39b	Solution A and pepsin, ½ per cent	Slight to fair. Do.
40a 40b	Pepsin, ½ per cent	Do. Do.
41a 41b	Solution B	Do. Do.
42a 42b	Solution B and asparagin, ½ per cent	Slight. Do.
43a 43b	Solution B and peptone, ½ per cent	Very slight. Do.
44a 44b	Solution B and casein, ½ per cent	Very good. Do.
45a 45b	Solution B and pepsin, ½ per cent	Culture lost. Do.
46a 46b	Bouillon	Slight to fair. Do.
47a 47b	Bean decoction	Very good. Do.
48a 48b	Beet decoction	Good to very good. Do.
49a 49b	Manure decoction	Very good. Do.
50a 50b	Manure	Do. Do.
51a	Wheat straw	Lost.
52a 52b	Solution A and wheat straw	Do. Do.
53a 53b	Solution B and wheat straw	Do. Do.
54a 54b	Solution B and NH_4NO_3 and cane sugar	Slight to fair. Do.
55a 55b	Solution B and cane sugar and $Ca(NO_3)_2$, ½ per cent	Very slight. Do.

TABLE V.—*Results of growth on media—First series of experiments*—Continued.

No.	Medium.	Extent of growth.
56a	Solution B and sugar and $Mg(NO_3)_2$, ½ per cent	Very slight.
56b		Do.
57a	Solution B and sugar and NH_4Cl, ½ per cent	Do.
57b		Do.
58a	Solution B and NH_4NO_3, ½ per cent	Do.
58b		Do.
59a	Solution B and $Ca(NO_3)_2$, ½ per cent	Do.
59b		Do.
60a	Solution B and $Mg(NO_3)_2$, ½ per cent	Do.
60b		Do.
61a	Solution B and NH_4Cl, ½ per cent	Slight to fair
61b		Do.
62a	Mushroom decoction	Do.
62b		Do.

TABLE VI.—*Results of growth on media—Second series of experiments.*

No.	Medium.	Extent of growth.
1a	Fresh horse manure (grass-fed animals)	None.
1b		Slight.
2a	Fresh horse manure, thoroughly washed, residue only used	Contaminated.
2b		Good.
3a	Filtrate, or liquid resulting from washing No. 2	Good.
3b		Contaminated.
4a	Decoction of fresh horse manure, as in No. 1	Fair.
4b		Do.
5a	Fermented horse manure, thoroughly washed	Very good.
5b		Do.
6a	Filtrate or washing from No. 5	Slight.
6b		Do.
7a	Rotted stable manure	Good.
7b		Contaminated.
8a	Decoction of green timothy hay	Good.
8b		Do.
9a	Residue from decoction in No. 8	None.
9b		Do.
10a	Strong bean juice	Slight.
10b		Contaminated.
11a	Weak bean juice	Good.
11b		Do.
12a	Strong decoction of mushrooms	Slight.
12b		Do.
13a	One-half strength decoction of mushrooms	Slight.
13b		Contaminated.
14a	Weak decoction of mushrooms	Slight.
14b		Do.
15a	Oat straw	Contaminated.
15b		Slight.
16a	Wheat straw	Good.
16b		Do.
17a	Corn meal	Fair.
17b		Do.
18a	¼ gram cane sugar in 25 c. c. solution A	Slight.
18b		Confined to nocules.
19a	¼ gram milk sugar in 25 c. c. solution A	Do.
19b		Slight throughout.
20a	¼ gram galactose in 25 c. c. solution A	Do.
20b		Slight, but contaminated.
21a	¼ gram cornstarch in 25 c. c. solution A	Slight at top.
21b		Lost.
22a	½ strength albumen (egg)	Confined to nocules.
23a	¼ gram glucose in 25 c. c. solution A	Slight at top.
23b		Do.
24a	¼ gram dextrose in 25 c. c. solution A	Fair throughout.
24b		Do.
25a	¼ gram mannite in 25 c. c. solution A	Fair.
25b		Contaminated.
26a	¼ gram glycogen in 25 c. c. solution A	Slight; contaminated.
26b		Fair.
27a	¼ gram maltose in 25 c. c. solution A	Slight at top.
27b		Do.
28a	¼ gram levulose in 25 c. c. solution A	Slight.
28b		Slight at top.
29a	¼ gram glycerin in 25 c. c. solution A	Confined to nocules.
29b		

TABLE VI.—*Results of growth on media—Second series of experiments*—Cont'd.

No.	Medium.	Extent of growth.
30a	$\frac{1}{4}$ gram potassium tartrate in 25 c. c. solution A	Very slight: contaminated.
30b		Do.
31a	$\frac{1}{4}$ gram magnesium tartrate in 25 c. c. solution A	Confined to nocules.
31b		Do.
32a	$\frac{1}{4}$ gram potassium lactate in 25 c. c. solution A	Do.
32b		Do.
33a	$\frac{1}{4}$ gram potassium lactophosphate in 25 c. c. solution A	Slight at top.
33b		Do.
34a	$\frac{1}{4}$ gram magnesium citrate in 25 c. c. solution A	Do.
34b		Do.
35a	$\frac{1}{4}$ gram magnesium malate in 25 c. c. solution A	Do.
35b		Do.
36a	$\frac{1}{4}$ gram calcium hippurate in 25 c. c. solution A	Good top.
36b		Do.
37a	$\frac{1}{4}$ gram asparagin in solution A	Slight.
37b		Do.
38a	$\frac{1}{4}$ gram urea in solution A	Confined to nocules.
38b		Do.
39a	$\frac{1}{4}$ gram peptone in solution A	Fair at top.
39b		Do.
40a	$\frac{1}{4}$ gram casein in solution A	Fair throughout.
40b		Do.
41a	$\frac{1}{2}$ gram benzoic acid in solution A	None.
41b		Do.
42a	$\frac{1}{5}$ gram benzoic acid in solution A	Do.
42b		Do.
43a	Solution A	Confined to nocules.
43b		Do.
44a	Solution B	Do.
44b		Do.
45a	Distilled HO	Do.
45b		Do.
46a	Decoction from productive old bed	Fair throughout.
46b		Do.
47a	Oak sawdust, only slightly rotted	Confined to nocules.
47b		Do.
48a	Gluten meal and water	Good throughout.
48b		Do.
49a	Cotton-seed meal and water	Contaminated.
49b		Do.
50a	Cotton-seed meal	Slight at top.
50b		Contaminated.
51a	$\frac{1}{2}$ gram asparagin in solution B	Slight at top.
51b		Do.
52a	$\frac{1}{4}$ gram asparagin in solution B	Fair.
52b		Do.
53a	$\frac{1}{2}$ gram urea in solution B	None.
53b		Do.
54a	$\frac{1}{4}$ gram urea in solution B	Slight at top.
54b		Do.
55a	$\frac{1}{8}$ gram urea in solution B	Slight throughout.
55b		Do.
56a	$\frac{1}{2}$ gram peptone in 25 c. c. solution B	Slight at top.
56b		Do.
57a	$\frac{1}{4}$ gram peptone in 25 c. c. solution B	Do.
57b		Do.
58a	$\frac{1}{8}$ gram peptone in 25 c. c. solution B	Fair at top.
58b		Do.
59a	$\frac{1}{4}$ gram peptone and $\frac{1}{16}$ gram $NaNO_3$ in solution B	Fair throughout.
59b		Slight.
60a	$\frac{1}{2}$ gram casein in 25 c. c. solution B	Very slight.
60b		Do.
61a	$\frac{1}{4}$ gram casein in 25 c. c. solution B	Fair at top.
61b		Slight at top.
62a	$\frac{1}{16}$ gram casein in 25 c. c. solution B	Fair throughout.
62b		Do.
63a	$\frac{1}{4}$ strength albumen (egg)	Slight at top.
63b		Do.
64a	Oil meal and water	Good throughout.
64b		Do.
65a	White pine shavings	Very small area, but copious.
65b		Do.
66a	White pine shavings with bean decoction	Do.
66b		Do.
67a	Asbestos with bean decoction	Confined to nocules.
67b		Do.
68a	Old flake spawn	Very good.
68b		Do.

It is not possible here to enter into a detailed discussion of the results, but attention is directed to the fact that under ordinary conditions *Agaricus campestris* does not give a copious growth when nitrogen is furnished from an inorganic salt and carbon in the form of the well-known sugars. Calcium hippurate in a solution of the necessary salts has almost invariably given better growth than other organic salts and carbohydrates. In general, casein has been a better source of carbon, or of carbon and nitrogen, than other proteids.

When the manure is of good quality it furnishes, in pure cultures, a source of necessary nutrients, whether fresh or fermented, whether as a decoction or an infusion (a cold aqueous extract).

Acid and alkaline media.—Manure which has undergone fermentation for a few weeks is usually slightly acid in reaction. Under certain conditions of fermentation the acidity is increased, and this is probably an important factor in making the manure from animals fed with green foods less valuable for mushroom work. Some acid tests were made of beds which had failed to yield satisfactory results, and in many instances it was found that the acid content was much above the normal. A small series of experiments was therefore instituted to determine the relative amount of acidity or of alkalinity most favorable for the growth of the spawn under pure-culture conditions. In this test there were also included several other edible fungi, the results of all of which are included in the table below. These experiments were made in large test tubes, and in such a test it was impracticable to determine absolute acidity or alkalinity, and from the results only a rough qualitative comparison could be anticipated. Potassium hydrate and lactic acid were used as reagents. The duration of the experiments was one month, and duplicate cultures were used in every instance.

Although the results are not wholly uniform, it may be inferred that in the case of *Agaricus campestris* a marked acidity of the medium would be unfortunate; *Calvatia cyathiforme*, on the other hand, seems to have grown somewhat better, in general, in the more acid media; *Coprinus comatus* grows under a wider range of conditions; and *Coprinus atramentarius*, in this instance, thrives in an alkaline medium. Further tests on a quantitative basis are required before definite conclusions may be drawn. This matter will also receive further attention when facilities are at hand for undertaking to better advantage than has yet been possible the practical growing of the other species, besides *Agaricus campestris*, included in this test.

TABLE VII.—*Results of tests of acidity and alkalinity.*

Medium.	Nature of stable compost.	Extent of growth.			
		Agaricus campestris.	Calvatia cyathiforme.	Coprinus comatus.	Coprinus atramentarius.
4 drops KHO	Fresh	Very slight	Very slight	Slight	1 good, 1 very slight.
	Rotted	Slight	do	Very slight	Contaminated.
2 drops KHO	Fresh	1 good, 1 fair.	1 none, 1 slight.	1 very good, 1 excellent.	Very slight.
	Rotted	Very good	None	Very good	Good
1 drop KHO	Fresh	Good	Very slight	Excellent	Very good.
	Rotted	Very good	None	do	Excellent.
Control	Fresh	1 very good, 1 fair.	1 good, 1 none	do	Very slight.
	Rotted	Very slight	Contaminated.	None	None.
1 drop acid	Fresh	1 contaminated, 1 very good	1 slight, 1 good.	Excellent	Very slight.
	Rotted	Very slight	Very slight	do	Do.
2 drops acid	Fresh	do	do	do	Do.
	Rotted	do	Very good	None	Do.

TEMPERATURE AND MOISTURE.

The temperature factor is, next to that of good spawn, perhaps the most important in mushroom growing. It has been frequently stated that mushroom growing is not profitable when the temperature may not be maintained more or less continuously at from 50° to 60° F. It is very probable that the exact temperature which may be considered an optimum will vary somewhat in different sections of the country. It will be noted later in detail that the temperature factor acts not so directly upon the growth of the spawn or the production of mushrooms as indirectly to render some other conditions of the environment injurious. It is best to consider that in practice the optimum temperature for mushroom growing varies from 53° to 58° F.

When the matter of temperature was first under consideration, a series of pure cultures of *Agaricus campestris* was placed at different temperatures in the laboratory in order to determine the rapidity of growth. It was soon found that a temperature above 60° F. and, indeed, as high as from 80° to 85° F., was much more favorable to rapid growth than a lower temperature, provided, of course, that the higher temperature did not encourage a too rapid drying out of the culture. It was soon definitely ascertained that the conditions of pure-culture growth are essentially different from those attending the growth of mushroom spawn in the bed. This was perhaps best indicated by comparing spawn grown in pots at 85° F. under impure conditions with similar spawn grown at 50° F. At the former temperature, even though the conditions of moisture were properly maintained, there was little or no growth. Foreign fungi, molds, and bacteria, as well as insects, were, however, abundant. At the lower temperature there was little or no evident appearance of other fungi, molds, or insects;

yet the mushroom spawn grows slowly and continuously so long as other conditions are maintained. From numerous experiments of this nature it is apparent that the temperature relation is one which is governed by the competition to which the mushroom spawn is subject in the bed. This is, of course, wholly in accord with the results obtained from the study of the relative growth made by mushroom spawn in fresh and composted manures.

The statement previously made, therefore, that the optimum temperature may vary slightly in different localities is true on account of the fact that the mites, insects, and other animal pests of mushroom growing may vary considerably in different localities, or under different conditions, even though there may not be a great variation, perhaps, in the bacterial and fungus flora of the compost upon which the mushrooms are grown. Certain insects, for example, are more abundant in a moist climate, but if special precautions can be taken to eliminate all such pests, the growth problem is confined to the interrelation existing between the mushroom spawn and the microscopic flora of the compost. Mushrooms grown in the open will probably show greater variation with reference to the temperature factor than those grown in caves or cellars.

While a number of interesting problems would be presented by a study of the interrelation of the mushroom mycelium with that of other microscopic fungi present in the compost, these are matters of detail; and it has been wholly impossible thus far to give any attention to suggestions which have been furnished by the experimental data. It may be possible that other species of mushrooms are more independent of insects and other microscopic fungi, and such fungi may therefore be more suitable for cultivation at high temperatures than is *Agaricus campestris* or any of its close allies. A considerable effort is being made to obtain spawn of certain species of Agaricus, and also of other edible mushrooms which make their appearance during the warm weather. At this time, however, it is not possible to say what results of value may be anticipated from this line of work.

The direct effect of a temperature above the optimum upon the sporophores is manifest through lengthening of the stipes and rapid expansion of the caps, ordinarily accompanied by toughness and decreased size. In other words, the lower grade market product is produced at the higher temperature.

The moisture factor is also one of importance. It is undesirable that the place in which mushrooms are grown should be very damp, or dripping with water. Nevertheless, a fairly moist condition of the atmosphere should be maintained throughout the growing and productive period. There should be gradual but slight evaporation from the surface of the beds, and sufficient ventilation to insure this is believed to be essential. It is certain that in poorly ventilated caves mushrooms do not succeed. On the other hand, in a dry atmosphere, or exposed to drying winds, mushroom beds soon cease to bear, while such sporophores as are developing may have their caps cracked and torn.

Mushrooms are grown in cellars, caves, or specially constructed houses largely on account of the fact that temperature and moisture are then practically under control. The nature of the structure or cellar which is constructed for mushroom growing must be determined, therefore, not merely by its expense, but by the effectiveness of the structure in regulating the factors indicated under the particular climatic conditions.

It is not possible at this time to discuss cellar or house construction, and the accompanying illustration of mushroom houses (Plate VI, fig. 1) must suffice to give an idea of the types which are in use.

PREPARATION OF THE COMPOST.

It is not to be understood that there is one and only one method of preparing compost for mushroom growing. Nor is it always necessary that the compost shall be in one particular stage of fermentation or decay. In fact, every change of condition elsewhere may necessitate a similar change in the amount of fermentation which may be most desirable. At the outset it should be understood that it is not the "fermentation" which is absolutely essential.[a] The

[a] Répin, l. c. (See translation in The Garden (London), February 5, 1898. Special reprint, pp. 10–16.) Here it is stated that "manure is rendered capable of supplying nutriment suitable for mushrooms only by means of fermentation;" further, that "all the higher orders of mushrooms, the spores of which I have succeeded in causing to germinate, have a sterile spawn of a similar nature." Again, the conclusion is expressed somewhat indefinitely that manure is "rendered suitable" by means of chemical combustion, which is said to proceed rapidly only at a temperature above 178° F.; that it is not the soluble substances in the manure which are valuable, but rather the cellulose matter, together with the necessary salts.

In this connection it is of interest to note that the material constituting many of the beds in the experimental cellar at Columbia, Mo., were fermented at comparatively low temperatures. A complete temperature record was kept of 18 small compost piles in which special kinds of manure were prepared, and in only one instance was the temperature in any pile more than 140° F. In some cases 120° F. was the maximum attained.

Répin implies that mushrooms will not grow in manure until there has been effected "the destruction of all the soluble organic matters, which disappear through the agency of bacteria or are consumed in the process of oxidation." Very simple nutrition experiments clearly demonstrate that these conclusions are erroneous.

It may be stated, however, that peculiarities appear when the fresh manure contains certain compounds which render it injurious; for example, the mycelium does not grow readily in pure culture upon fresh manure from animals fed almost wholly on green forage. Such manure is improved by fermentation.

"fermentation" is of itself a minor matter. In pure cultures, where sterile media are employed, mushroom spawn starts slowly, but finally grows best, in general, upon fresh (wholly unfermented) manure. It grows least well, or, rather, less densely, so far as tested, on very well fermented manure. This certainly indicates that it is not fermentation which is ordinarily advantageous. In practical mushroom growing, however, it is not possible to deal with pure cultures; and, therefore, other conditions of the environment must be correspondingly changed. The rapid oxidation action of bacteria, and perhaps of independent ferments, upon manure causes a considerable rise of temperature. At the higher temperatures (which may be maintained as long as there are present rapidly oxidizable food products) bacterial action is vigorous, and is unquestionably injurious to mycelial development. Wholly aside from the rise of temperature accompanying their activities, bacteria are otherwise injurious. In fact, manure which is put to ferment in a small test tube shows little or no rise of temperature above that of the place in which it is incubated. Nevertheless, the mycelium of the mushroom will not grow under such conditions. Rapid bacterial action is therefore prejudicial. Under those conditions where bacterial action is not rapid, fresh manure might be used to advantage; in other words, if the beds are so constructed that the manure ferments very gradually, without either excessive bacterial action or rise of temperature, then spawning might be made in fresh manure.

The old belief that rotten manure does not have the necessary strength—that is, does not produce so vigorous a mushroom growth as that which has been less transformed by bacterial action—has been confirmed by practical experiments. This loss of effectiveness is probably due, in part, to a change in texture or to other physical changes. In well-rotted manure there is ample food material to support a very good growth of mycelium in pure cultures. This has been chemically proved by sterilizing such manure and growing mushroom spawn upon it in pure culture. Nevertheless, by comparing (in Table VIII) No. 12 with Nos. 13, 14, and 15, it will be seen that beds prepared with well-fermented manure and left for some time before spawning do not yield so well. It is believed that here the physical condition has much to do with the result.

The latter does not by any means invalidate the following practice, which has commended itself to some very successful growers: The manure is piled in very large compost heaps, where it is kept moist and is turned only once or twice. It ferments very slowly. Then it is carted into the cave, or mushroom house, long before it could be considered in proper condition to be spawned. The beds (usually flat when this is the procedure) are made immediately. These are fairly well moistened and compressed, then left to undergo a gradual fermentation, which may require a month. When the manure shows a tendency to fall to the temperature of the room it is spawned. Meanwhile, it will doubtless be found that a heavy crop of some small species of Coprinus will have appeared. The presence of this fungus is not injurious, but rather it may be taken as an indication that the conditions are favorable.

Ordinarily the manure is obtained as fresh as possible. It should include the straw used in bedding the animals, and the quality of the straw will determine to some extent the value of the manure. The straw of cereals is far better than that of most other grasses. The more resistant straws seem greatly to improve the texture of the compost for mushroom purposes. Commercially it is a mistake to attempt to get the manure free from straw. If fresh manure is not obtainable, that which has been trampled by the animals is ordinarily rich, well preserved, and desirable. It ferments best in large piles, and these may be of considerable extent, about 3 or 4 feet deep throughout. If not uniformly moist the material should be sprinkled. At no time is a very heavy watering desirable. In from four days to a week or more the compost should be turned, or forked over, and a second turning will be required a week or ten days later. Water should be added only when necessary to maintain a moist (but not a wet) condition. With this amount of moisture, and with the piles deep enough to become fairly compact as a result of their own weight, there will be little danger of any injurious fermentation. During the normal fermentation the temperature may rise higher than 150° F. In from fifteen to twenty-one days or more, depending upon the conditions, the temperature will begin to fall, and the compost may be used in the construction of the beds. When used in the beds, it has ordinarily lost all objectionable odor, and the color of the straw has changed from yellow to brown. In figure 2 on Plate V is shown a shed in which the manure is composted during the summer.

As stated in Farmers' Bulletin No. 204:

> It is the custom with some growers to mix a small quantity of loam, about one-fourth, with the manure. This enables one to use the manure earlier; and, indeed, under such circumstances it may sometimes be used with but little or no composting. Nevertheless, the majority of growers have obtained greater success by the use of the manure alone, and this is also the writer's experience. Very well-rotted compost should not be used in mushroom growing if large and solid mushrooms are desired. When sawdust or shavings are employed for bedding the animals, the composting may require a somewhat longer period.

It has been the experience of some of the most successful growers that the use of shavings for bedding material in the stables does not injure the value of the product for mushroom work. The presence of a large amount of sawdust is, however, objectionable so far as the writer's experience goes. Compost containing much sawdust is necessarily very "short," and therefore the physical condition is not the most favorable for *Agaricus campestris*.

In another chapter attention is called to the fact that the value of the manure depends to a considerable extent upon the feed given the animals. It would not be wise to depend upon that obtained from stables in which hay and green foods are used to too great an extent. Moreover, it is not believed that compost made from the manure of cattle barns is in mushroom growing as desirable as stable manure.

In some cities the municipal ordinances require that the manure shall be promptly removed from the feeding stables or that it shall be disinfected. In the latter case crude carbolic acid, or even corrosive sublimate, may be used to secure this end. Manure thus disinfected is, of course, undesirable for mushroom work. For the same reason the manure of veterinary hospitals is of questionable value.

It is not wholly improbable that some other waste products of the farm, field, and forest may be utilized in mushroom growing; nevertheless, no such product has yet been found which, under the conditions of the experiment, has yielded sufficiently to make it of special interest in growing *Agaricus campestris*. Among the products which have been tested, either alone or in conjunction with some commercial fertilizer, are the following: Leaves of deciduous trees, needles of conifers, sawdust, cotton-seed hulls, cotton seed, corn stover, sorghum stover (or bagasse), rotten hay, sphagnum, and yeddo fiber. The writer is convinced that greater profit may be anticipated, for the present, at least, if the culture of *Agaricus campestris* is confined to manure; and if other edible forms which grow in the woods are used in beds of leaves, etc., as indicated elsewhere in these pages, it is quite possible that such a fungus as *Coprinus comatus* may be grown successfully in this latter way. It may, however, be too much to hope that the morel may also be thus made amenable to culture, although leaf mold is in nature the favorite habitat of this fungus.

From the prompt and abundant growth of *Agaricus campestris* on half-rotted leaf mold in pure cultures, it was thought that mushrooms might be grown to advantage upon this product. The practical experiments made to test this point are distinctly discouraging, as shown by reference to No. 17, Table VIII; Nos. 3 and 4, Table IX, and No. 11, Table X.

For the most part manure may be composted in the open air. It may, however, be prepared with greater uniformity under cover. During midsummer, protection may be desirable on account of drying out, while in the winter it is more important in case of excessive cold. If it is necessary to compost manure during the winter, moreover, the piles should be of considerable depth.

INSTALLATION OF BEDS.

In making the beds, as well as in other phases of mushroom work, regard must be had for all environmental conditions. The type of bed should be determined by convenience, and the size, to a certain extent, by the temperature to which the beds may be exposed. The flat bed, frequently referred to as the English type, is more commonly employed in the indoor work in England and America. With this type merely the entire floor space may be utilized, as illustrated in the frontispiece, Plate I, or the beds may be arranged in tiers of shelves. In figure 1 on Plate V a view may be had of the supports for shelf beds in a large commercial house. In this house there is the greatest economy of space. The shelf system gives the greatest amount of bed space and is certainly most economical where the floor space is an important factor. Such beds do not require great depth, but merely sufficient to insure an ample development of spawn. They should be from 8 to 10 inches deep after being firmed or compressed.

The ridge-bed system is employed almost exclusively in the caves about Paris. This system is also in use in open-air culture. It may be used to advantage in low cellars, caves, or houses when labor is not too expensive. Ridge beds increase slightly the surface area and permit of easy passage from one part of the cave to another. The size of such beds in caves, or under other conditions where the temperature remains practically uniform, should be not more than 2 feet wide at the base and 15 inches high, tapering gradually to the top when compressed. Slanting beds are commonly employed next to the walls. Large beds are desirable under changeable open-air conditions.

The prevalent opinion among amateurs that the bed should always be deep enough to maintain a considerable heat is believed to be erroneous. Grown under more or less uniform conditions, mushrooms seem to require no bottom heat, and the bed should fall to the temperature of the room some time after spawning. Bottom heat, and hence large beds, are, however, desirable when sudden changes of weather would so reduce the temperature of the bed as to delay growth. Under similar conditions, as well as in dry air, mulching may be required.

As previously stated by the writer in Farmers' Bulletin No. 204 of the Department of Agriculture—

> In any case, the manure is made up in the form of the bed desired and should be firmed, or compressed, to some extent immediately, in order to prevent drying out and burning when the secondary fermentation takes place. At this time the manure should be neither wet nor dry, but merely moist. The only practical test of the proper moisture content of the manure which can be relied upon is when, upon compression, water can not readily be squeezed out of it.

SPAWNING AND CASING THE BEDS.

From what has been said concerning the temperature requirements, it will be evident that spawn should not be inserted in the beds until the temperature has fallen low enough to insure successful competition on the part of the mycelium with other organisms. In many articles on mushroom growing it has been suggested that beds may be spawned when the temperature has fallen to about 90° F. From experience and observation, the writer can only conclude that such a temperature is frequently fatal, and it is believed that the temperature of the beds should be permitted to fall to 70° F. before being spawned. In fact, the most successful results have been obtained at temperatures from 65° to 70° F. It was formerly believed that if the spawn were inserted at 90° F. this higher temperature incited the rather dormant mycelium to rapid and vigorous growth. It is clear, however, that the rapid development of new mycelium from the pieces of spawn brick inserted is not so important a factor as suitable conditions for continued growth. If the temperature falls rapidly from 90° F. after spawning, however, no injury may result. Nevertheless, it is to be considered an unfortunate condition.

The bricks of spawn may be broken into from ten to twelve pieces, from 1½ to 2 inches square. These pieces may be inserted about 1 inch beneath the surface of the manure. In flat beds they may be placed from 10 to 12 inches apart throughout the bed, and in ridge beds the pieces should be inserted on each side alternately, one near the top and the next near the bottom. It is well to insert the pieces vertically, as the mycelium does not then seem so readily to suffer damping off. After spawning, the beds should again be firmed, and they are then ready to be cased or loamed whenever this process may seem most desirable. At the time of spawning the beds should be in the best condition possible for the growth of the mycelium. Delay in growth at this time is one of the surest indications of a light yield. If the bed contains the proper amount of moisture, and if the walls and floors of the house or cellar are sprinkled occasionally, so as to maintain a moist condition of the atmosphere, it is possible to avoid wholly the use of water upon the beds immediately after spawning. In no case should a bed recently spawned be heavily watered. The surface may be sprinkled, if there is a tendency toward drying out. The same test for moisture content as has been outlined previously in these pages in the chapter on preparing the manure should be followed. The beds should become gradually somewhat drier, however, during the growth of the spawn.

The absolute water content for the bed at the time of spawning should be about 40 per cent, although this will vary considerably, according to the conditions, and especially with relation to the quantity of straw in the manure.

If the spawn grows rapidly at first and spreads throughout the bed, it will not be injured by a slight drying out, or by a temperature even as low as 32° F. On the other hand, a continuous high temperature for several days, or excessive watering, is sure to result in an irreparable injury. In several instances where the experimental beds of the writer have been made during the late autumn, and where a vigorous growth of spawn has been secured before the advent of the coldest weather, the beds have remained unproductive throughout the winter months, or so long as the temperature remained intermittently below 40° or 50° F. With warmer weather, these beds have come into bearing several months later, and where the temperature has then remained favorable for some time a good yield has been obtained. In this case, moreover, the bed will bear much longer at a temperature of 60° F., or above, than if the temperature has been constantly in the neighborhood of 60° F. throughout the growing season of the spawn. As a rule, beds thus filled with spawn and then subjected for a time to cold conditions yield at the outset much larger mushrooms than beds exposed to a more constant temperature, even if this constant temperature may be the optimum.

At any rate, the beds must be "cased" as soon as convenient after the spawn is inserted. As a rule, one should wait from one to two weeks in order to be sure that the spawn is growing. Casing consists in applying to the bed a layer of loam from 1 to 1½ inches deep. In France the casing soil consists usually of calcareous earth, sometimes mixed with loam. Ordinary loam of almost any quality will suffice. This should be secured in advance, and it is well to protect it from the weather, so that at a convenient time it may be worked over and, if necessary, screened, in order to free it from large pebbles or trash. When the loam is applied, it should, on ridge beds, be carefully firmed. When cased a bed should require watering for the most part merely to maintain a moist surface.

MUSHROOM GROWING.

EXPERIMENTS AT COLUMBIA, MO.

The practical experiments in mushroom growing which have been undertaken at Columbia, Mo., were designed, in the first place, to determine the exact effect of conditions upon the growth of mushrooms, and in the second place to test or immediately apply the results obtained or suggested by the laboratory work. The effects of temperature, moisture, etc., have already been discussed, and the conclusions drawn have been based upon the most careful observations of the experimental beds, as well as upon the evidence which has been obtained by a personal study of the conditions in commercial mushroom houses and caves both at home and abroad. It is needless to give in detail the record of all failures or of poor yields invariably obtained when the conditions were unfavorable—that is, when they were beyond the limits which have been more or less definitely stated as requisite. On the other hand, the results which are given do not represent the best yields obtained; they are those which seem to be most instructive.

The experimental work has been seriously handicapped in one particular. With only one set of experiments (those recorded in Table VIII) has it been possible to maintain a temperature constantly between 50° and 60° F. Unfortunately a north basement room which gave those results during the winter of 1903–4 has not since been available for the work. The results are, however, comparative when not absolute.

The results given in Table VIII are referred to in various parts of this bulletin. Attention should be directed to the fact that many of these beds were yielding well when the experiment was necessarily closed to make room for a second series of experiments planned during the same winter. Beds Nos. 6, 9, 13, 25, and 40, for instance, each yielded between 8 and 15 ounces the day the experiment was closed, while beds Nos. 2, 10, 14, 23, 26, 30, and 37 each yielded 1 pound or more on the same day.

It is to be noted that a considerable number of beds in this series produced more than 1 pound per square foot, and some nearly 2 pounds for a similar area. It is certain that some beds would have yielded more than 2 pounds if they could have been permitted to produce longer.

TABLE VIII.—*Yields of experimental mushroom beds.*

Number of the experimental bed.	Material used in the bed.	Source of the spawn.	Number of days to produce mushrooms.	Yield in ounces first 30 days.	Yield in ounces second 30 days.	Total yield in ounces at close of experiments.	Area in square feet per bed.	Yield in ounces per square foot.
1	Fermented horse manure.	Alaska, old	27	53	54	107	6	18.0
2	do	Old American made	104	20	......	20	6	3.6
3	do	English, current year market product.	51	7	......	7	6	1.0
4	do	English, 2 years old				0	6	0.0
5	do	English, 1 year old				0	6	0.0
6	do	Alaska, U.S. Department of Agriculture.	51	47	68	115	6	18.8
7	do	Bohemia, U. S. Department of Agriculture.	53	48	17	65	5	13.0
8	do	Mixed varieties, U.S. Department of Agriculture.	51	78	34	112	6	18.6
9	do	Bohemia, U. S. Department of Agriculture, light spawning.	68	102	......	102	6	17.0
10	do	Bohemia, U. S. Department of Agriculture, heavy spawning.	46	71	65	136	6	22.6
11	do	*Agaricus amygdalinus*, old				0	6	0.0
12	Fermented horse manure (bed left for 2 months before being spawned).	Bohemia, U. S. Department of Agriculture.	61	5	......	5	6	0.8

TABLE VIII.—*Yields of experimental mushroom beds*—Continued.

Number of the experimental bed.	Material used in the bed.	Source of the spawn.	Number of days to produce mushrooms.	Yield in ounces first 30 days.	Yield in ounces second 30 days.	Total yield in ounces at close of experiments.	Area in square feet per bed.	Yield in ounces per square foot.
13	Fermented horse manure.	Bohemia, U. S. Department of Agriculture.	49	110	50	160	6	27.7
14, 15	....do	....do	61	241	40	281	12	23.4
16	Leaf mold	*Calvatia cyathiforme*	......	......	......	0	6	0.0
17	....do	Bohemia, U. S. Department of Agriculture.	......	......	......	0	6	0.0
18	Fermented stable manure; bed fairly compact.	Alaska, U. S. Department of Agriculture.	48	118	71	189	9	21.0
19	Fermented stable manure.	....do	53	93	30	123	6	20.5
20	....do	Bohemia, U. S. Department of Agriculture.	48	101	39	140	6	23.3
21	....do	Var.?, U. S. Department of Agriculture.	53	96	37	133	6	22.2
22	....do	American commercial more than 1 year old.	......	......	......	0	6	0.0
23	....do	American commercial, Bohemia	53	111	53	164	8	20.5
24	....do	....do	51	46	67	113	9	15.2
25	....do	Bohemia, U. S. Department of Agriculture. Loose cakes; dried.	46	22	50	72	6	12.0
26	....do	Bohemia, U. S. Department of Agriculture. Watered freely late.	49	74	75	159	6	26.6
27	....do	Bohemia, U. S. Department of Agriculture. Watered freely.	49	42	51	93	6	15.5
28	....do	Bohemia, U. S. Department of Agriculture.	46	89	30	119	6	19.8
29	....do	....do	55	90	55	145	8	18.1
30	Fermented stable manure and 5 pounds cotton-seed meal.	....do	51	129	146	275	9	30.5
31	Fermented stable manure.	English commercial, St. Louis	......	......	......	0	6	0.0
32	....do	English commercial, New York	......	......	......	0	6	0.0
33	....do	Bohemia, Americal commercial	42	70	32	102	6	17.0
34	....do	Alaska, American commercial	46	70	31	101	6	16.7
35	....do	French, commercial flake	......	......	......	0	8	0.0
36	Fermented stable manure and cotton-seed hulls.	Bohemia, U. S. Department of Agriculture.	53	47	96	143	9	15.9
37	Fermented stable manure; bed heavily compressed.	....do	61	......	......	104	6	17.3
38	....do	Var.?, U. S. Department of Agriculture.	46	58	46	104	6	17.3
39	Fermented stable manure and sphagnum.	....do	46	11	11	22	6	3.7
40	Fermented sheep manure.	....do	50	44	......	44	6	7.3
41	Fermented stable manure, cotton-seed hulls, and cotton-seed meal.	....do	46	18	39	57	8	7.1
42	Fermented cotton-seed hulls and cotton-seed meal.	Bohemia, U. S. Department of Agriculture.	55	......	......	5	9	0.6
43	Manure mold	....do	......	......	......	2	6	......
43	Sod	*Calvatia cyathiforme*. Pure cultures.	......	......	......	0	6	0.0
45	Old compost, left 2 months before spawning.	Bohemia, U. S. Department of Agriculture.	52	......	......	5	9	0.6

The series of experiments outlined in Table IX followed directly upon the series given in Table VIII. The beds in the first series were made in midwinter, and as the manure had been well fermented there was little or no rise of temperature after the beds were made. The spawn was therefore inserted at an unusually low temperature. During thaws in the late winter there was considerable seepage through the walls of the room. Some of the wall beds—Nos. 14 to 21—were seriously damaged, but although beds Nos. 7 to 13 were also wall beds seepage was not evident in this region. Within about thirty days after vigorous mushroom production began in this series the basement was flooded, and the work was therefore brought to an abrupt close. The yield up to that time is given, however, since in this series there are included many fertilizer tests.

TABLE IX.—*Yields of experimental mushroom beds in a north basement room, 1904.*

Number of the experimental bed.	Bedding material and fertilizer.	Spawn used.	Number of days to first picking.	Yield, in ounces, per bed.	Area of bed in square feet.
1	Stable manure and cotton-seed hulls.	Bohemia, U. S. Department of Agriculture.	48	33	6
2	....do	do	48	9½	6
3	Leaf mold and stable manure	do	48	38	6
4	....do	do	48	36	6
5	Stable manure and sphagnum	do	61	4	6
6	Stable manure and cotton-seed meal.	do	61	64	6
7	....do	do	66	73	6
8	Stable manure, timothy fed	do	73	2	6
9	....do	do	......	0	6
10	Stable manure, clover fed	do	......	1	6
11	....do	do	......	3	6
12	Stable manure, bran fed	do	66	84	6
13	....do	do	54	109	6
14[a]	Stable manure, corn fed	do	71	12	6
15[a]	....do	do	68	8	6
16[a]	Stable manure, oats fed	do	......	3	6
17[a]	....do	do	80	14	6
18[a]	Stable manure	do	71	24	6
19[a]	....do	do	66	40	6
20[a]	....do	do	71	17	6
21[a]	....do	do	68	55	6
22	....do	do	48	61	6
23	Stable manure and complete fertilizer: KCl, 1 ounce; KNO_3, 1 ounce; bone meal, 7 ounces.	do	64	55	6
24	Stable manure and incomplete fertilizer: $NaNO_3$, 1 ounce; bone meal, 7 ounces.	do	64	30	6
25	Stable manure and NaCl, 2 ounces	do	66	41	6
26	Stable manure and $NaNO_3$, 2 ounces	do	48	42	6
27	Stable manure and $MgSO_4$, 2 ounces	do	66	39	6
28	Stable manure and K_2SO_4, 2 ounces	do	64	46	6
29	Stable manure and kainit, 4 ounces	do	64	62	6
30	Stable manure and $CaCl_2$, 2 ounces	do	64	48	6
31	Stable manure and Na_2HPO_4, 2 ounces.	do	64	65	6
32	Stable manure and $(NH_4)_2SO_4$, 2 ounces.	do	54	41	6
33	Stable manure and $NaNO_3$, 1 ounce; kainit, 2 ounces.	do	68	30	6

[a] Some of the beds in this block (Nos. 14–21) were seriously injured by seepage water, and the results are untrustworthy.

TABLE IX.—*Yields of experimental mushroom beds in a north basement room, 1904*—Continued.

Number of the experimental bed.	Bedding material and fertilizer.	Spawn used.	Number of days to first picking.	Yield, in ounces, per bed.	Area of bed in square feet.
34	Stable manure	English commercial (ordered as fresh).	68	34	6
35	...do	Spawn from bed in full bearing	66	12	6
36	Stable manure, lime dressing	Bohemia, U. S. Department of Agriculture.	68	8	6
37	Stable manure, ammonium molybdate, ½ ounce.	...do		(?)	6
38	Stable manure, $ZnNO_3$, 1 gram	...do		(?)	6
39	Stable manure	*Agaricus amygdalinus*	68	7	6
40	...do	Bohemia, U. S. Department of Agriculture.	64	77	6
41	...do	English commercial (New York)	77	4	6
42	...do	Bohemia, U. S. Department of Agriculture.	64	33	6
43	...do	Spawn from old bearing bed		0	6
44	...do	*Pleurotus ostreatus*		0	6
45	...do	English commercial (Philadelphia)		0	6
46	Stable manure and sawdust	Bohemia, U. S. Department of Agriculture.		0	6
47	Stable manure	Var.?, American commercial	48	60	6
48	...do	Alaska, American commercial	64	22	6

From the experiments given in the foregoing table further proof is furnished of the fact that stable manure alone, when of good quality, is sufficient for the growth of mushrooms. The addition of nutrient salts as fertilizers has not, on an average, given any marked increase in yield, but rather the contrary. It is hardly possible that the quantity of salts used on the beds was too little to make the effect felt. On the other hand, it was not sufficient to be injurious. It is evident from the experiment in bed No. 29, for instance, that the addition of 4 ounces of kainit could not have been injurious. In some instances the results obtained by the use of fertilizers were poorer than where the manure alone was used. This, however, the writer believes to be due largely to differences in the spawn used, or the differences in condition owing to the location of the bed, for subsequent experiments with some of the salts which seemed to be either injurious or beneficial have not wholly confirmed these results. It is to be noted, however, from the experiment in bed No. 6 of this series and also from bed No. 30, in Table VIII, that the beds treated with cotton-seed meal have invariably yielded somewhat above the average. These beds do not come into bearing quite so rapidly as those in which manure alone is used. It is thought that this is due to the fact that bacterial action is at the beginning more rapid in beds containing cotton-seed meal, and that, consequently, when this wave of bacterial growth has passed the nutrition of the spawn is favorably affected. Experiments had already indicated that manure from animals which were fed a poor diet, such, for instance, as grass or hay alone, is much less valuable than where the animals are well fed. The experiments in beds Nos. 10 to 22 were designed to test the value of some different feeds. The writer was fortunate in being able to secure manure from work animals which were being used in feeding tests where very different foods were employed. Unfortunately, however, the mushroom beds were located next to a basement wall, and in beds Nos. 14 to 21 the results were vitiated by the fact that there was considerable seepage water in that region during the thaws and heavy rains of the spring. Nevertheless, it is believed that the experiments in beds Nos. 8 to 13 are trustworthy. An attempt was made to check these results by using some of this manure in tube cultures, and it was found that the manure used in beds Nos. 8, 9, 10, and 11 particularly was unfavorable for the growth of the mycelium even in the pure cultures.

On account of its stimulating action upon the spores of *Agaricus campestris* a small quantity of ammonium molybdate was applied to one bed, No. 37, in order to test its effect upon the growing mycelium. Moreover, since certain salts of zinc at considerable dilution have been found to increase greatly the quantity of mycelium produced by other fungi, zinc nitrate was employed in an adjacent experiment. The results of these two tests were the same. There was a profuse mycelial development and an abundant production of small deformed sporophores.

Table X also summarizes a series of some interest. These beds were spawned early in November, 1904. Soon after the spawn began to spread throughout the beds—about December 15—the temperature of the room fell to 40° F. From that time on until March 1, 1905, the temperature was constantly below 52°, and on several occasions as low as 32° F. After two or three weeks of warmer weather the beds began to bear vigorously, and the mushrooms, particularly the first ones, were of unusual size and of excellent flavor. Numerous individuals weighed from 6 to 8 ounces immediately after the separation of the ring, and a few mature specimens ranged from 10 to 14 ounces.

TABLE X.—*Yields of experimental mushroom beds—Third series.*

Bed No.	Material constituting bed.	Spawn used.	Comparative yield per bed, in ounces.
1	Stable manure	English commercial, 2 years old	0
2	....do	Columbia, "green" spawn, U. S. Department of Agriculture.	70
3	....do	Poor grade English commercial, recent importation.	16
4	....do	Good grade English commercial, recent importation.	49
5	....do	Good grade English commercial, 6 months old.	40
6	....do	American commercial	57
7	....do	....do	34
8	....do	....do	54
9	....do	U. S. Department of Agriculture, Columbia.	56
10	Rotted sawdust and stable manure	....do	31
11	Leaves and stable manure	....do	30
12	Sawdust	....do	3
13	Leaves	....do	6
14	Stable manure	American commercial, probably *A. arvensis*, var.	60
15	....do	American, *A. villaticus*	68

In some publications on mushroom growing the claim is made that old or practically exhausted beds may be brought into bearing again by heavy fertilization with liquid manure or with a weak solution of potassium nitrate. From a commercial point of view, no measurable success has resulted from any trials of this nature made by the writer; consequently, it is believed that exhausted beds should be immediately discarded. From the standpoint of mushroom sanitation, this is also particularly desirable.

VARIABILITY IN MUSHROOMS GROWN UNDER DIFFERENT CONDITIONS.

The writer does not intend to discuss even in a general way the relationships of the various forms of Agaricus—that is, those that may be considered allies of *A. campestris*—which he has cultivated or studied in the field. Some reference to the variability of common forms should, however, be made. For a comprehensive study of species and varieties, a knowledge of European forms as well as of those found in America is essential. Authors differ so widely in their descriptions of species, as well as in their conceptions of them, perhaps, that in the absence of unlimited material nothing short of confusion results from any attempt to harmonize opinions. It is sufficiently difficult to separate what many would regard as varieties of *A. campestris* from those of *A. arvensis*. When specific rank is bestowed also upon such forms as *A. pratensis*, *A. villaticus*, *A. magnificus*, *A. rodmani*, etc., the difficulties are greatly increased. The writer has grown many forms of Agaricus, and, as might be expected, there seems to be no form which will remain practically constant under variable conditions. Besides general size, size of spores, etc., some of the characters used in separating the common forms are color of gills; character of ring, particularly as to whether single or double; shape of stipe; color and markings of pileus; color of flesh, etc. In following the development of these characters in different forms, many variations will be found. *Agaricus campestris* grown on composted leaves shows very little pink in the gills. The color changes rapidly from dull pinkish-brown, or almost white, to a leaden hue. Several brown-capped forms, usually considered varieties of *A. campestris*, never show a bright-pink surface unless produced under exceptionally favorable conditions, moist air being a sine qua non. The ring is naturally variable. In any variety of *A. campestris* it is not uncommon for an edge of the partial veil to remain attached to the base of the stem as a volvate line, or this line may be left at any stage during the elongation of the stem. Again, if the lower margin of the partial veil on the stipe separates slightly from the stipe, and upon drying curves slightly upward, there is an indication of a double ring. A very good double ring appeared on a number of very vigorous specimens of an undoubted variety of *A. campestris* during the present season. It is possible that there is a greater tendency to produce a double ring when conditions are favorable for the production of the most vigorous mushrooms. *Agaricus arvensis* is also very variable with respect to the formation of a double ring, as also in the persistence of the partial veil.

The shape of the stipe is in many forms dependent upon the conditions. Under favorable conditions a brown variety of *A. campestris* may have a very short, thickened, equal stem, when grown on manure, and practically uniform at maturity, while the same form grown on decayed leaves may show in the main a stipe with thickened base, gradually tapering to the top. The color of the cap is of undoubted value as a varietal or specific character, yet it must be remembered that whether the surface be smooth or rough, merely fibrillose, or broken into scales of definite form, may depend entirely upon whether produced in moist air or in dry air, subjected to drying after being wet, etc. The color of the flesh is also dependent, to a considerable extent, upon the conditions. A specimen grown in even fairly unfavorable conditions will show the flesh somewhat darkened, and on exposure the characteristic pink tint will not be even momentarily visible. In other words, a considerable range of variation must be anticipated, and in comparisons there should be stated very clearly the conditions under which the particular forms are produced.

THE CULTIVATION OF VARIOUS SPECIES OF MUSHROOMS.

In Table X are given the results of a single test with *Agaricus arvensis*, or what is supposedly a brown variety of this species, and also of a single experiment with *A. villaticus*. In both cases the yield was excellent. It is not well to draw definite conclusions from individual tests, but it is believed that both of these forms will yield profitably in general culture under conditions similar to those required for *A. campestris*. Plate III, figure 2, indicates the size and compactness of the mature sporophore of *A. villaticus*. Moreover, both of the species above referred to are to be recommended for texture and flavor. Two forms of *Agaricus fabaceus* (see Pl. III, fig. 1), both with amygdaline odor and flavor, have been tried in relatively few experiments. In no case has the yield been very good, and further experiments will be required before it will be possible to state under what conditions these forms may be most successfully grown. At the Missouri Botanical Garden Prof. William Trelease has for some time grown successfully one of these varieties.

Owing to the profuse and rapid growth of the mycelium of *Coprinus comatus* in pure cultures, it was anticipated that it might easily be grown in beds. The few experiments thus far made indicate that in impure cultures (beds) of leaf mold the mycelium grows and spreads very slowly. Hot weather prevented the maturity of the tests, but no sporophores were produced during a considerable period. In similar experiments *Lepiota rhacodes* and *Tricholoma personatum* were used. The former has given unsatisfactory results thus far, but the latter is promising.

It is not yet time to report on the possibility of growing the better and larger species of puffballs and the morel. It has already been indicated that the mycelium of these fungi grows well in pure cultures. From the pure cultures it has also been demonstrated that spawn may be made, but it has not been determined under what conditions the fruit may be produced. Figure 1 on Plate IV shows a young specimen of one of the puffballs, *Calvatia craniiformis*, the spawn of which is produced with the least difficulty.

COOPERATIVE EXPERIMENTS.

During the winter of 1902–3 a small quantity of experimental spawn made by the writer was sent out to mushroom growers for trial; in 1903–4 this spawn was made in large quantity, and trial packages were sent to more than 100 growers or interested persons. At that time Farmers' Bulletin No. 204 had not been issued, and the instructions which could be furnished inexperienced growers were inadequate. Nevertheless, an attempt was made to obtain reports from all persons receiving the experimental spawn, even from those who had applied for and received spawn when the season was too far advanced for successful work except in caves and cool cellars. A number of reports were received, but, as might be expected, fully 50 per cent of these indicated that the conditions under which the experiments were made were wholly unsatisfactory, and that, therefore, no favorable results could be anticipated. Among those whose reports indicated that the conditions were favorable, or fairly favorable, only a small percentage reported failures, while four-fifths of those claiming success secured yields of more than one-half pound per square foot of bed space, many obtaining more than 1 pound per square foot. In two instances a yield of nearly 2 pounds to the square foot was reported. The frontispiece, Plate I, a bed in full bearing, and Plate VII, figure 1, showing the mushrooms as prepared for market, are photographs furnished by cooperating growers who are now also making spawn of pure-culture origin. It was suggested to growers who received the experimental spawn that a comparative test of the English or other commercial spawns with that received from the Department of Agriculture would be of interest. Comparative tests were made and reported by 10 growers. In most cases the English spawn, obtained at random on the market, failed to grow. In only one case did the English spawn prove better than the pure-culture product, and in this instance the spawn furnished by the Department when used was nearly one year old.

Failures may always be anticipated when attempts are made to grow mushrooms under adverse conditions, and it must be said that greater success was obtained from the cooperative work than could have been hoped for, considering the fact that many of the persons who sent in reports were wholly inexperienced and were practically unguided.

During the present year experimental mushroom spawn has been sent to more than 200 interested persons, and this will doubtless be the last general distribution of this product by the Department of Agriculture. Representing the varieties of *Agaricus campestris* commonly grown, mushroom spawn of pure-culture origin is now an established market product. In order that the standard of the American spawn may be maintained, spawn makers, dealers, and growers should see to it that only the fresh, recently dried product is used.

Nevertheless, it is hoped that this cooperative work may be carried forward, looking toward the development of better varieties or the bringing into culture and the testing of new species.

CAVE FACILITIES IN THE UNITED STATES.

Cave facilities in the United States are by no means so meager as has been supposed. There are in some sections caves from which rock for Portland cement has been mined. Some of these have been utilized for mushroom growing. There are also natural caves of great extent in many of the States of the Central West—especially in Indiana, Missouri, Kentucky, and Arkansas—as well as in Virginia.[a] The difficulty is to obtain caves within a convenient distance from cities, for stable manure becomes expensive if it must be hauled many miles or transported long distances by the carload. Again, caves should be easy of access, since after each crop every vestige of soil, manure, etc., of the preceding crop must be removed as a sanitary precaution. This is especially necessary since there is much waste space in most natural caves, and it becomes a very difficult or expensive matter to fumigate. If the cave system is extensive, it must also be possible to give it thorough ventilation. Many natural caves are the courses of subterranean streams. The latter are by no means objectionable if there is no danger from overflow. In many caves the stream has long since found a new channel and the cave is dry. Seepage water, usually accompanied by continuous stalactite and stalagmite formation, is undesirable. In some of the Eastern States coalpits or coal mines may be important for mushroom purposes. Where the coal mine is not too deep, or where perfect ventilation may be given, there is no reason why it is not entirely suitable for mushroom growing.

OPEN-AIR CULTURE.

In some sections of England and France open-air culture of mushrooms in beds is practicable during the late autumn and winter months, in which case the productive period may extend into the spring. The difficulties in the way of open-air culture are not merely those of maintaining a more or less uniform temperature, but also of maintaining practically constant conditions of moisture. For these reasons it is necessary to mulch the beds heavily with clean straw. In some instances a light mulch of straw is permitted to remain even during the period of production, for a rapid drying out of the surface would be hazardous or fatal. It is better, perhaps, to put the beds under some form of protection, such as an improvised cold frame.

In regions where the climatic changes are marked, open-air culture is probably not to be recommended during any season for commercial purposes. It is probable that there are some areas in the United States in which open-air culture might be practiced with profit. It has seemed that certain sections of California might be favorable for this phase of the work. In the interest of experiments

[a] The writer is indebted to Prof. C. F. Marbut for the information that caves are to be expected in the Silurian limestone, which occurs particularly in the extension of the Shenandoah Valley, in the bluegrass region of Kentucky, and in the Ozark region of Missouri and Arkansas; also in the Lower Carboniferous limestone, which extends into Indiana, Kentucky, Tennessee, and Missouri.

along this line the writer has made a special attempt to acquaint himself with the conditions in that section of the country. This has seemed particularly desirable, inasmuch as fresh mushrooms could not be shipped to the far West from sections in which they are at present grown in quantity. From the information obtained it is thought that successful open-air mushroom growing might be anticipated in those sections where the average temperature is between 48° and 55° F., provided there are relatively few days when the temperature falls as low as 32° F. At the same time, open-air culture can not be recommended for those sections in which dry winds are prevalent. As a rule, during the wet or winter season the rainfall is so light that heavy mulching would probably suffice to prevent injury from excessive wetting. Nevertheless, it seems apparent that even in regions most favorable for open-air culture some inexpensive partial protection against the changes of temperature due to direct sunlight, or against heavy rainfall, would be desirable.

It was also ascertained that *Agaricus campestris* appears naturally in some quantity during the months of January and February, or longer, during the rainy season. This, however, is also true of other species of fleshy fungi. The large size of some of the specimens of *Agaricus campestris* and *A. arvensis* found would seem to suggest that they were produced from an unusually vigorous mycelium. This may be the result of a condition analogous to that previously mentioned, where, on account of the low temperature of the atmosphere, the spawn may develop slowly through a considerable period, and finally, under favorable conditions, sporophores of unusual size are produced.

In the following table are given the monthly mean temperatures from several representative stations in California during the years 1899 and 1900. From this table it will be seen that so far as the mean temperature is concerned Eureka and San Francisco would be especially favorable during a large portion of the year. Independence and Red Bluff are likewise satisfactory, while San Luis Obispo, Santa Barbara, Los Angeles, and San Diego show a mean which is perhaps rather too high. The moisture of the atmosphere, the prevalence of hot winds, the variation in the daily temperature, and the number of hot or cold days must all be considered. From the data obtained, the general conclusion seems to be that the most favorable regions are those where conditions correspond closely to those of Eureka and San Francisco. This, however, represents a large region, including a considerable portion of the San Joaquin and of the Sacramento valleys. In a few places experiments have already been undertaken to determine the possibilities for the development of this work, but no definite recommendations can be made until the experimental evidence is at hand. It may be said, moreover, that some of the regions which seem to be too warm for open-air culture may be especially favorable during several months at a time for mushroom growing in ordinary cellars, or in very simply constructed mushroom houses. In those sections the winter and early spring months would doubtless give the most satisfactory conditions; and this period, fortunately, corresponds with the tourist season—a season when the market demands are greatest. It is also possible that with mulching and with simple protection, mushroom growing may be successful in some of the Eastern States.

TABLE XI.—*Mean monthly temperatures at points in California, in degrees Fahrenheit.*

Month.	Eureka.		San Francisco.		San Luis Obispo.		Santa Barbara.	
	1899	1900.	1899.	1900.	1899.	1900.	City.	F.H.S.[a]
January	47.5	50.4	53.0	50.7	54.2	56.2	53.0	55.4
February	44.4	48.6	51.6	53.6	54.4	56.2	54.6	58.0
March	48.0	50.5	52.2	55.2	54.0	58.2	55.3	57.4
April	48.2	50.0	54.6	54.0	56.4	54.2	57.9	59.3
May	49.6	54.4	52.6	57.0	54.0	61.6	59.4	59.4
June	52.0	56.2	56.9	57.6	62.4	63.9	62.6	64.4
July	54.8	56.4	55.9	58.2	64.4	64.2	65.5	68.1
August	55.9	57.0	58.3	59.7	64.0	64.9	66.9	68.9
September	54.8	56.6	58.2	63.3	65.5	64.4	66.1	69.9
October	52.0	53.8	59.3	58.8	59.6	62.8	62.6	64.8
November	55.9	53.3	56.8	56.3	57.4	59.8	59.1	64.7
December	48.0	50.8	49.6	50.2	54.3	55.6	55.6	58.4
Year	50.9	53.2	54.9	56.2	58.4	60.2	59.9	62.3

Month.	Los Angeles.		San Diego.		Independence.		Red Bluff.	
	1899.	1900.	1899.	1900.	1899.	1900.	1899.	1900.
January	56	58	56.0	57.1	40.2	46.6	48.8	48.8
February	54	58	53.4	57.2	46.5	48.1	51.6	51.1
March	57	60	56.4	59.1	50.5	54.9	52.2	58.6
April	60	57	58.0	57.1	59.4	52.0	60.8	57.6
May	60	64	58.0	60.6	60.0	65.8	63.2	67.0
June	65	67	61.4	63.9	74.2	75.4	77.9	76.8
July	70	71	65.6	67.1	80.4	79.4	82.0	82.6
August	69	68	65.8	65.7	72.6	72.4	73.8	77.0
September	70	67	65.5	65.3	74.6	63.5	78.0	69.9
October	63	64	62.7	62.8	55.4	58.8	61.0	60.0
November	62	66	61.0	63.7	49.4	50.4	54.4	54.8
December	58	60	58.7	59.7	43.1	43.4	45.5	45.4
Year	62	64	60.2	61.6	58.9	59.2	62.4	62.5

[a] Foothills or suburbs of Santa Barbara, at an elevation of 750 feet above the city.

Occasionally one reads of successful natural cultures of mushrooms; that is, the production of this plant in pastures, lawns, etc., under more or less natural conditions. At Columbia, Mo., the writer has made numerous attempts to spawn plats in pastures and lawns; but thus far failure has attended every attempt. The spawning has, moreover, been tried at every season of the year. It is believed that in the section of the country mentioned only exceptionally favorable seasons will permit any success in this phase of open-air culture.

MUSHROOM SPAWN MAKING.

The mycelium of the cultivated mushroom has long been known commercially as "spawn." From early times it has been recognized that mushrooms may be grown from spawn, and it is quite certain that in all attempts to propagate mushrooms spawn has been used for the purpose.

In France, in England, and in other countries in which the mushroom has long been grown it is recognized that it is not profitable continually to take growing spawn from one bed to be preserved as "seedage" for the next crop. The common expression is that the spawn "runs out" in about three years. There seem to be few or no definite experiments indicating the exact conditions under which the spawn in two or three years loses the power of vigorous mushroom production. Nevertheless, it is the almost unanimous opinion of all extensive growers that there is a marked diminution in the yield after several successive propagations from the spawn in the mushroom bed. This has seemed to be true in the writer's experiments, although it must be said that accidents to experiments undertaken have made it impossible to report at this time upon the nature of this running out. That deterioration does result is apparently a fact accepted by all scientific men who have given attention to mushroom growing. It is possible, however, that under certain conditions the spawn might be repeatedly propagated without loss of prolificness. It is not necessary to enter here into a discussion of possibilities or to attempt to explain why weakening might be evident under ordinary conditions.

A "chance" method.—For practical purposes it is necessary to renew the spawn and to secure, if possible, spawn which has not previously weakened itself by the production of mushrooms—known as virgin spawn. Natural virgin spawn may be found wherever "in nature" it has been possible for the spores to germinate and to produce a mycelium. Ordinarily such so-called "spontaneous" appearances of spawn may be anticipated in compost heaps, rich garden beds, pastures near the feeding places of animals, etc.

Many attempts have been made by practical growers to develop spawn from spores, sowing the gill portions of mature mushrooms in specially constructed beds; but the results, so far as the writer is aware, have not been satisfactory. As a rule, therefore, growers have been compelled to rely wholly upon a virgin spawn which has been obtained by chance. It is said that in the vicinity of Paris some persons make a business of searching for this virgin spawn, which they sell to the growers at a high figure. It is claimed that they become so adept in detecting the differences in the character of growth, the quality of odors, etc., that they can distinguish not only

Agaricus campestris, but also some of its varieties. In England much of the virgin spawn has been obtained from pastures. Where a "spontaneous" growth of spawn is observed, trenches are dug, and these are filled with good stable manure. The latter in time becomes penetrated, and it is highly prized for cultural purposes. As a rule, the virgin spawn is used in spawning beds, which, when well penetrated, are torn down, and the whole bed used as flake spawn in spawning the general crop. Again, the virgin spawn may be used in spawning the brick, or cakes, this being the form in which English spawn is usually made. However adept persons may become in the identification of various varieties of spawn by odor, etc., this must be considered essentially a chance method.

A "selective" method.—From what has been said it will be perceived that very little advancement could be made in the selection of desirable varieties of mushrooms, in varietal improvement and the like, so long as the chance method of securing spawn should prevail. The studies in the germination of mushroom spores previously referred to were encouraged by the apparent necessity of beginning with spores from mushrooms of known qualities in order to effect improvement. In recent years the investigations of Costantin[a] upon spore germination have found application in a department of the Pasteur Institute. By a secret method, mycelium is grown from the spores in pure cultures. These cultures, which are, of course, pure virgin spawn, are then offered for sale to the growers. This spawn does not seem to have received deserved consideration on the part of the growers. The secret method of effecting spore germination referred to by Répin[b] has also been practically applied by one of the largest seed firms in Paris. In general, however, French growers have not profited so much by the new methods, perhaps partially on account of the fact that these methods are not known and partially because of the expense of the new virgin spawn. It is to be noted that these methods imply pure cultures to begin with.

The successful germination studies with chemical stimulation mentioned in this paper were soon overshadowed by the discovery of the ease of making tissue cultures. The use of the latter method has been the means of a sudden advancement in spawn making in this country during the past two years, for many practical men have been quick to see the advantages which it offers.

Pure-culture precautions.—It has already been stated that the pure-culture method of making virgin spawn is not one which will prove successful in the hands of wholly inexperienced persons, or of those who are unwilling to spend time and use the utmost care in the manipulation of the cultures and the culture material. The use of

[a] Costantin, J., loc. cit.

[b] Répin, C., loc. cit.

pure-culture methods necessitates to a considerable extent a knowledge of the bacteria and molds which are everywhere present in the air and which are especially abundant wherever there are dusty or damp, moldy conditions. The principle of making pure cultures is briefly this: The materials, or media, and all the vessels employed must be sterilized, which implies being heated at a temperature sufficient to kill all germs present in the vessels or materials used. If the vessels used are test tubes or other pieces of glassware with small mouths, they should, previous to sterilization, be plugged with cotton batting. This cotton batting prevents, when carefully manipulated, the entrance of germs from the air, and therefore keeps the vessel or medium in a pure or sterile condition. If such a vessel is opened, this should be done in a room free from currents of air or falling dust particles; and, while open, tubes and other apparatus should be held in a more or less horizontal position, so that they will be less liable to contamination. It follows, of course, that the cotton plug, if removed, should not come in contact with any unsterilized substances. If, now, a small quantity of the growing mycelium of a mushroom from a pure culture is transferred to such a sterilized tube, using for this transfer sterile needles, or scalpels, there will be little danger from foreign organisms, and the piece of mycelium inserted will therefore grow as a pure culture free from all other fungi or bacteria.

The tissue-culture method.—In making pure cultures of mushrooms, large test tubes or wide-mouthed bottles may be used. These should be carefully cleaned, and, if possible, a sterilization should be given by means of dry heat as a preliminary precaution. In this event the tubes are plugged with cotton plugs and placed in a dry oven made for the purpose. They are heated to a temperature of about 150° C., and this temperature should be maintained for nearly an hour. Ordinarily, however, in rough work it is not essential to employ this preliminary sterilization. In either case the tubes are next partially filled (about two-thirds) with the manure, or half-decayed leaves, upon which it is desired to grow the virgin spawn. A plug is inserted in each tube, and the tubes are then sterilized in a steam boiler or under pressure. If sterilized under steam pressure, as in an autoclave, it is necessary to use about 15 pounds pressure and to allow the tubes to remain at this pressure for from fifteen minutes to half an hour. If the sterilization must be effected in a boiler or in an open water bath, it can only be done at 100° C., of course; and it is then desirable to boil the tubes for at least one hour on each of two or three successive days.

With the tubes thoroughly sterile, the next step is to make the cultures or inoculations. By the tissue-culture method it is implied that the inoculations are made from pieces of the tissue of a living mushroom. It is at this stage that selection may be made. One should procure from a bed of mushrooms in full bearing a mushroom which represents the most desirable qualities that are to be found. Size, quality, and general prolificness must all be considered, as well, also, as other characteristics in any special selections. One may desire, for instance, to select from a variety which yields throughout a long period—one which is resistant to higher temperatures, etc. Having found the mushroom from which it is desired to propagate, plants as young as possible may be used, and those which show the veil still intact are especially desirable. With a scalpel, or a pair of forceps, which has been sterilized by passing the blade through a gas flame, or even the flame from an alcohol or ordinary lamp, small pieces of the internal tissue may be removed, and these pieces transferred to the tubes, without, of course, coming in contact with any object whatever which has not previously been sterilized. It is a good idea to wash the mushroom first, so that no dust will be made. The plant may then be broken open longitudinally and bits of the internal tissue readily removed without fear of contamination when one becomes adept in this kind of manipulation. Immediately upon inoculation the cotton plug is replaced in the tube, and after all the tubes are inoculated they should be put out of the dust, preferably in a situation where the temperature is about that of an ordinary living room. In the course of several days a slight growth may be evident from the tissue if the conditions have been perfectly sterile. In the course of a week or more the growth should become very evident, and in three weeks the moldlike development of mycelium should spread to practically all parts of the medium in the tube. The method of making pure cultures and the laboratory apparatus usually involved are shown in Plate VI, figure 2.

When the tubes are thoroughly "run" the contents may be removed and used in spawning brick. The contents of a single tube may spawn several bricks when carefully employed. If no transfers are made of the growing mycelium from one lot of tubes to another, the writer has not found it at all impracticable or unfavorable to utilize this first lot of bricks later in spawning others. No further transfers, however, should be made from these bricks to others under any circumstances in spawn making. As elsewhere indicated, such a continuous transference is injurious to the vigor of the spawn and diminishes the quantity of mushrooms produced.

The commercial process.—The essentials in spawn making are (1) a uniform, compact manure brick; (2) vigorous and well-selected virgin spawn to be used in inoculating the bricks, and (3) favorable conditions for the storage of the bricks during the growth of the spawn.

It should be indicated that there is no one method of making brick spawn. The process may and will be varied by each spawn maker. Any skill or mechanical devices which will simplify or improve the process in any particular are to be recommended.

The materials entering into the composition of the brick are fermented stable manure, cow manure, and sometimes a small quantity of well-selected loam. Perhaps the chief value of these different constituents is as follows:

In the horse manure the mycelium grows most readily. The cow manure binds the materials together into compact brick. The loam, which is perhaps least essential, is supposed to prevent cracking or hardening of the surface, and therefore contributes to the appearance of the finished brick, at the same time tending to prevent rapid fermentation during growth. It also in some cases facilitates the uniform spread of the mycelium. If fresh manure is used, the necessity of using loam is perhaps to be emphasized.

In the experiments which have been made under the auspices of the Department of Agriculture these materials have been used singly and in various combinations, and it is beyond doubt that the relative proportions of these should be determined by the special conditions under which the spawn is made. Excellent results have been obtained by using a mixture of from two-thirds to three-fourths stable manure and the remainder cow manure. In this case the compost for the brick is subjected to fermentation previous to its use. When loam is employed it may be used in more or less equal proportion to the cow manure; and the quantity of stable manure should about equal that of the other two ingredients. If the straw present does not become sufficiently disintegrated during the preparation of the manure to enable one to make a smooth brick, it should be removed, in part at least.

The dry bricks ordinarily measure about $5\frac{1}{2}$ by $8\frac{1}{4}$ by $1\frac{1}{4}$ (to $1\frac{1}{2}$) inches. They should therefore be molded of somewhat larger size, perhaps 6 by 9 by 2 inches, since there is considerable contraction during drying. The mold consists merely of an oak frame of four pieces strongly riveted together. It may also be profitably lined with thin steel plates. In molding the brick one of two methods may be followed: (1) The compost may be thoroughly wet or puddled: then, with the mold upon a board of suitable width, the manure is compressed into it, the mold removed from the brick then formed, and the board pushed along for a succession of such impressions. The boards supporting the bricks are then disposed in racks and the bricks dried for a few days, or until they may be turned on edge for further drying out. (2) The compost may be used in a condition which is merely moist. It is compressed into the brick with some force, a mallet being often employed. The brick thus obtained is sufficiently rigid to be immediately handled if necessary. By this method, unless the compost has been in excellent condition, the bricks are not so smooth as might be desired for commercial purposes. In some instances they have then been subjected to a repress process, an old repress brick machine being adapted for the purpose. In such cases the bricks are made thicker to begin with. The second method has been discontinued by some who at first employed it.

Two methods are also employed in spawning: (1) The more common method is to insert into the brick near both ends a piece of the virgin spawn obtained for the purpose. A cut is made with the knife, the spawn inserted, and a stroke of the knife effectively closes the surface. This must be done as soon as the brick can be readily handled. (2) The bricks are dried until merely moist throughout; then, on being piled, nocules of spawn are placed between successive bricks, a piece at each end. In either case the bricks are not piled for the growth of the spawn until in good condition as to moisture content. This should be determined not by the surface, but by the interior of the brick. In the pile the surface will soon become moist. When the first method is employed it is sometimes customary to spread between the layers of brick in the pile a little moist manure or sawdust. It has been determined, also, that the absolute moisture content of the brick should be about 40 per cent, which is the same as for the mushroom bed. Tests of the moisture content of bricks growing well have varied from 35 to $47\frac{1}{2}$ per cent.

Occasional examination should be made to determine the temperature and the extent of growth. In order that the bricks may become thoroughly penetrated, more than a month will usually be required.

The most favorable conditions for the growth of the spawn are practically the same as for mushroom growing. A fairly moist atmosphere, maintained, if necessary, by spraying, and a more or less uniform temperature (55° to 60° F.) are to be preferred. The size of the piles will depend upon the other conditions; but if there is any danger of considerable fermentative activity the bricks should be so disposed as to permit perfect ventilation between two or more adjacent rows.

When the bricks are thoroughly "run" they are dried under cover before being shipped or stored in bulk, since in a moist brick the spawn would continue to grow and would soon produce small mushrooms or else would become moldy. Well-penetrated bricks of spawn are shown in Plate VII, figure 2. The areas of mycelial growth should be evident to the eye. The growth should be moldlike, however, rather than composed of very large threads or fibers.

The suggestion made in a previous publication that mushroom spawn should be sold by the brick (with a uniform standard of size) seems to have been adopted by American makers. The trade names suggested for the common types of *Agaricus campestris* in culture have also come into use. It is certain that these names, Alaska, Bohemia, and Columbia, designating respectively a white, a brown, and a more or less cream-gray form, do not include all forms in cultivation. Until a careful study has been made of varieties, however, this nomenclature will enable spawn makers to keep in mind certain types, and will make it possible for growers to ask for a spawn yielding a color demanded by their special markets.

THE VITALITY OF MUSHROOM SPAWN.

Many of the early experiments in mushroom growing undertaken by the writer were made in the hope of being able to ascertain the more frequent causes of failure and some of the chief difficulties encountered by American mushroom growers. The ordinary commercial spawn used by amateurs, that is, such as is obtainable upon the market during the winter months, was purchased wherever possible. Samples of this spawn were placed under conditions which were supposed to be most favorable for growth. Nevertheless, in the majority of cases there was no indication of the development of a new mycelium from the bricks of spawn thus obtained. From these results it was suspected that much of the spawn which reaches the amateur grower may be considerably injured, or even killed, by transportation or improper conditions of storage; for it must be supposed that most of this spawn is in good or at least fair condition when exported from Europe.

Subsequently the writer was able to look into the matter of spawn making in Europe and France, and he was convinced that the difficulty of securing good spawn in England is not a very serious factor. The same is true with reference to the material which is obtained by both extensive and small growers in France.

Special importations of some of the commercial English and French spawns were made, and this was packed, shipped, and stored under conditions as favorable as may ordinarily obtain. This spawn was imported during midwinter and stored until March or early April, when it was used in spawning some experimental beds. The conditions of the experiments were practically the same throughout, yet in not more than half the beds was there a favorable development of mushroom spawn. A distribution of the French spawn, both the commercial flake and the improved cake spawn, was made to several prominent American growers. Some of these growers experienced entire failure, while others reported that, after a slow beginning, beds spawned with this material made a good yield. The general conclusion, reenforced by observation and by the experience of practical growers, could only be that a large percentage of loss in mushroom growing is attributable to the injury suffered by the spawn after its preparation. This conclusion has been further strengthened by the experience of the past three years. From Table VIII, beds Nos. 1, 2, 4, 5, and 30, it will be seen that, under conditions where fresh spawn has invariably made a good yield, the spawn which is more than a year old is, for the most part, seriously injured or killed. To be exact, in only one case was there any production of mushrooms by spawn which had been kept for a year or longer. It must be said that no attempt was made to keep these spawns under similar conditions or under the most favorable conditions. For the most part the spawn was stored in the dry laboratory room, in which the temperature was more or less variable, but never extreme. The old American spawn which was used in experimental bed No. 1, in Table VIII, was stored in a basement room where the average temperature was undoubtedly cooler than that of the laboratory room.

From experimental beds Nos. 1, 3, 4, and 5, in Table X, it is again seen that old spawn is unreliable. In this particular case the material was furnished by a prominent mushroom grower—an English spawn importer. This spawn had been stored in a dry house and was therefore subject to similar conditions. In Table VIII, beds Nos. 31, 32, 35, and in Table IX, Nos. 34, 41, and 45, there is further proof of the loss of vitality in the imported spawn ordinarily offered for sale in many of our cities. In these cases spawn was bought on the market just as offered for sale to the amateur buyer; "best on hand" was asked for, but no stipulation was made that is should be of recent importation, and no guaranty was asked. The tests were not, therefore, to compare the very best English with the best American spawn, but merely to secure an indication of some of the causes of failure by the purchase at random of English and French spawn on the market. Even in times past the extensive mushroom growers have either imported their spawn direct, or made sure that they were obtaining the best product that the market could furnish. Unfortunately, it has not been possible to compare, in any experiments thus far concluded, the best English with the best American spawn.

The results seem also to indicate that brick spawn maintains its vitality longer than the flake material, and that brick spawn made of loose, light material is less retentive of vitality than that made after the formula commonly followed in England. This proves to be an unfortunate factor to be dealt with in the attempt to reduce by all means the weight of the brick. The reduction in weight would be most desirable, since freight upon this material adds considerably to the price of market spawn. To the poor keeping qualities of loose spawn is perhaps due the large number of failures with French flake spawn, and perhaps also some of the failures with the newer form of French brick spawn. The latter is made in the form of very small, thin bricks, which are unquestionably more affected by weather conditions than the larger English bricks.

These results have seemed to demand that special attention should be given to methods of spawn making in the United States in order that growers might be able to secure this product as fresh as possible. Moreover, it was desirable, as previously indicated, to attempt work leading to the selection and improvement of varieties. The success of the work in spawn making has been almost all that could have been anticipated. By the pure-culture methods described, several firms are now making grades of brick spawn which have yielded remarkably well. This fact is now thoroughly recognized by a large number of the best growers throughout the country. Probably as many as 50,000 bricks were sold during 1904, and it is perhaps to be expected that several hundred thousand will be sold during the present year.

It is to be regretted that it has not yet been possible to abandon the pure-culture process by means of which the virgin spawn is made while retaining the advantages of selection. Nevertheless, it should be remembered that the very difficulties of this process insure its use only by those who are able to give it their best attention and who will doubtless develop it to the fullest commercial extent. It has not been supposed by the writer that the work thus far accomplished will enable all mushroom growers to manufacture their own spawn with comparative ease. In other phases of horticultural work it is not so much to individual growers as to progressive seedsmen that we look for the best seed of improved varieties. The same thing apparently must be anticipated in the development of the mushroom industry. The growing of selected spawn may, in general, become a specialized process.

Nevertheless, it is believed that in time a method of spawn production from spores without pure-culture precautions will be developed. The necessity of developing immediately, or placing on a practical basis, the pure-culture process has temporarily directed the experimental work along other lines.

O

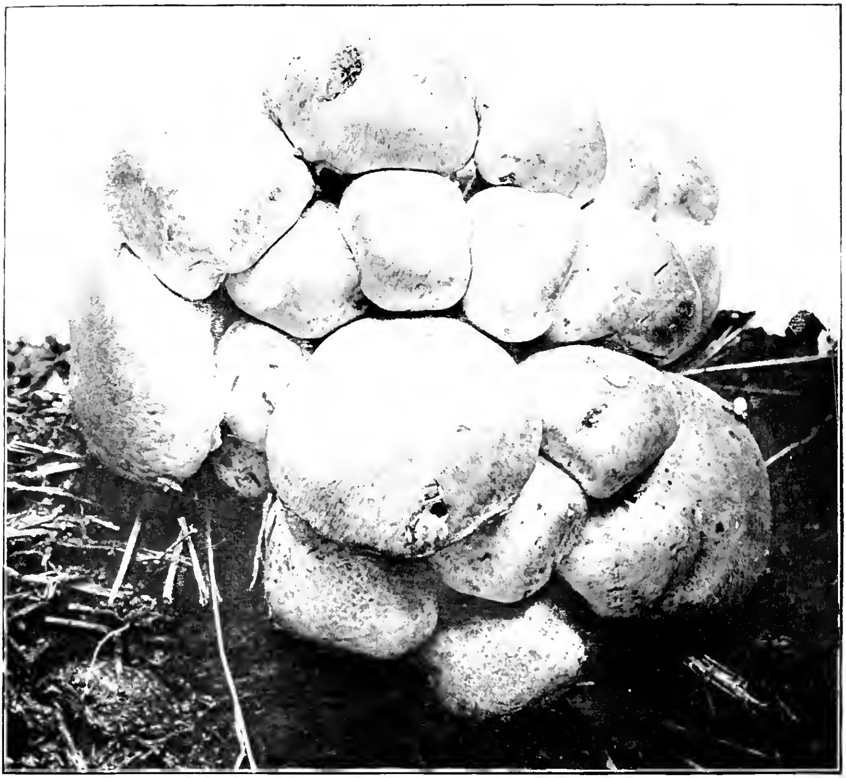

FIG. 1.—A FINE CLUSTER OF AGARICUS CAMPESTRIS, THE HORTICULTURAL VARIETY COLUMBIA.

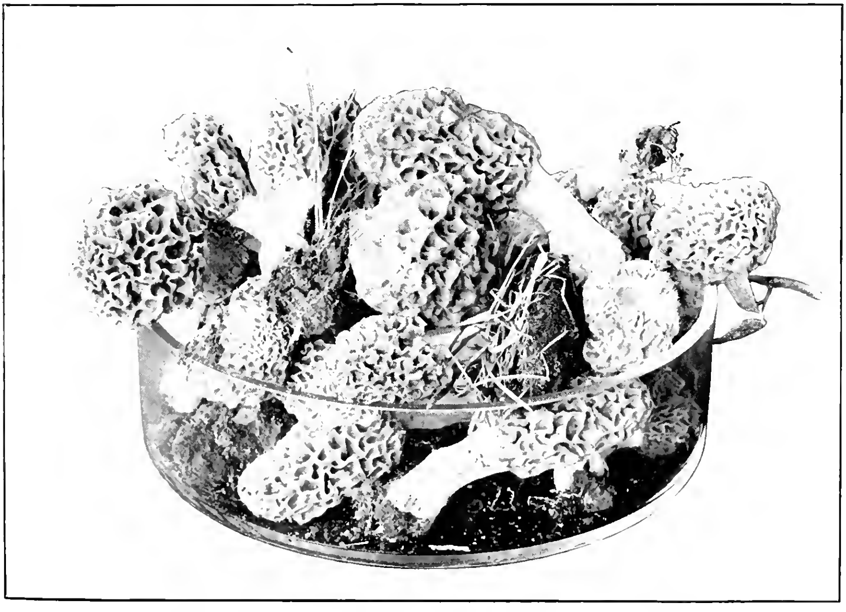

FIG. 2.—MORELS (MORCHELLA ESCULENTA), ONE OF THE FINEST EDIBLE FUNGI.

FIG. 1.—AGARICUS FABACEUS, THE ALMOND-FLAVORED MUSHROOM.

FIG. 2.—AGARICUS VILLATICUS, A PROMISING SPECIES, FLESHY AND PROLIFIC.

FIG. 1.—A YOUNG SPECIMEN OF THE COMMON PUFFBALL (CALVATIA CRANIIFORMIS).

FIG. 2.—THE OYSTER MUSHROOM (PLEUROTUS OSTREATUS), GROWING ON DECAYED WILLOW LOG.

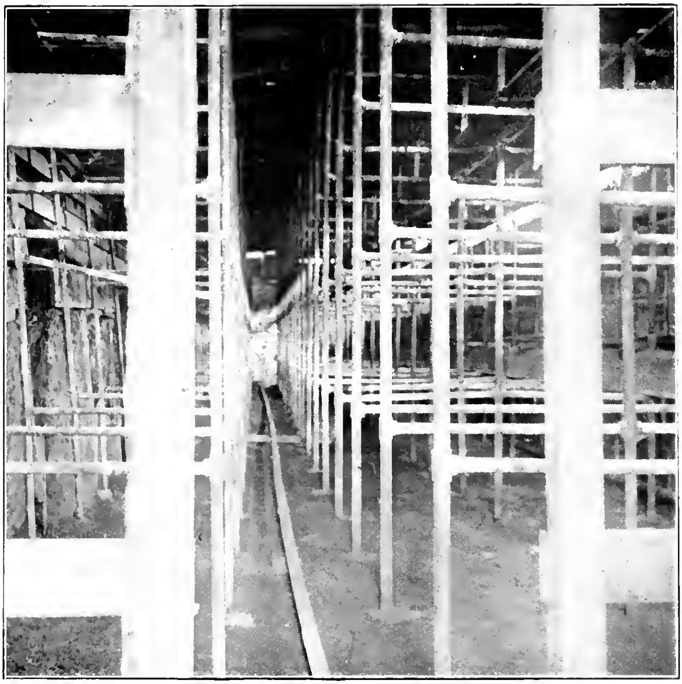

FIG. 1.—A MUSHROOM HOUSE PROVIDED WITH GAS-PIPING FRAMEWORK FOR SHELF BEDS.

FIG. 2.—THE PREPARATION OF COMPOST.

FIG. 1.—A LARGE MUSHROOM ESTABLISHMENT—A COMMON FORM OF MUSHROOM HOUSE.

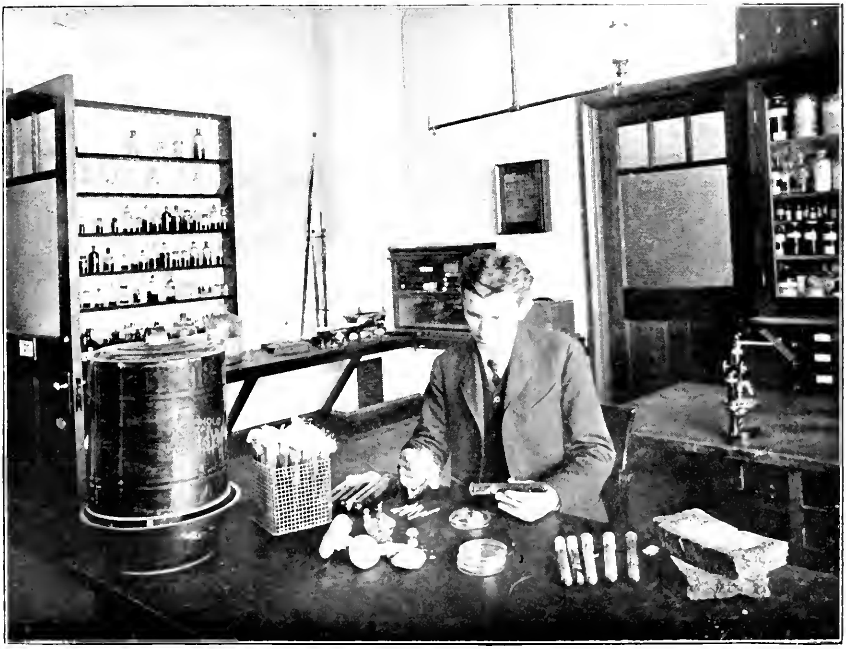

FIG. 2.—THE METHOD OF MAKING PURE CULTURES, SHOWING THE APPARATUS AND MATERIALS.

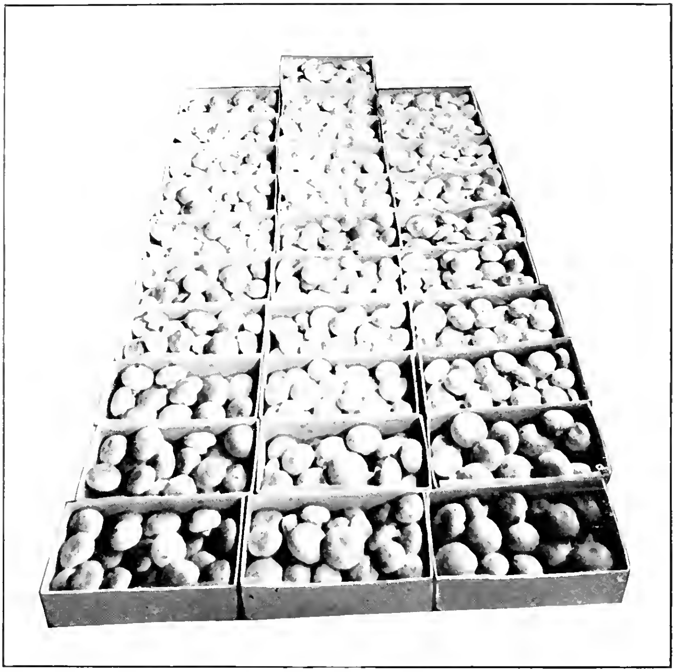

FIG. 1.—MUSHROOMS PREPARED FOR THE AMERICAN MARKET.

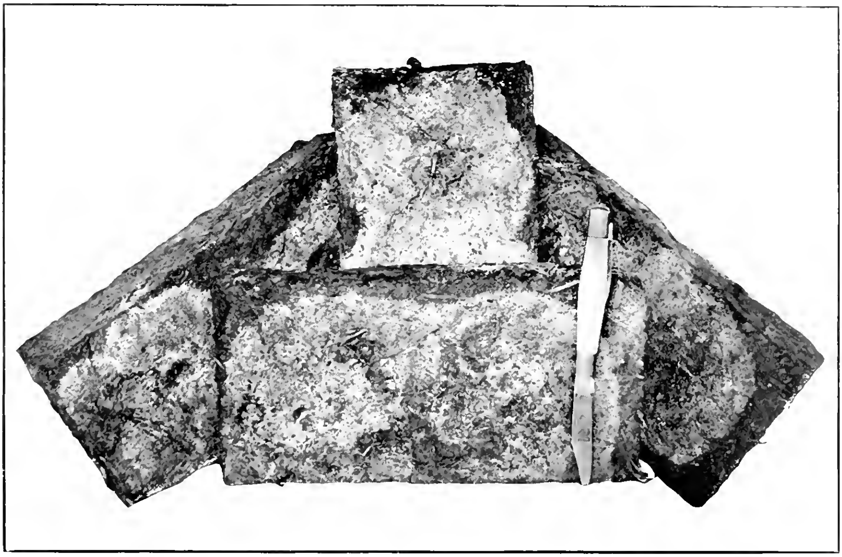

FIG. 2.—GOOD ("WELL-RUN") MUSHROOM SPAWN, BRICK FORM.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 86.

B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURE WITHOUT IRRIGATION IN THE SAHARA DESERT.

BY

THOMAS H. KEARNEY,
PHYSIOLOGIST.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED NOVEMBER 16, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate Divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory; and Dry Land Agriculture and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

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[Continued on page 3 of cover.]

PLATE I.

GENERAL VIEW OF THE OUED SOUF REGION FROM THE TOWN OF EL OUED, SHOWING SAND DUNES AND SUNKEN GARDENS OF DATE PALMS.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY — BULLETIN NO. 86.

B. T. GALLOWAY, *Chief of Bureau.*

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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[a] Detailed to Seed and Plant Introduction and Distribution.
[b] Detailed to Bureau of Chemistry.
[c] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 6, 1905.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 86 of the series of this Bureau the accompanying paper, entitled "Agriculture without Irrigation in the Sahara Desert."

This paper was prepared by Mr. Thomas H. Kearney, one of the physiologists of this Bureau, and the data for it were obtained on a trip which he made to northern Africa for the Office of Seed and Plant Introduction and Distribution, primarily for the importation into the United States of offshoots of valuable Tunisian date varieties. It is believed that the methods described may be useful in some cases in our southwestern desert regions where date culture is being introduced.

The accompanying illustrations are necessary to a clear understanding of the text of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In view of the interest in farming without irrigation that is now being manifested in the arid portion of the United States, an account of a region where agriculture is carried on under extremely adverse natural conditions is particularly timely. The present paper deals with a highly developed system of date-palm culture in the Oued Souf, a remarkable and little-known part of the Sahara Desert in northern Africa. Strictly speaking, it is not dry-land agriculture with which we have to do in the Souf region, for while the rainfall is practically nothing and irrigation is impracticable, the roots of the trees quickly find their way to ground water. However, it is quite possible that similar conditions may be found to exist in this country in some parts of the desert region of the Southwest, and that the Souf system, with or without irrigation, can be utilized there on a small scale in growing certain orchard crops with a view to forcing fruit to early maturity, so that it can be put upon the market much in advance of the bulk of the crop.

The Oued Souf was visited by Mr. Kearney at the end of November, 1904, the journey having been made from Nefta, in southwestern Tunis, where he had spent several weeks in a study of the date palm. This expedition to northern Africa was made under the auspices of the Office of Seed and Plant Introduction and Distribution of the Bureau of Plant Industry.

Acknowledgment is here made to Captain Bussy, Chef du Bureau Arabe at El Oued, for the cordial assistance rendered by him to Mr. Kearney during the latter's stay in the Souf region.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., August 22, 1905.

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AGRICULTURE WITHOUT IRRIGATION IN THE SAHARA DESERT.

INTRODUCTION.

In the great desert of northern Africa, stretching across in a belt from southeastern Algeria to the borders of Tripoli, is the region known as the "Erg." It is a land of enormous sand hills, some of which reach a height of 500 feet. Chain after chain of these great dunes, with knife-edge summits and steep slopes and trough-like valleys between, extend diagonally northeast and southwest across this part of the Sahara. (Pl. II, fig. 1.) It is like an ocean caught in a raging storm, with its huge billows rising skyward and held fixed and motionless. Not a leaf nor a blade of grass, not a bowlder nor a pebble mars the smoothness of the sand. Never is the least trace of water to be seen on its surface. The few drops of rain that fall at rare intervals are drunk up as soon as they touch the thirsty ground. Pure quartz sand it is, light yellow in color and so fine of grain that the least breath of air sends a little cloud of it curling off the sharp crests of the ridges. When a hard wind blows the air is filled with it, the sun is blotted out at noonday, and the traveler can hardly see his horse's head in front of him. The sharp-cornered particles of sand sting his face and blind and bewilder him. The vague tracks of camels and donkeys, the only roads through this wilderness, are quickly covered up, all landmarks disappear, and without an experienced guide one is sure to be hopelessly lost.

It is a desolate and unfriendly landscape, yet at times not without a weird beauty of its own. When the sun is high the glare is blinding and there is little to attract one in the scene. But in the early morning and the late evening the sand assumes a golden color, and the dense black shadows cast by the dunes bring out their contours in sharp relief. Then their surface is seen to be modeled by series of delicate ripple marks left by the wind, and one finds it hard to believe that when he climbs the next high ridge he will not see the ocean at his feet.

Who would suspect that amid these mountains of bare sand, where even the hardy shrubs and grasses of the desert find no foothold,[a] men can live by the products of the soil? Yet in the very heart of the Erg, two long days' ride east or west from the nearest habitations, there exists one of the most highly developed agricultural communities in the world. This is in the country known as the Oued Souf, situated in extreme southeastern Algeria (see fig. 1), about midway between the oases of southwestern Tunis and the Algerian oases known as the Oued Rirh, in which latter the date palm is grown by

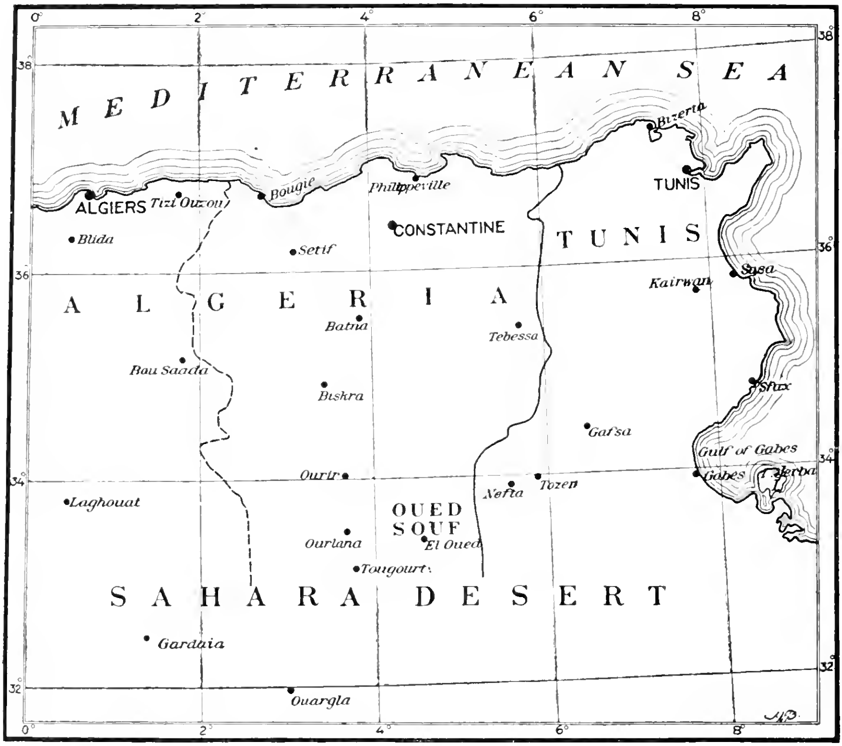

FIG. 1.—Map showing location of the Oued Souf with respect to other localities in Algeria and Tunis.

Europeans upon a commercial scale.[b] From El Oued, the capital of the Souf, it is about 70 miles southwest to Tougourt, the chief town of the Oued Rirh, and about the same distance northeast of El Oued is Nefta, the nearest oasis in Tunis. The elevation of El Oued is about 257 feet above sea level.

[a] Only eight species of flowering plants were found growing wild in the Souf region by Massart. See "Un voyage botanique au Sahara," p. 249 (1898).

[b] See Plate II (map) in Bul. 53, Bureau of Plant Industry, "The Date Palm," by W. T. Swingle.

From the tops of the lofty sand hills that surround El Oued an excellent view can be had, and there one can form a clear idea of the character of this remarkable country. (See Pl. I, frontispiece, and Pl. II, fig. 3.) Assuredly there are few regions where any sort of agriculture is carried on under more extraordinary conditions. As far as the eye can reach it rests upon an expanse of pure sand, heaved up into range after range of dunes.[a] In the hollows among these dunes are the gardens of date palms, sometimes mere pockets containing 10 or 20 trees, sometimes larger basins in which are groves of 50 to 100 palms.

Often the bordering sand hills are much higher than the tallest of the palms, so that many of the gardens can not be seen until one is on the very edge of the basin. In other places, however, the ridges are lower or gaps occur, allowing a cluster of feathery crowns to peep through. These are of such a dark green as to look almost black against the pale sand. A more striking contrast of colors could not be imagined. The trunks are rarely seen until one reaches the brink of the basin or pocket in which the palms are growing.

We have before us, in short, a network[b] of basins or hollows containing small groves of date palms and separated by great hills and ridges of sand. The aspect of the country is wholly different from the Oued Rirh in Algeria and the Djérid in Tunis, where each oasis is a dense continuous forest of date palms, containing often several hundred thousand trees,[c] and situated upon comparatively level land.

Such, then, is the country of the Souf, a land where there is practically no rainfall, where there are no streams nor springs nor flowing wells to furnish water for irrigation, where the soil is a pure hard sand devoid of organic matter and blown about in clouds by every wind, so that unceasing vigilance is needed to keep the gardens free from it, and where the summer heat is almost as great as anywhere in the world. Yet here the date palm grows to perfection, yielding fruit of better quality and in larger quantity than elsewhere in the Sahara. How this has been brought about we shall presently see in these pages; but first we should know what manner of men are they who have developed a flourishing agriculture in a land where Nature seems to frown most severely upon all efforts to win a living from the soil. The race that has succeeded so well in the face of such tremendous obstacles must needs be an interesting one.

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[a] The surface of these dunes is easily moved, even by a light breeze, but the core is said to be stationary and composed of stratified materials.

[b] The Arab word "erg" (plural areg) means "a vein."

[c] In 1899 there were only 192,000 date palms in bearing in the entire Souf region.

POPULATION.

There are about 25,000 people in the Souf region, 5,500 of whom inhabit the capital town, El Oued, and its immediate neighborhood. Several distinct tribes are included in this population, some being chiefly nomadic shepherds, and others more sedentary, devoting most of their time to the care of their gardens. They are for the most part a healthy and strong looking race, and are much more energetic than the inhabitants of other north African oases. This is doubtless partly due to the unceasing labor demanded by the conditions under which they live and partly to the fact that their climate is a healthful one, despite the intense heat of summer. There is no standing water nor even moist surface soil, and mosquitoes are said to be unknown. The dry air and the hot sand are not friendly to the germs of contagious diseases. The conditions are, therefore, very different from those in other oases of the Sahara, which are so overirrigated as to be mere swamps in summer, scourged with malarial fevers.

The inhabitants of the Souf region, who are called "Souafas," depend for a livelihood largely upon the products of their gardens, but they have other resources as well. The more nomadic tribes possess flocks of sheep and goats. They have almost a monopoly of the trade of camel drivers in a large part of the Sahara, guiding caravans eastward into Tunis, westward to Biskra, and far south into the heart of the great desert. Their camels are considered the largest and finest of the Sahara. The men of the Souf are indefatigable walkers, thinking nothing of traveling 20 or 25 miles a day through the loose sand. Their camel's-hair shoes, tightly bound around the ankles, are much better adapted to this sort of travel than the loose-fitting, heelless slippers generally worn by the Arabs.

In building their houses, as in cultivating their palms, the Souafas have many difficulties to contend with that are not experienced by the dwellers in other oases. Elsewhere in the Sahara, sun-dried brick, like the Mexican adobe, is the universal building material. But in the Oued Souf there is no clay to be had. Consequently the town of El Oued and all the villages of the region are constructed with irregular masses of grayish, crystalline, gypseous rock, cemented by plaster made from the same material, which thus furnishes both stone and mortar. Wood being very scarce, the roofs are not flat, wooden ones, but consist of rows of small, flattened cupolas, not unlike old-fashioned beehives, which give a very odd look to the cube-shaped houses. (Pl. II, fig. 2.) In its architecture, as in everything else, the Souf is unique. The immaculate cleanliness of the villages is surprising to the traveler who is familiar with the filthy streets of most Arab towns. The pure, dry sand is constantly drifting among the houses, and quickly buries all refuse.

CLIMATE.

Exact data in regard to the climate of the Oued Souf are not easily obtainable. The observations here given were made chiefly by a medical officer of the French army during the summer of 1884.[a] Unfortunately records covering a period of several years are not available.[b]

The summer temperatures are very high, few hotter localities being known in the Sahara. The monthly maximum shade temperatures observed by Escard in the summer of 1884 are as follows (in degrees Fahrenheit):

April	93	August	116.5
May	100	September	113
June	106	October	91.5
July	122		

In June, 1904, a maximum of 127.5° F. is said to have been reached. The sum total of temperature during the summer, a factor of the greatest importance in the ripening of the finer varieties of dates, is said to be greater in the Oued Souf than in the Oued Rirh and the Djérid. At the time of the writer's visit (November 22–26, 1904) cool, cloudy weather prevailed, and the nights were decidedly cold.

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[a] Escard, Etude médicale et climatologique sur le pays de l'Oued Souf. Archives de Méd. et de Pharm. Milit., 7: 33 (1886).

[b] Since the above chapter on climate was written the records of observations made at El Oued during the whole of 1904 and parts of 1903 and 1905 have been received, through the courtesy of the Director of the Meteorological Service of Algeria. These observations necessitate some modifications in the previously written discussion of the climate of the Souf. The absolute maximum temperature at El Oued in 1904 was 121.8° F. in May instead of 127.5° F. in June. The absolute minimum in 1904 was 32° F. The mean relative humidity during 1904 at El Oued was 58.8, which is lower than the normal at Tozer, in Tunis (60.8), but higher than the normal at Ouargla and Biskra, Algeria (47.2 and 48.4, respectively), and at Yuma, Ariz. (42.9). The sum of the monthly means of evaporation at El Oued in 1904 is 156 inches, while the normal at Tozer is 94 to 98.5 inches. The total precipitation at El Oued in 1904 was 3.23 inches, while the normal yearly total is 3.61 inches at Ouargla, 6.73 inches at Biskra, 5.1 inches at Tozer, and 2.83 inches at Yuma.

The observations on the prevailing direction of the wind during 1904 and the first half of 1905 do not agree with those made by Escard and quoted in the text, but the data are insufficient for an adequate discussion of this factor.

As the climatic factor which is most important in date growing is probably the effective temperature during the ripening season, a calculation has been made of the sum totals of daily mean and of daily maximum temperatures above 64.4° F. (18° C.) during the months of May to October, 1904, at El Oued, and, for the sake of comparison, of the sums for the same months of the same year at Ouargla and Biskra, Algeria; Tozer, in Tunis, and Mecca, in the Salton Basin, California. Records at Mecca for May and June, 1904, not being available, the records for those months at Imperial, Cal., were substituted in making

Almost every winter freezing temperatures are reached, although probably the minima are higher and frosts are less frequent in the Oued Souf than at Tougourt and at Tozer. In the winter of 1903–4 the absolute minimum was 32° F., and for several preceding winters 27° F.

In respect to atmospheric humidity, the absence of surface water probably tends to keep the air drier than is generally the case in the oases of the Sahara.

The rainfall is said to be even less than in the Oued Rirh, where the average yearly precipitation (at Tougourt) is only 5.3 inches. Most of the rain is divided between two periods—October to November, and February to March. The rains are generally torrential in character and fall during several successive days, with intervals of sunshine.

The sky is nearly always clear in summer. Toward the end of August light clouds appear in the morning and evening, but no rain falls until October. During the writer's four days' visit to the Souf

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the calculations for Mecca, experience having shown that the temperatures recorded at Mecca and at Imperial are very nearly identical.

TABLE I.—*Sum of daily mean temperatures above 64.4° F. (18° C.) from May 1 to October 31, 1904.*

Locality.	Degrees Fahrenheit.	Degrees centigrade.
El Oued, Algeria	3,672.6	2,040.3
Ouargla, Algeria	3,961.3	2,200.7
Biskra, Algeria	3,140.4	1,744.6
Tozer, Tunis	3,831.3	2,128.5
Mecca, Cal	3,591.5	1,995.3

The sum of daily means at Biskra for 1904 is nearly 200° F. lower than the normal, as based upon observations covering a period of 10 years (see W. T. Swingle, Bul. No. 53, Bureau of Plant Industry, p. 66), and the sum at Mecca for that year is about 400° F. lower than the normal for Indio, Cal., a few miles distant.

TABLE II.—*Sum of daily maximum temperatures above 64.4° F. (18° C.) from May 1 to October 31, 1904.*

Locality.	Degrees Fahrenheit.	Degrees centigrade.
El Oued, Algeria	6,325.7	3,514.3
Ouargla, Algeria	6,501.6	3,612.0
Biskra, Algeria	5,219.1	2,899.5
Tozer, Tunis	5,903.6	3,279.8
Mecca, Cal	6,370.1	3,539.0

In calculating the sums of daily maximum temperatures allowance was made for mean monthly minima falling below 64.4° F., in accordance with the practice suggested by Swingle (ibid., p. 67). The sum of daily maximum temperatures at Biskra during May to October, 1904, is about 250° F. lower than the normal for 12 years (Swingle, ibid., p. 68). The sum for Mecca is about 700° F. lower than that for Imperial, Cal., in 1902.

at the end of November the sky was overcast about half of the time, and there were occasional gusts of cold, drizzling rain.

Winds are probably more frequent and more violent in the Oued Souf than in the other groups of oases mentioned. It would appear, in fact, that windiness is the ordinary condition there. During the winter, northwest and northeast winds prevail. From April to October, however, the wind is generally from the south (the sirocco) or the southeast (the simoom). The sirocco is the hottest wind, but is less frequent than the simoom, which is generally more violent and transports more sand. All these are winds that blow more or less steadily for several hours and often days at a time. Cyclonic sand storms also occur, arising suddenly and lasting but a short time. Such storms are never accompanied by rain.

Owing to the lack of natural vegetation (see Pl. II), and the fineness of the sand with which the country is covered, strong winds carry with them a great deal of material, so that the face of the land is being constantly altered. This is shown by the fact that an apparently fresh wagon track noticed by the writer on his journey from Nefta was completely buried in many places by large heaps of sand. During his four days' stay in the Souf country, a strong wind blew constantly, often making travel difficult, as the particles of sand stung the face and made it hard at times to keep the eyes open. The air was frequently so full of sand that one could see but a few rods ahead.

The slopes of the dunes that border the gardens are very steep, so that when a heavy wind is blowing much sand rolls down upon the floor of the garden. Generally there is a fence or palisade along the crest of the dunes, made by sticking palm leaves or pieces of gypsum rock close together (Pl. II, fig. 3; Pl. III, fig. 1; Pl. IV, fig. 1), but this only partly arrests the blowing and drifting sand, and it is necessary to remove it frequently from the gardens. The task is a laborious one, as the sand must be carried up the steep hillside in baskets and dumped on the outer slope of the dunes. But if it were neglected, in a few years the trees would be buried, especially in smaller gardens. The writer saw several little gardens that had been abandoned by their owners where the basin was almost filled and only the crowns and a small part of the trunks of the trees still projected above the soil.

Another injurious effect of the sand-carrying winds is that when harvested the dates always have more or less sand adhering to the skin, and this must be brushed or washed off before they are fit for export. Dates that had been kept for some weeks in the houses of natives, and even those freshly gathered from the trees, were very unpalatable to the writer on this account; although the Souafas themselves do not seem to mind eating a good deal of sand with their dates.

WATER SUPPLY.

There is no surface water in the whole Souf country, excepting, possibly, a small sebka, or salt pond, of which the writer was told, but which he did not see. There are no natural springs, although ground water is everywhere very near the surface in the hollows among the dunes. It is said to occur sometimes in strata of pure quartz sand, sometimes in gypseous sand. The distance to standing water is said to reach as much as 40 feet in different parts of the region, although averaging considerably less; but in the bottoms of the basins in which date palms are grown it is encountered often at a depth of only 2 or 3 feet below the surface of the soil, thanks to the extensive excavation that has been done. In one garden, near the town of El Oued, the writer saw water standing at a depth of 6 feet in a large hole that had been dug to receive manure. The Souf oases are believed to mark the course of a buried Quaternary stream; Oued Souf means "murmuring river."[a]

As we shall presently see, the date palm is not irrigated in the Souf country, receiving at most a few waterings by hand during the first summer after planting. In almost all the gardens, however, shallow wells occur,[b] the water of which is used for household purposes and for irrigating small plats of garden vegetables. (Pl. III, fig. 3.) These are generally situated on the slope of the bordering dunes, 10 feet or less above the bottom of the basin, and water stands in them at a depth of 10 to 16 feet. In the town of El Oued the wells are much deeper than in the gardens, water standing in them at 30 to 40 feet. All this water is under a slight pressure, rising in the wells about 1.5 feet higher than the general water table. Small gardens of vegetables and tobacco,[c] irrigated from deeper wells, are also located in some parts of the region far above the bottoms of the basins. Practically no grain is raised, wheat and barley being brought by caravan from other parts of Algeria and from Tunis, to be exchanged for dates.

[a] It is difficult to obtain a very satisfactory idea as to the distribution of the ground water in the Souf region, its depth at various points, and the amount of excavation necessary to enable the roots of the palms to reach it easily. The natives themselves give the most conflicting answers to questions upon this subject, and there are serious discrepancies in the accounts that have been published by French authorities upon irrigation. The whole matter evidently needs to be carefully studied by competent hydrographers, a study which is certainly warranted by the rarity of this type of agriculture.

[b] In 1883 Rolland estimated that there were 4,431 wells in the Souf region.

[c] Tobacco growing, which is unrestricted in Algeria, is a profitable industry in the Souf country on account of that region's nearness to the frontier of Tunis, where the growing of this crop is forbidden by law and where the selling of tobacco is controlled by the government. Agents of the Tunisian tobacco monopoly frequently visit the Oued Souf to purchase supplies.

The plats of vegetables that are irrigated from wells in the date gardens are situated on terraces constructed in the side of the sand hills, usually 10 feet or less above the floor of the basin. (Pl. III, figs. 1 and 3.) The well water is raised by hand in a shallow bucket, generally made of basketware covered outside with pitch, but sometimes of goatskin, which is hung on the small end of a slender palm trunk and counterpoised by a piece of rock fastened to the large end. The pole is fastened by its center to a crosspiece that is supported by two vertical posts made of stouter palm logs or of cemented rock. The bucket is emptied into a little cement basin adjoining the well curb, whence the water flows through a system of small conduits into the plats that are to be irrigated. Flood irrigation alone is practiced. As there is no soil in the region from which ditch banks and ridges that will stand up when wet can be made, the conduits and ridges of the plats, as well as the lining and curb of the well, are made of the same dark-gray plaster with which the walls of the houses are cemented. Plugs of wool are used for stopping the conduits at places where water is to be diverted into the plats. Among the vegetables most commonly grown are cabbages, turnips, radishes, carrots, pumpkins, melons, watermelons, onions, tomatoes (a small-fruited sort), and peppers.

In parts of the Souf region, especially east of the capital town, El Oued, the water of the wells is said often to contain enough magnesium and other salts to make it disagreeable for drinking.[a] West of the town, on the other hand, the water is said to be generally very pure. The difference is thought to be sufficiently great to have a marked effect upon the quality of the dates, the most renowned Deglet Noors of the Souf region being produced near the village of El Amiche, where the water is purest. The peculiar character of the water supply of the Oued Souf is not without advantages. Eminent authorities are of the opinion that the underground sheet is abundant and that it is much less liable to exhaustion than in the Oued Rirh, where numerous flowing artesian wells exist.

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[a] Well water in the Souf, according to an analysis cited by Jus (Les oasis du Souf du Département de Constantine, Bul. Acad. d'Hippone, No. 22, p. 67 (1886), has the following contents of solid matter in grams per liter of water:

Sulphates	1.9993
Chlorids	.7769
Carbonates	.2999
Nitrates and dissolved organic matter	.0690
Silicates, etc., in suspension	.0335
Total	3.1786

Schirmer (Le Sahara, p. 261) states that the mean salt content of well water at El Oued is 2.77 grams per liter.

SOILS.

The soil of the whole Oued Souf region is a fine-grained, light-yellow quartz sand, which is practically uniform in character to a considerable depth.[a] Here and there beds of a coarse, rather soft, gypseous rock occur at a depth, it is said, of 10 to 20 feet and in strata 1.5 to 10 feet thick. The crystals of which this rock is composed are very large, often 1 foot long. They are often aggregated into masses which, on account of their shape, are known as "Souf roses."[b] It is therefore a fair inference that the Souf soils are sufficiently rich in lime. They are very poor in organic matter and doubtless in nitrogen. Other data as to their composition are wanting.

In the eastern part of the region the soil of all the gardens is said to be somewhat saline, and the writer was told that there is even a small sebka (salt pond) in that section, although he saw nothing of these conditions. There is said to be nowhere enough salt to injure seriously the palms themselves, but the yields of fruit are diminished by this cause, and the dates are somewhat smaller and of slightly inferior quality. Consequently, palms in full bearing in the gardens west of El Oued are worth from two to ten times as much as those in the gardens east of that town. The Souafas do not pretend to distinguish some varieties of the date palm as being more resistant to salt than others, as do the inhabitants of the Djérid oases, where the salinity of the soil is often very pronounced. Neither have they adopted any special methods of preparing and handling salt land by drainage, flooding, or otherwise, as is the case in the Tunisian oases. It is fortunate for the Souafas that their soils are not saline, or but very slightly so, as it is hard to see how they could possibly reclaim strongly saline lands in view of the conditions of water supply in their country.

THE DATE GARDENS.

Let us now have a closer look at the gardens. (Pl. III, figs. 1 and 2.) The craterlike basins which they occupy are generally circular or nearly so, and from 35 to 50 feet deep. The bottom is entirely given up to the palms. Descending to the floor of the basin,

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[a] According to Jus this hard quartz sand extends to a depth of 3.5 to 4.5 feet; next there are from 7 to 8.5 feet of a "reddish gypseous sand;" and then 3 to 3.5 feet of either "a fine quartz sand" or "a yellow gypseous sand."

[b] The composition of this rock, as given by Jus (ibid., p. 69), is:

	Per cent.
Quartz sand	37.00
Clay	5.10
Gypsum	41.40
Carbonate of lime	3.20
Carbonate of magnesia	1.50
Water	11.43

or "ghitan," as the natives term it, we find it to be a practically level expanse of clean, bare sand, checkered with the bright sunlight and the singularly black shadows that are cast by the trunks and leaves. (Pl. V, fig. 1.) The palms stand farther apart than in the gardens owned by natives in the Djérid and the Oued Rirh, but are not planted in rows and at equal intervals, as in the French plantations in the latter region. While native gardens elsewhere in the Sahara are a perfect jungle of various fruit trees, besides garden vegetables, barley, and alfalfa underneath the palms, in the Oued Souf one sees only scattered pomegranate and fig trees, and the groves have an unfamiliarly open and bare look. While in other oases the soil is often rich and black and is almost always moist, here it is quite dry on the surface. One misses, too, the irrigation and drainage ditches by which the gardens of the Djérid and the Oued Rirh are cut up into small plats.

Another feature of the Souf date orchards that immediately attracts attention is the enormous thickness of the trunks of the trees. They sometimes attain 3 feet in diameter. (Pl. V, fig. 2.) This is probably due to the trees being comparatively far apart, thus receiving plenty of light and air from every side, and is, perhaps, also to some extent a reaction to the buffeting of the sand-laden winds. At any rate, it is a useful character, giving the trees power to withstand the winds that prevail here to a greater extent than in the other oases of the northern Sahara. The relatively small height of the palms, which rarely exceed 30 feet in the Oued Souf, gives them a further advantage in this respect. Frequently, when the base of the trunk has become weakened and there is danger of the tree blowing down, the natives make a "dokana," or low, circular mound of soil, plastered on the outside, to strengthen it. (See Pl. V, fig. 1.)

The palms are almost invariably strong and healthy looking. The foliage is extraordinarily well developed, and the leaves commonly measure 15 to 20 feet long. The yields of fruit, as stated by the natives, are very heavy.

So unusual are the conditions under which date palms are grown in the Souf country that further details as to the methods used by the natives can not fail to be interesting.

PLANTING.

As the date palm is a tree that requires a great deal of water, it can evidently be grown in a dry country without surface irrigation only in places where its roots can quickly make their way to ground water. This is exactly the condition obtaining in the Oued Souf, where the palms are artificially watered only during the first summer after the offshoots are planted, and are then left to shift for themselves, so far as water supply is concerned.

As we have seen, the bottoms of the basins where the palms are grown are not only far below the summits of the surrounding sand hills, the height of which is increased by the sand removed in excavating the gardens, but are even considerably lower than the mean surface of the country. It is said that in starting a new garden the practice is first to sink a well in the bottom of the basin in order to find out the depth at which water stands. The floor of the basin is then scooped out until it is so near ground water that when a hole $1\frac{1}{2}$ to 4 feet deep is made to receive the young palm its roots will have to descend only about 1 or $1\frac{1}{2}$ feet to reach standing water. It is said that to attain the desired depth it is generally necessary to remove 10 to 20 feet of sand.

The date palm is always artificially planted in the Oued Souf, never springing up spontaneously from seed, as in other oases. It is never planted elsewhere than on the floor of the basins among the dunes, or at most a very few feet above the bottom. These basins are probably in all cases natural depressions, but are artificially deepened to facilitate the roots reaching ground water. New gardens are frequently started in unoccupied basins, and old ones belonging to enterprising owners are being constantly extended by cutting down the slopes of the bordering sand hills and planting a few palms every year or so. (See Pl. III, fig. 2.) The larger and better-situated basins are now all occupied by gardens, and for the newest plantations it is often necessary to use small, shallow depressions, where there is frequently room for but half a dozen trees. Sometimes the slope is not cut down quite to the level of the older part of the garden, the new palms being set out slightly above the level, on a terrace made in the side of the sand hills. (Pl. IV, fig. 1.) When planted on the slope or near the foot of it, sections of palm log or a number of palm leaves are placed on the uphill edge of the hole to check the drifting of sand into it.

Owing to the scarcity of offshoots in the Souf region, the work of extending the gardens does not proceed as rapidly as the energetic population could wish. The French attribute the nonproduction of offshoots in the Souf to the fact that the palms are so valuable there that it does not pay to let the offshoots develop, absorbing a part of the energy that would otherwise go to fruit production. They believe that the Souafas find it actually cheaper to send to the Oued Rirh for suckers, paying 40 to 60 cents apiece for them in addition to the cost of transportation, than to let them grow on their own trees. Economic considerations aside, however, it is probable that the date palm does not sucker as freely in the Oued Souf as in other oases, because of the dry condition of the surface soil, never wet by irrigation, and because the blowing sand tends to bury the young offshoots and to lacerate their tender buds. The natives, when questioned about the comparative rarity of offshoots at the base of their palms, reply simply that it is due to the absence of irrigation, without going into details. Whatever may be the cause of the deficiency, there is a great demand for offshoots, and to supply this demand caravans are sent to procure suckers, especially of the Deglet Noor variety, to Tougourt, or even as far as Ouargla, 135 miles away. In those oases they are produced more freely, the palms being irrigated.

Offshoots for planting are generally taken from the mother palm about the end of February. The natives say that they could be planted even earlier, but in that case the parent tree is likely to suffer from the access of cold air to the wound made in cutting off the sucker. In case the offshoots are removed in midwinter, their bases are slightly charred before planting, and this is thought to protect them from the cold.

The hole made to receive the young palm is sometimes as much as 6 feet in diameter, but probably in most cases less. Its depth, as we have seen, depends largely upon the distance to ground water, being generally $1\frac{1}{2}$ to 3 feet in the bottom of the gardens near the town of El Oued. A young palm was seen near El Oued that had been set out near a well about 6 feet above the bottom of a garden, in a hole $3\frac{1}{2}$ feet deep. (See Pl. IV, fig. 1.)

The palms are not set out in straight lines. They stand much farther apart than in gardens belonging to natives in other oases, 20 feet being the average distance. This wide planting is probably necessitated by the poverty of the soil, which is practically a pure sand, while the almost entire absence of subsidiary cultures makes the shade afforded by close planting less valuable than in other oases.

It is estimated that the planting and care of a young Deglet Noor palm up to the time it begins to yield costs $25 in the Oued Souf, as against $5 to $10 in the Djérid oases of Tunis.

CARE OF PALMS.

During the first summer after it is planted the palm may receive a few irrigations by hand with water from the well that is situated on the hillside in nearly every garden, although it is said that frequently no irrigation whatever is given. While still very small, before the leaves have grown out enough to project far above the mouth of the hole in which it is planted, the tree is protected from drought and from the cold of winter by covering the hole with palm leaves, dead pumpkin vines, etc.

When the palms are manured the sand that has piled up into a low mound around the base of the tree is removed and the soil beneath is thoroughly worked. This is apparently the only cultivation the trees receive.

FIGHTING THE SAND.

While elsewhere in the Sahara irrigation entails the heaviest labor connected with palm culture, in the Oued Souf it is the struggle that must be waged with the constantly encroaching sand that demands the tireless efforts of the gardeners. Every strong wind carries great volumes of sand. The slight fences of palm leaves and the low walls of gypseous rock that are constructed along the crests of the bordering dunes are only a partial protection against this invasion. Once over these weak barriers, the sand rolls down the steep slopes almost like water. The danger is always present, but is most pressing when the dates are ripening. Then bunches of fruit that hang close to the ground can be half buried by a few hours of high wind, and only the most strenuous efforts can save them. If a second storm occurs before the bulk of the sand is removed, the crop is hopelessly lost.

The work of cleaning out the basins is very laborious, being done, like the original excavation, almost entirely by hand. Travelers in this region have compared this work to the activities of ants, rather than of men. Laborers shovel the sand into baskets and carry them in a ceaseless procession to the top of the slope, their feet sinking deep into the flowing sand at every step. After a heavy sand storm the work must be continued from dawn to dark. In summer, during the blazing midday hours, the heat is too great for such heavy labor, and the removal of the sand goes on at night and in the early morning hours. At times a large part of the population of the region is engaged in this heavy task. It is paid for at the rate of 1 cent for every 5 baskets of sand, and the laborer has, in addition, the privilege of eating as many dates as he desires in the garden in which he is working. Only rich proprietors use the sturdy little gray donkeys of the Souf for transporting the sand from their gardens.

MANURING.

The soil of the Oued Souf is practically nothing but pure sand, containing even in the older palm gardens very little organic matter. Manuring is consequently essential not only to the production of good yields but even to the well-being of the palm itself.[a]

It is not uncommon in the Souf country to see palms that have thick trunks up to a certain point, above which they contract more or less abruptly to a much smaller diameter. In many cases, at a still greater height, the trunk again becomes thicker. This state of things is explained by the natives as due to a partial starvation of the tree at

[a] For that matter, manuring is generally practiced by good farmers in the oases of the Oued Rirh and the Djérid, although there the growing of leguminous food and forage crops (broad beans and alfalfa) helps to restore to the soil the nitrogen that is taken up by the palms.

the time when the trunk began to diminish in size. If manure is subsequently supplied to it, the palm is soon able to return to its normal rate of growth and the trunk again becomes larger.

Palms are not manured until they are 10 or 12 years old. At that age each tree usually receives 10 sacks (5 camel loads) of manure, half of which is applied on one side of the trunk the first year and the other half on the other side the following year. Thereafter, in order to obtain the highest yields, the trees should be manured every twelve or fifteen years, although sometimes thirty years are allowed to elapse between two manurings. Older palms receive as much as 14 sacks of manure (7 at each application). Camels' dung (see Pl. IV, fig. 2) only is used for date palms in the Oued Souf, although in the oases of Tunis that of donkeys is preferred, the natives there considering camel manure injurious where irrigation is practiced. The cost of a sackful of camel manure in the Oued Souf was stated by one informant to be 25 to 30 cents, while another placed it at 40 to 45 cents. In either case it is evidently an expensive article.

Manure is never used until it is thoroughly rotted, and even then it is not allowed to come into direct contact with the base of the tree. It is placed in a hole that is dug to a depth of 3 to 6 feet below the general level of the floor of the basin and at a distance of 5 or 6 feet from the foot of the palm. When several neighboring palms are to be manured at the same time, the hole is dug in the center of the space among them, and is made so large that none of the palms is more than 6 feet distant from its edge.[a] The hole is then filled with a mixture of one part manure and one part of a bright yellow sand called "baker," which is somewhat more loamy and probably contains more gypsum than the surface sand of the region, and is obtained at a greater depth. Unmixed manure is never used, even though thoroughly rotted, being considered injurious to the palm roots. The soil removed in digging the hole is never put back, being "dirty," as the natives express it.

October is considered the best season for applying manure, although March is also a good time. Unskillful growers sometimes manure their palms at other seasons, but this is thought to do more harm than good. Sometimes, unless the hole is opened and the manure removed as soon as the tree shows signs of injury, it is said to die from the effects of manuring at the wrong period.

The effect of manuring upon the yield is large and almost immediate. It is said that a tree which bears 200 pounds of dates one year will often give 400 pounds the season following if meanwhile manure

[a] One such hole, freshly excavated at the time of the writer's visit, occupied much the greater part of the area among four palms, being 12 feet long and 5 feet wide. It was divided unequally by a narrow ridge of soil left in place. The object of this division could not be learned.

has been applied. No distinction between varieties is made in the Oued Souf in manuring, nor, so far as could be ascertained, in regard to other cultural practices.

HARVEST.

At the time of the writer's visit (November 22–26, 1904) the date harvest had been completed in all the gardens of the Souf country. The Deglet Noor harvest is said generally to begin about October 25. In the Tunisian oases, on the other hand, the harvest of Deglet Noor and Fteemy dates—the two most important varieties—was at its height in November, and continued throughout December and even the earlier part of January. Of course, in the latter case many of the dates were ripe long before they were gathered, and the long duration of the harvest was largely due to the relative scarcity of the expert labor required, the crop being many times as large as in the Souf. Yet it seems certain that in the Oued Souf, dates, especially the Deglet Noor variety, ripen earlier than in the Oued Rirh oases of Algeria or the Djérid oases of Tunis. This would be expected from the fact that the summer is drier and likewise hotter in the Oued Souf than in the oases of the Djérid. Furthermore, the situation of the gardens, in hollows bordered by hills of light-colored sand that are generally higher than the tallest palms, is favorable to an early ripening of the dates, as they must receive a great amount of additional heat by reflection from the soil. More perfect natural conditions for forcing fruit to early maturity could probably not be found in the world.[a]

This greater heat and dryness of the Souf climate affect the fruit in other ways than merely by hastening its ripening. The dates produced are reputed to be the best grown in the Sahara. They seem, as a matter of fact, to be sweeter and at the same time drier and more solid than in the Djérid. This is especially true of the Deglet Noor, which is of decidedly firmer texture, containing less water. The Souf dates are said to keep better and to be more adapted to export than those of the other oases, showing less tendency to blacken and become moldy.

It was a matter of regret to the writer that the harvest was not witnessed in the Souf, although it could not be learned that the methods followed there differ from those practiced in other oases. So far

[a] Rolland (Hydrologie du Sahara Algérien, Paris, 1894, p. 222) describes the basins as "a sort of fiery furnace, under the influence of solar radiation. The dates here attain perfect maturity. Here are realized, better than anywhere else in the Sahara, the conditions assigned by the Arab proverb to the prosperity of the palm and the excellence of its fruits: 'Its feet in the water and its head in the fire of heaven.'"

as is known, the pollination of the female flower clusters in the spring is also effected in the same way as in the Oued Rirh.[a]

YIELDS.

It was impossible to secure very reliable statements of yields from the natives, but from all that could be learned these must be unusually large in the Souf country. The clusters of the Deglet Noor are said frequently to weigh over 55 pounds each, and to attain sometimes 90 pounds. Single trees of this variety, which is one of the lightest bearing kinds, sometimes yield as much as 330 pounds in the Oued Souf. It was estimated in 1883 that the date crop from the 175,000 palms (of all varieties) in full bearing then existing in the Souf region was 7,000,000 pounds. This would mean an average yield of 40 pounds per tree, as against an average yield of 28 pounds estimated to have been produced in the Oued Rirh the same year.[b] A good palm in full bearing is valued at from $50 to $130, according to the variety to which it belongs.

The practice of planting the trees farther apart than in other oases is perhaps one reason for the large yields. By wide planting, not only do the roots of each palm have a larger feeding area, but the trees do not shade each other so much and more of the fruit can develop and ripen. Moreover, the climatic and topographical conditions, as we have seen, are exceptionally favorable to the ripening of dates.

VARIETIES CHIEFLY GROWN.

As has already been indicated in this paper, date palms in the Oued Souf rarely, if ever, spring up from seed, as they do in other oases where the conditions are more favorable to the spontaneous development of the palm. They are propagated only by offshoots that are taken from the parent tree and planted by the grower. Consequently we do not see a multitude of seedlings, generally of very inferior quality and of almost endless diversity of characters, filling every waste corner and roadside and even crowding out good trees in gardens that are not well cared for. Practically every palm grown in the Souf belongs to some well-known and well-liked variety.

The number of varieties found in this region is considerable. Most of the gardens contain a mixture of several kinds, although in some of the recently created ones the tendency is to plant only one

[a] Described in Bul. 53, Bureau of Plant Industry, "The Date Palm," by W. T. Swingle, 1904, pp. 26–29.

[b] These estimates are quoted from Rolland (ibid., p. 324). The overwhelming importance of the date crop in the Souf region is shown by the fact that the same author states the value of the 1883 crop of dates to have been $301,730, while that of all other crops combined was only $20,900 in that year.

sort, most often the Deglet Noor. Nearly all the popular varieties of the Souf are also common in the Oued Rirh.[a]

On the other hand, some of the most characteristic Souf types are very rare in the Djérid oases of Tunis, only 70 miles away. Such individuals as occur there are mostly grown from offshoots that have been brought directly from the Souf. The principal variety common to the two regions is the Deglet Noor, which is now abundant in Tunis, but is said to have been first introduced into that country from Algeria about two hundred and fifty years ago. The Souafas still go to the Oued Rirh oases to procure offshoots, and they very likely brought thence those with which the first gardens were started among the sand hills of the Souf.

The most important of the numerous varieties of the Souf, in point of abundance as well as of quality, are, in about the order named: Deglet Noor, Rhars, Tafazween, Massowa, Deglet Beida, and Takermest. Of these Rhars is the earliest and Deglet Noor the latest to ripen. After the Deglet Noor, Tafazween is the best sort that is widely grown. It is a large, reddish-bay-colored, translucent date, very sweet and rich in flavor.[b] A highly esteemed but very rare variety is the Fezzani, which is said to be superior even to the Deglet Noor when dried, and to keep well for two years. Rhars, a variety that is celebrated for its heavy yields, is extensively planted.

In the Oued Souf, as in other oases of Algeria and Tunis, the Deglet Noor is the only variety that has any importance as an article of export to Europe. It is consequently the most valuable, the more so because the natives themselves generally esteem it above all others. Deglet Noor dates are carried from the Souf by caravan to Biskra, whence they are shipped by railway to the seaports. Souf Deglets are said to be about the earliest to reach the Biskra market. Their good keeping and shipping qualities have already been discussed as probably due to the peculiar climatic conditions, which give them an advantage over dates from oases where the palms are lavishly irrigated and the air is moister. On the other hand, they appear to be smaller than those in the Djérid and to be inferior in color and general appearance. The latter disadvantage is very likely due in great part to the sand-laden winds to which they are exposed. The Deglet Noor palm is said to be hardier in the Souf region than elsewhere, showing greater resistance to disease and to unfavorable climatic conditions. The foliage of the date palm appears to be less subject to the attacks of scale insects than in other oases, which is perhaps attributable to the extreme dryness of the atmosphere.

[a] Exceptions are said to be the Fezzani, Massowa, Ali Rashid, and Guettara varieties.

[b] Twenty offshoots of this variety were obtained from the Oued Souf for trial in the United States through the kindness of the French commandant at El Oued, Captain Bussy.

CONCLUSION.

The type of agriculture practiced in the Oued Souf is not dry-land farming, for it depends upon the ground water, which in the gardens is everywhere near the surface of the soil. It affords us, however, an excellent object lesson of what can be done under the most adverse natural conditions in producing a valuable crop, for throughout northern Africa the Oued Souf is renowned for the large yields of its date orchards and the high quality of their fruit.

It may be that nowhere in the United States are the conditions with respect to ground water such as to allow of a close imitation of agricultural methods used in the Souf country. One lesson is, however, to be drawn from them. The sand hills concentrate and reflect so much heat that the hollows among them are veritable forcing houses, where dates ripen considerably earlier than elsewhere. Have we not here a hint of what may be done in the Salton Basin and perhaps in other hot, arid regions in the Southwest where large sand dunes exist, and where artesian or other sources of water supply for irrigation are available? It seems certain that in pockets of this character excavated among the dunes the Deglet Noor and other valuable varieties of dates could be forced to early maturity.

Dates ripened in this way a few weeks ahead of the bulk of the crop would command a fancy price, especially as the quality of the fruit produced under these conditions would in all probability be exceptionally fine. Nor are the possibilities limited to the date palm. Other fruits, such as figs, pomegranates, and grapes, could perhaps thus be put upon the market in advance of those from any other locality in the United States. The experiment is certainly worth trying. The American fruit grower, awake as he is to every new idea, may find something worthy of imitation in the example of these sturdy inhabitants of a remote corner of the Sahara.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) General view of the Oued Souf region from the town of El Oued, showing sand dunes and sunken gardens of date palms.

PLATE II. Fig. 1.—High sand dunes east of El Oued. The group is standing on a ridge separated by a ravine from the very high dune in the background. Fig. 2.—A typical dwelling house of the Oued Souf, showing its cubical form and roof composed of flattened cupolas. Fig. 3.—General view of the Oued Souf region, showing sunken date gardens and sand dunes. Fence of dead palm leaves along crest of dune in foreground.

PLATE III. Fig. 1.—Near view of sunken palm garden and surrounding dunes. Vegetable garden in left foreground, showing small size of checks. Near it a young palm, planted in a hole. Fig. 2.—Gradual extension of a palm garden by cutting down bordering sand hills. Oldest palms in background, youngest in foreground. Fig. 3.—Vegetable garden irrigated by well near bottom of basin in which date palms are grown.

PLATE IV. Fig. 1.—Hole on slope of dune near bottom of basin in which a young palm is planted. Fig. 2.—Camel manure ready for application in a date garden.

PLATE V. Fig. 1.—"Dokana," or mound of earth and plaster for strengthening the base of a palm. Shows also distance between trees, absence of other cultures, and play of light and shadow on floor of basin. Fig. 2.—Rhars palm, showing thickness of trunk.

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FIG. 1.—HIGH SAND DUNES EAST OF EL OUED.

FIG. 2.—A TYPICAL DWELLING HOUSE OF THE OUED SOUF, SHOWING ITS CUBICAL FORM AND ROOF COMPOSED OF FLATTENED CUPOLAS.

FIG. 3.—GENERAL VIEW OF THE OUED SOUF REGION, SHOWING SUNKEN DATE GARDENS AND SAND DUNES.

FIG. 1.—NEAR VIEW OF SUNKEN PALM GARDEN AND SURROUNDING DUNES.

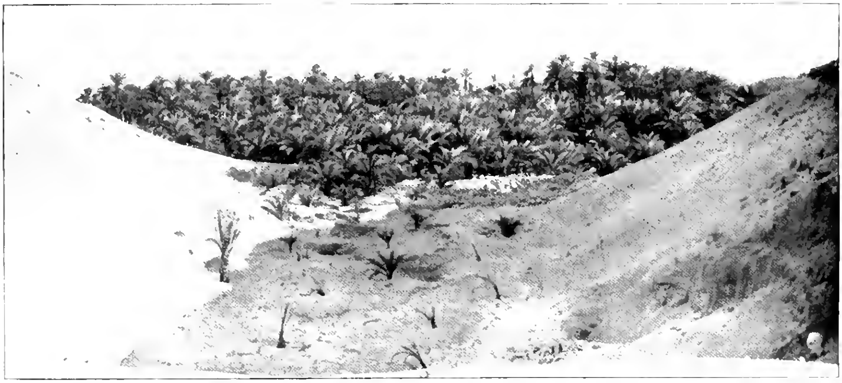

FIG. 2.—GRADUAL EXTENSION OF A PALM GARDEN BY CUTTING DOWN BORDERING SAND HILLS.

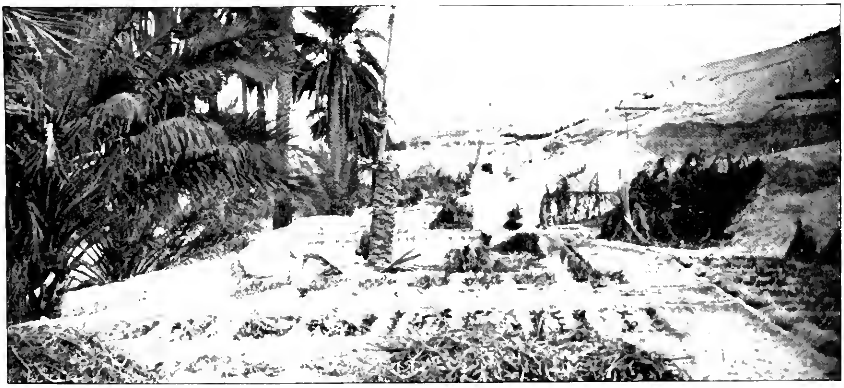

FIG. 3.—VEGETABLE GARDEN IRRIGATED BY WELL NEAR BOTTOM OF BASIN IN WHICH DATE PALMS ARE GROWN.

FIG. 1.—HOLE ON SLOPE OF DUNE NEAR BOTTOM OF BASIN IN WHICH A YOUNG PALM IS PLANTED.

FIG. 2.—CAMEL MANURE READY FOR APPLICATION IN A DATE GARDEN.

FIG. 1.—"DOKANA," OR MOUND OF EARTH AND PLASTER FOR STRENGTHENING THE BASE OF A PALM.

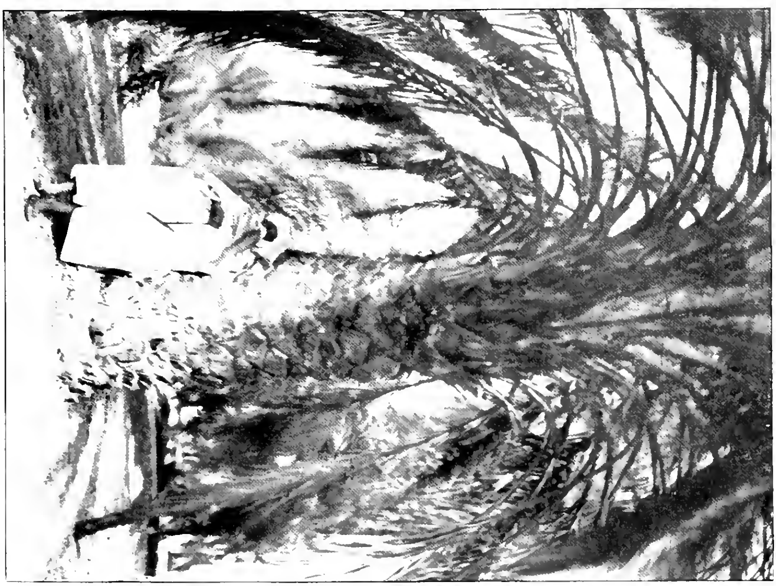

FIG. 2.—RHARS PALM, SHOWING THICKNESS OF TRUNK.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 87.

B. T. GALLOWAY, *Chief of Bureau.*

DISEASE RESISTANCE OF POTATOES.

BY

L. R. JONES,

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 7, 1905.

Sir: I have the honor to transmit herewith the manuscript of a technical paper entitled "Disease Resistance of Potatoes," which embodies a report upon investigations conducted in cooperation with the Vermont Agricultural Experiment Station.

This paper is a valuable contribution to our knowledge of disease resistance in European and American varieties of potatoes, and I respectfully recommend that it be issued as Bulletin No. 87 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The potato is one of the most important food crops of the United States. It is, moreover, one which is subject to a number of serious plant diseases. Some of these, notably the late-blight, can be controlled by spraying. Yet this remedy is not applied by all farmers, and the annual loss amounts to many millions of dollars. Other diseases, like dry-rot and the bacterial blight, are not controlled by spraying and require a different line of treatment. The subject of disease resistance in plants has received increased attention of late, and it is likely that the introduction of disease-resistant varieties of potatoes, by supplementing spraying and special cultural practices, will be of great practical value in lessening the waste caused by disease. Although but little has been done in the United States toward securing varieties resistant to disease, the attention of potato specialists in other countries has already been directed toward this aim.

As a preliminary step in our work, Dr. L. R. Jones, botanist of the Vermont Agricultural Experiment Station, was commissioned to inquire into the occurrence of potato diseases abroad and the methods employed for their control, particularly with reference to the production of disease-resistant varieties. Doctor Jones spent six months—from April to September, 1904—in this work.

In the course of Doctor Jones's European itinerary, information of more or less value was secured at the following places, successively, and this was supplemented by a considerable correspondence covering a somewhat wider area: Marseille, Naples, Florence, Munich, Halle, Berlin and vicinity, Dresden and vicinity, Bonn and vicinity, Wageningen (Holland), Amsterdam and vicinity, Groningen, Delft, Gembloux (Belgium), Paris and vicinity, London and vicinity, Reading, Cambridge, and Edinburgh and vicinity. The thanks of the Department are accorded to the various officials and other botanists in the countries visited, whose uniform courtesies made possible the success of the mission.

As shown in this report, a considerable number of varieties are reputed to be disease resistant. The best of these were selected by Doctor Jones, and limited quantities of seed tubers were imported by the Office of Seed and Plant Introduction and Distribution of the

Bureau of Plant Industry. These are now being tested in trials conducted in cooperation by the Bureau of Plant Industry and the State experiment stations in Vermont, Florida, Colorado, and Oregon, and by the Bureau at the Arlington Experimental Farm, near Washington. In order fully to acclimatize the foreign varieties, these trials will be continued for three years before a final report is made on their adaptation to American conditions. This test, together with the review of our present knowledge contained in this bulletin, will establish a proper foundation for future efforts in breeding better and more disease-resistant varieties. The field for such work is very large. Up to the present time most of the breeding has been for resistance to the late-blight (*Phytophthora infestans*), and this will continue to be the principal problem in the northern tier of States; but there is also much promise of success in securing new varieties to resist scab, dry-rot, bacterial blight, and other troubles, which in the Southern and Western States are more injurious than late-blight. It is hoped that potato specialists will give increasingly careful attention to this feature in their breeding and testing of varieties, for it is only by such a general interest and effort that the desired information can quickly be secured.

Albert F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological and
Physiological Investigations,
Washington, D. C., October 5, 1905.

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DISEASE RESISTANCE OF POTATOES.

INTRODUCTION.

Potatoes are liable to several diseases, some of greater economic importance in one part of the country, some in another.[a] The causes of most of these have been determined, and remedies of more or less practical value, chiefly spraying and seed disinfection, have been found. The success of the agents of the Department of Agriculture in securing disease-resistant varieties of various other plants has given an added interest to the question as to what may be expected in the way of securing disease-resistant varieties of potatoes. Inasmuch as this matter has engaged the attention of the potato specialists of Europe longer and more widely than has been the case in America, the attempt has been made to glean from their experience whatever may prove of assistance in furthering the work in this country.

In presenting the results it has seemed best for the sake of clearness to discuss briefly (1) certain general matters relating to potato culture in Europe; (2) the potato diseases which occur there, with comments on the resistance shown by particular varieties to each disease, and then (3) to summarize the information obtainable in America as to disease resistance of potatoes.

POTATO CULTURE IN EUROPE.

Potato culture was introduced from America into Europe more than three centuries ago. It was slower in its popularization there than in this country, but to-day the potato crop is relatively more important, both for food and for factory uses, in Europe than in America. This is partly attributable to the greater success of maize as a starch-producing plant in America and partly to the difference in economic

[a] Anyone not familiar with potato diseases should consult Farmers Bulletin No. 91, Potato Diseases and Their Treatment, by B. T. Galloway, which will be sent free of charge upon application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

conditions—land and labor values and food habits—between the two continents. In the British Islands the annual acreage in the last decade[a] was more than one and a quarter million; in France three times and in Germany six times this amount. The crop in Great Britain is chiefly used for human food; in France about 40 per cent is used in starch and alcohol manufacture, and in Germany like conditions exist, with the use of the potato for alcohol distillation promising to increase largely.

It is the German national policy so to improve processes of culture and manufacture that potato alcohol may rival, if not displace, petroleum for lighting and fuel purposes. Various organizations are aiding in this movement, including the Deutschen-Kartoffel-Kultur-Station and the Institut für Gährungsgewerbe und Stärkefabrikation. These institutions, maintained partly by private endowment and membership and partly by government aid, have been in operation about fifteen years. Under the directorship of Profs. C. von Eckenbrecher and W. Delbrück, respectively, they give attention to all matters pertaining to potato culture, starch manufacture, and distillation, including the breeding, selecting, and trial of new varieties. They work in close cooperation with the various German experiment stations and private potato specialists. No similar institutions were met with elsewhere in Europe, although the potato growers of England have organized during the last year an association of much promise, the National Potato Society.

In any comparison of European with American varieties the difference in popular taste must be kept in mind. The English market is like the American in giving preference to varieties with white flesh, rich in starch, and in making little use of potatoes except for human food. On the continent of Europe, however, only the varieties with yellow flesh are rated as of first quality for table use. These are relatively poor in starch and richer in protein than the white-fleshed varieties, and when cooked they are not sufficiently dry and mealy to suit the American taste. On the Continent the white-fleshed, starch-rich potatoes are demanded by the starch factories and distilleries, and as a result continental potato breeders have aimed to develop white-fleshed varieties of high starch content and large productiveness, regardless of table qualities, and anyone importing their varieties for use in America must consider these facts. It is from England, therefore, that we may expect the more promising varieties.

It is worthy of note in this connection that the difference in character of the potato in popular favor in different countries is closely related to differences in methods of cooking. The varieties with yellow flesh are inclined to sogginess when baked or boiled, but are admirably suited for frying. The starch-rich white potato, which is of

[a] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX (1896), pp. 387–430.

highest quality when baked, may go to pieces if boiled and will not hold together sufficiently for frying. In the latter case steam cooking gives better results than boiling in water.[a]

The methods of culture of potatoes vary somewhat in different European countries, as they do in America. In general, closer planting is practiced than in this country, which is partly explained by the greater number of unskilled laborers in Europe. A matter of more pertinence to the present discussion is that much more attention is given, especially in England, to the source and handling of seed potatoes than is generally the case in America. The best informed English growers considered that this has much to do with the question of disease resistance, as will be explained later. Indeed, it has come to be accepted by them that, for the best results, seed potatoes should be imported from some more northern region, at least as often as every third or fourth year, and this is done by many large growers every year. English growers use Scotch seed very largely. On the grounds of Sutton & Sons, Reading, England, a comparative trial was conducted during the summer of 1904 with a number of varieties, using seed from Scotland, middle England (Lincolnshire), and southern England, respectively. When these plats were visited in August, the vigor of the plants was in all cases greatest from the Scotch-grown seed and least from that grown in the south of England. In certain varieties the development of the tops was as two to one. At the Cambridge University farms, located in the famous potato region of Lincolnshire fens, it was said that Scotch-grown seed did better than home-grown there and in the Lincolnshire district generally.

A large potato-growing company of the Canary Islands uses German in preference to English seed, because the growth from the latter is too rank and the tubers are too large. Potato growers on the island of Jersey in recent years have sent to England and Scotland for their seed. Italy and the Mediterranean islands look to France and Germany largely.

While some American potato growers recognize the importance of the source of seed and attend to this point consistently, there is generally indifference, disagreement, or lack of information on this subject, as Fraser[b] has recently shown. It is a matter deserving of further careful inquiry and experiment.

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[a] The writer is indebted to Professor Petermann for calling his attention to these matters. For a further discussion of this subject reference may be made to Petermann, A., Etudes sur la pomme de terre, Bul. de l'Inst. Chim. et Bact., No. 70, Gembloux (Belgium), 1901; and Coudon and Bussard, Annales de la science agronomique, I, Paris, 1897. To the latter, credit may be given for showing that the behavior of the potato in cooking is primarily dependent not so much on the total percentage of starch contained as on the relative percentages of starch and protein. The proper proportion of the protein is necessary to hold the starchy mass together when cooked.

[b] Fraser, S., The Potato, New York, 1905, pp. 51–52.

The relation of the maturity of seed to its value has also received considerable attention in Great Britain. Some of the best practical potato growers prefer to have potatoes intended for seed dug before they are fully mature. i. e., while the tops are still green and the outer skin of the tuber rubs up easily. These tubers are then allowed to lie on the ground a short time to "harden" in the light, i. e., to dry and be slightly sunburned, before they are put into storage.

The practice of "boxing" is common and very highly commended. This consists of setting the tubers with "seed end" up in shallow boxes or trays in a dry, light room for some weeks before planting, so as to have strong, short sprouts started upon them. In this way quicker germination, stronger young plants, and a perfect stand are secured.

The general preference in Scotland and in England is for planting small tubers, one and one-half to three ounces, planted whole. If larger tubers are used they are cut, as in this country.

OBSERVATIONS ON POTATO DISEASES AND DISEASE RESISTANCE IN EUROPE.

Insects cause the European potato grower little annoyance or loss as compared with American conditions. Nowhere in Europe, so far as learned, is any use whatever made of insecticides upon potatoes, leaf-eating insects being practically unknown. On the other hand, diseases caused by fungi or bacteria or of nonparasitic origin are even more common and destructive than in America. In the following paragraphs is a discussion of the nature and relative seriousness of such diseases as came under the writer's personal observation, coupled in each case with the evidence secured as to disease resistance. The less important and nonparasitic maladies are discussed first, reserving until later the consideration of the late-blight and rot.

CERTAIN MINOR DISEASES.

INTERNAL BROWN SPOT.

The peculiar disease of the potato called internal brown spot is as well known to plant pathologists and practical potato specialists in Europe as in America. The writer learned nothing more about it on the Continent than is set forth by Frank,[a] who reached only negative conclusions. It is considered not to be a parasitic disease, and no remedy is known and no suggestions are made except the doubtful one of avoiding the use of diseased tubers for seed. In England and Scotland several potato specialists[b] of wide experience gave evidence of like

[a] Frank, A. B., Kampfbuch gegen die Schädlinge unserer Feldfrüchte, "Buntwerden oder Eisenfleckigkeit," p. 211.

[b] Prof. J. H. Middleton, Messrs. Sutton & Sons, and Thomas A. Scarlett.

purport. The trouble is frequently observed, and is most commonly termed "sprain." It is not propagated in seed or soil and is non-parasitic. It is considered to be the direct result of malnutrition associated with unfavorable soil conditions, resulting either from too dry conditions or from the lack of potash or lime. It is frequent in light, dry soils during dry seasons, and is never seen on heavy, strong, moist soils. The remedy, in the judgment of the specialists cited, lies wholly in attention to cultural conditions and the choice of varieties.

Some varieties are more liable than others to internal brown spot and should not be used on soil that favors the disease; e. g., Mr. Scarlett stated that the British Queen variety is especially predisposed to "sprain." The primary remedy, however, lies in selection and treatment of the soil—i. e., in avoiding dry soil—and in so cultivating as to conserve moisture, while using lime and potash liberally.

FILOSITÉ, OR GROWING-OUT.

The names "filosité" and "growing-out" are applied in France[a] and England, respectively, to various forms of secondary outgrowths from tubers. Examples that were shown to the writer were in some cases merely "prongy" tubers, while in others stolons starting from the eyes produced secondary small tubers. Delacroix describes conditions where the seed tubers send out an abundance of weak shoots, both above and below ground, but these soon die without yielding any crop. The latter type is therefore allied to the curl disease of the potato.[b] The less serious forms of growing-out are attributed to climatic and soil conditions, especially to a long, wet autumn following a dry summer. The more serious types of the disease, especially as occurring in France, are attributed to varietal weakness or "running out." In both France and England the use of seed from any plants showing this tendency was condemned as tending to give a crop of generally reduced vitality.

LEAF-SPOT.

Since there has been a difference of opinion among pathologists as to the occurrence and destructiveness of the fungus *Alternaria solani* in Europe, the writer was led to keep an especially close watch for it. Prof. P. Sorauer kindly sent specimens from Europe some years ago corresponding fully with the leaf-spot disease caused by this fungus,

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[a] See Delacroix, G., Sur la filosité des pommes de terre, Jour. de l'Agriculture, December, 1903.

[b] Frisolée (French), or Kräuselkrankheit (German), is a common but not very serious potato malady of Europe, of which the cause is not clear, but apparently it is associated with varietal weakness and malnutrition. It is characterized by dwarfish plants bearing an excessive number of rather undersized leaves, which are down-curled and brittle. The tops have thus a dense or bushy appearance. They may be quite as green as normal plants.

and termed early-blight in America. It is known, therefore, that it occurs in Europe, but it can not be as common and destructive as it is here, for no trace of it could be found in any of the fields visited. Much was seen, however, of a leaf-spot disease which bears a superficial resemblance to it. This was shown us first by Dr. Otto Appel in the experimental fields of the board of health at Dahlem, near Berlin. Later it was seen elsewhere in Germany and in England. Apparently there has been a confusion of this with our American early-blight,[a] but both Doctor Appel and Professor Sorauer stated that there was no fungus present in this leaf-spot disease, and the writer's examinations confirmed this. The cause of this trouble has not as yet been clearly established, but since Appel and Sorauer both have it under observation, further advice may be expected upon it in the near future. Opportunity was presented to compare the relative development of this trouble on different varieties in the trial grounds of the University Farm, Cambridge, England, in the latter part of the summer. There was a considerable difference in the amount of spotting of the various varieties, but none was altogether free from it.

SCABBINESS OF TUBERS.

POTATO SCAB.

Scab-like diseases, i. e., those characterized by surface erosions of the tubers, are frequent in Europe and apparently more varied in nature than is recognized to be the case in America. Yet nowhere does injury to the crop from such diseases approach that which is common in this country. This is in some ways surprising and unexplained. A disease closely resembling in appearance the common American type of scab was frequently seen, but growers everywhere in Germany, France, and Great Britain testified that it is not common or destructive enough to be of much practical importance. Scientific men are not agreed either as to the cause of the disease or as to the possibility of benefit from seed disinfection. But few recommended this treatment, and no practical potato grower was met who practiced it. The most puzzling thing, in the light of American experience, is that potatoes are grown year after year continuously or in the shortest of rotations on the same soil without increase of scabbiness. In each of these countries potatoes are often grown on the same soil for ten or twenty or even forty successive years with practically no trouble

[a] See Frank, Kampfbuch, p. 220. Apparently the disease mentioned above is the same as Frank's "Pockenfleckigkeit." Frank was altogether mistaken in considering it the same as the American "early-blight," as Sorauer subsequently showed. See also Bahna, J. J., Blattbraune der Kart.; Zeitsch. f. Land. u. Fortwirtsch., 2: 113 (March, 1904). Prof. C. von Tübeuf comments upon this article and reviews the literature in the June, 1904, number of the same journal.

from scab.[a] Since this is often on rich and heavy land, such as would develop scab under like treatment in America, the European experience is difficult to understand. Does not our type of disease exist there, or is it less virulent because of some difference in the climatic and soil conditions? The writer is not prepared to answer with full confidence, but his judgment favors the second suggestion.

Europeans, both pathologists and practical men, recognize more than one form of disease under the name of scab (the German "schorf," Dutch "schurft," French "la gale"). Frank's subdivisions[b] of "schorf" into four kinds—flach, tief, buckel, and buckel-tief schorf—were familiar to the continental pathologists interviewed, but the general opinion is that these are simply forms of one common disease, the variations being attributable to the season of attack or to varietal or vegetative conditions of the potato. Frank's specimens of "tief-schorf" were seen in the museum of the board of health at Berlin and have the appearance of the common American scab.

As to the cause, opinions differ.[c] The German pathologists who have given most attention to this disease consider the commonest German form to be due to a fungus similar to Thaxter's *Oospora scabies*, but perhaps not identical with it. In Holland doubt was expressed as to the common Dutch form of potato scab being a fungous disease at all, while in Belgium and France it is considered a parasitic disease, but due to bacteria (*Micrococcus pellicidus* Roze) rather than to fungi.[d] In England *Oospora scabies* is held responsible for only the minor part of the trouble, *Sorosporium scabies* Fisch. being the commoner parasite.

VARIETAL RESISTANCE TO SCAB.

As already stated, none of these scab diseases has proved of sufficient economic importance to attract much attention from practical potato growers in Europe. Probably most of the diseases would yield to the seed-disinfection treatment practiced for potato scab in America, yet this is nowhere used by European growers, so far as learned. The only valuable data as to the relative susceptibility of varieties to scab are those furnished by the reports of Professor Eckenbrecher,[e] whose results point to certain newer varieties as being comparatively free from scab, while others are quite susceptible. Age of the variety,

[a] See Sutton, A. W., Potatoes, Jour. Roy. Soc., XIX, pp. 387–430 (1896).

[b] Kampfbuch, p. 170.

[c] These conclusions are the result of conferences with a number of men and reference to the publications of others. Among those who have given this disease careful consideration in their respective countries and whose opinions were learned are Professors F. Krüger, Berlin; Ritzema-Bos, Amsterdam; Marchal, Gembloux; Roze and Delacroix, Paris; Massee and Cooke, England.

[d] Roze, E., Histoire de la pomme de terre, Paris, 1898, p. 275.

[e] C. von Eckenbrecher, Berichte Deutsch.-Kart.-Kult.-Stat., 1903 and earlier.

however, seems to be of less consequence than it is with the blight, for while one of the least resistant is Daberschе, an old standard, one of the most resistant is Richter's Imperator, also an old variety. Other varieties reported as preeminently scab resistant are Irene and Professor Wohltmann. Boneza and Pomerania are reported resistant, but to a less degree. Seed of all these have been secured for trial in this country. Early Rose is found especially liable to scab there as it is in America. It will be better, however, to postpone the discussion of resistance to scab as shown by American varieties of potatoes until the latter part of this publication.

OTHER SCAB-LIKE DISEASES.

Rhizoctonia.—This was seen on potato tubers in Europe even more commonly than it occurs in America, but most European pathologists regard it as nonparasitic. Those who consider it as a facultative parasite attribute little injury to it generally, although some think it capable of causing rot, as described by Frank.[a]

Spongospora solani Brun.—This fungus is said[b] to cause a scab-like disease in the north of Europe. This disease occurred[c] to a considerable extent on potatoes secured by the writer's order from Groningen, Holland.

Superficial scurvy diseases attributed to other fungi occur in Europe. Frank[d] describes one such caused by *Phellomyces sclerotiophorus*, but Doctor Appel told the writer that this had not proved serious in Germany. Johnson[e] reports it as causing some trouble in Ireland. In England another scurf disease of somewhat similar appearance is attracting attention. It occurred on the Eldorado seed potatoes imported with our order from Scotland, and the cause is apparently the fungus *Spicaria nivea* Hors.[f]

Oedomyces leproides Trabut.—This is a fungus[g] which attacks the young sprouts or eyes of the tubers, stimulating them to abnormal, cauliflower-like growth, of which the dark color has given rise to the popular name black-scab. The writer did not see this disease on the

[a] Kampfbuch, p. 194.

[b] Ibid., p. 176.

[c] Found and identified by James Birch Rorer.

[d] Kampfbuch, p. 182.

[e] Johnson, T., The Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, Vol. III, No. 1 (1902).

[f] So identified by Dr. Ernst A. Bessey. Dr. Thomas Milburn, of the Midland Agricultural and Dairy Institute, England, advises the writer by letter that he is engaged in a special study of this disease. He finds it to occur on most English varieties, Evergood and Sutton's Flourball being by far the worst, while East Anglian and Sutton's Discovery are the only ones he has found entirely free from it.

[g] This also occurs on beet roots. See Massee, Geo. A., Textbook of Plant Diseases, p. 225.

Continent, but while in England Dr. M. C. Cooke sent specimens, as did also Dr. John Wilson, from Scotland. It is regarded as capable of causing much harm, but fortunately has not as yet become common.

POTATO STEM DISEASES.

BLACKLEG.

"Schwarzbeinigkeit," or blackleg, is a name applied to a disease seen commonly in central Europe. It is characterized by the blackening and rotting of the main stem, accompanied by a checking of the growth, uprolling, yellowing, and ultimate death of the leaves, and more or less rotting of the tubers. It has been exhaustively studied in recent years by Appel[a] in Germany, who concludes that it is due to bacteria (*Bacillus phytophthorus*, and perhaps other allied species), which either enter from the soil or are carried in the seed tuber. These start the disease below ground, the rot proceeding, as a rule, from the seed tuber to the young plant. Appel's conclusions are generally accepted by pathologists in Germany, Holland, and Belgium, and, so far as learned, in England.

The writer had opportunity to see much of the German disease in the vicinity of Berlin, and to verify Doctor Appel's observations, in a measure, in his own laboratory. Later (August) the same malady was seen in England, where it is said to be common, though apparently less troublesome than Appel reports it from Germany. All of the personal observations of the writer therefore lead to an indorsement of Appel's conclusions both as to the bacterial nature of the disease and as to its widespread occurrence and economic importance.

In France a similar if not identical disease is attributed to bacteria. Delacroix, who has studied this, considers the organism causing the disease, which he calls *Bacillus solanicola*, to be specifically distinct from that described by Appel. He kindly showed the writer specimens of the French disease in his garden in Paris, but it was in a stage so much more advanced than that seen in Berlin that a comparison of the two does not seem justifiable.

Of course, the possible occurrence of these stem diseases in America was kept in mind. The writer has never seen much, if any, of the same trouble in potato fields in the Northeastern States and adjacent Canada which have come under his observation. Certainly it is not so common in America as it is in Europe. The symptoms correspond, however, somewhat closely to certain diseases attributed to Rhizoctonia in the South and West.[b]

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[a] Appel, O., Arb. aus Biol. Abt. Gesundheitsamte, 3: 364 (1903).

[b] See especially Selby, A. D., Ohio Exp. Sta. Buls. 139 and 145, and Rolfs, F. M., Colo. Exp. Sta. Buls. 70 and 91.

The only remedies proposed or practiced for blackleg in Europe consist in selection of sound seed, careful avoidance of rotten tubers or those taken from a diseased crop, attention to rotation of crops, since the germs may persist and accumulate in the soil, and the use of disease-resisting varieties. None of these methods has been tested carefully enough to establish its merits.

The chief evidence as to varietal susceptibilities or resistance to blackleg is that of Appel.[a] He states that while no varieties have been shown to be entirely free from the disease, the evidence is that thick-skinned, starch-rich, late varieties are in general more resistant than thin-skinned, starch-poor, early varieties. The Daberscbe he finds to be the most resistant of the widely used German sorts, while the Rose varieties are especially liable to blackleg. Contiguous plats of the Daberscbe and White Rose in Doctor Appel's grounds showed this difference very clearly at the time of the writer's visit in July, 1904, the Rose being badly diseased, the Daberscbe but slightly. At the Deutschen-Kartoffel-Kultur-Station distinct evidence of variations in disease resistance was found. It was stated at this station that in the trial grounds the red varieties were in general found to be more resistant than the white.

A considerable development of this disease was noticed at the University Farm, Cambridge, England, where extensive variety trials were being conducted. The observations of Mr. H. Henshaw, who had immediate charge of these, were in agreement with those of Doctor Appel as to the association of the disease with the rot of the seed tuber, and he regarded it as a bacterial malady. There was a difference in the amount of the disease on different varieties, but Mr. Henshaw found none wholly free from it. At the time of this visit Factor and Up-to-Date were noticeably freer from the trouble than any other varieties there under trial. They were about alike in this, as, indeed, in all other characters. Doctor Delacroix cited as especially resistant to his bacterial disease in France the variety La Czarine. He also stated that the variety Geante Bleue is resistant, but to a less degree. Laurent observed in his work on bacterial diseases that the maximum of resistance was shown by the varieties Chardon, Pousse-debout, and Chave.

OTHER STEM DISEASES.

Several other potato stem diseases have been reported in Europe, but since the writer did not study them in the field and learned nothing beyond what is recorded in literature they will be passed with brief mention. Prillieux and Delacroix have described another bacterial stem disease in France attributed to *Bacillus caulivorus*. Rhizoctonia is common on potato stems as well as tubers, but none of the patholo-

[a] Arb. aus Biol. Abt. Gesundheitsamte, 3: 408 (1903).

gists conferred with regards it as a parasite of importance on either. Professor Marchal, of Gembloux, said, however, that he sometimes found a basidiomycetous fungus, *Hypochnis solani* Prill.,[a] causing a blackleg-like stem disease in Belgium. Prof. T. Johnson, of Dublin, sent specimens of *Sclerotinia sclerotiorum*, which at times causes a destructive stem disease in Ireland, called "yellow blight." He also reports[b] the occurrence in Ireland of bacterial stem diseases, including what he believes to be the malady termed brown-rot in America and shown by Dr. Erwin F. Smith to be caused by *Bacillus solanacearum*. In none of these cases was anything learned as to relative varietal resistance to the disease in question.

LATE-BLIGHT AND ROT DUE TO PHYTOPHTHORA INFESTANS.

Late-blight and rot due to *Phytophthora infestans* occurs in Europe even more widely and destructively than in America, being recognized as the most important malady in all the countries visited by the writer—Italy, Austria, Germany, Holland, Belgium, France, and the British Islands. There was less unanimity of opinion than was anticipated as to the probable life history of the fungus, and consequently as to the remedial treatment. While all agreed that it lives over in the seed tubers, the opinion was frequently expressed, by scientific and practical men alike, that there is probably some hibernation in the soil, either in tubers left in the field or in the haulms. Possible hibernation in the tubers is to be associated with the fact that potato tubers left in the soil are not killed by frost in southern England and the south of Europe. The value of Bordeaux mixture as a remedy is recognized generally. Spraying is consistently advocated and practiced in the British Islands—especially Scotland and Ireland—the Netherlands, Italy, and portions of France. Germany has been surprisingly backward in accepting or even fairly testing this remedy. The reason seems to be that some of the experiments conducted by scientific men have shown injury to the plants, and so they have pronounced against it. No other remedial treatments are in common use. No one indorsed or practiced any method of seed disinfection. No particular culture methods were advocated or condemned other than attention to fertilization. There was a general agreement that excessive use of nitrogenous fertilizers, either chemicals or composted manures, increases the loss from this disease. Much attention is being given, however, to the relation of varieties and of source of seed to disease resistance, and the results are of sufficient importance to merit the somewhat detailed report which follows.

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[a] Probably identical with *Corticium vagum* var. *solani* Burt, which is the fruiting stage of the common Rhizoctonia of the potato.

[b] Johnson, T., Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, III, No. 1 (1902)

RESISTANCE AS SHOWN TOWARD LATE-BLIGHT AND ROT.

HISTORICAL STATEMENT.

Doubtless examination of the earlier writings upon the potato disease known as late-blight and rot would show that from the beginning of its ravages differences have been observed in the resistance of varieties. Any such records of the thirty years from 1845 to 1875 would have no practical value now, since the varieties then in use have passed out of culture; nor would they have much scientific significance, owing to the lack of exact knowledge then as to the cause of disease. Going back to the origin of the varieties still in cultivation, it is found that in the early seventies an unusual amount of attention was focused upon the matter of the potato disease, as to causes and remedies. Ninety-four essays secured by the Royal Agricultural Society of England in 1872 showed agreement that an underlying cause was the degeneracy of the varieties then in culture.[a] The necessity for the production of new varieties was emphasized. The introduction of improved American varieties into England at about this period was most beneficial and stimulating to the potato specialists of that country.[b] These varieties were made the parents in further breeding. The best production of this revival was the Magnum Bonum, originated by James Clark from a cross of Early Rose with Victoria and introduced by Sutton in 1876. Experience with this variety laid the foundation for belief in possible disease resistance in potatoes both in England and on the Continent. Magnum Bonum soon became the standard main-crop variety of Great Britain and so continued until within the last fifteen years, when it yielded to Up-to-Date and others. It is still in considerable favor on the Continent.

Charles Darwin in 1877–78 became interested in the possibilities of disease-resistant breeding. Francis Darwin[c] states that Mr. James Torbitt, of Belfast, bred and selected varieties to secure disease

[a] See Jour. Roy. Agr. Soc. Eng., XX : 291 (1884).

[b] Dean, A. Potato Improvement in the Past Twenty-five Years. Jour. Roy. Hort. Soc., XII : 41 (1890).

Mr. C. G. Pringle, who was then the foremost potato breeder in America, states that the demand from Europe for new American varieties was very active at that period, and continued until the fear of the Colorado potato beetle led to the prohibition by European governments of further importations of potato tubers from America. Thereupon Mr. Pringle supplied B. K. Bliss & Sons with specially hybridized potato seed, which was sent abroad in considerable quantity.

[c] Life and Letters of Charles Darwin, II, pp. 519–522.

The writer learns from Prof. T. Johnson, of Dublin, that Torbitt has been dead some twenty years. He was in the wine trade and raised varieties of potatoes for the berries, or seed balls, which he used as a source of material for wine. All of his varieties have disappeared except one coarse, red one, which was and is proof against disease.

resistance, his method being to cross-fertilize, rear the seedlings, and expose them ruthlessly to infection, retaining only those showing some degree of resistance. In this work he received much encouragement and some financial aid through Charles Darwin.

A committee of the English House of Commons, reporting in 1880 upon the potato disease, found all its witnesses concurring in the necessity for the production of new varieties with increased disease resistance.[a] Parliament was asked to give financial aid for experiments aiming to produce new and disease-proof varieties, but it did not do this. Earl Cathcart, in commenting on this report, states that—

All potatoes have deteriorated in their disease-resisting powers. A variety from seed takes four to six years for its establishment, and under the most favorable circumstances a good variety might be expected to degenerate in twenty years. The production of new varieties is of national importance.

Apparently through the influence of Cathcart, Baker[b] was led to make an exhaustive comparative study of the genus Solanum in order to advise as to the relation of the cultivated varieties to the several wild species of the American continent preparatory to breeding experiments in which these might be used. As a result, two species were considered worthy of further trial in the attempt to improve disease resistance, viz, the Darwin potato, *S. maglia*, from the Chonos Archipelago, and the Uruguay potato, *S. commersonii*. Cathcart furnished Sutton with the former and he hybridized it with the common *S. tuberosum*. Sutton[c] reports that, beginning in 1886—

Although many hundreds of flowers of *S. maglia* were artificially fertilized with pollen from cultivated varieties, only five were successful, resulting in five berries. From these but two seedlings were secured and only one of these showed any promise whatever, the second having to be grown under glass to prevent its dying. * * * This hybrid, although a vast improvement on *S. maglia*, is far behind the ordinary potato in appearance, crop, and quality. The seedling * * * grown for eight years, in 1894 was slightly diseased, although previously free from attack.

Sutton still has the *S. maglia* and this hybrid in propagation at Reading, where the writer saw them in August, 1904. Phytophthora was then more rampant on the foliage of both of these and on *S. commersonii*, which he also has, than on the average potato plants in his fields. No hybrids of *S. commersonii* had been secured by him previous to this. Mr. Lasham, potato specialist for the firm, has been giving renewed attention to the possibilities of species hybridization, and showed the writer balls which he considered to contain hybrid seeds of *S. tuberosum* × *commersonii*.

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[a] Jour. Roy. Agr. Soc. Eng., XX: 291 (1884).

[b] Baker, J. G., A Review of the Tuber-Bearing Species of Solanum. Jour. Linn. Soc., London, XX, 489–507 (1883–84).

[c] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX, 387 (1896).

Interest in the possibilities of *S. commersonii* has recently been stimulated by the experiments inspired in France by Prof. E. Heckel,[a] who believes in the economic possibilities of this species when improved by longer culture and perhaps by hybridizing, and has distributed it quite widely in France with this end in view. One French horticulturist, Labergerie,[b] claims already to have succeeded in producing a variety of edible quality, large yield, and superior disease resistance. This was seen growing in the grounds of Vilmorin-Andrieux & Co., at Paris. This firm was not yet convinced of the practical value of the plant, and since Labergerie refuses to send out any of these potatoes for trial at present, judgment must be reserved.

Returning to the consideration of the varieties of the common potato, it is found that during the last decade increasing attention has also been given to their comparative disease resistance. This has been well summarized by Prunet.[c] The main facts developed are as follows: Sorauer[d] in 1896 considered the evidence to date as showing that the highest degree of disease resistance was possessed by Magnum Bonum, the following showing some degree of resistance: Blaue Riesenkartoffel, Richter's Imperator, Athene, Reichskanzler. Rostrup,[e] writing about the same time from Denmark, places Magnum Bonum at the head as a disease-resisting variety, with Richter's Imperator and Champion as somewhat resistant.

In this connection it is noteworthy that Magnum Bonum has yielded its place in popular favor in Great Britain for main-crop purposes to Up-to-Date and other varieties, even while holding its reputation on the Continent. During the last decade these standard varieties in turn have been "running out," and the demand in England for something to take their place has stimulated potato breeders and seed specialists to direct their attention very generally to the development of a disease-resisting main-crop variety. The greatest efforts in breeding have been made during the last four years, while speculation in the most promising of the varieties produced has been at fever heat for the last two years, during which time many new varieties, more or less disease resistant, have been pushed to the front. There are now so many potato specialists in Great Britain breeding and handling varieties of reputed disease resistance that it is impracticable to mention all. Archibald Findlay,

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[a] Heckel, E., Sur le *S. commersonii*, Rev. Hort. de la Soc. d'Hort. et de Bot. des Bouches-du-Rhone, No. 581, pp. 200–206 (December, 1902); also, Contrib. à l'étude botanique de quelques solanum tuberiferes, Ann. de la Faculté des Sciences de Marseille, vol. 8 (1895).

[b] Labergerie, M., Le *Solanum commersonii* et ses variations, Bul. Soc. Nat. d'Agric. de France, March, 1904.

[c] Prunet, A., Le mildieu de la pomme de terre, Rev. de Viticult., XVII, 663; XVIII, 97 et seq. (1902).

[d] Zeitsch. f. Pflanzenkr., VI, 284 (1896).

[e] Tidsskrift f. Landbrugets Planteavl, 1895, 1896, 1897.

of Mairsland, Auchtermuchty, Scotland, has originated some varieties of high repute; Sutton & Sons, of Reading, England, have also taken a prominent part in this work. Scotland-grown seed of all the leading varieties can be secured from Thomas Scarlett, of Edinburgh, and Mr. Scarlett has some promising varieties of his own introduction. Anyone desiring more specific information should secure the publications of the National Potato Society from its secretary, Walter P. Wright, Postling Vicarage, Hythe, Kent, England.

Meanwhile the German Potato Station has been making extensive tests, doing some breeding and encouraging several potato breeders.[a] These efforts have not been directed primarily to disease resistance, but the station has taken note of this feature and published the data regarding all varieties tested.

While the results of this work in Europe have been collected or correlated by no one, the writer was able to gather considerable information, in addition to that already referred to, from conversation with potato specialists, especially in Great Britain. This, together with what has been learned in America, is made the basis of the following discussion. It is to be regretted that it is impracticable to give detailed credit in some cases to those who kindly furnished the information.

THE MEANING OF DISEASE RESISTANCE.

Although potato specialists, especially in England, apply the term "disease proof" to their favorite varieties, this is not to be taken literally. No variety has as yet shown itself to be absolutely proof against disease. The writer personally collected leaves infected with the blight fungus from two varieties which were said to be "disease proof." Absolute resistance against the blight fungus has not as yet been and may never be secured. Varieties are known, however, which show a relatively high degree of disease resistance. This may be shown in the delay in date of appearance of the blight on the leaves or its slower progress after appearing, and still more clearly in the relatively small amount of loss from rot of the tubers. Most of the exact observations made in Europe have been based on this latter difference.

DISEASE RESISTANCE AND VEGETATIVE VIGOR.

Disease resistance and vegetative vigor are closely associated, although the factors involved are not necessarily identical. In any consideration of the problems of the life and death of the potato plant it must be remembered that the potato has two natural methods of

[a] The most active of these are Paulsen, Cimbal, Richter, and Dolkowski. Graf Arnim-Schlagenthin, of Nassenheide in Pommern, is an extensive breeder and dealer in new varieties, as is also F. Heine, of Hadmersleben.

reproduction, the true seed produced in the berries or "balls" following the blossoms, and the tubers produced below ground. Reproduction by seed is a sexual process, that by tubers is vegetative. Both are exhaustive of vitality. The two are in a certain sense physiologically opposed to each other and can not well be carried on at the same time by the plant. Under the natural conditions of the wild potato plant in Mexico, and doubtless elsewhere, seed production precedes tuber formation. In Europe and northern America, with a shorter season and intensive culture, the two processes overlap. As a result there is, just after the potato plant comes into blossom, a period when the natural tendencies within the plant toward seed production above and tuber formation below are such as to subject it to unusual physiological stress. This has been termed the "critical period"[a] in the development of the potato plant.

Usually the blossoms fall without the setting of the fruit, and the plant then passes into a stage where its energies are devoted to tuber formation alone. Once well started upon this vegetative period, its growth is more or less indeterminate, i. e., there is no clearly defined natural terminus to the life of the cultivated potato plant. Instead, there is the gradual decline in vegetative vigor which may prepare the way for early-blight and other diseases characteristic of weakling plants. It is noteworthy that the destructive attacks of the late-blight fungus occur, as a rule, after the blossoming period has passed. So far as the evidence goes it seems to suggest that high vegetative vigor enables the plant to ward off in some degree the fungus attack.

There is, moreover, a natural decline in vigor, or "running out," with the age of the variety. The length of life of a variety depends upon numerous conditions, and is an indefinite matter in any case. It is ordinarily placed by potato specialists at from twelve to twenty years. As a variety begins to "run out" it apparently shows, among other things, a lessened degree of general disease resistance. Thus Magnum Bonum had the highest reputation in this respect from its origin in 1876 until about 1890 in Great Britain. On the Continent it has remained longer in favor. Up-to-Date has held a like place during the last decade in Great Britain, and Richter's Imperator has a similar record in Germany. These statements are based upon the popular verdict, not upon exact experiments; but the belief that disease resistance decreases with the age of the variety is firmly established in the minds of specialists in potato culture in Great Britain, at least so far as concerns resistance to Phytophthora.

There is little definite evidence regarding the relation of vegetative vigor to resistance to other diseases, but so far as it is formulated it

[a] See Jones, L. R., Certain Potato Diseases and Their Remedies, Vermont Exp. Sta. Bul. 72: 4 (1899); also The Diseases of the Potato in Relation to Its Development, Trans. Mass. Hort. Soc. (1903), Part I: 144.

favors the general applicability of the idea. The production of berries, or seed balls, is held by some English breeders to be an indication of such vigor, and therefore presumably of disease resistance, although no one claims that the absence of these is equally strong evidence in the opposite direction. It is worthy of passing note that berries are formed much more commonly in Europe, especially in Germany and Holland, than in America, apparently because of climatic differences.

THE RELATION OF HYBRIDITY TO DISEASE RESISTANCE.

By a "new variety" of potato, as the term is commonly used, is meant one recently developed from the seed. Sports may appear and are indeed frequent in some varieties. These will, however, be mentioned later. The seed in all cases presumably represents a sexual origin, i. e., comes from a fertilized flower, but this may have been either self-fertilized or cross-fertilized. One would expect greater vigor to result from the cross-fertilization, and potato breeders are of the opinion that it is secured. On the other hand, while varieties recently originated from seed may show a high degree of disease resistance, this is not necessarily the case according to the verdict of English and German breeeders, many new varieties proving as susceptible as old ones.

Reference has already been made to the work of Cathcart and Sutton in England and of Heckel and Labergerie in France based on the hope of advantage from using one or another of the wild Solanums for such hybridizing. There are interesting possibilities along this line, since there are many wild forms of *S. tuberosum* in addition to other species of tuberiferous Solanums. Thorough trials of these are now being made by Stuart[a] at the Vermont Experiment Station which will be reviewed later in this paper. It should be emphasized at once, however, that while the use of the wild Solanums does offer interesting possibilities, there is no record of practical success from their use, if we except the doubtful one of Labergerie's variety of *S. commersonii* previously referred to. On the other hand, great practical improvements have been secured by various breeders from crossing varieties of cultivated potatoes.

IMPROVEMENT BY SELECTION.

All plants tend to vary. One of the commonest ways to improve plants is by selection from among the varying individuals. For the first two years after their origin, variants, or "rogues," are not uncommon with the seedling potato, but the variety is "fixed" by the weeding of such rogues before it is distributed for general culture, and

[a] Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

thereafter very little variation occurs. Some modification is to be expected, nevertheless, and among other things there may be variation in disease resistance. It seems worth while, therefore, to keep a lookout for individual plants which show especial resistance to the blight when this is epidemic about them. The tubers of such individuals deserve to be carefully saved apart and planted, in order that it may be seen whether their resistance is a fixed and inheritable character or the result of some chance difference in environment. Such selection has already been undertaken by three persons to our knowledge: Appel in Germany,[a] Stuart in Vermont,[b] and Fraser in New York;[c] but no practical results have as yet been secured.

ARE EARLY OR LATE VARIETIES THE MORE RESISTANT?

The blight never becomes serious until the midseason of potato growth is passed; thus in our Northern States its worst ravages come in August and September. Therefore early varieties, as a rule, escape. But this is simply because they mature before the blight is epidemic. So far as evidence has been secured, both in America and Europe, when the early varieties are planted late enough to expose them to the disease alongside of the later ones, the early varieties as a class suffer the worst. For example, the most complete destruction by rot which the writer ever saw was with a late crop of Early Ohio potatoes attacked by the disease in September. Woods,[d] of Maine, has also found early varieties especially susceptible.

RELATION OF SOURCE OF SEED AND CULTURAL METHODS TO DISEASE RESISTANCE.

The opinions of highly intelligent potato growers in Great Britain are especially worthy of note. One of the first concerns with them is the source of their seed. Mention has already been made of the experiments at Sutton's grounds, showing the superiority of northern-grown seed. It was found to be the general verdict of practical men in Europe that northern-grown seed is more highly disease resistant, as well as more productive. If one is to aim for the best results in health of crop, therefore, attention should be directed to quality and source of seed as well as to variety.

Practical men as well as scientists generally agree that methods of culture also determine to a considerable degree liability to disease. These act not only indirectly as they affect moisture content or other physical conditions of the soil, but more directly as they affect the

[a] Appel, Otto. Die diesjährige Phytophthora-epidemie, Deutsche Landw. Presse, XXIX: 685 (1902).

[b] Vermont Exp. Sta. Bul. 115, p. 139.

[c] Reported in correspondence.

[d] Woods, C. D., Maine Exp. Sta. Rpt., XIX: 181 (1903).

vigor or inherent disease resistance of the plant itself. Seed dealers in this country, as well as in England, have also expressed a preference for seed from a crop that has not been very highly fertilized, especially with nitrogenous manures. The most detailed study along this line is that of Laurent,[a] whose results indicate that nitrogenous fertilizers predispose both the foliage and the tubers of the plants to the attacks of Phytophthora. This is in harmony with the general opinion of practical potato growers, that high manuring increases the liability to disease.

COMPOSITION AND CHARACTER OF TUBERS AS RELATED TO ROT RESISTANCE.

There is considerable evidence that the chemical composition of the tubers bears a direct relation to resistance to rot. Paulsen[b] claimed that varieties rich in nitrogen compounds are less resistant to disease than those rich in starch. He classed most of the early varieties in the first category and found the larger percentage of the second class to be of the late varieties. The table varieties of better quality were also of the first category.

Petermann[c] has recently made field and laboratory studies at the Belgium Experiment Station. These led him to practically the same conclusions, viz, (1) that varieties richer in amids are more liable to rot, although of superior table quality; and (2) that varieties relatively richer in starch, including several recently originated German factory varieties, are less liable to rot but are of inferior quality for table use.

Sorauer[d] has published similar conclusions, and he made more detailed statements as to his belief on this point in conversation last summer. In general, he believes that the varieties richer in protein are more liable to disease, while those richer in starch are more resistant. This probably explains his observation that the yellow-fleshed varieties, which are in higher repute in Germany for table use, are more liable to disease[e] than the white-fleshed varieties which are grown for factory purposes. His further observations in harmony with this idea are that the thicker and rougher skinned red varieties[f]—e. g., Daberche—have a higher degree of disease resistance, coupled with relatively high starch and low protein content, whereas the thin-skinned white varieties, which are more liable to the disease, have

[a] Laurent, Recherches exp. sur la mal. des plantes, Ann. Inst. Past., XIII, pp. 1–48 (1899).

[b] Biedermann's Centralbl. Agr. Chem., 1887, p. 107.

[c] Bul. Inst. Chim. et Bact. Gembloux, 70 (1901).

[d] Jahresber. d. Sondersaussch. f. Pflanzensch., XII and XIII (1902 and 1903).

[e] See evidence of this also in Jahresber. d. Sondersaussch. f. Pflanzensch., XIII, 1903.

[f] See also statement that red varieties are in general more resistant; Jahresber. d. Sondersaussch. f. Pflanzensch., XII, 1902.

proportionately less starch and more protein. As a rough empirical test he considers that if, when a fresh tuber is cut open, the flesh browns quickly on exposure to the air and the vascular bundles darken soon, it is evidence of high protein content, and therefore of liability to disease, whereas the reverse condition is evidence of probable disease resistance. Professor Sorauer also emphasized to the writer his belief in the relation of soil, manuring, or other cultural condition to disease resistance. The testimony secured elsewhere in Germany, as well as from American sources, is in harmony with these ideas so far as it goes.

While character of skin is probably a less reliable index to rot resistance than is chemical composition, yet the writer has learned of several potato experts in America, as well as others in Europe, who regard the red varieties, especially such as have a rough skin, as less liable to rot than are the white thin-skinned varieties. The Dakota Red has often been cited as an example of this class in America. Abundant evidence can be found, however, especially from English experience, of high disease resistance coupled with a thin, white skin. Breeders aiming at disease resistance need not turn from the white-skinned varieties.

CHARACTER OF STEM AND FOLIAGE AS RELATED TO DISEASE RESISTANCE.

In connection with the question of the relation of the character of the stem and foliage to disease resistance it is not safe to go far in generalizing. Mr. Lasham, potato expert and breeder with Sutton & Sons, considers that a stem that is strong, rough, and hard, almost woody at the base, is an important character if the plant is to be most highly disease resistant. The nature of the foliage is considered by others to be of greater importance, the preference being for small leaflets, rough and relatively thick rather than large and flabby. A rich dark-green is preferred to the lighter colored foliage. It seems inherently probable that the character and color of foliage should stand in close relation to the other matters which have with more certainty been shown to be related to disease resistance, viz, general vigor and capacity for starch manufacture. Those giving further attention to disease resistance may, therefore, well bear these suggestions in mind.

DISEASE-RESISTANT VARIETIES OF EUROPE.

When all the factors are considered, two important things become evident: First, that no variety will maintain its disease-resistant qualities indefinitely, losing them sooner in one locality than in another; second, that no one variety will be equally disease resistant in all countries, i. e., what is best suited to one may not be to another.

Hence we must expect much conflicting evidence regarding the same variety, especially as grown under different conditions and in different countries.

The most satisfactory way will be to summarize separately the evidence obtained in each country visited in Europe, followed by that from America.

The greatest activity in breeding for resistance occurs in Great Britain, and next to this in Germany, while France has recently shown special activity in one line. There were secured from each of these countries all the varieties of especial promise for trial in America—comprising a total of nearly one hundred. By no means all of these have an established reputation as being highly disease resistant, although all will be tested for this as well as other characters.

Experience has shown that the transference of a variety from Europe to America, or the reverse, is likely so to disturb the equilibrium of the plant that the developments of the first year are scarcely normal. At least two years are necessary for the adequate testing of imported varieties. Commercial growers should therefore make only trial plantations of any European variety until its adaptability to American conditions has been proved. Seed of the varieties secured will be under trial at several points this season and next. While it does not seem worth while to publish the full list of these in advance, the following are selected as representing the varieties or types most strongly indorsed in their respective countries for disease resistance.

GREAT BRITAIN.

More attention has been given to this question in Great Britain than anywhere else. Careful comparative observations are recorded as to the relative disease resistance of all the leading varieties. The last report of the National Potato Society specifies the following eight varieties as the best for disease resistance, named in the order of their merit. The writer appended certain facts as to the origin and characters of each. All are white skinned, white fleshed, of excellent quality, of high general vigor, and heavy yielders.

TABLE I.—*The most disease-resistant varieties of potatoes in Great Britain, as announced by the National Potato Society.*[a]

Order of merit.	Name of variety.	Originator.	When sent out.	Season.
1	Evergood	Findlay	1896	Medium late.
2	{Discovery	Sutton	1903	Late.
	{Royal Kidney	Findlay	1896	Second early.
3	Northern Star	do	1901	Late.
4	Sir John Llewelyn	Harris	1900	Early.
5	King Edward VII	Butler	1901	Medium.
6	Eldorado	Findlay	1903	Medium late.
7	Factor	Dobbie	1898	Late.

[a] Annual Report, National Potato Society, 1: 36 (1904).

Two points brought out by the foregoing table are worthy of especial note: First, the remarkable success of one man in producing four of these eight varieties, showing that there is something more than chance in their development; second, the comparatively recent origin of all. For the latter fact there is probably a double explanation: (1) The loss of disease resistance with age of the variety; (2) the remarkable activity of British potato breeders during the last few years, with the aim above all else of securing increased disease resistance.

It should be remarked that there are a number of more recent introductions which promise to rank with the best of these varieties, but they have not as yet been so fully tested.

GERMANY AND HOLLAND.

The potato-growing industries of Germany and Holland have much in common, and similar or identical varieties are used. Data were not available for making so definite a selection as in Great Britain. The following are probably representatives of the highest grade of disease resistance achieved:

TABLE II.—*The most disease-resistant varieties of potatoes in Germany and Holland.*

Name.	Originator.	Season.	Color of skin.
Mohort	Dolkowski	Late	White.
Irene	Paulsen	Medium late	Red.
Geheimrat Thiel	Richter	do	White.
Professor Wohltmann	Cimbal	Late	Red.
Boneza	Dolkowski	Medium late	Do.
Eigenheimer	(Holland)	Medium early	White.
Paul Krüger	do	Late	Do.

The first five varieties have been imported from Germany. All of these are of the white-fleshed, starch-rich type which is being developed there primarily for factory rather than for table use. They are, however, reputed to be of fair quality except, perhaps, in the case of Irene. These, like the British varieties, are of comparatively recent introduction.

The Holland varieties are of a similar type except that Eigenheimer has a yellowish-tinted flesh.

FRANCE AND BELGIUM.

The conditions are similar in France and Belgium. Neither country has varieties of much promise for trial in our Northern States. In Belgium the varieties recommended as being most highly resistant to blight and rot were the recently originated German factory types like those already mentioned, to which might be added Topas and Professor Maercker. The verdict in France was similar, Professor Maercker again being commended, along with the English varieties

Magnum Bonum and Royal Kidney. The indorsement of these comparatively late, white-fleshed, starch-rich potatoes in France and in the other continental countries is the more significant when one remembers that the chief aim with potato specialists there is to produce the yellow-fleshed potato rich in protein.

DISEASE-RESISTANT VARIETIES OF AMERICA.

Until two or three years ago no systematic attempt was recorded, so far as the writer has learned, to determine the relative resistance to blight and rot of potato varieties in America. Of course this would not imply that individual growers have not observed these differences, but they are rarely matters of record, and as a rule are based only upon limited observations. Only two or three potato-seed dealers are advertising disease-resisting varieties with any prominence this year, and these are in all cases comparatively new and little-tried sorts.

INVESTIGATIONS AT THE EXPERIMENT STATIONS.

Promising investigations have been inaugurated at several of the State agricultural experiment stations which should soon supply data for more reliable conclusions than are now possible. Woods,[a] of the Maine station, and Green,[b] of the Minnesota station, have each reported results of variety trials as to disease resistance.

Woods found a marked difference in the ability of varieties to withstand both blight and rot. As a rule the earlier varieties were soonest attacked. The variety Rustproof showed the highest degree of foliage resistance and also the least rot, viz, only a little more than 1 per cent, whereas the average of all varieties under trial was more than 30 per cent.

Green found that the loss from rot varied widely with varieties, ranging from 1 per cent in the most resistant to 40 per cent in the least resistant types. Potatoes of the type of Sir Walter Raleigh and Rural New Yorker resisted rot better than those of any other class. Of the 49 varieties tested, only two, Clay Rose and an unnamed seedling, were practically free from rot. These trials will be continued.

Observations on disease resistance have also been made by Macoun at the Central Experimental Farm, at Ottawa, Canada. He has kindly advised the writer, in correspondence, of his conclusions. The following varieties have shown especial disease resistance as judged by appearance of blight on the foliage: Holburn Abundance and Professor Maercker are most resistant, with Swiss Snowflake, State of Maine, and Rural Blush only a little less so.

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[a] Woods, C. D., Maine Exp. Sta. Report, XIX: 181 (1903).

[b] Green, S. B., Potatoes at the University Farm, Minn. Exp. Sta. Bul. 87 (1904).

WORK AT THE VERMONT STATION.

The most extensive work on potatoes has been done by Stuart, who two years ago inaugurated at the Vermont station variety trials as to disease resistance, supplemented by breeding experiments. Professor Stuart has kindly supplied the following summary of his results to date:[a]

Eight varieties were under trial in 1903—Dakota Red, Enormous, Green Mountain, Rustproof, Squire, Sir Walter Raleigh, and two of Manum's unnamed seedlings. In 1904 the same varieties were used, with the addition of June, Mammoth Gem, Minister, New Queen, State of Maine, Sutton's Discovery, nine more of Manum's seedlings, *S. commersonii* from Doctor Heckel, of France, a Peruvian variety from the United States Department of Agriculture at Washington, and four Mexican varieties furnished by Mr. C. G. Pringle. The latter included two cultivated varieties termed Monterey and Mexican, and the two wild species, *S. polyadenium* and *S. stoloniferum*. Observations have been made as to both foliage and tuber resistance. As to foliage, none was wholly free from blight, but there was a marked difference, some being quickly and entirely destroyed, while others suffered only slightly. In 1903 Rustproof headed the list in this respect, and Dakota Red was second. In 1904 those showing greatest foliage resistance were as follows, in the order of their resistance: Monterey, *S. commersonii*, *S. polyadenium*, Rustproof, Sutton's Discovery, June, Mexican, Mammoth Gem, and Manum's No. 3. Dakota Red did not equal its 1903 record.

Judged by resistance of tubers to rot, Dakota Red made the best showing of the varieties which were tested for two seasons, but there was some rot in it both years. Of those added to the series of 1904 several varieties gave a crop of tubers entirely free from rot, namely *S. polyadenium*, *S. commersonii*, Sutton's Discovery, June, and the two Mexican varieties. It is noteworthy that these are likewise the varieties which showed the least blighting of the foliage. Possibly the absence of rot is in some degree attributable to the lessened amount of infection of tubers from vines in consequence of this, although there were adjacent plants showing badly diseased foliage.

Selection.—In 1903 a few plants in the varieties grown were observed to remain green longer than the others. The tubers from these were saved and were planted in 1904 along with others of the same variety that succumbed much earlier. So far as could be noted no increased disease-resistant qualities were transmitted to the offspring of these plants.

[a] For further details see Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

In view of the limited number of varieties tested and the consequent restricted scope of observation, it would hardly be justifiable as yet to give an expression of opinion as to the probable outcome of such a line of investigation. These observations are to be continued on a much larger scale the coming season.

Hybrid and other seedlings.—Seedlings were grown in 1903 from the Mexican species supplied by Mr. Pringle—*S. polyadenium*, *S. stoloniferum*, and *S. bulbocastanum*. This number has recently been augmented by *S. verrucosum* and a wild form of *S. tuberosum*. In 1904 some of these were successfully hybridized with the cultivated potato.

While it is yet too early to say very much regarding the possibilities of developing a commercially desirable disease-resistant variety of potato through the hybridization of wild species with our cultivated varieties, there seems good reason for believing that improvement may result from such crossing, especially as to disease resistance.

In addition, a large number of seedlings of the common potato were grown in 1904. Among this number several vigorous-growing plants were noted, which remained quite green up to the time of digging. Some 50 of the more promising of these were saved for trial the coming season. Selections were based on vigor of vine, size and yield of tubers, and freedom from rot.

One of the most interesting and instructive features of the seedling experiment was the object lesson it presented of the extreme vigor of some of the plants, showing quite plainly that one of the best sources for increasing the vigor lies in the production of new varieties from seed. Proper fertilization and good tillage are also important aids in increasing the vigor and disease-resisting powers of the vine.

While the data in hand do not warrant broad generalizations, the following inferences are drawn by Professor Stuart:

(1) Some varieties are less subject to vine injury than others.

(2) Some show a greater tuber resistance to rot than others.

(3) With some there seems to be a fairly close relation between resistance of vine to disease and of the tuber to rot.

(4) Selection has not given visible increase of resistance.

(5) Hybridization and the growing of seedling plants, followed by careful selection, seem to offer a more logical method of securing disease-resistant varieties than does selection.

INFORMATION SECURED BY A CIRCULAR OF INQUIRY.

In order to secure all information possible as to the relative merits of the varieties now before the public, a circular letter of inquiry was sent recently to various experiment station officers and to about two hundred potato specialists in the United States and Canada[a] asking their opinions and the basis for them. There was a surprising lack of agreement upon any one variety as being especially disease resistant. The replies indicate several things: (1) That very few American potato specialists have up to the present time given careful attention to this question; (2) that there are few varieties in common use which have preeminent worth as disease resisters; and (3) that in so large a geographical area local conditions affecting culture and disease are so widely variant as to prevent close comparisons or broad generalizations. No less than 38 varieties were commended as showing resistance to blight or rot. Of these, 26 were commended only once, while the other 12 were favorably spoken of by two or more persons. Still other varieties were mentioned, but not with sufficient positiveness to entitle them to a place in the following list. Those named more than once, with the locality in which they were indorsed, are as follows:

TABLE III.—*The best varieties of potatoes in the United States and Canada, as reported by various experiment station officers and potato specialists.*

Variety.	Number of indorsements.	Localities in which commended.
Dakota Red	10	Canada (4); Maine (3); Massachusetts; Michigan; New York.
Irish Cobbler	5	New York (2); Maine; Ohio; Rhode Island.
Green Mountain	5	Maine (2); Massachusetts (2); Vermont.
Doe's Pride	3	Maine (2); Michigan.
Norcross	3	Maine; New York; Vermont.
White Beauty	2	Maine; Minnesota.
Professor Maercker	2	Canada; Rhode Island.
Ionia Seedling	2	New York.
Quick Lunch	2	Pennsylvania; Vermont.
Rustproof	2	Vermont.
Sir Walter Raleigh	2	Minnesota; New York.
Vermont Gold Coin	2	Pennsylvania; New York.

The following varieties were mentioned once each, the commendation coming from the locality mentioned in parentheses: American Wonder (Minnesota); Babbitt (Maine); Bonanza (New York); Boss (Vermont); Buffalo (Maine); Burbank (New York); Cambridge Russet (New York); Carmen No. 3 (Ohio); Clarke's Pride (Maine); Clay Rose (Minnesota); Crines Lightning (New Jersey); Delaware (Minnesota); Enormous (New York); Gem of Aroostook (Rhode Island); Gloria (Rhode Island); Harris Snowball (New York); Holborn Abundance (Canada); Imperial Mills Prize (Maine); Keeper (New Hampshire);

[a] The writer is indebted to the following experiment station officers for helpful advice: Professors Macoun, Canada; Woods, Maine; Rane, New Hampshire; Stuart, Vermont; Brooks, Massachusetts; Wheeler and Adams, Rhode Island; Fraser and Stewart, New York; Buckhout, Pennsylvania; Halsted, New Jersey; Selby, Ohio; Taft, Michigan; and Green, Minnesota. Much information has been secured from the replies of leading potato growers and seed dealers. It is regretted that it is impracticable to give detailed credit to these correspondents.

Professor Kuehn (Rhode Island); Million Dollar (Michigan); Orange Blossom (Vermont); Rural New Yorker No. 2 (Vermont); Scabproof (Wisconsin); Squier (Vermont); Star of the East (Maine); State of Maine (Canada); Swiss Snowflake (Canada); Virgirosa (Vermont); Westfield (Vermont); White Scotch King (Minnesota). In addition three unnamed varieties received favorable mention from Vermont.

From these reports it is observed that certain varieties like Dakota Red, Rustproof, and Keeper have very well proved powers of disease resistance, but lack other desirable characters to make them popular varieties. Several of the standard main-crop varieties are in some degree disease resistant, and doubtless owe their general popularity, in a measure, to this fact, although it has not been clearly defined. To this group belong Carmen's best productions—Carmen No. 3, Sir Walter Raleigh, Rural New Yorker No. 2, and Rural Blush—Green Mountain, State of Maine, Delaware, Enormous, and White Beauty. Irish Cobbler is highly spoken of as disease resistant, but it is a question whether this may not be in part due to its early maturity, by virtue of which it escapes the worst ravages of Phytophthora.

There is also a very promising series of new seedlings which should be carefully watched as to disease-resisting characters, among which may be especially mentioned Norcross, Star of the East, and Babbitt (Johnson Seed Company); Vermont Gold Coin (Burpee); Ionia Seedling (Dibble); Harris Snowball (Harris & Co.).

It is encouraging to learn from the replies that several of the newer German and English varieties which are reputed disease resisting in their home countries have upon trial in America made a good showing. This is evidenced by the reports from the Rhode Island and Canada stations favorable to Professor Maercker, Gloria, Professor Kuehn (German), Holborn Abundance (English), and Swiss Snowflake.

RESISTANCE TO SCAB.

It is a matter of common observation that some varieties of potatoes are more liable to scab than are others. Reference has been made earlier in this publication to conclusions to this effect reached in Germany. So far as known the only American publication recording the results of comparative trials as to scab resistance is that made by the Vermont Agricultural Experiment Station in 1901–2.[a] Thirteen varieties were tested in 1901 and fourteen in 1902 in soil badly infested with scab germs. While all showed some scab, there was a considerable difference in the amount. Sir Walter Raleigh made a good showing both years, but an unnamed seedling sent by Mr. A. E. Manum, his No. 56, was more highly resistant. These trials established the writer's confidence that still more resistant strains may be secured by

[a] Jones, L. R., and W. J. Morse. Vermont Exp. Sta. Report, XV: 225 (1902).

breeding and selection. Prof. William Stuart, of the Vermont station, has undertaken this work in connection with the development of resistance to blight and rot.[a] He has made further trials during the last two years, but without conclusive results as yet.

A request for information as to relative scab resistance was inserted in the circular of inquiry, already referred to, recently sent to American potato specialists. Most of the replies to this question were negative in character, but a number gave interesting information, some of which is especially pertinent. The strongest evidence as to scab resistance comes from Mr. Hiram Presley, of Port Huron, Mich., a potato specialist, who has tested hundreds of varieties during the past thirty years. He commends the Cambridge Russet as practically exempt from scab. Mr. Frank Paddock, of Perry, N. Y., gives like evidence.

Carmen No. 3 is highly spoken of as scab resisting by several growers in Ohio, New York, and Vermont, but one Michigan correspondent condemns it.

American Giant receives strong indorsement from Freehold, N. J., and vicinity; Salzer's Scabproof from Wisconsin, and Aurora from Vermont. Favorable reports come from New York regarding Sir Walter Raleigh and Irish Cobbler, and from Canada regarding McIntyre.

The following were each commended by one correspondent from the localities mentioned in parentheses: Best (Maine); Doe's Pride (Maine); Early Freeman (Ontario); Keeper (New Hampshire); Seneca Beauty (Michigan); Squier (Vermont); White Beauty (Michigan); White Elephant (New Jersey); White Scotch King (Minnesota).

On the other hand, the Early Ohio and some of its seedlings are condemned as especially liable to scab. Early Rose, Bliss Triumph, and Beauty of Hebron are also reported to scab badly.

It is encouraging to note that in some cases the same variety is rated as in a high degree resistant to both diseases, the scab and the late-blight and rot. A similar coincidence will be found if a comparison is made of the lists of German varieties showing resistance to the several diseases discussed earlier in these pages, and the same thing was observed in some degree with the English varieties.

This indicates that the attributes which give power of resistance against one disease are not incompatible with those operative against another. Indeed, it is not unlikely that the general characteristics of disease resistance may prove to be similar or the same for these various maladies. If so, it will prove the easier to secure the model potato, which, while possessing that which is desirable in quality and productiveness, shall, in addition, show the highest degree of resistance to the various diseases. This is an ideal worth striving for.

[a] Vermont Exp. Sta. Bul. 115, p. 139.

SUMMARY.

The aim of this bulletin is to present in concise form what is known about disease resistance of potatoes. Much of this information is from European sources.

Certain minor diseases of obscure nature, but apparently nonparasitic, are first considered—the internal brown spot, filosité, and leaf-spot. Among remedial measures for each is the selection of resistant varieties.

Scab diseases of tubers are in most, and perhaps in all, cases of parasitic origin—fungous or bacterial. Apparently the variety of these is greater in Europe than in America, but the severity is less in Europe. It is undecided to what extent the American type of scab occurs in Europe, so a close comparison of conditions and remedies is not practicable. In Germany certain varieties are known to be more scab resistant than others, among them being Richter's Imperator, Professor Wohltmann, and Irene. The same is true in America, Cambridge Russet leading the list, so far as is known. Other American varieties showing a considerable degree of resistance are Carmen No. 3, American Giant, Sir Walter Raleigh, and Irish Cobbler. Scabproof and Aurora are also highly commended for scab resistance.

Various stem diseases of the potato are known. The commonest type in Europe is termed blackleg (Schwarzbeinigkeit), a bacterial disease. It is not known to occur in America, but it resembles certain maladies which do occur here and which are as yet imperfectly understood. Varietal resistance to blackleg is not fully established, but apparently Dabersche and certain similar thick-skinned, starch-rich late varieties are more resistant than thin-skinned, starch-poor early varieties of the Rose type. Factor and Up-to-Date showed a considerable degree of resistance to blackleg in England. La Czarine and other varieties are reported to show resistance to a bacterial stem disease in France.

The late-blight and rot due to the fungus *Phytophthora infestans* occurs more commonly in Europe than in America. Attention has been given for many years to relative varietal susceptibility to this disease, especially in Great Britain and in Germany. Varieties of superior disease resistance are known in both countries, and a number of the most promising from these and other European sources have been imported for trial.

The following statements are tentatively formulated as to the nature of resistance toward blight and rot and the character of the varieties exhibiting it:

(1) Disease resistance in potatoes is relative, not absolute, no variety known being wholly proof against late-blight and rot.

(2) It seems related to general vegetative vigor, and is therefore in a measure dependent upon cultural and developmental conditions and tends to decrease with the age of the variety.

(3) It can be restored by originating new varieties from seed, especially of hybrid origin. Not all seedlings show superior disease resistance.

(4) The use of other species of tuber-bearing Solanums for hybridizing offers some promise, but no practical results have yet been secured.

(5) Possibly the disease resistance in established varieties can be improved by selection, but this has not been proved.

(6) Early varieties may escape the disease by maturing before it becomes epidemic, but when similarly exposed they are as a class less resistant than late varieties.

(7) The source of seed tubers is a matter of importance, northern-grown seed giving plants of superior disease resistance in Europe. Seed from a crop that was not too highly fertilized is probably preferable. Possibly tubers are better for seed purposes if dug before they reach full maturity.

(8) High fertilization, especially with nitrogenous manures, lowers the power of the plant to resist both blight and rot.

(9) Varieties relatively rich in starch are more resistant to rot; those richer in protein are more susceptible to it.

(10) So far as skin characters are an index, the red varieties with thick and rough skin seem more resistant as a class than the thin-skinned white varieties.

(11) So far as stem and foliage characters are concerned, the evidence favors the stem that is hard, rough, and rather woody at the base, and the leaf that is small, somewhat rough, and dark colored.

The varieties rated highest as to disease resistance in England are Evergood, Discovery, Royal Kidney, Northern Star, Sir John Llewelyn, King Edward VII, Eldorado, and Factor.

In Germany and Holland the following represent the best types: Mohort, Irene, Geheimrat Thiel, Professor Wohltmann, Boncza, Eigenheimer, and Paul Krüger.

In Belgium and France no improvement as to disease resistance has been made over the best English and German types.

In America, trials as to disease resistance have been conducted at some of the experiment stations, notably in Vermont, where experiments in breeding and selection for increased resistance are under way. These results have been correlated with information recently secured by a circular of inquiry addressed to a large number of potato specialists in the Northeastern States and in Canada. From these it appears that a wide variation is shown in disease resistance among the varieties now in cultivation in America, but that no one variety is preeminent.

Among those which have been widely tested, the following deserve mention as of the resistant class: Dakota Red, Rustproof, Irish Cobbler, Sir Walter Raleigh, Doe's Pride, and White Beauty. Certain European varieties of the disease-resistant type seem to retain that character when grown in this country, e. g., Professor Maercker and Sutton's Discovery. There is much of promise in certain new varieties under trial at the Vermont station. Several new sorts of reputed disease resistance have recently been placed on the market by American seedsmen, e. g., Harris's Snowball, Dibble's Ionia Seedling, Burpee's Vermont Gold Coin, and Johnson's Norcross, Star of the East, and Babbitt. Those having opportunity should carefully observe the relative disease resistance of these and also of other new varieties.

The evidence at hand seems to justify the hope that the coordinated efforts of potato specialists working from both the practical and the scientific standpoints may soon result in the development of varieties of potatoes combining general excellence with a high degree of disease resistance. All who can do so are urged to aid toward the accomplishment of this end.

O

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 88.

B. T. GALLOWAY, *Chief of Bureau.*

WEEVIL-RESISTING ADAPTATIONS OF THE COTTON PLANT.

BY

O. F. COOK,

BIONOMIST IN CHARGE OF INVESTIGATIONS IN THE AGRICULTURAL ECONOMY OF TROPICAL AND SUBTROPICAL PLANTS.

ISSUED JANUARY 13, 1906.

WASHINGTON:

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1906.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 26, 1905.

Sir: I have the honor to transmit herewith a report on "Weevil-Resisting Adaptations of the Cotton Plant," and to recommend it for publication as Bulletin No. 88 of this Bureau. This report has been prepared by Mr. O. F. Cook, bionomist in charge of investigations in the agricultural economy of tropical and subtropical plants. It contains an account of his observations and experiments which show that some of the varieties of the cotton plant have definite weevil-resisting characters. The establishment of these facts opens new and unexpected lines of approach to cultural solutions of the weevil problem.

The investigation of cotton referred to in this report was begun in March, 1904, through the Laboratory of Plant Breeding, there having been set aside for it from the emergency cotton boll weevil appropriation a part of the funds which had been devoted to the breeding of weevil-resistant cotton. The existence of a field culture of cotton in the presence of the boll weevil had been ascertained by Mr. Cook during a visit to Guatemala in 1902, and it was hoped that the immunity of the cotton might prove to be due to some weevil-resistant quality.

The first result of detailed observations was the discovery of the weevil-eating kelep or so-called Guatemalan ant, which has been made the subject of previous reports through the Bureau of Entomology. It now appears that the usefulness of this insect is not limited to the boll weevils which it catches and kills. By making a regular field culture of cotton possible in the presence of the boll weevil it has contributed in an important manner to the development of the weevil-resisting characters here described. The cotton plant, it seems, has been greatly modified in protecting itself against the ravages of its insect enemy. Not only has it attracted the kelep to its service and developed other means of defense which are more direct, but even the lint, on the peculiar character of which the commercial value of the crop depends, appears to find its chief use to the plant in excluding the weevil larvæ from the seed. Our Sea Island and Upland varieties have been raised for long periods in regions where the boll weevil did not exist and, as was to have been expected, are largely lacking in protective features. The Kekchi cotton, on the other hand, which has continued its development in a weevil-infested region under the protection of the keleps, has by far the largest number of weevil-resisting characters.

The fact that weevil-resisting adaptations really exist, as shown in numerous instances in the present report, emphasizes the necessity of a thorough study of our cultivated cottons for the purpose of taking advantage of any and all protective characters.

It is possible, as Mr. Cook suggests, that the Guatemalan variety of cotton which he has discovered, and which has such a surprising number of weevil-resisting adaptations, may not prove suited to cultivation in the United States, but even in that case the value of the present paper on weevil-resisting characters would not be diminished, for it will serve as a help to all who may engage in seeking and developing such characters in the types of cotton now cultivated in our country.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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WEEVIL-RESISTING ADAPTATIONS OF THE COTTON PLANT.

INTRODUCTION.

The fact that Central American varieties of cotton have developed weevil-resisting adaptations has already received preliminary notice.[a] A third visit to Guatemala, in the spring of 1905, has given opportunity for further studies of the protective characters of the native varieties and for comparing them with the types of cotton now cultivated in the United States. For this purpose plantings of Upland and Sea Island varieties have been made in Guatemala, and as the season advanced other tests of the Guatemalan and United States varieties were arranged under very different climatic conditions in Texas and at Washington.

These opportunities of comparative observation have revealed a series of protective adaptations of such number and nicety as to furnish a unique and well-nigh incredible instance of selective development. The statement of the former paper may be repeated with emphasis, that the presence of the weevil-eating kelep has enabled the Indians of eastern Guatemala to maintain since very ancient times field culture of cotton in the presence of the weevils, with the result that there has been developed a dwarf, annual, short-season variety with numerous features which, in the absence of sufficient numbers of keleps, afford material assistance in protecting the crop against the ravages of the weevil.

Whether this Guatemalan cotton can be made of direct use in the United States or not, it demonstrates the existence in the cotton plant of weevil-resisting characters. The new variety has lint of good length and quality, so that its utilization in the United States depends upon its adaptability to our climate and methods of culture.

As already explained in publications devoted to the kelep, the weevil-eating propensities of that insect were discovered in 1904 during a visit to Guatemala which had been undertaken in the hope of finding a weevil-resisting variety of cotton. It had been observed

[a] Cotton Culture in Guatemala. Yearbook of the United States Department of Agriculture for 1904, 475–488; Science, N. S., 20: 666–670, November 18, 1904.

two years before that a field of dwarf cotton cultivated by the Indians did not suffer from the boll weevils, though these pests were abundant on a "tree cotton" a short distance away.

The kelep afforded an entirely unexpected and yet very striking explanation of the fact that cotton was being grown as a regular field crop in a region which had probably been infested with weevils for many centuries, if it were not, indeed, the original home of the species. That there was an insect in existence specially qualified by structure and habits to attack, disable, and devour the boll weevil, was welcome news in the United States, and in accordance with cabled instructions from the Secretary of Agriculture numerous colonies of the keleps were brought home and colonized in the cotton fields of Texas.

The finding of the kelep explained the failure of the weevils to prevent cotton cultivations in eastern Guatemala, and seemed at first to diminish the prospects of weevil resistance in the cotton itself. Nevertheless, the intention of studying Guatemalan varieties of cotton and the cultural methods in use in that country was not abandoned, and the results are not without bearing on the original question of the causes of the apparent immunity of the Guatemalan cottons, and also upon the more practical question of securing cotton varieties and cultural methods by which the injuries of the boll weevil in the United States may be reduced to a minimum.

The Guatemalan cotton protected by the keleps is a genuine Upland variety, very early and productive, with a fiber of good length and texture, as already stated. In addition to features which directly favor the keleps, it has many other qualities which may render it useful, even without its insect guardians. In former reports it has been compared with the very early Upland varieties, such as King and Parker; but comparative tests made in eastern Guatemala show that the native variety, which it is proposed to call *Kekchi*, represents a very distinct type of this important cultivated plant. It belongs to *Gossypium hirsutum*, the Upland species or series of varieties, in the sense that it is not a Sea Island, Egyptian, or Kidney cotton,[a] but it is distinctly more different from any of the Upland varieties now cultivated in the United States than these are from each other. It has not been ascertained that the Kekchi cotton in its

[a] The Sea Island cotton is so called because cotton of this type is cultivated on the Sea Islands of South Carolina, long famous for the excellence of their product. The Sea Island cotton came originally from Barbados, whence also its botanical name, *Gossypium barbadense*.

Upland cotton gained its name as a means of distinguishing it from the Sea Island, being cultivated in the interior, or "upland," districts of the Southern States. The Upland type of cotton was recognized as a distinct species by Linnæus under the name *Gossypium hirsutum*, but many subsequent writers present form is suited to cultivation in the United States, but it has, without any doubt, new and significant characters which must be regarded as factors in cultural solutions of the weevil problem. (Pl. II, fig. 1.)

Although cotton was not found to be planted as a regular field culture in any localities in Guatemala where the keleps do not exist, small quantities are produced in the interior plateau region about Rabinal by what may be called dooryard cultivation, and these, too, have suggested cultural factors and expedients which may not be without practical bearing.

The present paper can claim to make only a beginning in the bionomic study of the question, but it shows at least that the weevil problem has many avenues of approach on the botanical side.

The cotton of Guatemala and neighboring countries has maintained an existence, at least, in the presence of the weevils, and has suffered an acute natural selection with reference to its ability to protect itself against the weevil or to secure the assistance of allies, such as the keleps. That no commercial cotton crop is raised or exported from such districts does not prove that they are unworthy of scientific investigation, or that they are not likely to yield materials and suggestions of practical value in meeting the invasion of weevils which is now so serious a menace to the cotton industry of the United States.

Some of these weevil-resisting adaptations have been of use in securing for the cotton the assistance of the keleps. There are others which, if properly utilized, might render these interesting insects unnecessary. Tropical America has been serving for thousands of years, evidently, as a laboratory for this class of experiments. Texas was invaded only yesterday—a decade ago. Now that we are forced to engage in the strife, the first preliminary should be, it would seem, to take stock of the weapons which nature has forged.

The present report was planned and partly written before the discovery of the true nature of the best of the weevil-resisting adaptations—the proliferation of the tissues of the buds and bolls. Some of the characters here described may have no value except as suggestions, but taken together they may be of interest as an outline of the results of the very long period of selection to which the presence of the boll weevil has subjected the Central American varieties of the cotton plant.

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have erroneously confused it with the Old World species *Gossypium herbaceum*, which is not cultivated in the United States, though often so reported.

The Egyptian and Kidney cottons belong to the Sea Island series, and are of American origin. The Kidney cottons seem not to have been cultivated on a commercial scale, but they are very widely distributed in tropical America. The name refers to the fact that the seeds of each compartment of the boll are grown together into a small compact mass, in shape suggesting a kidney.

SELECTIVE INFLUENCE OF THE BOLL WEEVIL.

The boll weevil exerts a most prejudicial effect upon the cotton crop, but, unlike most parasites, it does not cause disease or debility in its host plant. The young buds and bolls are merely pruned away, as it were, the purposes of the weevil being the better served when the plants remain vigorous and continue to produce more buds and bolls, in which more eggs can be laid and more larvæ brought to maturity. Nevertheless, if no bolls are allowed to develop no seed can be set. The fate of the cotton crop in wet seasons in Texas shows that without some form of protection the plant would have been extinct long since in all localities reached by the boll weevil.

The long contact between the boll weevil and the cotton plant in Central America has given ample opportunity for the latter to profit by the selection which the insect itself has provided. Every difference by which a cotton plant was able to resist or to avoid the weevil and thus ripen more seeds than its fellows would give it a distinct advantage, quite as if the selection were consciously carried on by the planter or the plant breeder. The case is different from that of the recent improvements of many of our cultivated plants by selection for the increase of some particular quality already existing. Such improvements can often be made appreciable, or even highly valuable, in comparatively few years, but under the desultory Indian methods of cultivation long periods of time would be required for the origination and accumulation of such characters as these protective adaptations.

Climate and other local conditions must also be taken into consideration. An adaptation which would be effective in one set of climatic conditions may be of little use, or even a positive disadvantage, in others, as, for example, the prompt shedding of the parasitized buds. In a dry region the falling of a bud to the superheated, sun-baked earth insures the death of the weevil larva, either by the heat directly or by the complete drying out of the tissues in which the larva is embedded. In the moist districts of eastern Texas, however, this expedient is quite ineffective, the larvæ often developing even better when the buds fall off and lie on moist soil than when they remain attached to the plant.

It need not surprise us to learn also that the weevil-resisting adaptations shown by the Kekchi and other cotton varieties of Central America are shared, to some extent, by those already known in the United States, since the whole Upland type of cotton appears to have been, originally, a native of the Central American region. Varieties which reached the United States from Mexico and the West Indies may, however, have had little or no contact with the weevil for many centuries, while in Central America the struggle for existence has remained severe and continuous down to the present day.

It is now known that in the plateau region of Mexico the long dry season effectually excludes the weevil, so that varieties of cotton from the Mexican highlands, instead of being weevil-proof, as sometimes represented, may have no immunity whatever when brought into the much more moist climate of the cotton belt of the United States.

The Kekchi cotton of Guatemala, on the other hand, has to a much greater degree than any of the varieties now grown in the United States the very qualities which experiment has shown to be effective for the mitigation by cultural means of the injuries inflicted by the boll weevil. That it has, in addition, other features not possessed by our United States varieties, or not hitherto interpreted as weevil-resisting adaptations, need not be looked upon as anything outside the normal order of nature, but is entirely in accord with what appears to be the biological and agricultural history of the cotton plant in Central America.

GENERAL PROTECTIVE CHARACTERS.

DWARF HABIT AND DETERMINATE GROWTH OF KEKCHI COTTON.

Although Guatemala is a tropical country and the climatic conditions are suitable for the growth of cotton throughout the year, the Kekchi cotton is cultivated only as an annual, and is smaller and more determinate in its habits of growth than the Upland varieties now known in the United States. It soon attains its full height, and after a crop of bolls has set on the lower branches there is a definite tendency to cease growing or producing new buds. The later upward growth of the plants seems to be supplementary, as it were, to the formation of the bolls; often there appear to be no more flowers formed, and many of those which come seem to be undersized, as though the plant were really mature and were approaching the natural termination of its existence. Our Upland varieties, on the contrary, continue to produce throughout the season hundreds of small squares on each plant which serve only as breeding places for the weevils.

The explanation of the high development of these short-season qualities of the Kekchi cotton is doubtless to be found in the custom of the Indians, who pull up the cotton as soon as the bulk of the crop has ripened to make room for the peppers, which are always planted with the cotton. For the Indians the peppers are an even more important crop than the cotton, so that when the time comes for clearing away the cotton they do not wait for the plants which may have delayed maturity. Late bolls, even, would never come to maturity or furnish seed for planting. The result has been a very long-sustained selection for early bearing and uniform ripening of the crop. Some of our earliest Upland sorts may begin blossoming as soon as the Kekchi, but they show far less tendency to determinate growth.

The development of earliness has been assisted, no doubt, by the climatic conditions which prevail in eastern Guatemala. The rainy season oftens begins before the cotton harvest is completed, so that the later bolls are very likely to become diseased, or, if they reach maturity and open, the lint is often beaten to the ground and made too dirty for use in spinning and weaving. In either case the seed is not harvested.

The Indians believe that even if they did not pull the cotton up it would not become a perennial, but would die out completely, even to the roots, during the rainy season. Seeds scattered accidentally in the plantation at harvest time are rotted by the rain and do not germinate, so that little or no volunteer cotton is carried over from one season to another.

If the Kekchi cotton were the only variety planted in Guatemala and the weevil had there, as in the United States, no other food plant than the cotton, the insects might all die off between April or May, when the cotton is pulled up, and October, when the next crop is planted. There is, however, enough perennial "tree" cotton in the country to keep the pest from becoming exterminated. Moreover, the question of additional food plants in Guatemala is still open.

The importance of securing short-season varieties of cotton for the United States can hardly be overestimated, since, as already intimated elsewhere,[a] there is no longer any reason to hope that the more severe winters of the northern districts of the cotton belt will give any protection against the weevils.

As long as the weevil was confined to the southern part of Texas, where the cotton could survive the winter, the destruction of the plants as soon as possible after the maturing of the crop was the only measure calculated to seriously reduce the number of weevils. It was also essential to plant cotton as early as possible in the spring to avoid the weevils bred on the volunteer, or hold-over, cotton which negligent planters had left in the ground. The extension of the pest farther north and the possibility of securing cotton varieties with determinate habits of growth introduce several new considerations. The hold-over cotton is eliminated from the problem, but in the more northern latitudes, where the cold comes earlier and the temperature remains lower throughout the winter, it may often happen that there will be no period in which the weevils can be reduced by starvation, unless time can be secured for this purpose in the spring by the planting of short-season varieties of cotton.

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[a] Cook, O. F., 1905. Progress in the Study of the Kelep, Science, N. S., 21: 552.

Instead of colder winters being unfavorable to the weevils, there is every probability that cold sufficient to keep them in a torpid, inactive condition will preserve their noxious lives much better than warm and pleasant weather, which enables them to continue active and thus deplete their vital energies. The winter of 1904–5 was one of unprecedented severity in Texas, both in absolute temperature and in continued cold and wet, and yet the weevils were able, in many localities, to infest heavily the early plantings of cotton to a far greater extent than in previous years.

The farther north the locality the more will the efficiency of cultural methods of avoiding the boll weevil depend upon the planting of quick-maturing varieties of cotton. It is true that in a favorable season the cotton planted first would set its crop soonest, and thus escape a part of the damage suffered by adjoining fields of later growth, the earlier fields breeding weevils to attack in larger force the later plantings. But instead of insuring a decrease of the number of weevils in a given locality and checking the propagation of the pest, very early planting by a part of the farmers of a community might tend, after an early fall and a cold winter, to the opposite result, since it would save the lives of large numbers of weevils which would otherwise perish before the cotton, if sown a few weeks later, would be large enough to furnish the weevils with food. Dr. Herbert J. Webber states that planting could probably be deferred even to the middle of June without impairing the chances of a crop as large as that which can be obtained in the presence of the weevil.

There would seem to be little object in planting cotton where the weevils are as abundant as in some places in southern Texas in the spring of the present year, 1905. Nevertheless, the opportune occurrence of a few weeks of dry weather was able, even then, to greatly improve the prospects of a crop. No matter how bad the weevils, the planter still has hope that dry weather may come and save his crop from being a total loss. As long as indeterminate varieties are planted this possibility will always make it difficult to carry out a general policy of early destruction of the plants.

Some of our Upland varieties of cotton are early enough in the sense that they begin flowering and fruiting very promptly, but unless the season is very dry they will produce a continuous succession of buds until they are pulled up or frost cuts them off. The earliness of practical value is not to be shown merely by the date of flowering, but by the date of ripening the crop of bolls and of ceasing to form new buds in which weevils can breed. If the improvements noted in other parts of this report can be realized in practice, it would no longer be necessary to destroy the cotton plants in order to put an end to the breeding of the weevils. It would then become practicable and desirable to regulate planting so as to bring the growing period of the cotton at the most favorable season for a rapid development of the crop, and thus to give the weevils the shortest possible opportunities for breeding.[a] If the fall and winter had favored the survival of many weevils, planting could well be deferred until the weevils had disappeared, a fact which could be ascertained by starting early a few observation plants from which the weevils could be carefully picked by hand as long as they continued to appear.

The extent of the mortality of the boll weevil in the spring has been well shown in the investigations reported by Mr. W. D. Hunter on the effects of applying Paris green to the very young cotton as a means of destroying the weevils which had lived through the winter. Numerous dead weevils were found in the poisoned fields, but equal or even greater numbers were found in those to which no Paris green had been applied, and the conclusion was drawn that a large proportion of the weevils, which pass the winter in a state of hibernation or torpidity induced by the cold, perish through starvation or other causes in the spring, after the weather has become warm enough to render them active again and permit them to renew their search for cotton plants on which to feed and lay their eggs.[b]

It is easy to understand, too, that after the weevils have been reduced by the cold to a condition of inactivity involving an almost complete suspension of the vital functions, the lack of food and the lapse of time can make very little difference with them. Starvation comes much quicker during warm weather while they are going actively about, so that it is the autumn and spring which must be relied upon to reduce the numbers of the weevils rather than the cold periods of the winter months. Messrs. Hunter and Hinds have also noted as significant the fact that of weevils captured at the middle of December, 15.8 per cent passed the winter successfully, while of another lot captured a month earlier, only 1 per cent survived. Their conclusions were as follows:

> It is evident that the weevils which pass the winter and attack the crop of the following season are among those developed latest in the fall and which, in consequence of that fact, have not exhausted their vitality by oviposition or any considerable length of active life.

With these facts in mind it becomes plain that no objections need be raised on general biological principles to the introduction of new

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[a] A determinate variety of cotton would also avoid the cultural disadvantages incidental to very early planting, for if the weather happens to turn cold and wet the cotton is often either killed outright and has to be replanted or, what is still worse, it becomes permanently stunted and unproductive.

[b] Hunter, W. D., 1904. The Use of Paris Green in Controlling the Cotton Boll Weevil, Farmers' Bulletin No. 211, U. S. Department of Agriculture.

quick-maturing varieties of cotton from tropical countries on the ground that cold weather will exclude them from the United States. The early spring is the only time in which they will be likely to encounter adverse conditions in this respect, and if varieties can be secured which are able to mature a satisfactory crop in a short season, these quick-maturing qualities will far more than compensate for any lack of ability to withstand cold weather in the early spring.

The Kekchi cotton may prove, however, to be quite as tolerant of cold as the other Upland varieties now cultivated in the United States.[a] In its native country it is planted in October and grows throughout the winter months in mountain valleys where temperatures of between 40° and 60° F. are not infrequent. (Pl. I.)

VARIATIONS IN THE KEKCHI COTTON.

Very great diversity of size, habit of growth, and other features exists in the Indian cotton of the vicinity of Secanquim and Cajabon. The plants cultivated by Mr. John H. Kinsler on the United States system were also very different from any grown by the Indians, being much more robust and compact than in the more crowded native fields. The spreading lateral branches and low, compact growth of the Kekchi cotton, as shown in Plate II, figure 1, might have cultural disadvantages if these tendencies were to be maintained in regular field cultures. Such, however, is not likely to be the case. When growing closer together the plants are more upright and less leafy below.

To what extent the differences observed thus far represent varietal characters can scarcely be determined without a field test of the apparently different strains, side by side. The broken, precipitous nature of the country renders it impossible to rely upon comparisons of the conditions of the different fields.

The conservative agricultural habits of the Indians would tend to the continued planting by one man or family of the same seed for long periods of years, which might well conduce to the formation of separate strains. The low germinating power of the seed may possibly be due to such inbreeding, though it is more likely that it deteriorates because of the humidity of the climate.[b] Nevertheless, our experiments were sufficient to prove that even among plants grown from seed raised by the same Indian there were very appreciable

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[a] This was shown to be a fact before the report was printed. See p. 18.

[b] The Indians appreciate the fact that the cotton seed does not germinate well. They are accustomed to plant six seeds together, from which two or three plants usually reach maturity, often with one or two insignificant dwarfs underneath. The yield per plant in these crowded fields is naturally very small, but the larger individuals often bear from 20 to 30 bolls. At Rabinal from 6 to 10 plants in a cluster is the rule, the product of the individual being still further reduced.

differences, sufficient to have a very practical bearing upon the question of securing strains having the special characters required in the United States. Indeed, there was nearly as much diversity among the Guatemalan plants as among all the Upland varieties, though these were in some cases unusually variable, as a result apparently of the transfer to new and unwonted conditions of climate and soil.

The usual number of locks or cells in a boll of the Kekchi cotton is four, but bolls containing three or five are not uncommon; often they are on plants which have otherwise the usual number.

There is also considerable diversity on the same plant in the shape of the bolls, some, for example, remaining quite conical and pointed, while others round out to near the apex. One plant was observed in which the bolls were very nearly spherical. The involucre was also unusually large. The plant had an unusually deep red or blackish color, and was distinctly more vigorous than its neighbors, as often happens with mutations.

It is not at all probable that a close selection has ever been practiced by the Indians, so that a wide diversity of mutational characters may be expected when once the variety has been brought under careful observation.

The stems and petioles of the Kekchi cotton plant are dark red, or at least spotted with red, and the leaves turn dull red with maturity. The bracts and bolls are green when young, but with age and exposure to the sun become more or less tinged or spotted with red.[a] The outer involucral nectaries also turn deep red, especially the two upper ones, even while the buds are still very young. The great majority of the leaves are simply three-pointed, but many of them have an additional smaller lateral point on each side near the base.

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[a] One plant at Secanquim showed a very decided instance of variegation with white and red, though the latter color might have been due to an increased tendency of the white portions to take the red discoloration common on normal leaves. The lower branches of the plant show only normal green coloration, and a part of the upper branches is also normal in color and size, and with fruits rather above the average size. The variegated branches do not regularly alternate, nor do they come all from one side, but they might still have connection with the phyllotaxy. There seem to be two stages of the variegation, a white and a light greenish-yellow; the latter may belong only to young leaves. Both are distributed with the utmost irregularity, and both may affect the upper surface of the leaf while the under surface remains green, or vice versa, though the latter condition is much less common than the former. The etiolated portions of the leaves, involucres, and fruits do not attain the full size of the corresponding normal organs, so that the parts affected are more or less unsymmetrical, though where the variegation is slight this result may be apparent, or if it be complete the symmetry is not affected. Except for two premature bolls the seed was not ripe, and these were from the normal lower part of the plant.

EFFECTS OF GUATEMALAN CONDITIONS ON UNITED STATES VARIETIES.

The behavior of the United States varieties under changed climatic conditions in Guatemala is interesting in several ways. The "King," which in the United States appears to resemble the Guatemalan variety most nearly, here loses most of its distinctive characters and breaks up into a variety of types, many of which would not be recognized in the United States as at all related to King. One of these is a "limbless" or "cluster" variety, which for a time appeared to Mr. Kinsler as a very promising new sort. It was smaller and distinctly earlier than King plants of the normal type, and seemed likely to be more productive, but only a few bolls developed, and these proved to be of abnormal form, with deep grooves or notches across the tip.

One of the features in which the change of climate seems to produce remarkable effects is that of earliness. The King, which in the States is looked upon as the earliest variety, is found by Mr. Kinsler to be somewhat exceeded in this respect by "Allen," which has not been looked upon as a competitor. The Sea Island and Egyptian varieties, too, prove to be much more precocious than was expected. Some of them begin flowering almost as soon as the Upland sorts. The Rivers variety of Sea Island cotton, in particular, was very early, robust, and productive, distinctly ahead of the near-by Jannovitch, though not so tall.

ACCLIMATIZATION OF KEKCHI COTTON IN THE UNITED STATES.

It was not unexpected that the Kekchi cotton would show a change in its method of growth on being transferred to Texas. New conditions of soil and climate often cause notable disturbances of the organism. Some of the tropical cottons planted in Texas for experimental purposes have grown into large bushes without showing the slightest tendency to produce fruit or even flowers. In 1904 cotton from Peru planted at Victoria, Tex., grew most vigorously to a height of 18 feet, but remained quite sterile. It is possible, however, that even in their own country these were what are called "tree cottons," which usually grow to considerable size before beginning to flower. Letters from Mr. Kinsler, in charge of our experimental plot at Pierce, Tex., relate a similar behavior on the part of the Kekchi cotton, which at that place has grown large and rank; but toward the end of July it was beginning to fruit, so that the ripening of seeds in Texas is to be anticipated.

Two or three years will probably suffice to diminish this abnormal vegetative vigor, due to the stimulus of the new conditions, and permit a return to the normal earliness of the variety. Similar results have attended the introduction into Texas of Mexican varieties of corn. The plants grew 14 feet high the first year and bore very little seed; in the following seasons they became smaller, earlier, and more productive.

The probability that the Kekchi cotton can be grown even at the northern limits of cotton cultivation is strongly indicated by the results of an experiment at Lanham, Md. (1905). In favorable seasons cotton can be grown to maturity as far north as Washington, but the present year has been very unfavorable, the summer months being for the most part cool and rainy, and with several intervals of unusually low temperature. The cotton, which was planted intentionally in rather poor soil, to avoid too great luxuriance of growth, germinated very badly and remained small and stunted until August. The Kekchi rows have, however, produced more plants, and more of these have grown to maturity than with any of the domestic or foreign varieties included in the test. The Kekchi type has also remained more constant in Maryland than did the King variety when grown in Guatemala, though there are obvious differences between individual plants. Two plants in particular were found to have numerous buds, some ready to blossom before any of the others had begun to show signs of productive maturity.

It might be feared that a variety newly introduced from a tropical country would be likely to suffer more from low temperatures than our United States varieties, but this seems not to be the case with the Kekchi cotton, even when the cold is carried down to the freezing point. There were light frosts in Lanham about the end of September, just sufficient, as it happened, to do appreciable damage to cotton in low ground. The Kekchi plants did not suffer more than the American Upland varieties. The difference, if any, was in favor of the Kekchi cotton, perhaps on account of the closer foliage.

Many annual plants, even those of tropical origin, are most vigorous and productive at their northern limits of growth, not, as has been supposed, because this is the coldest part of their range, but because the heat and sunlight, necessary to plant growth, are greater during our summer months than can be secured in a similar time in the Tropics, owing to the much longer days of our northern latitudes.[a]

The Pachon cotton from western Guatemala, though it has grown taller at Victoria, Tex. (52–79 inches), than at Lanham, Md. (30–40 inches), has produced numerous buds in Maryland, but none in Texas. The Kekchi cotton also appears to have been more productive at Lanham than at Victoria, to judge from a recent partial report from Mr. Argyle McLachlan.

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[a] Cook, O. F., 1902. Agriculture in the Tropical Islands of the United States, Yearbook of the United States Department of Agriculture for 1901, p. 367.

It is very possible, therefore, that if the Guatemalan variety is able to thrive in the United States it will ripen its crop here in even less time than it requires in Guatemala, and this is rendered the more probable from the fact that in Guatemala the cotton has to be planted in the rainy season and is obliged to exist for the first few months under conditions of excessive moisture. The dry season of this district is short and uncertain. For two years, 1903 and 1904, the Indians were unable to burn their clearings, so that the corn crop failed and the community was reduced to the verge of starvation. The cotton crop, in normal seasons, is said to be planted in the latter half of October and ripens in March.

The introduction of a dwarf, short-season cotton would require, of course, something of a change in cultural methods in the South, since the smaller size of the plants will need to be compensated by closer planting. It will be readily understood that to secure the setting of a crop in the minimum of time as many plants as possible should be set at work. The question is not that of the maximum product for each plant or for a given area. With the weevil in the field the time factor becomes of chief importance.

Little is gained in reality by the rank growth of the larger varieties; in fact there is a distinct loss in earliness, even though some bolls are set in the early part of the season. If these are overshadowed and starved by the continued upward growth, the crop is delayed and the lower part of the plant becomes, on the whole, distinctly unproductive.

EARLY BEARING FACILITATED BY LONG BASAL BRANCHES.

The earliness of the Kekchi cotton is made possible by the fact that the bolls are nearly all borne at the base of the plant, the upper branches and their foliage serving merely to assist in bringing to maturity the fruits which are set while the plant is still very young.

Like several other tropical economic species, such as coffee, cacao, and the Central American rubber tree, the cotton plant has two kinds of branches—the true or primary branch, which arises in the normal position of branches in the axil of the leaf, and the secondary or fruit branches, one of which arises at the side of each primary branch. In most varieties only a few of the true branches are developed: often none at all. They are almost always plainly indicated, however, by a small bud or a stunted leaf or two, in case the bud has not remained entirely dormant.

Cotton plants are either right-handed or left-handed in the sense that on the same plant all the secondary branches come out on the same side of the primary branches. It is possible, therefore, to determine by its position whether any particular branch is a primary or a secondary. But the function of the two sorts of branches does not always remain as distinct as in the coffee and cacao. A primary branch, like the main stem, never bears any flowers; it produces only leaves and other branches, mostly secondary.

Secondary branches, on the other hand, produce normally a flower bud at the axil of each leaf, and this rule holds very generally, except that at the lower part of the plant it sometimes happens that a branch which has the secondary position functions as a primary; that is, instead of bearing buds and flowers it produces only leaves and secondary branches. In the Kekchi cotton, as grown crowded together in the Indian fields, the primary branches seldom appear, but when more space is allowed and the soil is fertile it is usual for two branches to start from the axil of each of the lower leaves, one promptly producing flowers, the other assisting in the rapid increase of the leaf surface of the plant and of its power to elaborate food.

Under the popular idea that plants draw their food from the ground the possession of branches which bear little or no fruit might be looked upon as an undesirable character, but when we take into consideration the fact that the leaves instead of the roots are the true assimilating organs of the plant it becomes apparent that a variety of cotton which develops its lower primary branches may have an advantage in earliness over one which is obliged to depend for its foliage upon secondary or fruit-bearing branches. In the matter of determinate habits of growth these primary branches are also a feature, because they enable a plant to produce a full quota of leaves without unduly increasing the number of fruiting branches and thus continuing to add to the number of superfluous buds.

The most obvious characteristic of the Kekchi cotton as it grows in our experimental plots is the long basal branches, which often equal or exceed in length the main stem itself. The most prolific branches of the United States varieties are those which come out from the main stem at the height of about a foot, but the bulk of the crop on the Kekchi cotton is borne much closer to the ground. (Pl. II, fig. 2.) The long basal branches facilitate the early ripening of a uniform crop of cotton, but they will not be an advantage under all circumstances; as, for example, in dry regions where the weevil can be held in check by open culture. The necessary exposure of the fallen squares to the full sunlight on hot, dry soil would be interfered with by a plant of low spreading habit and dense foliage.

EARLY REJECTION OF SUPERFLUOUS SQUARES.

That the Kekchi cotton has a limited or determinate growth and does not take advantage of the perpetual summer to become a tree or even a large bush is evident from the fact that in the latter part of the season most of the flower buds and leaf buds blast and fall off while still very young, before the weevil would give attention to them. By the time the first of the cotton is beginning to ripen, most of the plants have ceased flowering and no new leaves are being put forth. Generally there are bolls only near the base of the plant.

It is a normal character of the cotton plant that the fruiting branches shall produce a bud at each node or joint; that is, at the base of each leaf. If all these buds were to be retained and treated impartially to the food materials which the plant is able to supply, the result would undoubtedly be disastrous, since the plant would be able to bring very few of its fruits to maturity, perhaps none at all, unless a part of the burden were removed by the weevils or by other outside causes.[a] It is under the necessity of throwing off a part of its load of fruit at one stage or another of its development, the younger the better.

The rejection is accomplished by the formation at the base of the peduncle, or fruit stalk, of special layers of cells of soft texture, which soon disintegrate and allow the bud or young fruit to fall off. This is one of the many instances of the prodigality of nature, which makes so many allowances in advance for the accidents which beset the existence of all living things. The waste of buds is, perhaps, not so large in proportion among the perennial "tree" cottons, which form a considerable shrub before beginning to blossom. In cultivation, however, the tendency has always been to encourage early bearing, and thus reduce the early vegetative period of the plant and bring it to a precocious maturity. The result is that fruiting branches are produced, even on young plants, and buds are formed out of all true proportion to the actual productive power.

The habit of rejecting a large part of the squares and bolls is especially obvious in the "cluster cottons," varieties in which the branches are abnormally shortened, so that the leaf surface of the plant is still further reduced. This cuts down still more the productive power of the individual plant, though there may be a gain in the number which can be grown on a given area.

But cluster cottons have not learned to moderate their promises to correspond with their powers of performance, and continue to set vast numbers of buds, flowers, and bolls, which they are unable to ripen. The same is true to a less obvious extent of all our Upland varieties, but until the advent of the boll weevil the superfluous buds were not a serious factor, and the waste under favorable conditions was often well compensated by the power to recover and set a new

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[a] In Texas it is believed that rain at the time of flowering reduces the crop to half the normal quantity, or even less. The explanation given is that water settles in the flowers and prevents fertilization. This might serve as an additional indication that cotton originated in a dry climate.

crop when in unfavorable seasons the earlier buds were lost, or when, as occasionally happened in southern Texas, there was a liberal top crop, or second period of bearing, late in the autumn months.

The presence of the weevil alters all these factors. The superfluous buds become positively detrimental, for they furnish the breeding grounds for successive generations of weevils and enable the pest to attain in the latter half of the season such numbers that a top crop not only becomes utterly impossible, but a menace is prepared for the cotton of the following year. For, although only a small proportion of the weevils live through the winter, the number of survivors undoubtedly has a very practical relation to the supply maintained at the end of the previous season, and this again is merely a question of this persistent production of buds, now much worse than useless.

A short-season variety of cotton having a sufficiently determinate habit of growth would by itself constitute a solution of the weevil problem. The Department's entomological investigations in Texas indicate that it is only the weevils hatched in the last month of the growing season—in October or November—which have a prospect of surviving the winter. A cotton which ceased to produce buds after July or August would remove the chance of wintering over from all the weevils except the few that might develop in the bolls, an almost infinitesimal number compared with those that now attain maturity in the squares. Much would be gained, of course, if all planters would promptly pick their cotton and then pull up and destroy the plants, being especially careful to collect the infested bolls. But to carry out efficiently such a programme is difficult and expensive.

To what extent, if any, the Kekchi cotton will meet this need of a short-season determinate variety, it is too early to form an opinion, but the fact that it has these qualities to a higher degree than any of the varieties hitherto known in the United States must be accepted as evidence, at least, that the possibilities of this method of protection have not been realized. In the latter part of the season the Kekchi cotton ceases the upward growth of the main stem and its branches and regularly drops the greater part of its buds before they are large enough to be entered or fed upon by the weevils, and the analogies to be drawn from the habits of other plants will justify persistent efforts toward the development in this and in other stocks of the habit of rejecting the buds still earlier or of not forming them at all after the first crop of fruits has set. Many plants have, in fact, exactly this habit so desirable in cotton; they continue to flower until permitted to set seed.

SEASONAL BEARING OF PERENNIAL VARIETIES.

The continued existence of perennial cottons in weevil-infested countries, like Guatemala, proves the presence in these also of means of protection. One of the most important is, doubtless, the production of an annual crop at a definite season, leaving the weevils without opportunity to breed in the intervening months, thus greatly reducing their numbers.

The popular impression that tropical plants take advantage of the continuous summer climate and blossom continuously is correct only for a small minority. Where there are definite wet and dry seasons many tropical plants have alternating periods of growth and rest almost as pronounced as in temperate climates, and even in regions of continuous humidity there are some species which shed their leaves annually and rest for a time.

A further general reason for a simultaneous annual blossoming of all the flowers of a species is undoubtedly to be found in the greatly increased opportunities of cross-fertilization, just as many insects swarm and many birds and mammals collect in flocks before the breeding season. Simultaneous flowering is carried to a remarkable extreme among the bamboos, where whole species grow for long series of years without flowering, and then flower and die at once over long distances and in spite of local diversity of conditions which might be expected to advance or retard maturity.

Accordingly, while it would not be reasonable to insist that perennial varieties of cotton have adopted the habit of annual flowering only because of the boll weevil, the analogy of other plants may be invoked to show that such a character can be brought about by selective influence. The weevil could certainly assist in the development of such a tendency, especially if there were a season of the year in which the insects were less numerous, from climatic or other external causes as yet unknown.

The tropical varieties of cotton are, as is well known, mostly perennial, and some of them develop into trees of considerable size, the trunk attaining a diameter of 6 or 8 inches, and the main branches a length of 15 or 20 feet. The existence in Mexico of tree cotton immune to the weevils has been reported, but as yet this has not been substantiated. Possibly the weevil has not yet penetrated some of the remote and arid parts of the republic. In eastern Guatemala, at least, the tree cottons appear to enjoy no immunity from the weevil, and at the time of the visit of the writer it was often impossible to secure uninjured bolls, even as samples of the varieties. The native cottons of the island of Cuba, according to Mr. E. A. Schwarz, also have the habit of annual blossoming, in the intervals of which the number of the weevils becomes greatly reduced. The cutting back of the cotton by the Indians at Rabinal, as described in the next paragraph, is an artificial means of attaining the same end, but the native Sea Island cotton, found at San Lucas, and the Kidney cotton, at Tucuru, are the best Guatemalan examples of this protective habit.

ANNUAL CUTTING BACK OF PERENNIAL VARIETIES.

While the annual variety of cotton protected by the keleps is the basis of the only field culture found in eastern Guatemala, the Indian population of the central plateau about Salama and Rabinal raise small quantities of cotton in their dooryards by means of another cultural expedient, apparently of great antiquity, as indicated by the extent to which the plant is adapted to the cultural conditions. The variety is perennial and has very small and inactive nectaries, possibly as an adaptive result of the dryness of the climate.

Most of the perennial varieties begin bearing only after the plants have attained considerable size, but the Rabinal cotton is a notable exception to this rule and avoids injury from weevils by the very prompt flowering and fruiting of the new shoots.

The weevils are present in numbers, and are frequently seen crawling about on the plants in a leisurely manner quite different from that which they affect in regions stocked with keleps. At the time of our visit not a single boll or bud of any except the smallest size could be found which had not been attacked by them. Nevertheless, a crop of cotton is secured at another season. In the month of April the Indians cut back all the bushes to the ground, and as the cotton is always planted immediately about the doors of their houses, where the chickens and turkeys congregate, the mortality of weevils at this time is probably very great. The protection of the domestic birds doubtless continues until the new shoots have grown out of reach.

As soon as the plants are a few inches high they begin flowering, and before the weevils are sufficiently increased in numbers to become injurious a crop has been set. Flowers and fruit are commonly borne on the lower branches, only 6 or 8 inches from the ground. The Indians say that if the cotton is not cut back, but allowed to grow tall, they get no crop. The fact is that by that time the weevils are too numerous to permit normal bolls to be formed. Our search for such was quite in vain on both our visits to Rabinal. One boll which gave no certain external proof of injury was wrapped up in a paper and retained as a sample, but was overlooked in packing and not transferred to the preserving fluid. When the paper was unwrapped a few weeks later three dead boll weevils were found.

The Rabinal cotton crop is evidently not large, but the harvest is said to be regular, and the area of fertile land in this district is so small that none of it is wasted. Much foreign thread is now imported, however, for weaving in the native looms. The industry has greatly declined in the last century, perhaps because chickens have been generally substituted for turkeys, which were formerly the only domestic fowl possessed by the Indians.

All attempts at establishing field cultures of cotton in this region have failed. The local public, which does not take the weevil factor into consideration, is firmly persuaded that cotton will not bear except in the heavy, rich soil of the dooryards of the Indian villages.

HAIRY STALKS AND LEAF STEMS.

The weevil on foot is a rather slow-moving, clumsy insect, and it has been ascertained in the course of the investigations conducted by Messrs. Hunter and Hinds that its movements on the plants are to a great extent impeded by hairy stalks and leaf stems. The smooth Egyptian and Sea Island varieties were found to be more susceptible to weevil injuries than the hairy Upland sorts. The Kekchi cotton is still more hairy, however, than the United States varieties, and gains an added advantage from this fact.[a] The longer it takes the weevils to climb from one bud to another the greater are the chances of their being caught by the keleps. The latter insects, owing to their much longer legs and the claws with which their feet are armed, are not only able to travel readily over the hairs, but find them of definite assistance. On smooth surfaces they are much less adroit in catching and stinging the boll weevils. In our experiments, too, they seemed to prefer the hairy Upland cottons to the smooth Sea Island varieties.

The difference between the two insects in this respect may also be illustrated by the fact that the keleps are unable to ascend a perpendicular surface of clean glass, a feat which the weevils accomplish without difficulty.

That the Guatemalan cotton was more attractive to the keleps than the United States Upland and Sea Island varieties planted in adjacent rows seems to be indicated by a census of our plot experiment, taken April 19 by Mr. Argyle McLachlan. Kelep nests were found at the bases of 41 per cent of the plants of the other varieties,

[a] Though distinctly hairier than our ordinary Upland varieties, the Kekchi cotton is exceeded in this respect by two other Guatemalan types, as well shown in a field test at Lanham, Md. The Pachon cotton obtained by Mr. William R. Maxon in the Retalhulen district of western Guatemala is distinctly more hairy than the Kekchi variety, though it seems to be lacking in other weevil-resisting features. The involucral bracts are not closed any more than in the Sea Island or Egyptian types. The most hairy cotton of all is the Rabinal variety, at least in the form it has taken at Lanham. The plants are very much more robust in every respect than at home in Guatemala, and the hairy covering shares in this increased vigor.

while 76 per cent of the plants of the Kekchi cotton were favored with kelep nests. This apparent preference may be somewhat exaggerated, perhaps, in view of the fact that the plants were often farther apart in the rows of the Kekchi cotton, the seed having germinated very irregularly. Moreover, the superior attraction of the Kekchi cotton for the keleps may not have consisted entirely in the greater hairiness or the more abundant nectar. The compact foliage and spreading lower branches of the Kekchi cotton give greater protection from the midday sun, which the keleps utilize by greater activity in the middle of the day.

With the Sea Island varieties it seemed obvious, however, that the smooth stems, more open habit, and smaller supply of nectar result in distinctly less attention from the keleps. From 9 or 10 o'clock on hot days they foraged very little, and seemed to have quite disappeared from these varieties, though still to be found in considerable numbers on the stems of the Upland varieties and most of all on the Kekchi cotton, which appears especially adapted for the comfort and convenience of the keleps.

It was noticed, however, that the keleps went much more often into the involucres of the Sea Island and Egyptian varieties than into those of the Kekchi cotton, for the simple reason, probably, that they can get in more easily.

In the latter part of the season, after the weevils had gained a footing in this field, Professor Pittier noticed a very decided preference on their part for the Egyptian varieties, though it seems certain that this type of cotton had never been planted in the country before. The partiality of the weevils might be explained, perhaps, on such grounds as the relative absence of the keleps, and also the ease of access to the buds of the Egyptian cotton allowed by the more open involucres. However, a slight change of food or of conditions of growth is often a distinct advantage to plants and animals, so that a direct preference for a new variety as food might reasonably be expected, and similar instances are known.

The greater hairiness of the stems and the presence of the keleps may also explain why the weevils in Guatemala were seldom seen walking about on the cotton plants as they do in Texas. On the other hand, they take to wing very readily and seem to prefer to alight in the open flowers, the only places on the cotton plants where they are safe from the keleps.

The petals are so smooth that the keleps seldom descend into the flowers, and when they do sometimes appear to be unable to climb out. The petals of the Sea Island sorts are smooth even on the margins, sometimes entirely so, while those of the Upland varieties are fringed with fine hairs well up on the sides, if not all the way round the apex.

The liability to capture by such an insect as the kelep may also afford an explanation of the peculiar sedentary habits of the male weevils, which often remain stationary in one involucre for long periods, or as long as their food supply lasts. It is necessary for the females to go about in search of fresh squares for egg laying, but similarly active habits on the part of the males would subject them to unnecessary danger.

PENDENT BOLLS.

The early bearing of the Kekchi cotton is made possible, as already noted, by the unusual development of the lower lateral branches, which often have a drooping habit, leaving the buds and bolls in pendent position, intead of upright. There are several advantages in this arrangement, one being that the instinct of the weevils leads them to the upper portion of the plant. In a very badly infested field without kelep protection, the only bolls which escaped the weevils were a few lying close to the ground on these lower pendent branches of the Kekchi cotton. Only at the time of flowering does the peduncle curve upward and give the flower its normal upright position. Thus these drooping lateral branches of the cotton, which seem to hide the buds and bolls away from the weevil, may be looked upon as a short step in the direction of such phenomena as the cleistogamous flowers of violets which remain buried in the ground, or those of the peanut which, after flowering, burrow into the soil to ripen their seeds.

The flowers of the cotton plant open in a more or less directly upright position, and this is retained by the boll in most varieties. In the so-called "stormproof" sorts, however, the bolls hang down, and this is looked upon by many planters as a distinct advantage, since when the boll is ripe and open the rain does not beat into it and wet the cotton or wash it out, but is shed by the protecting outer shell and involucre.

On pendent bolls the external nectaries are brought upward, so that there is no danger of an abundant secretion of nectar being lost by dropping off. The surface of the nectary is papillate and has a somewhat waxy appearance. The secretion often collects as a distinct drop. The nectaries are also more readily visited by the keleps, and the young bolls are likely to be better protected by them. If these remained upright, the weevils would be more likely to alight and enter the involucre at once.

The drooping habit may have a mechanical explanation as the result of the weakness of the comparatively slender lateral branches. It is also to be connected, perhaps, with the habit of early flowering and fruiting, since this would bring heavier bolls upon smaller and softer branches which would be twisted over by their weight. In the later and more upright varieties the flowers are not formed until the wood of the branches has hardened and become strong and rigid. Pendent bolls may thus be said to be incompatible with the cluster habit, which is brought about by the abnormal shortening and thickening of the lateral branches, which are able to hold their flowers and fruits rigidly upright, except as they may be turned sidewise by being crowded together. The cluster cottons, too, have the undesirable tendency to an abnormal multiplication of squares and young bolls, many more than the restricted leaf surface of the plant will enable it to ripen. This superabundance of flowers and fruits gives, however, the greater encouragement to the weevil, and uses up vegetative energy which could be better employed in the prompt ripening of the bolls already set. It is no uncommon thing, however, for even half-sized bolls of cluster cottons to die without any sign of external injury or disease, while other varieties close by remain perfectly healthy. The cause is probably to be found in inadequate nutrition, but this might also be expected to give them increased susceptibility to injury from parasitic enemies of every kind.

It is not unlikely, too, that the drooping habit may be connected with the greater size of the inside nectaries of the Guatemalan variety. These are, as far as we have seen, larger than in any other American variety yet known; but the Asiatic cottons, which have the inside nectaries still larger and more active, are also more definitely pendent. The involucre is grown together at the base, as though to more thoroughly protect the nectaries from above—from the sun, which would dry up the secretion, and from the rain, which would wash it off.

The nectar is formed in great abundance, and Mr. F. J. Tyler, of this Department, has called attention to the fact that the surface of the nectaries of the Asiatic cottons, instead of being merely papillate, as in the American Upland varieties, has a covering of close-standing fine hairs, to which its velvety appearance is due.

Finally, it may be remarked that for cotton with upright bolls the inside nectaries are often an element of danger, since when the secretion is abundant and is not removed it flows along the bases of the involucre and may serve as a medium for the germination of parasitic fungi or bacteria. Bolls are not infrequently found diseased around the base, apparently from this cause.

EXTRAFLORAL NECTARIES.

The cotton plant is not without floral nectaries similar to those of related genera, consisting of fringes of nectar-secreting hairs lining the pits inclosed between the bases of the petals. The nectar serves, doubtless, the same purpose as in other plants, the attraction of the honey-loving insects through which cross-fertilization is secured. It does not appear, however, that the floral nectaries of the cotton have any connection with the problem of weevil resistance, although the weevils seem in Guatemala to spend a considerable part of their time in the flowers, which are indeed the only safe places for them on plants protected by the keleps. It had been noticed from the first that the keleps seldom visit the cotton flowers, and Mr. Kinsler has learned a very adequate explanation of this fact, namely, that they are able to climb out of the flowers only with considerable difficulty, and sometimes remain imprisoned in spite of all their efforts to escape.

The functions of the extrafloral nectaries of plants are, as far as can be ascertained, similar to those of the floral nectaries to the extent that they attract insects, but beyond this there is a fundamental difference; the floral nectaries and highly colored floral organs serve to secure visits of flying insects and thus maintain intercommunication and cross-fertilization between the different members of the same species, in spite of the fact that the individual plants are rooted fast in the ground. The extrafloral nectaries, on the other hand, attract to the plants insects which will remain upon them as permanent residents, and this is the end secured by the extrafloral nectaries of the cotton.

It may be objected by some that no use or benefit to the plant has been ascertained in the case of many species which have extrafloral nectaries and other insect-attracting devices. Much remains to be learned concerning these marvelous biological specializations, and there are two obvious alternatives which need to be canvassed before belief in the adaptive nature of extrafloral nectaries and analogous structures can be destroyed. The character and extent of many such specializations show that they have existed for a long time. They may have served protective purposes no longer apparent. The other consideration is that some of the symbiotic specializations existing between such plants as Cecropia and Acacia and their insect inhabitants have arisen through selective encouragement, much as the special characters of our domestic plants and animals have been developed. It may be sufficient, in other words, that the nectaries or other structures be of use to the insects which have done the selecting. It may seem absurd to think of bushes or trees as having been domesticated by ants many thousands of years ago, but the wonder is no greater than that ants and termites regularly maintained subterranean fungus gardens ages before mushroom culture was undertaken by man.

NECTARIES OF THE LEAVES.

The midrib of each leaf bears on the under side an oblong pit, from which a drop of nectar may often be seen to exude. This is collected and eaten by the keleps, which are thus induced to visit all parts of the plants, especially while they are still small.

The habit of collecting the nectar was not previously known to exist among the insects of the family (Poneridæ) to which the kelep has been referred. Nevertheless, the fact is not open to question. The process is easy of observation in even greater detail than with the true ants or the bees, because the keleps do not, like these insects, have the art of regurgitating their food. They merely lap the nectar up to form a drop, which, protected by the widely opened mandibles, is carried into the nest to feed the queen and the young.

Nectaries, or at least nectary-like depressions, are to be found probably on the leaves of all varieties of cotton, though very small and apparently inactive on some of the larger tree sorts.[a] The shape of the nectaries also varies greatly in the different species and varieties, some being longitudinal, others transverse, and still others crescentic or even sagittate. Some varieties have nectaries on the three principal veins, and some even on five veins.

The leaf nectaries of the Kekchi cotton are to be found on the midrib of the leaf about 1.5 cm. from the base. They consist of a rather shallow longitudinally oval depression surrounded by a broad raised rim. The midrib often appears distinctly narrower above the depression than below it, as though there were extra tissues to supply it. The secretion is quite active, nearly all the nectaries showing a small amount of liquid, which sometimes spreads out on the adjacent surfaces.

These nectaries furnish, as might be expected, a medium favorable for the growth of molds or fungi, and there is often a considerable network of dark-colored fungus mycelium creeping in and about the moistened depressions, and with occasional erect, needlelike points, which may be fruiting bodies.

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[a] This was not true, however, of a Mexican "tree cotton" of the Upland type grown in the Department's experimental plots in Texas last year. Large nectaries were generally present on three veins of each leaf, and the midvein often had two. They were of the crescentic or sagittate type, but often extremely long and distorted. Another Mexican tree cotton, with a different type of lighter green foliage, suggesting that of Bixa, had nectaries only on the midvein and these reduced to a narrow groove. The vein was not thickened nor the margins raised. The two varieties were about as different as could well be with respect to nectaries. Neither produced either flowers or fruit, so that their true relationships were not to be ascertained.

EXTERNAL NECTARIES OF THE INVOLUCRE.

The Guatemalan cotton protected by the keleps has three broadly oval or reniform pits at the base of the involucre, one at the middle of the base of each of the involucral leaves.[a] These are larger, deeper, and more active than the nectaries of any of the Texas varieties as yet observed, though there is very great diversity of size and nectar-secreting activity. In some of the varieties these nectaries are reduced to mere rudiments or are entirely wanting. The depression may be present, but with no secreting tissue. The variety nearest approaching the Guatemalan cotton in having large and active nectaries is the Redshank, but the King and other related sorts also have fairly large nectaries.

The drooping or pendent position of the bolls in the Kekchi cotton may be correlated with the special development of these nectaries, as already noted. In the middle of the day the keleps are not very active, but the nectaries are sometimes full to overflowing. If the bolls kept the erect position usual in the varieties cultivated in the United States the nectar would frequently drop off and be lost, but when the fruits hang down the cuplike nectaries are brought uppermost and hold the liquid much longer.

The evolutionary origin of these nectaries is fairly obvious. The bracts are to be looked upon merely as modified leaves, with nectaries which have increased in size and activity as the leaves have become smaller and more specialized.

INNER NECTARIES OF THE INVOLUCRE.

As though to induce the keleps to come inside the involucre and thus more effectually protect the young buds and bolls against the weevil, the Guatemalan cotton is also provided with unusually large interior nectaries, alternating in position with those of the outer series and thus placed opposite the edges of the involucral leaves or bracts. These inside nectaries, like the outside ones, are larger and more active than those on most of the cottons cultivated in the Southern States, but the closing of the involucre and the devolopment of the inside nectaries have been carried much farther in the Old World cottons belonging to the species *Gossypium herbaceum*. Here the external nectaries are quite wanting, but the internal ones are enormously larger and heartshaped, and secrete nectar in such quantities that it often flows out in the groove between the adnate

[a] Instances are occasionally found where only two nectaries are developed, but such deficiencies are much less frequent than in other varieties of the Upland and Sea Island series. The Rabinal cotton commonly has only two external nectaries. The Old World cottons thus far observed have no nectaries in this position.

bracts to moisten the edges of the involucre. As yet, however, the purpose of these adaptations in the Asiatic cottons is entirely unknown, both the boll weevil and the kelep being absent in the Eastern Hemisphere.

The botanical homology of the inner nectaries is somewhat different from that of the outer. They correspond in all probability with the nectaries which are found on the calyx of some of the species of Hibiscus, but there the calyx is large and covers the buds and each sepal bears a nectary near its middle.

NECTARIES OF GUATEMALAN SEA ISLAND COTTON.

A variety of Kidney cotton planted in small quantities by the Indians at Trece Aguas, Guatemala, has the outer nectaries very variable in size and commonly quite wanting.[a] The inside nectaries seem always to be developed and are unusually large, being exceeded, as far as known, only by those of the Asiatic varieties. The nectar secretion is also very abundant. No weevils were found upon this cotton, nor any keleps.

On the other hand, the free-seeded Sea Island cotton found by Mr. Kinsler in the San Lucas[b] neighborhood, not far from the kelep cotton culture of Secanquim, reverses again the tendency of the Kidney cotton to the great development of the inner nectaries and the suppression of the outer. The latter are, in the San Lucas cotton, nearly always present, of rather large size, and of a red color. The inner nectaries are often rudimentary or quite absent.

CONTINUED SECRETION OF NECTAR.

Our Upland varieties commonly secrete nectar only at the time of flowering, but in the Kekchi cotton the liquid continues to exude until the boll is nearly or quite full grown, thus securing the protec-

[a] This variety not infrequently produces flowers with only two bracts, closely appressed, like a clam shell. In one such instance there were two nectaries at the base of each bract, or, to be more exact, two separate nectaries on one side and one partly divided nectary on the other, as though the nectary belonging to the deficient third bract had separated into two parts and joined the other nectaries.

[b] This San Lucas Sea Island cotton is probably the variety in which the weevils were found abundant in 1902, when the first intimation was gained that the Kekchi cotton had means of protection against the weevil. The San Lucas cotton is attacked not only by weevils, but by another long-bodied insect larva, evidently lepidopterous, that gnaws through the boll at the ends, both from above and below, and eats out the seeds. Nothing of the sort has been seen in the fields protected by the keleps. There was also noticed in this cotton an occasional abnormality closely comparable to the navel orange. Rudimentary parts like a small secondary boll were found in the middle of bolls otherwise normal. The orange tree and the cotton plant belong, it may be remembered, to related families.

tion of the keleps for a longer period. The temporary character of the secretion in our United States sorts was reported by Professor Trelease several years ago.

In Guatemala, however, the young bolls seem to be quite as efficient as the flowers. It is even possible that this generosity on the part of the plant is excessive, since if the number of keleps is small they may find all the nectar they need on the lower bolls, and hence have less inducement to inspect other parts of the plant. Under favorable conditions in Texas the cotton plant produces a much larger number of flowers than in Guatemala, so that what is lacking in quantity may be made up by numbers, in case it should become possible to utilize the keleps in Texas.

RACTLETS SUBTENDING INNER NECTARIES.

The Kekchi cotton is distinguished from all our Upland and Sea Island types by the more regular presence and much larger size of a series of bractlets, a pair of which usually subtends each of the inner nectaries. In other varieties these are either wanting entirely or are rare and rudimentary.[a] The bractlets are inserted somewhat obliquely, with their margins in contact below the nectary.

Sometimes they serve to conduct nectar to the edge of the involucral bracts, the nectar following along between the slender bractlets like ink between the nibs of a pen, as though to coax the keleps inside the involucre. This must happen rather infrequently, however, to judge from the great irregularity in the size of the bractlets. Sometimes they are half an inch or more long, and extend well into the angles of the involucre, or even project outside. (Pl. III.) Nevertheless, it

[a] Professor Trelease, who studied the American Upland varieties, appears not to have found the bractlets in pairs. He says: "These glands (the inner nectaries) belong in reality to an inner whorl of three bracts, alternating with the outer ones, but generally wanting. In stunted plants, especially as cold weather comes on, one or more of these inner bracts may be found." (See Comstock, 1875, Report upon Cotton Insects, 324.)

The shape and position of the bractlets seem to warrant the suggestion that they represent the stipules of the outer bracts instead of an independent inner whorl of bract leaves which has first become specialized and then become rudimentary. The suggestion has the further warrant in that it may help to explain the numerous involucral appendages of some of the related plants, which range about the number 9—that is, 3 leaves and 6 stipules. The normal number should be 6, if the two whorls of leaves were represented. One of the Guatemalan species of Hibiscus examined with this interpretation in mind seemed to confirm it by showing very often 3 of the appendages broader than the others, though the total number varied from 8 to 11, with an irregularity quite comparable to that of the bractlets of the cotton. Even the bracts of the cotton sometimes vary, involucres of 2 bracts being found occasionally, and in rare instances 4.

may well be questioned whether these inner bractlets have remained unusually large in the Kekchi cotton because they have a definite function or because of the greater size and activity of the adjacent nectaries.

A variety of cotton called Pachon, planted rather extensively in the Retalhuleu district of western Guatemala, and likewise protected by the keleps, is similar to the Kekchi cotton in many respects, including the possession of these large stipular bracts subtending the inner nectaries, but with the addition that the bracts are fringed with long hairs, as though to hold the nectar the better. This may also be the function of the hairs which cover the nectaries of the Old World cottons

EFFICIENCY OF THE KELEP PROTECTION.

The special development of the extrafloral nectaries in the Kekchi cotton has been noted in former reports, it being the nectaries which attract the keleps to the cotton plant. That the kelep preys upon boll weevils and protects the cotton crop was learned last year, but it was still possible to question the practical value of this form of defense. Such doubts would not have survived an inspection of our recent experiments in Guatemala. A small field of cotton just outside the kelep area was attacked by the weevils in such numbers that not a single normal boll developed on any of the United States Upland and Sea Island varieties. In the field protected by the keleps the weevils obtained no footing until the plants were well grown and an excellent crop of full-sized bolls had been developed.

To test the efficiency of the keleps as destroyers of boll weevils and as protectors of cotton would be possible in Texas only by stocking a large area with keleps—a difficult and expensive undertaking. No small tract would give a fair indication, since the weevils from the whole neighborhood would continue to come in, and, although they might soon be captured, would be able to do vastly more damage than would be possible if the whole region were stocked with keleps.

In Guatemala, however, it was quite possible to contrast a protected with an unprotected piece of cotton by the simple expedient of planting outside the area occupied by the keleps. A more striking result could hardly be imagined. For several weeks, during which the two plots were under continuous observation, the one remained almost entirely free from weevils and weevil injuries and set an excellent crop, while in the other scarcely a flower opened or a boll developed. The very few exceptions were on the concealed drooping branches of the native Kekchi cotton.

The weevils became, indeed, too numerous for their own prosperity and fed upon and destroyed the very young buds before they were old enough to breed larvæ. Twenty-five fallen squares collected and examined from under the plants of the plot without keleps yielded only 6 larvæ, or 24 per cent. They even attacked the young leaf buds, as observed last year at Rabinal.

A large proportion of the injuries were caused by feeding punctures, but this only emphasizes the fact that the number of weevils which migrated into this plot was sufficient for a complete destruction of the crop, and since the other experiment protected by the keleps was much nearer to the fields of the Indians there is every probability that the weevils would have been, if possible, even more numerous if the keleps had not been at hand to catch them.

The unprotected plot was located at about one-quarter of a mile outside of the belt of Indian cotton culture, on land not inhabited by keleps. The weevils lost no time in finding the new field. Infestation was complete, and quite as destructive as in Texas, the weevils being so numerous as to overcome whatever resistance the cotton might have been able to oppose to smaller numbers of the pests. The Sea Island, Egyptian, and United States Upland varieties were not permitted to produce flowers or even full-sized buds, and even the native Guatemalan varieties shed their squares before the persistent onslaughts of the weevils.

Cotton is regularly cultivated by the Indians in this immediate neighborhood, and Indian plantings more or less infested with weevils were to be found within short distances of the protected field. Nevertheless, the keleps proved to be sufficiently abundant on this piece of ground to completely exclude the weevils. There were enough, indeed, to protect with apparent impartiality all the kinds of cotton included in the experiment, but if the numbers had been less and the plants had been closer together, as in the Indian fields, we may be sure that those producing the most nectar would have received the most protection from the keleps.

The weevils were seldom to be found in the plot stocked with keleps as long as the Indian cotton remained in vigorous growing condition, but about the time the Indian cotton ripened, the weevils seemed to make a more determined raid on our field, and along one side nearly every plant suffered somewhat, though the weevils could rarely be found except in the open flowers, which seem to be recognized as their only safe roosting places. In a week or ten days there was a distinct falling off, so that very little damage was being done, and there was another short interval of practically complete protection. But after this a renewed onslaught began and the numbers of weevils gradually increased, the Upland and Sea Island plants continuing to produce thousands of new squares in which the weevils were able to breed, quite as in the United States.

That the keleps are definitely attracted to the cotton plants, as stated in previous reports, is fully demonstrated by the fact that many of the colonies moved their nests to new burrows excavated immediately at the bases of the cotton plants. In some parts of the field the proportion of cotton plants having kelep nests established about their roots reached nearly 75 per cent, whereas the chance that the positions of the cotton plants which stood in regular rows would coincide with those of kelep nests would not be one in hundreds.

The success of this experiment would seem to justify fully the suggestions made in connection with the first announcement of the discovery of weevil-resisting adaptations of the cotton plant, namely, that the protection which these Central American varieties had been able to secure from the kelep had afforded them an opportunity, perhaps unique, of developing other resisting adaptations. The Kekchi and other related cottons, though having no monopoly of weevil-resisting characters, furnish, however, the only instance as yet known to scientific observation in which a field culture of cotton has been maintained for long periods of time under climatic conditions favorable to the boll weevil.

In Central America, at least, the secretion of nectar by the cotton is not a useless or meaningless function, as observers of the plant in other parts of the world have sometimes supposed. The cotton is not the only plant upon which the kelep can live, nor the boll weevil the only insect upon which it preys. To secure the attention and obvious preference of the kelep the cotton has been obliged to put forth the superior attractions provided by its numerous extrafloral nectaries.

This additional proof of the value and efficiency of the kelep does not affect, of course, the possibility of acclimatizing it in the United States. A more extended search in Guatemala resulted in finding the insects under a wide range of conditions, and at altitudes of from 200 to 2,000 feet. It lives and thrives, moreover, in soils very much drier than those to which it was supposed last year to be confined. Last year's experiments in Texas indicated likewise that the kelep withstands drought much better than it does standing water in its burrows, and care is being taken this season to locate colonies with a view to adequate drainage.

OTHER NECTAR-BEARING PLANTS VISITED BY THE KELEPS.

The honey-collecting habits of the keleps are not confined to the cotton. Another favorite is a species of Bidens (*B. pilosa*) called by the Indians "tshubai," which has considerable value as a forage plant, being of quick growth and succulent texture.

The preference of the kelep for the tshubai as a second choice after cotton was noted last year, but no explanation was found, though the plant was searched for nectaries. It was noticed by Mr. Kinsler that the keleps seemed to be giving especial attention to the midrib near its junction with the veins of the lower divisions of the leaf. Our lenses then revealed the fact that there are two minute raised wings or margins running along the upper side of the midrib and petiole, forming two narrow grooves in which the nectar is evidently secreted. The grooves are also protected by a row of fine hairs which project across them from the raised margin. The behavior of the kelep thus receives a practical explanation, and the tshubai finds a regular place next to the cotton among the plants protected by the kelep. The nectar-secreting habit of the tshubai may also explain its being eaten so readily by stock, and may help to give it standing as a forage plant, in spite of its weedy and unpopular relatives.

A second member of the composite family often visited by the keleps is the "sajal," a species of Melanthera (probably *M. deltoidea*), which also has local value as a forage plant, being eaten greedily by horses and mules, even in preference to grass. No nectaries have been found on this. A third composite, not yet identified, produces nectar in small depressions at the base of the leaf on the under side.

THE INVOLUCRE AS A PROTECTIVE STRUCTURE.

Cotton is the only plant known to be attacked by the boll weevil, and it is also unique among its relatives in the possession of a large leafy involucre. This may be a mere coincidence, or it may be that the weevil has had a considerable influence in the development of the involucre, depending upon the antiquity of the contact between the insect and its host plant. The involucre has, it is true, functions other than the exclusion of the weevils, since it takes the place of the calyx in protecting the young bud, but the reduction of the calyx probably followed the enlargement of the bracts, instead of preceding it. But however originated, the large bracts have, at the present time, a definite value in the problem of weevil resistance. There are several specialized characters which appear as though definitely calculated to increase the efficiency of the involucre in excluding the weevils from the young buds.

INVOLUCRAL BRACTS GROWN TOGETHER.

Both the Kekchi and Rabinal cottons frequently have the involucre closed at the base, the three bracts being grown together, thus making it impossible for the weevils to enter from below. In the Sea Island and Egyptian varieties, as well as in some of the Upland sorts, the bracts are not merely divided to the base, but they often have the lower corners rolled back, thus leaving an open passage for the weevils. The Rabinal cotton much excels all the other varieties thus far studied in the extent to which the bracts are grown together at the base. Sometimes they are united for a quarter or even a third of their length. (Pl. IV, fig. 1, and Pl. X, fig. 1.)

APPRESSED MARGINS OF BRACTS.

In both of these Guatemalan varieties the margins of the bracts of young involucres are firmly and closely appressed, in striking contrast with the Sea Island and Egyptian varieties, where the bud is commonly exposed even when very young. This form of protection is effective while it lasts, but in the Rabinal cotton the involucre is too small, and the growth of the young bud soon separates the bracts and permits the entrance of the weevil. The United States Upland varieties are intermediate between the Sea Island and the Kekchi cottons in the degree to which the involucres are closed and the margins fitted together. A large proportion of the Upland involucres give ready access to the weevils, while most of those of the Kekchi cotton remain effectively closed for a longer period, as will be understood after a survey of the other involucral characters which conduce to the same result.

In one respect the firmly closed involucres of the Rabinal cotton seemed almost like an advantage to the weevil rather than the contrary, for the insect is not admitted to the bud until it is about large enough to furnish a place of development for a larva. The plant having taken control, as it were, of this relation, the weevils have not needed to possess an instinct against the destruction of young buds. Those of the open involucred Sea Island varieties often were attacked while still altogether too small to bring a larva to maturity. The advantage of the closed involucres lies, no doubt, in the fact that they shorten the period of access and allow some of the buds to escape which would be punctured either for feeding or for egg laying if the weevil has a longer opportunity. (Pl. IV.)

The Rabinal cotton culture is that in which the plants are cut back yearly to the ground. During the next month, or until the buds begin to develop on the new shoots, the weevils have no breeding places and nothing to feed upon except the leaves and leaf buds. In patches where the weevils are abundant the leaf buds are eaten out so persistently as to seriously interfere with the growth of the plants, and the very young flower buds were also reached in some instances by boring through the involucres. When attacked at this stage the buds wither and drop off. They serve the weevils only for feeding purposes, and their use in this way only postpones the time when breeding can be resumed.

The cotton at Rabinal was often overrun by two species of small black ants, identified by Dr. W. H. Ashmead as belonging to the genera Solenopsis and Tapinoma.[a] There was no indication, however, that these afforded any protection against the weevils, although they might, perhaps, act as watchmen and scare weevils away when they happened to be present on buds or bolls where weevils had alighted, like other small ants which have been reported as attacking the boll weevil. The keleps belong in an entirely distinct category in being able to sting and carry off the weevils and make regular use of them as food. Instead of being of service to the cotton these small ants at Rabinal were a distinct injury; the Solenopsis was taking care of plant lice,[b] which often infested the cotton to a decidedly harmful extent. It continues and supplements the work of the boll weevils in stunting and distorting the plants. When the aphids are very numerous, the leaves are badly curled and growth is greatly impeded.

LARGE INVOLUCRES OF KEKCHI COTTON.

The Kekchi cotton has the bracts of the involucre much larger in proportion to the contained bud than the Rabinal cotton or than any of our Upland varieties. The possession of larger bracts constitutes a distinct weevil-resisting adaptation, since it permits the involucre to be more effectively closed and the protection to be continued for a longer time. Sooner or later, of course, the bracts must be separated by the growing bud. The larger the bracts the longer the bud can continue to grow before spreading the bracts apart. (Pl. IX, fig. 1.)

Prof. H. Pittier, who had charge of the Secanquim experiment in the latter part of the season, was especially impressed with the protective utility of the larger bracts of the Kekchi cotton, as shown by the following summary of his observations:

> The large size of the bracts in proportion to the floral bud is a very important protective feature. In the Kekchi cotton the amplitude of these bracts is such as to completely inclose the bud at all times before the anthesis, and even in cases when they happen to be slightly separated the occlusion is maintained by the long hairs which fringe them on all sides. The length of these hairs constitutes a serious obstacle to the progress of the weevils, whose tarsi can not obtain a firm hold on the solid surface. I have seen them drop to the ground after many awkward attempts to gain access to the squares, while on the other hand the keleps did not seem to be impeded at all by the bristles.

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[a] The material was not sufficient for a conclusive determination of the species. Doctor Ashmead says: "You have two distinct species of ants here. One, No. 1, belongs to the family Myrmicidæ and is apparently the worker of *Solenopsis picea* Emery; the other, No. 2, belongs to the family Dolichoderidæ and is apparently the worker of *Tapinoma ramulorum* Emery. I am sorry you did not have the different sexes, so that I could make positive of the species. In Solenopsis, as you probably know, there are four or five different forms, and it is not easy to identify from a single form."

[b] These have been identified by Mr. Theodore Pergande as *Aphis gossypii*, a species well known in the United States.

To show the increased size of the bracts in the Kekchi cotton, I have carefully measured over 250 squares of five of the most promising varieties of the Upland species. The dimensions taken were the length of the floral bud, and the length and breadth of the bracts. The table, in which these data are condensed in a comprehensive form, shows a decided advantage in favor of the Kekchi cotton.

TABLE I.—*Dimensions of floral buds and bracts of several varieties of cotton compared.*

Length of floral bud (millimeters).	Kekchi.			Parker.			King.			Allen.			Jewett.		
	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.
		mm.	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*
5- 6	1	20	11												
7- 8	1	28	18	2	25	19				1	26	20			
9-10	6	39	27	13	31	20	5	33	19	18	34	21	3	38	26
11-12	5	42	30	16	36	24	7	34	23	10	34	22	2	36	21
13-14	3	42	30	18	39	25	9	40	24	18	37	23	10	39	26
15-16	4	42	30	8	38	23	6	44	25	13	39	24	7	41	28
17-18	3	47	33	6	39	26	6	40	24	5	39	25	5	39	30
19-20	2	52	30	3	43	24	4	42	26	1	49	29	1	52	38
21-22	1	37	27	3	48	26	1	43	25	1	40	26	2	47	34
23-24	3	47	36	1	36	25	2	41	26	5	40	23			
25-26	2	42	30	3	37	25				1	32	21	1	48	33
27-28				2	44	25	2	40	25	5	42	25			
29-30				2	45	24	1	49	28						
31-32				1	47	30									
33-34													1	42	32
Total	31			78			43			78			32		

The advantage is particularly notable with respect to the greater width of the bracts, which enables them to remain much more effectively closed at the angles. In the Parker, King, and Allen varieties the bracts very seldom attain a width of 30 mm., while in the Kekchi cotton the average width for all except the smallest buds is above 30 mm.

OPENING, OR FLARING, OF BRACTS AVOIDED.

The unusually large and well-closed bracts of the Kekchi cotton have another practical use in keeping the bud from drying out, as explained in the discussion of proliferation.

The external indication of this difference is that in the Kekchi cotton punctured squares commonly do not open, or flare, by the spreading apart of the involucral bracts, while among the Upland and Sea Island varieties flaring is the regular rule. Quite a percentage of the squares of Abbasi, Parker, King, and other varieties stand well open normally before any injury has occurred, but the Kekchi cotton seldom or never exposes its squares before flowering. The larger and broader involucre is also able to permit the protrusion of the flower without losing the power of closing and remaining shut for a considerable period after flowering, while the Parker and King varieties often remain quite open, so that the young boll is fully exposed to the weevils.

An example of the promptness with which weevil injuries cause the involucres of our Upland cotton to open is well shown in a note by Mr. McLachlan:

On August 8, at 2 p. m., a small cage was placed over a small plant of Parker cotton, and 5 female and 2 male weevils were introduced. The plant possessed 36 squares, 4 flowers, and 9 bolls. The morning after the weevils were put into the cage several of the squares had flared and one had fallen. It would seem that the mechanical forces of the square are quickly affected by the work of the weevils. Here, of course, the punctures were numerous, because of the many weevils on the plant. Some of the squares were riddled with feeding and egg punctures.

The buds of Kekchi cotton often recover from three or four punctures, though they might not do so if these were all made at the same time. But it often happens that squares with numerous feeding punctures remain closed and wither up without flaring.

HAIRY MARGINS OF INVOLUCRAL BRACTS.

In addition to their larger size, the bracts of the Kekchi cotton have the marginal teeth or laciniæ more numerous and more hairy than those of our Upland varieties and able to afford more of an impediment to the entrance of the weevils. The difference was very pronounced in our experimental plot, where King, Parker, and other familiar American sorts were planted beside the Kekchi. It is as superior in this respect to the other Upland varieties as they are to the Sea Island.

The Kekchi and Rabinal varieties, though both belonging to the Upland series and having many similarities, have also very distinct differences, as, for example, in the present character. The small, firmly appressed bracts of the Rabinal cotton have the marginal laciniæ few and small; sometimes the edges are nearly entire, or merely toothed. The hairy covering is also reduced to a fine, short coat, which can afford little or no impediment to the weevils.

EXTENT OF PROTECTION BY INVOLUCRE.

That the closed involucres do indeed contribute to the protection of the young buds from the weevils became very obvious in one of our experimental plots at Secanquim, located about a quarter of a mile outside the belt of Indian cultivation of cotton. There being no keleps to afford protection, the cotton soon became thickly infested with weevils, and very few bolls were allowed to develop on any of the plants. There was a notable difference, however, in the age at which the buds were punctured. As already stated, the edges of the bracts of some of the Sea Island and Egyptian varieties separate at a much earlier period than those of the Upland varieties, and the weevils commonly attack them in their very early stages, and even while they are altogether too small to permit the development of a weevil larva. It has been pointed out already by Messrs. Hunter and Hinds that the smooth stems and petioles of the Sea Island and Egyptian cottons render them much more readily susceptible to injury by the boll weevil than are the Upland types, and if we add to this the disadvantage arising from the later development and the more open involucres the possibility of protecting the long-staple cottons against the weevils seems small indeed.

Instead of being immune to the boll weevil, as at one time hoped, the Egyptian and Sea Island varieties seem to be most lacking in weevil-resisting adaptations, as might, indeed, have been expected in view of the fact that they have been developed in regions to which the weevil has not yet penetrated. The Kidney cottons, which may be looked upon as representing the Sea Island type on the mainland of the American continents, have, as will be seen later, a peculiar feature of protective value.

ADVANTAGE OF OPEN INVOLUCRES.

It will be apparent from the facts already recited that the partly closed involucres of the Sea Island and Upland varieties now cultivated in the United States serve little or no purpose in resisting the boll weevil. On the contrary, they often appear to be an advantage to the insect, serving, as they do, to hide the parasite from its enemies and protect it against the application of insecticides or capture by insectivorous birds.[a]

The great variation in the size and shape of the involucre in the different varieties of cotton suggests the practicability of securing sorts with open involucres or with these structures reduced to small dimensions. If the weevils were to be caught by insectivorous birds, like the Cuban oriole, whose weevil-eating habits have been discovered by Mr. E. A. Schwarz, open involucres would be a distinct advantage. It might then be possible also to apply Paris green or other insecticides to young buds which are, except in the early spring, the exclusive feeding places of the weevils.

The practicability of an open involucre will need, however, to be considered from another standpoint. It must be ascertained whether the young buds will bear full exposure. Unlike most of the related plants, the cotton bud is not protected by a calyx. The involucre may be necessary as a substitute, especially in dry climates. In humid

[a] Dr. H. J. Webber states that the desirability of open involucres has been appreciated and that selections of Upland varieties with a view to the development of this character have been made.

regions, however, this requirement might be relaxed, and it is in such places that the injuries of the weevils are the greatest.[a]

BEHAVIOR OF PARASITIZED BUDS.

SHEDDING OF WEEVIL-INFESTED SQUARES.

In a dry climate, like that of the Mexican plateau region, the dropping of the squares in which the weevils have deposited eggs would constitute a very effective adaptation. The weevil larvæ do not survive a thorough drying out of the squares. It is only in the arid districts of Mexico that the cotton plant has shown its ability to escape from cultivation and maintain itself without human assistance, if indeed it be not in some places a truly indigenous wild plant, as several botanists have reported. But in a moist region like the cotton belt of eastern Texas this habit of the plant has no practical use, since as many of the weevils die when the injured squares remain attached to the plant as when they fall to the ground.

"It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. Some plants, however, shed the injured squares more readily than do others. It seems to be a matter of individual variation rather than a varietal character. Thus occasional plants retain a large proportion of their infested squares, which hang by the very tip of the base of the stem. Normally the squares are shed because of the formation of an absciss layer of corky tissue across their junction with the stem. In the case of the squares which remain hanging, the formation of this layer seems to be incomplete, or else it becomes formed in an unusual plane, so that while the square is effectually cut off, it merely falls over and hangs by a bit of bark at its tip. In this position it dries thoroughly and becomes of a dark brown color. Plants showing 6 or 8 of these dried brown squares are quite common in infested fields. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not all destroyed. * * *

"It seems a conservative estimate, therefore, to say that fully one-third of these exposed dried squares may be expected to produce adults. Considering the exposed condition of such squares this seems to be a very high percentage. * * * The observations made, however, certainly show that a complete

[a] After the above had been written it was observed that the Pachon cotton from western Guatemala, grown in an experimental plot at Lanham, Md., has the peculiar feature of a large calyx, which completely covers the young bud and extends above it into long, slender, hairy tips. It may be that this is to be looked upon as still another weevil-resisting adaptation. The weevils would be able, undoubtedly, to bore through the calyx, but the hairy tips might hinder their access to the bud. The bracts are much smaller and much more open than in the Kekchi and Rabinal varieties, but the laciniæ, or teeth, along their margins are rather stiff and are clothed with numerous hairs, stronger and more bristlelike than in the Kekchi and Rabinal varieties, and able to keep the laciniæ from closing together. It may be that the greater rigidity of the laciniæ and the bristles gives better protection than the open position of the bracts would indicate. The case is in reality quite different from that of the Sea Island varieties, where the bracts are both naked and open.

drying of the square does not necessarily destroy the larva, and that a square may undergo far more exposure to direct sunshine than had been supposed possible without causing the death of the larva or pupa within."[a]

It is to be remembered, however, that such disconnected squares are thoroughly dampened every night by the dew, and that a small amount of moisture may pass out from the plant through the shred of dead tissue. In either case the hanging boll might get more moisture and less heat than if lying on the dry ground, exposed to full sunlight. Suspended bolls are exposed to air temperatures only.

If no other means of avoiding the weevil becomes practicable a great extension of the cotton production into the semiarid districts of western Texas, Oklahoma, and even Kansas is to be expected. The long days of the more northern districts will conduce to the shortening of the growing season, and if dry weather cuts down the yield the loss is likely to be neutralized by more or less complete protection against the weevils.

These contradictory effects of the same adaptation depending upon climatic condition may render necessary a complete differentiation of the cotton varieties of wet and dry regions.

It is not improbable that the Upland varieties previously known in the United States came originally from the more or less arid regions of Mexico, where absence or very small development of the basal branches keeps the ground from being constantly shaded and gives better chances for the weevils to be killed by the drying out of the fallen squares.

Our Upland cottons are undoubtedly of American origin, but the region from which they came has not been ascertained. Some of the Texas varieties are said to have been brought from Mexico. Coronado's Journal of the earliest Spanish exploration in Arizona and New Mexico contains many references to the cultivation of cotton by the Indians. There can be little doubt that the agricultural Indians of the Gulf region also cultivated cotton, though no documentary evidence of the fact seems to have come to light as yet.

It is highly probable that the original home of the cotton plant, and of the boll weevil as well, was in a somewhat arid region, since it is only under such conditions that the weevil would be effectually prevented from increasing to the fatal degree of destroying its host plant, and thus cutting off its only means of subsistence. On the other hand, it was only in a humid country like eastern Guatemala that many of these weevil-resisting adaptations would be likely to develop if, as now appears, it has required the selective influence of the boll weevil itself to bring them to their present advanced development.

[a] Hunter, W. D., and Hinds, W. E., 1904. The Mexican Cotton Boll Weevil. Bul. 45, Division of Entomology, U. S. Department of Agriculture, pp. 73 and 74.

The adaptive character of this habit of shedding the parasitized squares seems to be confirmed by the fact that it depends upon the existence of a special layer of soft cells which readily break down when the bud is injured. Many plants have such cells as a means of shedding their fruits, but they seem not to be prevalent among the relatives of the cotton. The cotton itself does not drop the ripe bolls, and even the empty shell often remains long after the seeds are gone.

The drier the climate the more effective is the prompt shedding of injured squares. Whether there are other adaptations thus especially suited to dry climates is not yet known, our studies having been confined mostly to humid regions.

Dr. Edward Palmer, who has spent many years in botanical explorations of the dry plateau region of Mexico and who discovered that the boll weevil was a cotton pest, states that in several localities where the cotton was formerly grown without difficulty the introduction of irrigation improvements has proved disastrous. With the assistance of the moist soil the weevils are now able to reach maturity in large numbers and complete the devastation of the crop, quite as in Texas. The irrigated soil affords a situation favorable for the development of the larvae in the fallen squares.

This is said to have been the case about Parras, and at Rio Verde, below San Luis Potosi. The culture of cotton has declined also in the "Huasteca Potosina," the tropical district between San Luis and Tampico, and on the Pacific side of Mexico, along the Santiago River above San Blas, as well as about Tepic. Doctor Palmer saw cotton growing in a wild condition in the fences at the old mission, San José de Guaymas, 6 miles from the commercial port; again at Mulege, Lower California, across the Gulf from Guaymas, the latter a much-branched, prolific tree, producing a nankeen-colored lint. About Guaymas cotton was formerly utilized by the Indians as tinder, after being dipped in a solution of saltpeter. The same facts were observed by Dr. L. O. Howard in 1899 at San José de Guaymas.

COUNTINGS OF FLARED AND FALLEN SQUARES.

An attempt was made in connection with our Guatemalan experiment to secure data on which a definite statement might be based regarding the extent to which the different varieties were protected by their involucral characters, but the problems are too complex to be reached except by more elaborate statistical studies than were practicable at that time.

Countings were made, for example, of the flared and fallen squares—that is, of those which it might be supposed that the weevils have injured—and of the number of weevil larvae, proliferations, etc., found inside them. The results in percentages do not agree, however, with the facts obvious in the fields; indeed, they greatly misrepresent them. Thus the percentage of weevil injuries in flared and fallen squares does not appear very much higher in the Kekchi cotton than in the Sea Island and Upland varieties; yet as a matter of fact the squares of the Kekchi cotton seldom flared for any other reason than weevil injuries, and much less often for this cause than did those of other varieties. Many small squares of the Kekchi cotton fall off, however, before they are large enough or open enough to be attacked by the weevils.[a] This takes place in the other varieties to a much smaller extent, but with them the apparent percentage of weevil injuries among flared squares is much diminished, because many squares stand open and appear as though beginning to flare, even before the weevils have attacked them.

PROLIFERATION OF INTERNAL TISSUES OF BUDS.

The protection of the buds does not end with devices for the exclusion of the adult weevils, nor with the rejection of those in which they have laid their eggs. It is also possible for the plant to heal the wound, and bring the injured bud to maturity by preventing the growth of the weevil larva. Where the climate is dry the weevil larvæ in the rejected buds are killed, as already explained. The humid climate alternative of the falling of the parasitized squares is proliferation, the growth inside the bud of loose, watery tissue in which the larva does not develop. Whether the larva is killed by smothering, starving, or poisoning, or by some combination of these, is not yet known. Starvation is a sufficient explanation, since the material with which the larva becomes surrounded can be no adequate substitute for the highly nutritious pollen grains on which the infant larva would otherwise feed.

Proliferation is much more frequent in the Kekchi cotton than in any of our United States varieties, as far as known. The first and second punctures are commonly resisted successfully, but the third, fourth, or fifth attempt may succeed in the development of a larva. The proportion of weevil punctures rendered ineffective by proliferation was found to run well above 50 per cent, sometimes between 80 and 90. (Pl. V.)

The promptness and efficiency of proliferation bear an inverse proportion to the size of the buds. As the latter grow larger the mass of anthers inside becomes less compact, and the other tissues become too

[a] Professor Pittier found in the latter part of the season that the buds of the Kekchi cotton were sometimes cut away at the base and left hanging in a wilted condition. These were at first taken for flared squares as the result of weevil injuries, but it was later ascertained that this was not the case, though the true cause was not learned. The damage was done in the night.

nearly mature to put forth new growth. If the presence of the larva at this stage is sufficient to cause the bud to fall off, the development of the parasite to maturity is well assured, the large bud affording good protection and adequate food.

In the Kekchi cotton, however, such late attacks very seldom cause the bud to fall off. Larvæ developed in the larger buds are turned out of doors, as it were, by the opening of the flower. The tendency of injured buds to persist is notably greater than in the United States, either because of some physiological difference between the varieties, or because of the larger and more firmly closed involucres of the Kekchi cotton, which keep the buds surrounded with a moist atmosphere and protect it against drying out while the new tissues are forming to heal the wound and encyst the egg.

In the closely planted Indian fields the squares seldom flare as in the Texas varieties. They generally remain in place and continue to grow until the bracts have reached nearly their full normal size. In fields partially protected by the keleps the weevil larvæ do not seem to develop in buds as small as in Texas. Proliferation may partly explain this delay and also the more firmly closed involucres, but in our unprotected plot the weevils were able by repeated punctures to infest smaller squares and reach maturity in them, after they had fallen to the ground.

The behavior of weevil larvæ inside the squares in Guatemala seems also to differ appreciably from that observed in Texas where younger squares are usually much more accessible to the weevils, and are commonly punctured. In Texas the larvæ regularly grow to maturity, depending for food upon the pollen, which is completely eaten out. In Guatemala this very seldom occurs. Small squares with well-developed weevil larvæ are rarely found under normal conditions, nor do the larvæ depend upon the pollen as their principal article of diet, as in Texas.

Several reasons for this difference may be considered. The first is that the larger and more firmly closed involucre of the Kekchi cotton gives the buds several days of protection, so that the average size would naturally be larger. The examination of large numbers of squares picked at random from the Indian cotton fields by Messrs. Kinsler and McLachlan show also that a very large proportion of the punctures are followed by proliferation, and that this means of protection is much more efficient in the younger squares. Another reason must be sought, however, for the failure of the larvæ to eat the pollen of the large buds where proliferation is less prompt and less frequent. The impression might be gained that the pollen of the Kekchi cotton is in some way not acceptable to the weevils, since even when there is an abundance of pollen at hand they prefer to eat out the style and central column of the flower, and thence down into the ovary or young boll. After this has been consumed the larvæ return to the upper part of the bud to finish the remainder of the pollen.

Nevertheless, this suggestion of a protecting quality in the pollen itself can not be accepted with much confidence because the weevils showed in numerous instances that they could live and thrive upon the pollen of the young squares, quite as in the United States. This occurred in the experimental plot where there were no keleps, and the weevils were very numerous and persistent in their attacks. After two or three punctures the squares flared and fell to the ground in the usual manner, and in these the weevil larvæ were able to reach maturity.

A more probable reason for the usual failure of the larvæ to eat the pollen as freely as in the United States is furnished by the opinion of Mr. W. D. Hunter, that the original habit of the weevil was to attack the bolls, like related species of Anthonomus, which live upon various kinds of fruits.[a] If this be true with reference to the boll weevil we may think of the Guatemalan members of the species as having retained somewhat more of the ancestral habits which with them are definitely useful, because the cotton variety with which they have to deal has perfected, to a larger extent than the Texas varieties, the art of proliferation.

As a further indication of the greater strength among the Guatemalan weevils of the instinct of attacking the ovary of the bud may be mentioned the fact that a very large proportion of the punctures occur low down—that is, on or below the level of the apex of the young boll. The larva commonly eats directly to the center of the bud and hollows out the apex of the young boll. This habit gives rather less opportunity for successful proliferation than in Texas, because the cavity hollowed out by the larva lies below the level of the staminal tube, the tissues of which are the most active in proliferation. The Kekchi cotton shows occasionally another form of proliferation not recorded from Texas, namely, that of the base of the corolla. Sometimes this enlargement takes place in an outward direction, forming a wart or protuberance on one side of the bud, as shown in Plate VI. In other instances the direction is reversed and the ingrowing edges of the wound made by the weevil fill the internal cavity and prevent the development of the larva. The proliferation of the corolla, besides being less

[a] A new species of Anthonomus with habits closely identical with those of the boll weevil, but parasitic on the pepper plant (Capsicum), has been discovered recently in Texas by Mr. E. A. Schwarz. This gains an added interest from the fact already noted that it is the regular custom of the Indians of Alta Vera Paz to plant peppers among the cotton.

frequent than that of the staminal tube, is probably also less effective, since the weevil larvæ could escape before it into the center of the flower while the proliferation from the staminal tube grows outward, as though to meet the intruder and keep him separated from the more special organs.

The habit of the larvæ to seek the center of the bud and gnaw off the style is responsible for the loss of large numbers of younger bolls which have suffered no direct injury from the weevil. Even though the larva be subsequently killed by proliferation or though the flower drops off and carries the larva with it, the lack of pollination must prevent the development of the young boll unless parthenogenesis takes place, which seems improbable.

Larvæ were found in several instances in nearly full-sized buds about to open, and in another case a more than half-grown larva was found inside the central column of an open flower. More or less distorted flowers with unmistakable signs of previous proliferation in the bud stages are commonly found in the Kekchi cotton fields.

Summarizing the results of the study of proliferation in the Kekchi cotton, it may be said that although the frequency of proliferation in the young squares is very great, its efficiency in preventing the breeding of the weevils is somewhat less than might be expected in Texas, owing to the difference of food habits among the weevils. If the Texas weevils are as consistent in their habits as now supposed, the introduction of the Kekchi cotton or of a similar proliferating variety might be of great benefit as a preventive measure. The extent, however, to which it could be made to compass the complete destruction of the weevil would depend somewhat upon the degree, if any, to which they might return to the habit shown in Guatemala of feeding upon the ovaries or boll rudiments rather than upon the pollen of the young buds, an important and hitherto unsuspected difference in habits between the weevils of Texas and those of Guatemala.

CAUSES AND CONDITIONS OF BUD PROLIFERATION.

That the proliferation is occasioned by the injuries of the weevil is too obvious to admit of doubt, but it may be of much practical importance to learn the exact way in which the new growth of tissue is brought about. The disturbing factor might be either mechanical or chemical. The new growth may be a direct response to injury of the weevils in feeding or laying eggs, or it might be stimulated indirectly by the secretions of the young larva, or by chemical changes or decay of the damaged tissue. A second mechanical possibility is that of pressure developed in the young and rapidly growing bud.

The burrowing of the weevil relieves this pressure at one point, and may thus furnish the exciting cause of the rapid growth in this direction of the tissue of the staminal tube.

It seems not improbable that a relation will be found between the method of culture and the extent and frequency of proliferation. Open-field conditions, with much bare ground about the plants, would increase the daily exposure of heat and dry air, and this would conduce to the wilting of the punctured squares, which might then be expected to flare and fall off instead of remaining to proliferate. The result of weevil work in our open-culture plots was obviously different from that in the more crowded cotton fields of the Indians. On the widely separated plants the squares often fell off and permitted the larvæ to develop, as in Texas, except that there was still a distinct tendency on the part of the larvæ to attack the pistil and ovary first, before eating out the pollen.

PROLIFERATION IN OTHER VARIETIES.

Proliferation is by no means confined to the Kekchi cotton, but probably occurs, occasionally at least, in all the Upland and Sea Island varieties. A noteworthy Guatemalan Sea Island cotton was found by Mr. Kinsler in the aldea of San Lucas, a few miles from Secanquim.[a] Both the buds and the bolls afforded fine examples of effective proliferation. Even the Egyptian varieties showed a distinct ability in this direction. In one instance no less than 17 of 23 punctured squares of Jannovitch had proliferated, and 15 cases seemed to have been effective.

Proliferation ceases to occur when the bud has become too large. The anthers are no longer so closely packed together and the tissues of the staminal tube are too nearly mature. By that time, however, the style may be sufficiently developed to furnish adequate food. It is well known, however, that the period of development of the weevil larvæ may be greatly prolonged, and this would seem likely in the present instance, since the tissues of the styles must be less nutritious than the pollen. The delay also would be advantageous, since it would permit the young boll to become larger.

[a] This variety is peculiar in having about half of each seed covered only with a very fine, short, bright bluish-green lint. The upper half bears the long white fiber, and is smooth and black when this has been removed. Some of the plants had excellent crops of bolls, unusually uniform in size and apparent age, as though the habit of seasonal flowering were well accentuated. The variety is evidently perennial and grows to a height of from 6 to 8 feet, but on the other plants the leaves, flowers, and bolls were much reduced in size. The plants were all occupied by small black ants. On some of them no weevils nor any indications of weevil injury were found, but others only a few rods away were badly infested.

But as the power of effective proliferation declines in the larger buds another factor of protection comes into play. The later the attack of the weevil the greater is the chance that the bud will mature and the flower will open and turn the weevil larva out of its quarters to die. And since buds commonly mature which have been attacked while still young enough to proliferate, it is easy to understand why attacks made in the later stages seem to be effective only in exceptional instances.

An element of uncertainty often attaches to the enumeration of weevil injuries because of the difficulty of finding the egg or very young larvæ of the weevil in the squares which have been only recently attacked. This is especially true in small squares where the anthers are still white and of about the same color, size, and general appearance as the eggs. The possible error does not, however, materially affect the result, since it is to be expected that the same proportion of bolls will proliferate and the same percentage of weevil larvæ develop as in the squares which are far enough advanced to show definite results.

PROTECTION OF THE BOLLS.

If it be true, as already intimated, that the original habit of the weevil was to attack the boll instead of the bud, the opportunity for the selective development of protective characters of the boll has been greater. This suggestion seems to accord with the results, since the boll of the Kekchi cotton has a series of protective characters even more striking and effective than those of the involucre and the bud.

PERSISTENCE OF FLOWERS.

As long as the flower remains in place the young boll is thoroughly protected, the weevils having no means of access except by boring through the withering tissues, which seems not to be attempted. In the Kekchi cotton the flower falls only when detached by the swelling of the young boll. This may also be true of other varieties. (See Pl. IX.)

The frequent sequel of proliferation in the bud, as noted above, is the loss of the young boll through lack of pollination. This is especially true in Guatemala, owing to the tendency of the weevil larvæ to eat away the style. On one occasion Mr. Kinsler collected from a field of Indian cotton 28 young bolls showing signs of debility. These measured from 13 to 20 mm. in length, most of them about 15 mm. None of the smaller bolls showed signs of weevil injury, but in many of them the ovules were already shriveling up. A few punctures were found in some of the larger bolls, and in some of these proliferation had occurred. The development of the weevil larvæ to maturity seemed unlikely in any case, because the unfertilized ovules were already withering.

Presumably there are various stages and degrees of fertilization. Some of the stigmas of proliferated buds seem to have adequate pollen, so that the bolls can develop normally, while others obtain none at all or only a little. The persistence of injured flowers is much greater. They may not fall off at all, and often remain attached by the withered style to the boll when nearly full size.

It thus happens that injured flowers protect their young bolls longer than the others, but in most instances such bolls remain small or unsymmetrical, presumably as a result of inadequate fertilization. It is quite possible, however, for normal bolls to develop occasionally from weevil-infested buds which never open, for the style often pushes through and becomes fully exposed, so that fertilization by pollen from another flower might readily take place.

IMMUNITY OF VERY YOUNG BOLLS.

For reasons not yet ascertained, the weevils in Guatemala seldom or never attacked the very young bolls. This may be due to a conservative instinct on the part of the weevil, like that which forbids the laying of any additional eggs in a bud already parasitized.[a] It is not impossible, however, that the oil glands with which the surface of the young boll is very thickly beset may have a protective function. As the boll grows larger the glands do not appear to increase in numbers, but become separated much more widely. On bolls of the Kekchi cotton the oil glands are usually absent from a distinct longitudinal band running down the middle of each carpel. (Pl. VII.) A large proportion of the weevil egg punctures are made along this naked band, although very few of them take effect. The wall is thicker here, and the weevil in boring meets the tough lining of the boll chamber at an angle, and is seldom able to penetrate. If this interpretation of the facts be correct, the naked band constitutes a veritable weevil trap, a device for inducing the weevil to make its punctures and lay its eggs in the part of the boll where they can do no harm.[b]

To ascribe a protective value to the oil glands is not unreasonable in view of the fact reported by Messrs. Quaintance and Brues,

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[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil, Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 78.

[b] This peculiarity of a glandless longitudinal band in the middle of each carpel was also noticed in a variety of cotton cultivated by the Moqui Indians of Arizona, grown in 1904, in the Department's plant-breeding experimental field at Terrell, Tex. The Moqui cotton is interesting also by reason of its short, squarish, distinctly apiculate bolls, more like some of the Old World cottons than are those of other members of the Upland series.

that the Egyptian cotton, the bolls of which are excessively oily, is on this account immune from the bollworm.[a] The oil contained in the glands has a deep-brown color, a sticky, molasses-like consistence, a disagreeable, pungent odor, and a sharp, resinous taste, suggesting turpentine or Canada balsam.

The development of the oil glands seems to be especially great in the Egyptian variety known as Mit Afifi, and the glands are more superficial. By slight pressure, or by drawing the nail across the surface, the oily liquid is freely obtained. Most of the Upland varieties have the oil glands much more scattering and deep set than the Egyptian sorts, and it is not possible to squeeze the resin out of them in any such manner.

On Redshank and other Upland types the resin glands are marked by slight superficial depressions, but a cross section shows them to be well below the surface, with several layers of chlorophyll-bearing cells between. On the Egyptian sorts the glands are also set in depressions, but the gland itself is very close to the surface, and makes the bottom of the depression again convex, the superficial layer of cells being very thin. It seems to break spontaneously in some instances; at least there are frequently small spots of hardened resin, and very slight pressure brings out the dark, gummy fluid. The fingers receive a permanent brownish stain, which with the acrid, biting sensation experienced when the liquid is applied to the tongue, increases the probability that substances of a definitely protective character are present. It is well known that many of the aromatic oils are for some reason highly distasteful or even fatal to many insects.

The Sea Island and Kidney cottons have the oil glands conspicuously developed, like the Egyptian varieties, but the Old World cotton (*Gossypium herbaceum*) is in this, as well as in other respects, more nearly related to the American Upland cotton (*Gossypium hirsutum*). The Aidin (Asia Minor) variety of *Gossypium herbaceum* has the oil glands rather small and deep set, with the superficial pits rather shallow, more so than the Ceylon or Korean types.

Even the petals of the Guatemalan Kidney cotton found at Trece Aguas[b] contained oil glands. The color of the petals was a uniform pale yellow, without purple spots on the inside, but in the upper

[a] Quaintance, A. L., and Brues, C. T., 1905. The Cotton Bollworm, Bul. 50, Bureau of Entomology, U. S. Department of Agriculture, p. 71.

[b] The Kidney cotton at Trece Aguas is called *paiyi*, and seems to have little or no relation in the minds of the Indians with the dwarf Upland cotton, which is called *nok*. In the Secanquim district, only a few miles away, this name *paiyi* (pronounced like the English words *pie ye*) is not recognized. Kidney cotton, though apparently not now planted by the Indians, is not entirely unknown to them. They call it simply *che nok*, or tree cotton.

half specked with minute brown glandular dots.[a] The oil glands of the bolls of this Kidney cotton are apparently quite as strongly developed as in the Egyptian varieties, or even more so. They are distributed very irregularly over the surface, and are not lacking above the dissepiments, along the middle of the carpels. The position and structure of the glands seem also to be the same as in the Egyptian cottons. They are close to the surface and show as distinct black spots, there being no green tissues over them as in the Upland and *herbaceum* types.

I am indebted to Mr. Guy N. Collins for the suggestion that the present inefficiency of the oil glands as a means of protecting the cotton from the boll weevil furnishes no argument against the adaptation of the glands nor their development through the selective agencies of the boll weevil itself. This fact is sufficiently obvious when once stated, but it is not commonly taken into account in considering questions of this kind. We may be sure that the gradual development of a protective character like the oil gland would carry with it a corresponding increase in the power of the weevil to avoid or to endure the injury. The ultimate value of the device would depend on whether the glands were able to keep ahead of the weevils in quantity and distastefulness. The readiness with which the boll weevils attack the Egyptian cotton renders it obvious that oil is now no adequate protection, but the preference of the weevils for the unprotected strips of the bolls of the Kekchi cotton indicates that the weevils still dislike the oil, though they may have foiled the attempt of the plant to protect itself in this way.

There are two attendant facts which under certain circumstances might readily obscure the immunity of the young bolls. Many such small bolls fall off, a particularly large number it seemed from our row of Parker cotton, but an examination of these failed to show anything in the way of weevil injuries, except such as had been inflicted while the bud or flower was still in place, the style and a small apical cavity having been eaten away in numerous instances. Many small bolls were to all appearances quite uninjured. They may have been rejected by the plant as supernumerary, the plant being unable to furnish the food material needed to bring them to maturity, or they may have failed of fertilization as a result of weevil injuries to the bud or from other causes, such as the absence of bees, which were extremely scarce in the Guatemalan cotton fields. The frequency with which the boll weevils were found inside the

[a] The flowers of the Kekchi cotton are pure creamy white when young and as long as they remain open. When old and rolled together they become a pinkish red. They are not yellow or bluish at any stage. The stamens and pistils are also nearly white, the latter with rows of oil glands showing as small grayish dots.

cotton flowers and well dusted over with pollen suggests the possibility that in this district at least they were a not unimportant agency of cross-fertilization. The performance of such a service by the boll weevil would be comparable to the famous case of the yucca and its moth, the plant being dependent for cross-fertilization upon its insect parasite. The weevils eat the pollen from the bud; that they visit the flowers for the same purpose seems highly probable. The investigations of Messrs. Hunter and Hinds have shown, indeed, that a pollen diet is a necessity for the complete sexual maturity and reproduction of the weevils; if without buds to feed upon they seldom copulated and never laid eggs.[a]

RAPID GROWTH OF YOUNG BOLLS.

Mr. John H. Kinsler, who gave careful attention to the earlier stages of the Guatemalan experiment, gained an impression that the young bolls of the Kekchi cotton increased in size with a rapidity distinctly greater than that of the United States Upland varieties planted alongside. It was not practicable to establish the fact by carrying out a series of daily measurements, though it was possible to ascertain from dated tags used in connection with the hybridization experiments that the Kekchi cotton can grow bolls to full size in less than a month from the time the flower opens. Plate IX, figure 2, shows on the right two bolls of Kekchi cotton less than a month from flowering. On the left are the two largest bolls from an adjoining plant of King, the seed of both varieties having been sown the same day.

Such an acceleration of the growth would be of very obvious utility in lessening the period in which the danger of infestation is greatest. A large proportion of the weevils found in adult bolls of Kekchi cotton were in "locks" or compartments of diminutive size, showing that the infestation had taken place while the boll was less than half grown. Indeed, the weevils seldom seem to be able to affect lodgment in bolls more than half grown, although numerous attempts are made in fields where the weevils are numerous. The following field note describes such an instance:

A boll showing many external marks of weevil punctures was found on being cut up with care to have been attacked at least fourteen times. In five cases the outer wall seemed not to have been penetrated, but in nine others there had been complete perforations. All of these had been closed, however, by proliferation from the inner surface, and no living larvae were found.

Such persistent attacks, however, may finally induce a diseased condition which interferes with the normal growth of the boll, even

[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil. Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 113.

though the weevils be successfully resisted. Such injured bolls often show a brownish discoloration of the interior tissues near the base and connecting with the nectaries, which may indicate a bacterial disease, to be discussed later. Sometimes this affects the walls only, sometimes one or more seeds and the surrounding lint.

THICK-WALLED BOLLS.

In the Kekchi cotton there are considerable variations in the thickness of the outer wall of the boll. Not infrequently the wall equals or exceeds the length of a weevil's snout, so that only the largest or longest snouted weevils would be able to make an opening into the interior cavity. It was noted, also, that on the inside such bolls are often quite free from these injuries or small larvæ, though numerous attempts may have been made. Large larvæ or pupæ may be found, but these have come, obviously, from eggs laid while the boll was still young. On some plants the development of large thick walls takes place very promptly, so that a protective character of considerable value might be obtained if this feature could be increased and rendered constant. Early development of the thick walls was indicated by the fact that the young seeds and lint did not fill the cavity, and the seeds were still far from mature. Instances might be drawn from other plants where the growth of the pod or seed vessels far outruns the seeds at first, so that the development of such a character in cotton might reasonably be expected.

Even when a wall thicker than usual has been bored through, the egg must be laid on the outside of the mass of lint which still intervenes between it and the young seed, so that the larva's chances of development are greatly lessened. As will be shown later in the discussion of proliferation in the bolls, the instances are very numerous in which, although the wall is penetrated, no further damage results; either the egg is not laid or the development of the larva is prevented by proliferation. In any event the boll escapes further injury, and it is a very significant fact that in the dissection of a large number of such bolls of Kekchi cotton scarcely any young larvæ were found, in spite of the fact that most of them had been punctured not once only, but many times.

TOUGH LININGS OF CHAMBERS OF BOLLS.

The three, four, or five chambers which contain the locks of cotton in the unopened boll have each a complete membranous lining. In the Kekchi cotton, at least, this is extremely tough and parchment-like, even in bolls not yet full grown and in which the seeds are not yet fully formed. This membrane is readily separable from the more fleshy external layers of the boll, and though flexible, it is very firm and incompressible, and resists tearing unless considerable strength be exerted.

A large percentage of attempted punctures of the larger bolls failed because the weevils are unable to penetrate this protective lining. This fact is readily determined by the study of radial sections of the outer wall through the warts which mark the weevils' points of attack. The different texture of the new tissue which has closed the wound shows, usually, that the cavity eaten out by the weevil extended down to the tough basal lining, even when no evidence of the injury has become apparent on the inside. In other instances, also very frequent, the new tissue, developed as a result of the irritation of the attempted puncture, exceeds the cavity and causes an inward swelling or prominence of the inner lining analogous to the projecting warts which are the usual external indication of weevil punctures.

It occasionally happens, too, that the projection of the new tissue occurs almost entirely in the inside, the external wart being very slightly developed or not at all, though the new tissue and the inner swelling show that a puncture had been attempted.

The utility of this lining as a means of excluding the boll weevil seems not to have been considered heretofore, and there has been no opportunity as yet to compare the Kekchi cotton with other varieties with regard to this feature.[a] Certain it is, however, that in the Kekchi cotton the parchment lining is almost as firm and tough as that which surrounds an adult coffee seed. And it is certain, also, that a very large proportion of the attempted punctures of the bolls failed to bore through this inner wall of defense.

The examination of a large number of bolls, which were full size or nearly so, though still far from maturity, in most cases failed to find more than a very few instances, if any, of very recent perforation, though there were large numbers of instances where the weevils had gnawed their way down through the parchment and deposited an egg. In many such cases the proliferation or new growth induced by the injury causes the parchment to be raised up from the wall on the inside to form a blister-like, rounded protuberance. (Pl. VIII.) Eggs laid outside the parchment are firmly embedded in the new

[a] Since this was written Mr. McLachlan has reported the existence of the same form of protection in Upland varieties in Texas. The following note describes the results of injuries inflicted upon the bolls of a plant of Parker cotton in four days from August 8 to August 12, 1905:

"The 9 larger bolls, when opened, were found to have 28 weevil eggs deposited in them; 6 had struck the dissepiment; 12 were not entirely through the shuck of the boll (either not more than half way there or else stuck in the tough inner tissue of the shuck); the others were embedded in the lint. In only two instances was there any proliferation apparent. The outer shuck had proliferated at the wound and in one case had encysted the egg. The other had merely forced the egg to one side, having begun the development too late."

growth and do not appear to hatch, or if they do the larvæ are not able to do any damage, since they can not penetrate into the interior of the boll. It quite frequently happens that eggs are laid in the sinus or groove between the linings of two locks, but without penetrating the parchment of either. The tissue is here somewhat looser than in other parts of the wall. In a few instances it was observed that the larvæ had hatched, but no case was found which indicated that larvæ hatched outside the parchment lining had been able to penetrate to the interior cavity.

PROLIFERATION FROM THE WALL OF THE BOLL.

The wall of the boll offers an active form of weevil resistance by proliferation, in a manner somewhat analogous to that of the proliferation of the square. The channel excavated by the weevil is closed by the new growth, which continues to push out on the inner surface of the wall in the form of a rounded, blister-like protuberance of loose tissue. This surrounds and encysts the weevil egg, and prevents its development. A section through the mass of new tissue shows the egg embedded in it or pressed against the lint. Proliferation often takes place even when the tough lining of the chamber has not been penetrated, and then appears as a prominence underneath the membrane.

It has been seen from the preceding paragraph describing the thick walls and tough lining that in the Kekchi cotton, at least, the weevil is practically excluded from the boll after the boll has reached about three-quarters of its full size; but even in its younger stages also there is a measure of defense through the formation of new tissue as a result of the irritation set up by the weevil's injuries in a manner analogous to that which induces the formation of galls and other vegetable excrescences.

The first result of the proliferation is to fill up and heal the wound bored out by the weevil. The cavity is not only completely filled, but in most cases a wartlike prominence is formed on the outside, and if the parchment lining or the inner wall has been penetrated the new proliferating tissue also grows through on the inside and often spreads out as a biscuit or button shaped protuberance of soft white or transparent tissue several millimeters in diameter and readily visible to the naked eye. (Pl. VIII.)

There are two alternatives in the fate of an egg destroyed by proliferation. Either it is completely surrounded in the proliferating tissue outside or inside of the parchment wall or it is carried on the apex of the proliferation down against the lint and flattened between the growing surfaces. After the egg has disintegrated and disappeared its position is frequently shown by a minute brown stain. Such a discoloration often spreads back into the loose tissue and then gradually extends over the whole lock of cotton of that particular chamber. The seeds fail to develop and finally shrivel up.

If the proliferation results, as usual, in the death of the weevil egg or young larva, the process of abnormal growth ceases with the formation of a knob or button of the new tissue on the inside of the wall of the boll. When, however, the young weevil escapes destruction and continues to eat and grow, the proliferating tissue also continues to increase, until in some instances the whole compartment is filled with a silvery-white cheesy material which seems to arise not only from about the original perforation of the outer wall, but also from other parts which have been injured and irritated by the presence of the weevil larva. This, with other facts already stated, seems to show that in some varieties of cotton, at least, the tendency to proliferation is very general, or, in other words, constitutional, which warrants a larger hope of increasing this character and making it uniform by selection.

When proliferation, which results from the presence of the weevil larva, has become very extensive and fills the entire compartment, the weevil larva is sometimes found to have eaten through the dissepiment into the next chamber, perhaps to escape starvation. Such extensive proliferation, accompanied by the failure of the seeds to develop, means, of course, that the weevils gained entrance while the boll was still very young. Moreover, if the boll had been older there would have been plenty of food for the larva without the necessity of entering a second compartment. Finally, the dissepiment would have been too tough for the larva to penetrate easily.

Further proof of the fact that the weevil larvæ are seldom or never able to gain a footing in the larger bolls is to be found in the fact, already stated, that the weevil larvæ found in them are nearly always in undersized compartments, much smaller than those which have remained uninjured, and have thus been able to continue their normal development.

It is to be supposed, perhaps, that if the weevils could gain access to large bolls and feed upon the nearly adult seed they would be able to develop in less time than they usually spend in reaching maturity on the rather poor provender they secure among the abnormal tissues which arise after they have entered the young bolls.

The exclusion of the weevil from the large bolls has been evidently not only an important measure of protection for the cotton, but it has probably compelled the weevil to accustom itself to a gradually longer and less prosperous development in the boll. The development of the weevil-resisting adaptations on the part of the cotton plant has left the insect with two opposite alternatives. It must enter the boll early and submit to a very long period of development or enter the square late and develop very promptly. The insect has been able, as we know, to avail itself with a large measure of success of both these alternatives, but it is not without encouragement for future progress in weevil resistance to know that the plant has so successfully guarded itself in two parts of its life history.

If additional evidence be needed to show that the food supply obtained by the weevil larvæ in the bolls is very different from that in the squares, it is to be found in the large, firm-walled cells of compacted excrement with which they surround themselves in the bolls before reaching maturity. The food being of a much coarser nature and the period of development about three times as long, the amount of waste material is naturally very much greater. If feeding upon the boll is, as now appears probable, the ancestral habit of the weevil, it need not surprise us that the protective adaptations of the boll are more numerous and effective than those of the bud, which may have been attacked by the weevil in comparatively recent times.

TIME REQUIRED FOR PROLIFERATION.

In connection with the experiments in Texas, Mr. McLachlan attempted to ascertain the time required for proliferation to take place after the injury had been inflicted. The amount of proliferation and the time required for it to develop may be expected to depend much on external conditions. Squares of Parker cotton showed no development in six hours, but observation on bolls showed that proliferation was complete in twenty-four hours. Two of Mr. McLachlan's observations are described in the following notes:

On August 14, at 9.15 a. m., a wire cage was placed over a plant of King cotton, and four weevils, of which at least two were females, were put inside. Later, three more were introduced. At the time there were 11 bolls, 39 squares, and 1 flower on the plant.

On August 17, at 1 p. m., 11 bolls and 18 squares were picked, a little more than three days being allowed for the weevils to work. There was no rain, and of the 18 squares examined only one revealed proliferated tissue, though the weevils had scarred the buds in more than 33 separate places and had deposited 15 eggs. But the bolls showed better results. They had been scarred at 32 different points, and 23 eggs were discovered when the bolls were cut open. In 12 cases inward proliferation of the "shuck" had destroyed the eggs. Several of the incited growths had caught the egg, encysted it, and carried it along, inclosed at the apex, as they pushed their way into the lint. As in the Parker cotton examined a short time ago, weevils seem to have some difficulty in getting the egg through the shuck of the boll. In dry weather it appears that the King cotton is as backward as the Parker in proliferation in the squares, but in bolls proliferation goes forward as well in dry as in wet weather.

On the 30th of August, at 10.15 a. m., a boll (half grown and tender) was bagged with a weevil. At 6 p. m. of the same day an egg puncture was found on the fruit, but at 8 a. m. of the 31st no further injury had been inflicted. At 12 m., September 1, four more egg punctures were discovered, and the boll was pulled and examined. The first puncture was then forty-two hours old and the other four some twenty-four hours old. The examination revealed marked proliferation in every case, with no greater growth in that of forty-two hours' duration than there was in that of twenty-four. Eggs had been laid inside the wall of the boll, since it was easy, in the case of young, tender fruit, for the weevil to cut an opening to the lint. But every one of the five eggs had been encysted by the proliferated tissue. It is quite possible that one or two of the punctures reckoned as twenty-four hours old were still more recent.

EFFICIENCY OF ADAPTIVE CHARACTERS OF BOLLS.

The amount of protection afforded in Guatemala by the weevil-resisting characters of the bolls might be greatly underestimated if it were to be supposed that the weevils make numerous attacks upon the bolls for the purpose of feeding upon them.

In their accounts of the habits of the boll weevil in Texas, Messrs. Hunter and Hinds have devoted a chapter to "effects of feeding upon squares and bolls,"[a] but in Guatemala no indications were found that weevils punctured the larger bolls for any other purpose than egg laying. It is true that the outer surfaces of bolls are frequently marked with scars of weevil punctures from which no larvæ have developed and no internal injuries have resulted, but these failures can be explained in other ways than by the supposition that the weevils feed upon the tough and innutritious outer walls of the bolls. In Guatemala, at least, it appears that the weevil scars on large bolls mark attempts at egg laying, though for a variety of reasons already recited most of them are not effective. The only instance where weevils were found feeding in bolls in Guatemala was at Rabinal. Two weevils were together attacking a small boll, and had eaten out large superficial pits, quite unlike the punctures in which eggs are laid.

Feeding punctures in bolls are referred to by Mr. McLachlan in a note dated at Victoria, Tex., August 31, 1905. Such injuries were not found, however, to lead to the formation of external warts which could be mistaken for egg punctures, doubtless for the reason which Mr. McLachlan gives:

> It has been noticed that in bolls no proliferation occurs following the injury from a feeding puncture, however serious that may be. Furthermore, from the above and other observations it is apparent that proliferation is not excited by the egg puncture or the egg, unless the puncture extends through the inside tissue and the egg is fixed in the tissue or has been pushed through it to the lint. In that case a dense knob of proliferation occurs on the inner side of the shuck, in the center of which the egg is often encysted. There must be a constant irritant like the egg, with an opening to give it access to the lint, in order to occasion the specialized growth. As a suggestion it might be noted that all the egg punctures are sealed by the adult weevil at the time of egg laying, while the feeding punctures are left open.

[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil, Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 59, Pl. VIII.

The feeding experiment reported by Messrs. Hunter and Hinds[a] shows that weevils fed exclusively upon bolls lived less than twenty days, while those fed upon the squares lived nearly seventy days. The bolls proved to be much less suitable for food than the leaves, on which the weevils were able to prolong life for thirty days and upward, though no eggs were laid on a leaf diet. It may be that in Texas, where the army worms sometimes destroy all the leaves, the weevils might be driven to gnawing the bolls for food, but in Guatemala the plants remain in full leaf throughout the growing season.

BACTERIAL DISEASES FOLLOWING WEEVIL INJURIES.

In the study of the bolls of the Kekchi cotton three diseased conditions were observed, some or all of which may be of bacterial origin, the bacteria having been introduced, perhaps, by the weevils at the time of egg laying. None of these diseased conditions is frequent, and as they do not permit the fruit to reach normal maturity it seems very unlikely that they can be introduced into the United States with the seeds. It may be stated in addition that the seed obtained by Mr. Kinsler in the season of 1905 has been carefully selected in the field and comes from the earliest and most vigorous bolls.

The first of the diseased conditions consists in a white deliquescence of the immature seeds and lint as though the lock had been dipped in milk. There is also a distinct odor of fermentation. Another disease turns the seed and lint brown. Though observed only in bolls which have been punctured by the weevil, there was often an apparent connection between the disease inside and the large extrafloral nectaries. A column of transparent or somewhat discolored tissue extends from each nectary obliquely upward to the cavity of the boll. This may be a symptom of the disease or it may indicate that bacteria find their way into the bolls by way of the nectaries.

The third abnormal condition was also indicated by a brown discoloration of the wall and contents of the affected compartment of the boll. The seeds and lint soon die and shrivel. No special indication of bacterial activity was noted, and it may be that the death of the weevil egg or larva has some prejudicial effect upon the surrounding cells, as suggested by the brown discoloration already noted in describing the effects of proliferation. Such a disturbance might continue to spread and thus cause the death of the young seeds.

BREEDING IN BUDS A DERIVED HABIT.

The fact that the weevil larvæ are found in the young buds of the cotton plant and also in the full-grown bolls has been taken to mean that it affects all the intervening stages as well. This would imply

[a] Hunter, W. D., and Hinds, W. E., l. c., pp. 34–35.

also that if the weevil fed originally upon the bolls it has followed back to earlier and earlier stages and finally to the bud. The facts already detailed seem to prove, however, that this is not the case. The weevil does not attack the very young bolls, nor does it operate while the flower is open or while it remains in place, though in a withered condition. The hatching of the weevil larva in the large buds is likewise ineffective because the larva is deprived of shelter when the flower opens. It seems necessary to believe, therefore, that the parasitism of the weevils upon the buds of the cotton is a habit quite distinct from that of its relations to the boll. The habit of breeding in the bud marked a new departure in the biological history of the insect and not a gradual change from the previous habit of infesting the bolls only. Nevertheless, the change of habits need not be thought of as anything very remarkable from the standpoint of the insect. A cotton bud is very much larger than a small boll. The peculiarity lies in the plant rather than in the insect, since very few plants afford a continuous and abundant succession of large, pollen-filled buds. It is this quality of the cotton plant which has enabled the weevil to develop its peculiar and highly destructive secondary habits of feeding upon the buds and using them as breeding places. If the boll weevil were restricted, like related beetles, to parasitism upon the fruit of the cotton, it would have remained a comparatively harmless and agriculturally insignificant enemy. These considerations may assist in a better appreciation of the extent to which the weevil's power of injury would be diminished if we could obtain a variety of cotton with a fully determinate habit of growth, one which would cease producing buds as soon as a crop of cotton had been set.

The much more rapid development of weevil larvæ in the bud is to be connected, doubtless, with the much richer food offered by the mass of pollen, but it may represent also a somewhat more definitely adaptive specialization of the life history of the weevil, for it is generally a question of eating the pollen promptly or not at all. If the bud falls off on moist ground the pollen would be completely decomposed long before the larva could develop, at the rate at which it grows in the boll, and if the bud did not drop off, but continued to grow, the flower would open and turn the larva out. It is obliged, therefore, to do damage fast enough to keep the flower from opening, and must then eat the remaining pollen before it spoils and leaves the larva too hungry and stunted to pass through the final metamorphosis into the adult stage. In a cotton which has a highly developed habit of shedding the injured buds it would not be so necessary for the larva to attack the pistil. It may be that this policy on the part of the weevils in Guatemala has a use to the weevil as being necessary to prevent the opening of the flower and cause the falling of the bud.

The diversity in size of the boll weevils, while not unprecedented among insects, is unusual, and not without biological significance in the present connection. An explanation of the variation in size is to be found, no doubt, in the varying amounts of food which the weevil larvæ can obtain, but there is needed, none the less, a special adaptability on the part of the weevil to permit it to reach a normal reproductive maturity in spite of very unfavorable conditions. The smaller weevils probably have less than a quarter of the weight of the large ones, which means that they are able to develop with a correspondingly small proportion of the food required to raise a full-sized weevil. The weevils developed in the bolls have a much greater uniformity of size. The small weevils are at once a means and a result of the acquisition of the habit of living in the buds, and especially in the small ones, where the supply of food is often very small.

RELATION BETWEEN PROLIFERATION IN BUDS AND IN BOLLS.

The analogy of the mucilaginous tissue found in the young fruits of okra and other relatives of the cotton would lead us to expect that proliferation could occur more readily in the boll than in the bud, which may mean that all the varieties which proliferate in the bud will do so in the bolls as well.

It was at first supposed that if the buds proliferated but not the bolls the result would be merely a postponement of the breeding season of the weevil for two or three weeks, or until the bolls had time to develop. Such a delay would be of great practical importance in retarding for that length of time the effective breeding period of the weevils. Moreover, most of the eggs of the weevils which had passed through hibernation would be lost by being laid in the buds, which would further keep down numbers in the early part of the season. There is, however, the further and still more important consideration, that the period of development of the weevil in the boll is very much longer than required for it to mature and emerge from the square.[a]

[a] Determinations of the length of the life cycle in bolls have been made only in a few instances. In 7 cases between August 15 and November 11, 1903, the average time required from the deposition of the egg to the escape of the adult from the opening boll was sixty-one days. The average effective temperature for the period was 31.7° F., and the average total effective temperature required for development in bolls was therefore 1,933.7° F., or nearly two and one-half times as much as in squares. Several larvæ often develop within a single boll. They appear to remain in the larval stage until the boll becomes sufficiently mature or so severely injured as to begin to dry and crack open. When this condition of the boll is reached, pupation takes place, and by the time the spreading of the carpels is sufficient to permit the escape of the weevils they have become adult.—Hunter, W. D., and Hinds, W. E., The Mexican Cotton Boll Weevil, Bul. 45, Division of Entomology, U. S. Dept. of Agriculture, 1904, p. 75.

Moreover, it seems that the adult weevil does not come out through the wall of the boll, but waits to be liberated when the boll opens to maturity. This would mean that if proliferation can exclude the weevil from breeding in the squares it would afford a practical solution of the problem, since instead of merely delaying the emergence of the first brood of weevils for two or three weeks, none of them would be able to set about the work of destruction until the crop had begun to ripen, and all danger of appreciable damage would have passed. It seems, therefore, that the proliferation in the squares is the much more valuable characteristic to be considered in seeking for a weevil-resistant cotton. Proliferation in the bolls is very desirable, but the absence of it should not be allowed to figure very largely against a variety which might have a pronounced tendency toward proliferation in the bud. Nevertheless, other factors must enter the calculation, for thin-walled bolls might allow the weevils to escape earlier. In moist weather the bolls might not crack open, but give the weevils comfortable shelter all winter, as would seem to have been the case in the spring of 1905, when various observers noted that some of the weevils seemed to have the appearance of having emerged only recently from the pupal condition, their very light color showing that their outer covering of scales was still in place.

The probability is, however, that the proliferation in both places will be found to depend upon the same internal factor or quality, so that it will be safe to assume that a high degree of proliferation in the bud could be taken as an index of what might be expected from the bolls. This would simplify the problem of selection by permitting us to confine our attention to the buds.

PROTECTION OF SEEDS BY LINT.

Like the large leafy involucre, the lint is also a peculiar feature of the cotton plant which may prove to have a practical connection with the weevil. Cotton is the only food plant of the boll weevil, and only the cotton, of all the related plants, has an abundant provision of lint. Some of the species of Hibiscus have the seeds slightly silky, but the cotton stands quite alone in the length and abundance of the hairy covering which grows out from the seeds at the time the bolls are most subject to weevil injuries.

From the standpoint of those who believe that all characters are useful to the organisms which possess them, the interpretation of the lint as a weevil-resisting adaptation will not appear unreasonable, since it can scarcely be claimed that there is any other use of the lint so important to the plant as protection of the seeds from the weevils. In other respects the lint seems rather a disadvantage than otherwise. In a humid tropical country the seeds, if left to themselves, remain inclosed in the tangled mass of lint and usually rot. Birds might carry the lint away to build nests, and in so doing might assist in scattering the seeds, but in most of the varieties the seeds are to be detached only with difficulty.

Composed as it is of nearly pure cellulose, the lint can afford very little nourishment, even in the younger stages. Between the lint and the watery proliferating tissue the weevil larva must find the inside of a cotton boll a very inhospitable place unless it can penetrate to the seeds. Dead and moribund larvæ are occasionally found in these unfavorable situations. And even the seeds themselves do not provide so favorable a food as the pollen, as shown by the much longer time required by the larvæ to develop in the boll than in the square.

PROTECTIVE SEED ARRANGEMENT IN KIDNEY COTTON.

Further intimation of the protective value of the lint is to be found in the very peculiar Kidney cottons, so called because the seeds are crowded together in the central angle of the chamber and adhere firmly to each other, thus forming a small, kidney-like mass. This unique arrangement brings all the lint to the outside of the seed, and may be the explanation of the fact that the Kidney cottons are the only representatives of the Sea Island type which have gained a wide distribution on the mainland. The separate-seeded Sea Island cottons came from Barbados, where the boll weevil did not exist and has not yet been introduced. (See Pl. X, fig. 2.)

The outer wall of the boll of the Kidney cotton is notably thinner than that of Kekchi cotton, so that the beaks of the weevils could reach through without difficulty. But with the layer of lint to supplement it the wall becomes, for practical purposes, much thicker than in the free-seeded varieties. The inner parchment lining is rather tough, though apparently less so than in the Kekchi cotton.

The Indians about Trece Aguas, Guatemala, are said to recognize the weevils as enemies of the dwarf cotton, but it is the local opinion that the Kidney cotton is proof against them.

No weevils were found on the two bushes of Kidney cotton examined in that locality, but these were single plants growing near Indian houses several miles away from the nearest field culture. In a forest-covered country like this part of Guatemala the luxuriant and tangled vegetation may well impede the flight of such an insect as the weevil. And if it lives, as supposed, only on cotton, its chance of reaching a single bush of tree cotton would be very small. That the buds and young bolls of the Kidney cotton are able to offer any absolute resistance to the weevil seems very improbable, and the abundance of weevils found on the large tree of Kidney cotton at Tucuru last year proved that the immunity, if any, is not general.

The Kidney cotton, though commonly treated as a distinct species under the name *Gossypium peruvianum*, agrees with the Sea Island type in all its characters except the peculiar arrangement of the seeds. If this should prove to be an adaptive feature the idea of specific distinctness would have little left to support it.

CULTURAL VALUE OF KIDNEY COTTON.

The possession by the Kidney cotton of a definite weevil-resisting adaptation would naturally raise a question regarding its cultural value. It belongs to the Sea Island series, and has the long, fine fiber and smooth seeds. The growing of the seeds together in masses would still further facilitate picking and ginning operations. The bolls, too, of this Guatemalan Kidney cotton, at least, are larger than those of any of the Sea Island varieties.

It is not likely, however, that any of the varieties of Kidney cotton thus far known will be found of use in the United States, for all are perennial "tree cottons," which have refused thus far to flower or fruit in the period of growth allowed by the shorter summers of our Temperate Zone. In tropical regions this objection would not hold, and there appears to be no reason why the Kidney cottons should be disregarded in the search for varieties suited to the various soils and climates. The Trece Aguas Kidney cotton, for example, seems to thrive well in a humid mountain climate considered by the natives to be unfavorable for the annual Kekchi cotton, which is planted several hundred feet lower down.

THE NATURE AND CAUSES OF ADAPTATIONS.

To explain how such characters as the weevil-resisting adaptations arise involves an interpretation of general evolutionary questions upon which the scientific world is still by no means agreed. Nevertheless, it is evident that students of such subjects should conduct and describe their investigations in accordance with some consistent plan or policy, if their writings are to be understood or their facts intelligibly recorded. Moreover, it would be scarcely reasonable to maintain that such characters can be further increased by selective influence unless it could be believed that they had been assisted in the past by the same agency.

It seems necessary to state that in the present report it is not assumed that the weevil-resisting characters have arisen as direct protective responses to the injuries, or that they are the results merely of stimulation or irritation caused by the weevils, as other writers on evolutionary subjects might hold. Nor have they been thought of as caused by selection in any strict sense of the word. Though constituting a most striking instance of the results of selective influence, it is believed that the cotton plant must first have originated in some measure the protective characters before the external conditions (in this instance, the weevils) could make them of advantage to the plants and thus encourage their further development.

The older theory that environment and natural selection are the efficient or actuating causes of evolutionary change has lost many adherents in the last decade, especially among those who found themselves unable to credit any longer the idea that all the characters and differences of plants and animals are, or have been, of use to them. It has been shown, too, by Professor Weissman and his followers, that direct adaptations or responses of individual organisms to the environment are seldom or never inherited by their offspring. To take the place of the doctrine of direct environmental influence in evolution it has been suggested that there may be an internal "hereditary mechanism," as it has been called, which determines adult characters in advance, in the reproductive cells, so that modifications of the specific or varietal type can arise suddenly. Selection would determine, of course, which of such new "mutations" should survive, but it would be a mere accidental coincidence if the new character happened to fit the conditions better than the old.

It is possible, however, to explain evolutionary progress and selective adaptations without ascribing them either to external causes or to theoretical internal mechanisms. The diversity which plants or animals of the same parentage often show under the same conditions makes it evident that there is no precise mechanism which determines their form in advance, and all attempts at securing any absolute uniformity or "fixity" of form and color have failed. The fact is that organisms, even of the same species or variety, are normally diverse, and must have ancestry mixed by interbreeding if bodily vigor is to be maintained for any great number of generations.

The generalized "specific type," which is a product, as it were, of this diversity and interbreeding, is constantly and gradually changing, and in many ways at once, though in some characters more rapidly than in others. Selection, while in no strict sense a cause of this vital motion of the species or variety, may profoundly influence the direction and rate of change. Selection, in other words, explains adaptation, but does not explain evolution.[a]

The word adaptation is used in more than one sense by writers on biological subjects. Some treat as adaptations the changes of form or structure by which many plants and animals are able to conform to the needs of different conditions. There are several plants, for example, which have normal broad leaves when they grow on land, and very narrow and much-divided leaves when they grow submerged

[a] Natural Selection in Kinetic Evolution, Science, N. S., 19:549, 1904.

in water. Some plants are hairy in dry localities, but are nearly naked in humid districts. Others treat these direct responses to external conditions under the heading of accommodation, and reserve the word adaptation for characters which appear regularly in a species or variety, but which fit it for some special condition, such as that presented to the cotton plant by the boll weevil. It has seemed proper, therefore, to discuss as protective adaptations any characters which seem to give the Central American varieties an advantage in withstanding the attacks of the weevil, particularly if it can be shown also that the presence of the weevil would tend to the preservation and extension of the given character.

In the strict sense of the words, the weevil-resisting adaptations of the cotton plant would include only those characters which have been increased by the selective influence of the boll weevil, but in the broader practical sense we may treat as a weevil-resisting adaptation any feature which tends to limit the destructiveness of the insect.

The adaptive nature of some of the characters of the Central American varieties discussed in the present paper is reasonably obvious, but in other instances extended studies in developmental biology and primitive agriculture might be necessary to determine the origin and development of a varietal characteristic which may have significance in the weevil problem.

It is easy to understand that so injurious an insect as the boll weevil has exerted a definite selective influence ever since its remote ancestors turned their attention to the cotton. Perhaps its earlier food plants were completely exterminated. The nearest living relatives of the cotton are the species of Hibiscus, Paritium, and Thespesia, none of which is known to have any attractions for the weevil. It is evident, too, that in the presence of the weevil the cotton plant would have met long ago a like fate if it had not been able to take on its various adaptive characters. That so many of the features by which it differs from its nearest relatives have such obvious connection with the weevil would certainly justify the belief that strong adaptive influence had been at work, even if the other circumstances were unknown.

In thinking of the relation between two organisms like the weevil and the cotton we often fall into the error of too great humanizing, so to speak; that is, we ascribe too great intelligence or too complete a reaction to cause or conditions. Thus the weevil, although highly specialized in some of its instincts, has, of course, no equivalent for the human judgment. It will puncture, as already seen, buds much too small to raise a larva, and will lay its eggs in the rind of the boll, where the larvæ can never develop. If the conditions are too favorable to the weevil, as in humid regions, it would undoubtedly exterminate its own host plant by permitting the cotton to produce no seed. Paradoxical as it may at first seem, we may, nevertheless, believe that the best conditions for the perpetuation of the weevil are those which are not altogether favorable to its unlimited multiplication.

CONSCIOUS AND UNCONSCIOUS SELECTION.

There are two principal ways in which improved varieties of cotton and other cultivated plants come into existence. The first is by sudden or abrupt changes, or sports; also called mutations, saltations, and discontinuous variations. These are represented in cotton by the occasional appearance of a plant with brown lint,[a] deeply divided leaves[b] (okra cotton) or very short branches (cluster cotton). The Guatemalan varieties represent a second type of evolutionary history, in which improvement is accomplished by more gradual progressive change, fostered and accelerated by selection.

Two forms of selection are commonly recognized, natural and artificial, the latter effected by man, the former by circumstances of the environment. This distinction is of doubtful value in any case, and quite obscures the important point in the evolutionary history of cotton and other plants domesticated by primitive man. It would be much better to think of selection as either conscious or unconscious, and between these two a very practicable difference exists. Conscious selection implies the preservation of individuals having a desired quality in the highest degree, while unconscious selection, whether by man, animals, or inanimate conditions, means merely the rejection of the most unfit, so that the improvement of the species or variety is gradual. Conscious selection acts, of course, much more

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[a] In Guatemala several tribes of Indians prefer brown cotton, and for certain garments use brown cotton only. Separate plantings of brown cotton are not made in the neighborhood of Secanquim, where our experiment was located, but there were said to be such at Cajabon and Lanquin, only a few leagues away. The Cajabon people have a dark-brown cotton called "canch nok," and a lighter brown called "canni nok."

On the Pacific slope Mr. William R. Maxon found considerable culture of a brown cotton called "ixcaco." At Antigua a similar brown variety is said to have been grown formerly in considerable quantities, the common name of which is "cuyuscate." It was not learned that any special religious use or significance is attached to brown cotton in Guatemala, as is said to be the case in Peru and in India.

[b] Some may be inclined to interpret these as reversions and to argue that the deeply divided involucral leaves may be a reminiscence of an ancestral character of the cotton. Or it may be that the divisions attained by the involucral leaves represent a tendency of specialization which the remainder of the leaves sometimes share by mutation, in accordance with the principle of translocation of characters recently formulated by Dr. R. G. Leavitt (Contrib. Ames Bot. Lab. No. 3).

speedily than unconscious, but is subject to the serious danger of weakening its protégés by inbreeding, if the selection be too rigid and persistent.

The unconscious selection by which the development of the protective characters of the Guatemalan types of cotton has been encouraged differs in no respect from the progress by which adaptive evolution takes place in nature. The Indians have planted and harvested the crop, it is true, instead of the birds or other natural agents, but they have been entirely unconscious of the struggle for existence to which the cotton plant was being subjected by the presence of the boll weevil. The Indians were only another factor, along with the dry and moist climates, the keleps, and the turkeys. The problem has been solved in a genuinely natural fashion, and affords an excellent illustration of the nature of selective influence in evolution.

Instead of representing the final possibilities of improvement in characters which give protection against the boll weevil, the Indian varieties of cotton may be looked upon rather as affording materials which conscious selection can render still more valuable. The proliferation character, for example, might never be brought to uniform expression by unconscious selection, because the possession of it would give the individual plant no advantage over its neighbors in the production of seed. The proliferating plant might produce no weevils itself, but the free movement of the insects would keep the general average the same. Indeed, a plant might easily sacrifice all its buds, set no fruit at all, and thus fail to perpetuate itself. Proliferation can become a direct advantage to the individual plant only under conscious selection. The full value of the newly ascertained protective adaptations will not be known until they have had the direct selective encouragement now commonly accorded to desirable characters of other cultivated plants.

It may appear remarkable that such definite and potentially valuable characters as the weevil-resisting adaptations of the Kekchi cotton should have remained so completely unrecognized hitherto. The explanation of this doubtless lies in the fact that cotton culture is practiced in Central America largely by the Indians and very little by the foreigners or the more intelligent part of the native community, so that it had not received scientific study. Even the existence and utility of the keleps, though apparently known to the Indians from ancient times, had entirely escaped the attention of the European residents of the country. That the Indians should have come to recognize the keleps as beneficial and necessary to a full crop of cotton, although not knowing that the weevils injure the cotton or that the keleps eat the weevils, only shows in higher relief the completely unconscious character of the selection conducted in this system of primitive agriculture. The Indians of Alta Vera Paz are extremely stolid, uncommunicative people, from whom little information is likely to be obtained except as replies to direct questions. Familiar from their earliest childhood with the agricultural lore of their own tribe, it does not occur to them that these everyday incidents can be of interest to the white stranger, or if they perceive his interest they learned long since to fear it as a danger of further intrusion. Even our own cotton experiments were misunderstood as a menace of additional demands for lands from the white men who now own so large a part of the country.

SUMMARY OF ADAPTATIONS.

If the facts stated in the present report have been correctly observed and interpreted, we must admit that the cotton plant is in a high state of adaptive specialization in its relations with its now famous insect enemy, the boll weevil. Indeed, it may be that the most distinctive and important characters of the plant, from both the botanical and the agricultural standpoints—such as the involucre, the nectaries, the oil glands, the large bolls, and the very lint itself—are adaptive features which the selective influence of the weevil has brought to their present degree of development.

CLASSIFICATION OF ADAPTATIONS.

The adaptations of the cotton plant might be summarized from three different standpoints. A historical treatment would proceed from the adaptations of the bolls to those of the buds. Breeding in the buds, for instance, was evidently a later adaptation on the part of the weevils which has called for a second set of the protective characters on the part of the plant.

It may be better, however, to classify the adaptations as such, without special regard to their historical sequence of derivation. The more practical purposes are served by dividing the adaptations into four groups: (1) Those calculated to avoid the weevils by general habits of growth; (2) those which exclude the weevils, or at least hinder their operations in the buds and bolls; (3) those which attract insect enemies such as the weevil-eating kelep; (4) those which prevent the development of the weevil larvæ, even after the eggs have been laid.

ADAPTATIONS TO AVOID WEEVILS.

1. Determinate growth.
2. Early bearing.
3. Long basal branches.
4. Early rejection of superfluous squares.
5. Seasonal bearing of perennial varieties.
6. Prompt bearing after cutting back.
7. Hairy stalks and leaf stems.
8. Pendent bolls.
9. Rapid growth of young bolls.

ADAPTATIONS TO EXCLUDE WEEVILS.

1. Involucral bracts grown together at base.
2. Closely appressed margins of involucral bracts.
3. Margins of involucral bracts strongly laciniate and hairy.
4. Unusual size and width of involucral bracts.
5. Calyx produced into slender hairy laciniæ.
6. Persistent flowers.
7. Oil glands (?) of very young bolls.
8. Thick-walled bolls.
9. Tough linings of boll chambers.

ADAPTATIONS ATTRACTIVE TO THE KELEP.

1. Nectaries of leaves.
2. Large outer nectaries of involucre.
3. Large inner nectaries of involucre.
4. Bractlets subtending inner nectaries.
5. Continued secretion of nectar.
6. Hairy stalks and leaf stems.
7. Dwarf, compact habits of growth.

ADAPTATIONS TO PREVENT DEVELOPMENT OF WEEVIL LARVÆ.

1. Shedding of weevil-infested buds.
2. Proliferation of internal tissues of buds.
3. Proliferation from the walls of the bolls.
4. Absence of oil glands over dissepiments.
5. Growth of lint on seed.
6. Compacted seeds (Kidney cotton).
7. Lint confined to outer end of seed (San Lucas Sea Island cotton).

ADAPTIVE CHARACTERS OF DIFFERENT TYPES OF COTTON.

The third standpoint for viewing the adaptive characters is that of the different types of cotton. All varieties share, to some extent, the older adaptive features, but the special characters are accentuated in different degrees in the various types. Our study has been directed toward the Kekchi variety, both on account of its relation to the keleps and because it has seemed to possess by far the largest series of adaptive features. But now that the existence of adaptations of practical value has been ascertained it will be necessary to canvass the field thoroughly.

ADAPTATIONS OF KEKCHI COTTON.

An enumeration of the adaptations of the Kekchi cotton is scarcely necessary, because that variety has nearly the whole series and most of them in a more accentuated form than the other types thus far studied. The few exceptions are noted below.

ADAPTATIONS OF RABINAL COTTON.

1. Prompt bearing after cutting back.
2. Very hairy stalks, leaf stems, and involucral bracts.
3. Closely appressed margins of involucral bracts.
4. Involucral bracts grown together at base.

ADAPTATIONS OF PACHON COTTON.

1. Involucral bracts margined with stiff laciniæ and bristles.
2. Calyx large, the divisions slender and hairy.

ADAPTATIONS OF SAN LUCAS SEA ISLAND COTTON.

1. Definite seasonal bearing.
2. Lint confined to outer half of seed.
3. Proliferation in buds.
4. Proliferation in bolls.

ADAPTATIONS OF KIDNEY COTTON.

1. Definite seasonal bearing.
2. Seeds compacted at center, covered with thick layer of lint.

ADAPTATIONS OF UPLAND COTTON.

1. Shedding of weevil-infested buds.

This is the only weevil-resisting character in which the Upland varieties excel the Kekchi cotton, but, as already explained, the habit is of practical use only in dry climates. The Upland cottons share, however, a large number of the adaptations, though in a less degree than in the Kekchi. Thus there is proliferation both in buds and in bolls, the stems and petioles are somewhat hairy, the habit of growth is somewhat reduced from the tree-cotton stage, the nectaries are often large and active, the involucral bracts are sometimes well folded together, etc.

And now that the possibility of weevil resistance has been shown, variations may be found in all probability among our United States varieties which will enable weevil-resisting strains of the Upland sorts to be developed. At this stage of the inquiry it is too much to hope that the Kekchi type will prove to be adapted to the wide diversity of conditions to be found in the cotton belt. Either the Kekchi or the native cottons, or both, are likely to require extensive modification before the full value of the weevil-resisting adaptations can be realized.

CONCLUDING REMARKS.

The protection afforded by the weevil-resisting adaptations is most effective at the two ends of the period of development, but continues in varying degrees from the young bud to the ripe boll. Under favorable conditions an extremely small proportion of the weevil eggs develop to maturity. Instead of a single attack being fatal to a bud or boll, the same fruit at its different stages may resist numerous punctures and egg-layings. The young bud is protected for a time by the closed involucre. After the weevils have gained entrance the first egg, and often the second or third, may be rendered harmless through the proliferation of the bud in its younger stages. Proliferation becomes less certain as the bud increases in size, but if egg laying be delayed a few days too long the development of the larvæ is rendered impossible by the opening of the flower. Then ensues another period of immunity while the withered flower remains in place and while the bolls are still too small to be attacked. Between about the quarter and the three-quarter size the bolls can still be parasitized, though proliferation reduces the successful attempts to a very small percentage. But after the lint has grown out, the lining has hardened, and the walls have become thick, the boll is well-nigh impregnable, though the surface may be roughened by a dozen or a score of warts, which mark the location of as many persistent but ineffectual attempts to gain entrance.

As an instance of adaptive specialization the cotton plant seems destined to a very high rank. The development of such a series of protective characters can scarcely be explained except upon the supposition that the culture of cotton in Guatemala is extremely ancient, and of this there are many other indications.

The practical utilization of these protective characters in the cotton industry of the United States may require the solution of many preliminary problems of acclimatization and adaptation, as well as of physiology and cultural methods. The proliferation characters, for example, appear to be much more pronounced in some varieties than in others, but they are also affected, probably to a very considerable extent, by conditions of climate or soil which check the growth of the plant or cut down its water supply and thus reduce the normal turgidity of the tissues.[a]

The weevil-resisting characters are much more highly developed in the variety of cotton cultivated by the Kekchi Indians of eastern Guatemala than in any other type yet known, and it produces also large bolls and lint of good length and quality, so that it may be of value in the United States. But even though the Kekchi cotton in its present form should prove, for any reason, not to be adapted to cultural conditions in the United States, it demonstrates, at least, the fact that the Upland type of cotton is capable of assuming other characters which will render it far better adapted to cultivation in the presence of the boll weevil than the varieties hitherto grown in the United States.

---

[a] That the transfer to Texas will not destroy the proliferating habit of the Kekchi cotton is shown by the following report from Mr. McLachlan:

"On the 23d of August Mr. Kinsler and I made a comparative examination of four varieties of cotton at Mackay, Tex., to determine the nature of their proliferation. Rows of Kekchi cotton from Secanquim and Lanquin, and two of native Upland varieties (Parker and King) were compared. The results, in brief, are that in squares the Kekchi cotton proliferated much more readily than did the native varieties. In the bolls all four varieties were about equally active in this protective adaptation. The extent of proliferation in the Guatemalan bolls was, if different in any way, somewhat greater than in the native varieties."

No end is in sight of the new problems and adjustments of cotton culture occasioned by the invasion of the weevils, and no assurances can be given in advance regarding the utility of the weevil-resisting adaptations, any more than with the kelep, or so-called "Guatemalan ant." Both have a present value, however, in proving that the weevil is no invulnerable dragon which it is hopeless to resist. Instead of having no enemies, as long supposed, the weevil is regularly preyed upon by the active and efficient kelep. And instead of there being no remedies which can be used against the weevil, it is now found that the cotton plant itself has a whole series of weevil-resisting characters—a whole boll weevil armory, as it were, from which we may select and sharpen the weapons which prove best suited to our purposes.

The weevil period of each year, that in which the damage is done, extends from the time when the squares are large enough for egg laying to the period when a full crop would normally be set. If the value of the cotton crop be divided by the number of days of this period, the result will show the value of each day of protection. It has been estimated by Mr. W. D. Hunter that the boll weevil damaged the cotton crop in 1904 to the extent of $20,000,000. It is therefore a very conservative estimate that when the pest shall have spread over the other cotton-growing States the damage will be well beyond a million dollars a day for the growing season—in unfavorable years probably two million dollars or more a day. Each day of protection which can be secured by the utilization of weevil-resisting adaptations will have, therefore, very definite and considerable value, so that the study and perfection of this group of characters are sure to be the objects not only of formal scientific study on the part of specialists but of general interest and consideration on the part of the practical cotton-growing public.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Valley at Secanquim, Alta Vera Paz, Guatemala, the scene of experiments with weevil-resisting cotton.

PLATE II. Fig. 1.—Mature plant of Kekchi cotton, to show small size and determinate habits of growth, compact foliage, and long basal branches. Fig. 2.—Plant shown in figure 1, opened to show numerous large bolls and habit of fruiting on basal branches.

PLATE III. Involucres of Kekchi cotton, opened to show external and internal nectaries, bracts, and bractlets. (Natural size.)

PLATE IV. Fig. 1.—Involucres of Rabinal cotton, showing connate and closely appressed involucral bracts. (Natural size.) Fig. 2.—Open involucres of Egyptian cotton. (Natural size.)

PLATE V. Fig. 1.—Young buds of Kekchi cotton, showing numerous weevil punctures. The buds were split in half so that the full number of punctures could be seen. (Natural size.) Fig. 2.—Buds of Kekchi cotton (same as fig. 1), showing successful proliferations. (Natural size.)

PLATE VI. Large buds of Kekchi cotton, the distortion indicating proliferation. (Natural size.)

PLATE VII. Weevil-infested bolls of Kekchi cotton, showing larger number of punctures along the middle line of the carpel, where the oil glands are absent. (Natural size.)

PLATE VIII. Carpels of Kekchi cotton, showing method of proliferation. (Natural size.)

PLATE IX. Fig. 1.—Kekchi cotton, successive stages of the boll. Fig. 2.—Kekchi bolls (right): King bolls (left), to show comparative size. (Reduced to about one-half natural size.)

PLATE X. Fig. 1.—Rabinal cotton, showing foliage, connate bracts, and weevil-infested bolls. (Reduced.) Fig. 2.—Bolls and seeds of Kidney cotton, showing oil glands and protective arrangement of lint and seeds. (Reduced.)

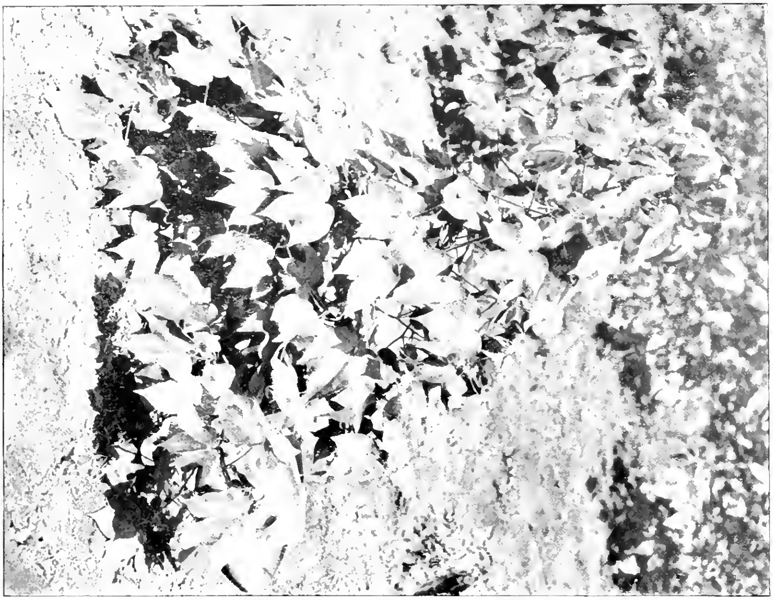


FIG. 1.—MATURE PLANT OF KEKCHI COTTON.

FIG. 2.—KEKCHI COTTON PLANT WITH BOLLS.

INVOLUCRES OF KEKCHI COTTON, SHOWING NECTARIES AND BRACTLETS.

(Natural size.)

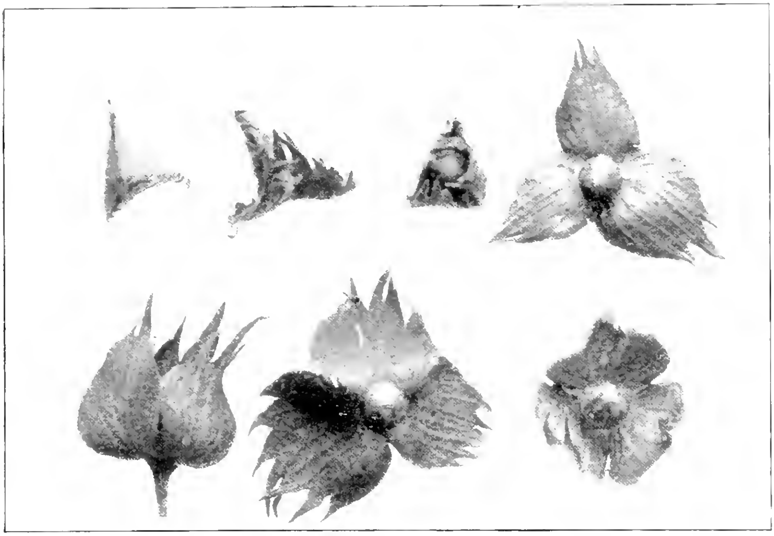


FIG. 1.—INVOLUCRES OF RABINAL COTTON, SHOWING CONNATE AND APPRESSED MARGINS.

(Natural size.)

FIG. 2.—OPEN INVOLUCRES OF EGYPTIAN COTTON.

(Natural size.)

FIG. 1.—YOUNG BUDS OF KEKCHI COTTON WITH WEEVIL PUNCTURES.

(Natural size.)

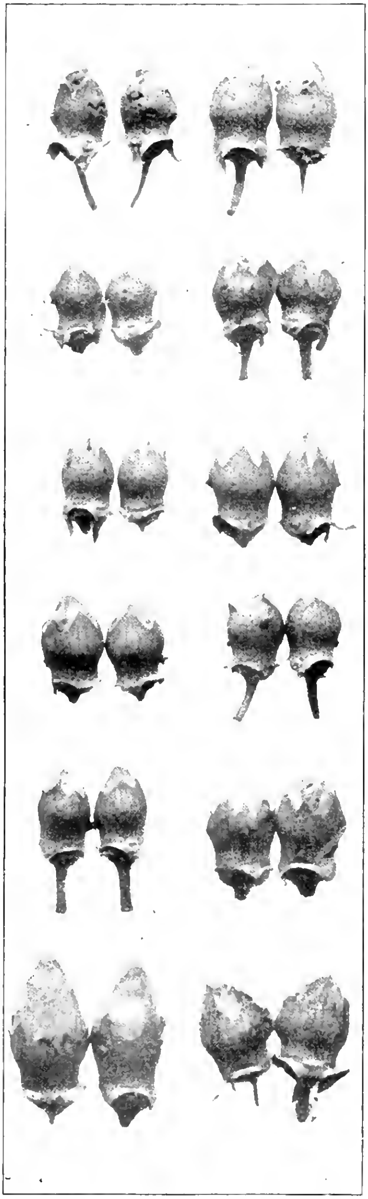
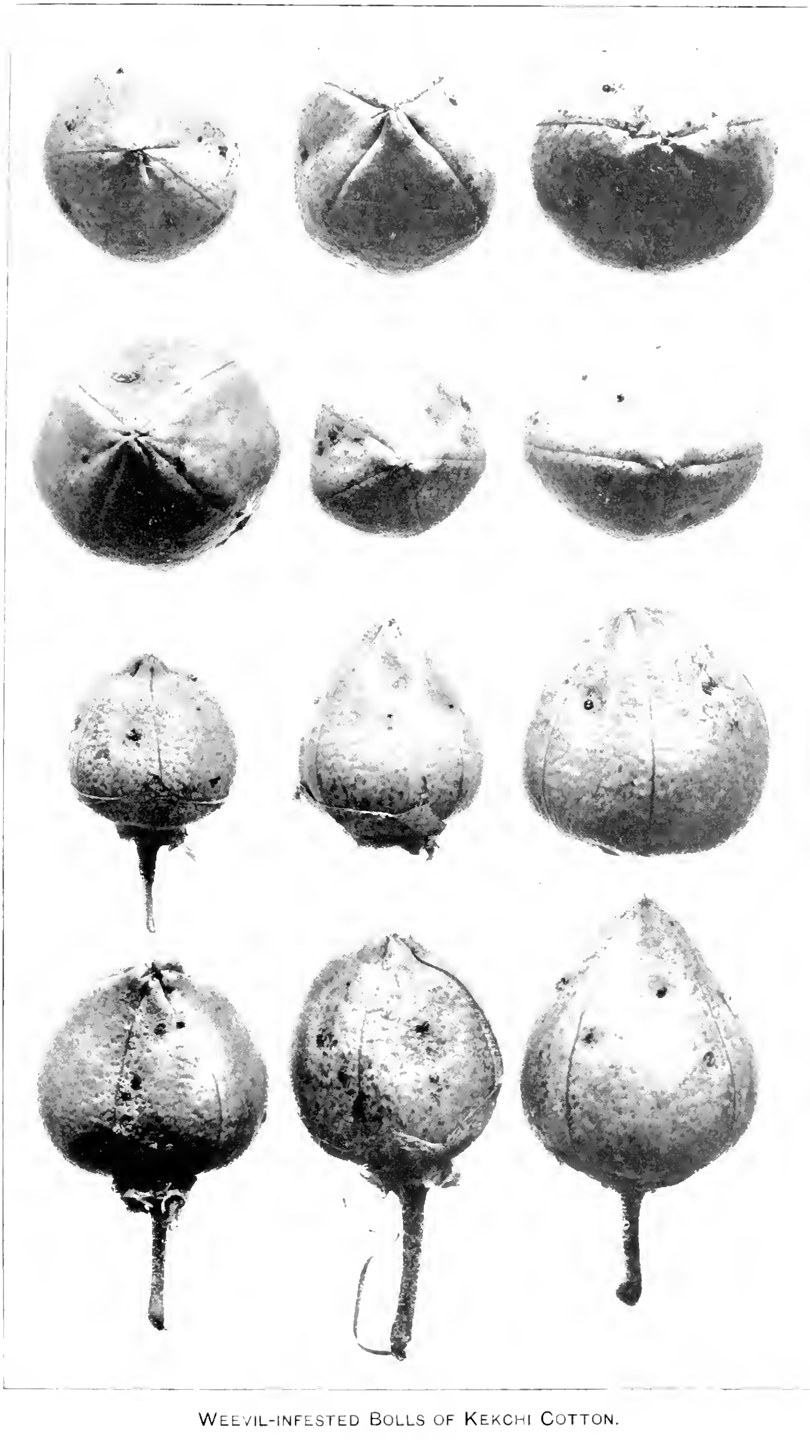


FIG. 2.—BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)

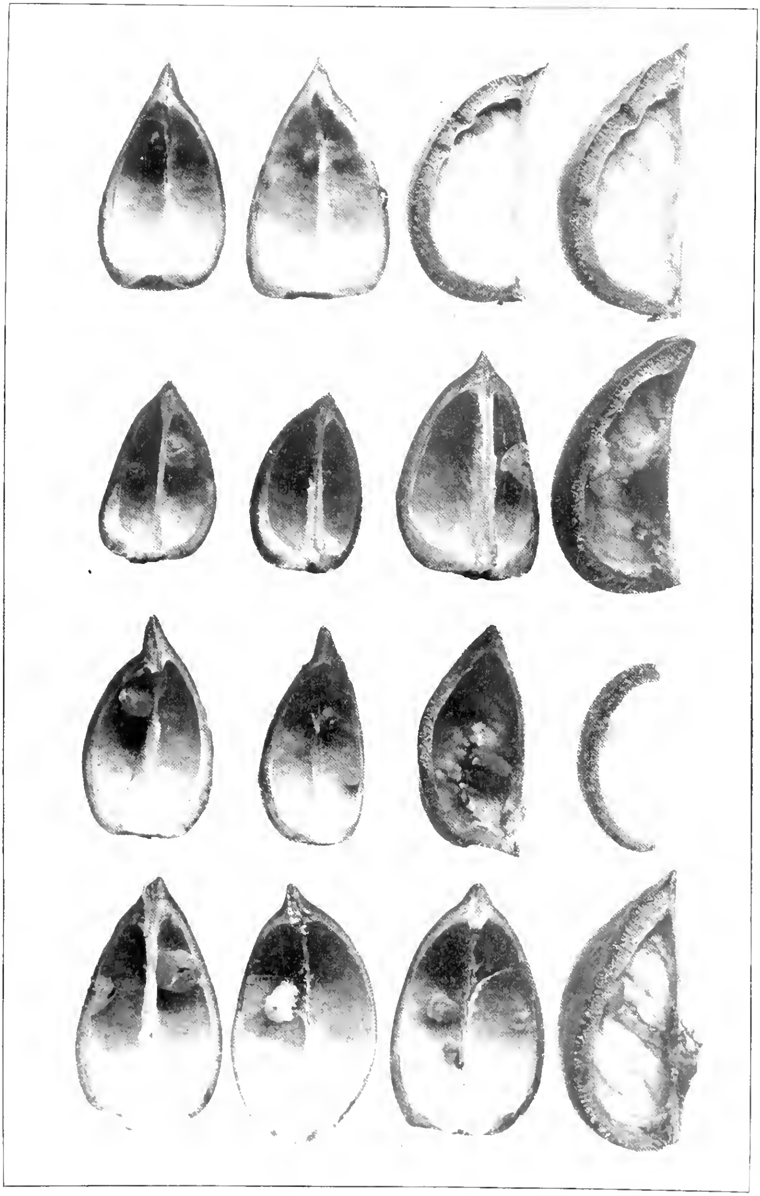
LARGE BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)



WEEVIL-INFESTED BOLLS OF KEKCHI COTTON.

(Natural size.)



CARPELS OF KEKCHI COTTON, SHOWING PROLIFERATION.

(Natural size.)

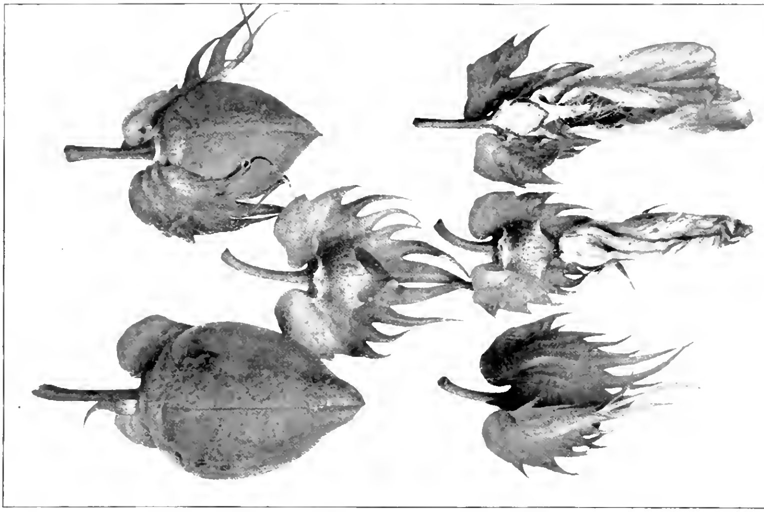


Fig. 1.—Kekchi Cotton, Successive Stages of the Boll.
(Reduced.)

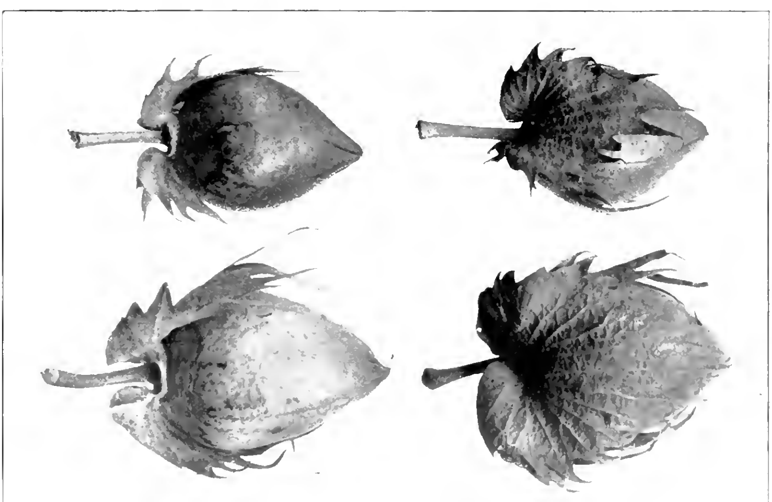


Fig. 2.—Kekchi Cotton Bolls (Right) Compared with King Bolls (Left).
(Reduced.)

FIG. 1.—RABINAL COTTON WITH BOLLS.
(Reduced.)

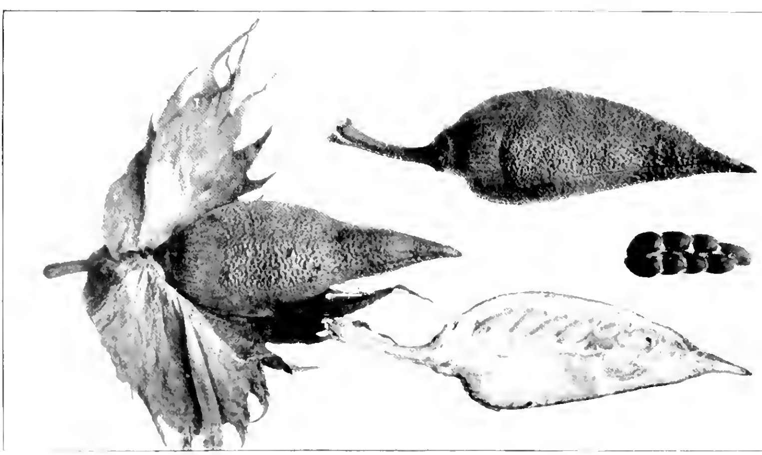


FIG. 2.—BOLLS AND SEEDS OF KIDNEY COTTON.
(Reduced.)

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 89.

B. T. GALLOWAY, *Chief of Bureau.*

WILD MEDICINAL PLANTS OF THE UNITED STATES.

BY

ALICE HENKEL,

ASSISTANT, DRUG-PLANT INVESTIGATIONS.

ISSUED JANUARY 16, 1906.

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GOVERNMENT PRINTING OFFICE.

1906.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory, and Dry Land Agriculture and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 89.

B. T. GALLOWAY, *Chief of Bureau.*

WILD MEDICINAL PLANTS OF THE UNITED STATES.

BY

ALICE HENKEL,
Assistant, Drug-Plant Investigations.

Issued January 16, 1906.

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B. T. GALLOWAY,

Pathologist and Physiologist, and Chief of Bureau.

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DRUG-PLANT INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 30, 1905.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 89 of the series of this Bureau the accompanying manuscript entitled "Wild Medicinal Plants of the United States." This paper was prepared by Miss Alice Henkel, Assistant in Drug-Plant Investigations, and has been submitted by the Physiologist in Charge with a view to its publication.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In connection with the work of Drug-Plant Investigations many inquiries are received from various parts of the country asking for a list of the drug-producing plants of the regions concerned and for information as to the parts of the plants used in medicine, etc. It being impossible to comply with requests of this nature in any satisfactory way, Miss Henkel was asked to compile a list of the drug plants of this country, using as a basis the catalogues of dealers in crude drugs and the standard works on systematic botany. It has seemed from an inspection of these lists and of much current pharmaceutical literature that the recent changes in botanical nomenclature have succeeded one another too rapidly to permit the drug dealer and the pharmacist to keep pace with them. This has resulted in considerable confusion in regard to botanical names, and in some cases in the matter of the common names of drug-producing plants. In such a list as that herewith presented the opportunity for helping to clear up this situation has seemed worth improving. The recent appearance of the new Pharmacopœia, in which the botanical nomenclature has been revised, has seemed to emphasize the desirability of making this attempt, since the names in the case of official plants will be fairly definitely fixed among pharmacists for the next ten years. In the accompanying list the pharmacopœial names are given and a revision of the nomenclature of the unofficial drugs is also presented. Mr. Frederick V. Coville, Botanist, has kindly revised the botanical names used in this publication.

It is hoped that this compilation will tend to unify usage among those who have to do with crude drugs and drug plants.

RODNEY H. TRUE,
Physiologist in Charge.

OFFICE OF DRUG-PLANT INVESTIGATIONS,
Washington, D. C., October 12, 1905.

WILD MEDICINAL PLANTS OF THE UNITED STATES.

In the preparation of this bulletin only such wild medicinal plants as have a commercial value were considered; that is, such as were usually mentioned in the trade lists of drug dealers throughout the country. Plants that were found listed by only one or two firms have been omitted.

Both official and nonofficial drugs are included in this list. A number of drug plants that were official in the United States Pharmacopœia for 1890 have been dropped from the Eighth Decennial Revision (1900), which became official on September 1, 1905, and a few new ones have been added. In this bulletin the drugs that were official in the Pharmacopœia for 1890 are so indicated, while those of the new edition are marked simply "official."

In the following list the information on each species is given under the accepted botanical name. This name and that of the family to which the plant belongs occupy the first line of the description. Botanical synonyms, if any, are mentioned, and these are followed in the next line by the most common names. A few words of information indicating the most important features of habit and stature, as well as the sort of situation in which found, together with the geographical distribution in the United States, are then given in each case. This information is too meager for the identification of the plants concerned in all cases, but it was impossible within the space limits of a publication such as this to include more descriptive matter. The parts of the plants used and the official status of the product close the description. Unless otherwise indicated, the products mentioned are used in the dried state.

Abies balsamea (L.) Mill. **Pine family (Pinaceae).**

Balsam-fir; Canada balsam tree.

Slender, evergreen, native tree, 50 to 60 feet high, occurring in damp woods from Newfoundland to the high mountains of southwestern Virginia, west to Minnesota, and northward.

Parts used.—Balsam, known as Canada turpentine, Canada balsam, or balsam of fir (official); also bark (nonofficial).

Abies canadensis Michx. Same as *Tsuga canadensis.*

Abies nigra Desf. Same as *Picea mariana.*

Abscess-root. See *Polemonium reptans.*

Absinth. See *Artemisia absinthium.*

Absinthium. See *Artemisia absinthium.*

Acacia, false. See *Robinia pseudacacia.*

Acer rubrum L. **Maple family (Aceraceae).**

Red maple; swamp-maple.

Large, native tree, often 120 feet in height, growing in swamps and low grounds from Canada to Florida and Texas.

Part used.—Bark (nonofficial.)

Achillea millefolium L. **Aster family (Asteraceae).**

Yarrow; milfoil; thousandleaf.

Perennial weed, 10 to 20 inches high, common in fields and waste places nearly throughout the United States, especially eastward; naturalized from Europe and Asia.

Part used.—Herb (nonofficial).

Acorus calamus L. **Arum family (Araceae).**

Calamus; sweet-flag.

Native, herbaceous perennial, about 2 feet high, found in wet and muddy places and along streams from Nova Scotia to Minnesota, southward to Florida and Texas.

Part used.—Unpeeled, dried rhizome (official).

Actaea alba (L.) Mill. **Crowfoot family (Ranunculaceae).**

White cohosh; white baneberry; necklace-weed; rattlesnake-herb.

Native, perennial herb, 1 to 2 feet high, found in rich woods from Nova Scotia to Georgia and Missouri, and northward; most common from Indiana and Kentucky to Pennsylvania and New York.

Parts used.—Rhizome and rootlets (nonofficial).

Actaea racemosa L. Same as *Cimicifuga racemosa.*

Actaea rubra (Ait.) Willd. **Crowfoot family (Ranunculaceae).**

Synonym.—*Actaea spicata* var. *rubra* Ait.

Red cohosh; red baneberry; rattlesnake-herb.

Native, perennial herb, 1 to 2 feet high, found in woods from Nova Scotia to the Middle States, west to the Rocky Mountains; most abundant from New England to Ontario.

Parts used.—Rhizome and rootlets (nonofficial).

Actaea spicata var. *rubra* Ait. Same as *Actaea rubra.*

Adam-and-Eve. See *Aplectrum spicatum.*

Adder's-tongue, yellow. See *Erythronium americanum.*

Adiantum pedatum L. **Fern family (Polypodiaceae).**

Maidenhair-fern.

Native fern, 9 to 15 inches high, growing in rich moist soil in woods in Canada and almost all parts of the United States.

Part used.—Herb (nonofficial).

Aesculus glabra Willd. **Buckeye family (Aesculaceae).**

Ohio buckeye; fetid buckeye; smooth buckeye.

Small, native tree, 20 to 40 feet in height, found in woods and on river banks from Pennsylvania south to Alabama, westward to Michigan and the Indian Territory.

Parts used.—Bark and fruit (nonofficial).

Aesculus hippocastanum L. **Buckeye family (Aesculaceae).**

Horse-chestnut.

Large tree, 60 feet or more in height. Escaped from cultivation, southeastern New York and New Jersey. Native of Asia.

Parts used.—Bark and fruit (nonofficial).

Afterbirth-weed. See *Stylosanthes biflora.*

Agrimonia eupatoria (of American authors, not L.). Same as *Agrimonia hirsuta.*

Agrimonia hirsuta (Muhl.) Bicknell. **Rose family (Rosaceae).**

Synonym.—*Agrimonia eupatoria* of most American authors, not L.[a]

Agrimony; tall hairy agrimony.

Perennial herb, 3 to 4 feet high, found in woods and thickets from New Brunswick to Minnesota and Nebraska, south to North Carolina; also in California. Native.

Part used.—Herb (nonofficial).

Agrimony. See *Agrimonia hirsuta.*

Agrimony, tall hairy. See *Agrimonia hirsuta.*

Agropyron repens (L.) Beauv. **Grass family (Poaceae).**

Synonym.—*Triticum repens* Beauv.

Triticum; couch-grass; dog-grass; quack-grass.

A troublesome grass in cultivated land from Maine to Maryland, west to Minnesota and Missouri; sparingly distributed in the South. Introduced from Europe.

Part used.—Rhizome, gathered in spring (official).

Ague-tree. See *Sassafras variifolium.*

Agueweed. See *Eupatorium perfoliatum* and *Gentiana quinquefolia.*

Alder, black. See *Ilex verticillata.*

Alder, common. See *Alnus rugosa.*

Alder, red. See *Alnus rugosa.*

Alder, smooth. See *Alnus rugosa.*

Alder, tag-. See *Alnus rugosa.*

Aletris farinosa L. **Lily family (Liliaceae).**

Star-grass; false (not true) unicorn-root;[b] colic-root.

Native, perennial herb, 2 to 3 feet high; in dry, sandy soil from Maine to Minnesota, south to Florida and Tennessee.

Part used.—Rhizome (nonofficial), gathered after the plant has flowered.

Allspice, Carolina. See *Butneria florida.*

Allspice, Florida. See *Butneria florida.*

Allspice, wild. See *Benzoin benzoin.*

Alnus rugosa (Du Roi) K. Koch. **Birch family (Betulaceae).**

Synonym.—*Alnus serrulata* Willd.

Tag-alder; common alder; red alder; smooth alder.

Native shrub, or sometimes a small tree, occurring in swamps and marshy borders of streams from the New England States west to Minnesota and southward to Florida and Texas.

Part used.—Bark (nonofficial).

---

[a] According to Bicknell (Bul. Torr. Bot. Club, 23: 508–525, 1896), the name *Agrimonia eupatoria* L., long used in local floras and text-books for the agrimony of the Eastern States, has been doing duty for a group of related species, of which at least five are now clearly recognized. Furthermore, Doctor Britton (Bul. Torr. Bot. Club, 18: 366, 1891) states that the true *Agrimonia eupatoria* is not known at all as an American plant. The native plant to which the name *Agrimonia eupatoria* has been most frequently applied by American authors is *Agrimonia hirsuta* (Muhl.) Bicknell.

[b] The name "true unicorn-root" has long been applied to *Aletris farinosa*, but as "unicorn-root" was the common name first given to *Chamaelirium luteum* (*Helonias dioica*), this should more properly be called the true unicorn-root and *Aletris farinosa* the false unicorn-root.

Alnus serrulata Willd. Same as *Alnus rugosa*.

Alsine media L. **Pink family (Silenaceae).**

Synonym.—Stellaria media Cyr.

Common chickweed.

Small, annual herb, probably introduced from Europe, and now common in fields and around dwellings throughout the United States.

Part used.—Herb (nonofficial).

Althaea. See *Althaea officinalis.*

Althaea officinalis L. **Mallow family (Malvaceae).**

Althaea; marshmallow; sweatweed; mortification-root.

Perennial herb, 2 to 4 feet high, naturalized from Europe; occurs in salt marshes, coast of Massachusetts and New York, and in Pennsylvania.

Parts used.—Root from plants of second year's growth, deprived of the periderm (official); leaves and flowers (nonofficial) are also used.

Alum-root. See *Geranium maculatum* and *Heuchera americana.*

Ambrosia artemisiaefolia L. **Ragweed family (Ambrosiaceae).**

Roman wormwood; ragweed; hogweed; stammerwort.

Coarse, native weed, annual, 1 to 3 feet high; in waste places, eastern United States, west to British Columbia and Mexico.

Part used.—Herb (nonofficial).

Ampelopsis quinquefolia Michx. Same as *Parthenocissus quinquefolia.*

Amy-root. See *Apocynum cannabinum.*

Anagallis arvensis L. **Primrose family (Primulaceae).**

Red chickweed; red pimpernel; scarlet pimpernel; shepherd's-weatherglass.

Low, spreading, annual herb, naturalized from Europe, and growing along roadsides and in fields almost throughout the United States.

Part used.—Herb (nonofficial).

Anaphalis margaritacea (L.) Benth. & Hook. **Aster family (Asteraceae).**

Synonyms.—Gnaphalium margaritaceum L.; *Antennaria margaritacea* Hook.

Everlasting; pearly everlasting; large-flowered everlasting; cottonweed.

White-hairy or woolly perennial herb, native in dry soil from Newfoundland to Alaska, south to North Carolina and California.

Part used.—Leaves (nonofficial).

Andromeda arborea L. Same as *Oxydendrum arboreum.*

Anemone patens var. *nuttalliana* A. Gray. Same as *Pulsatilla hirsutissima.*

Angelica, American. See *Angelica atropurpurea.*

Angelica atropurpurea L. **Parsley family (Apiaceae).**

Synonym.—Archangelica atropurpurea Hoffm.

Purple-stemmed angelica; American angelica; masterwort.

Tall, stout, perennial herb, 4 to 6 feet high; native in swamps and damp places from Labrador to Delaware and west to Minnesota.

Parts used.—Root and seeds (nonofficial).

Angelica, purple-stemmed. See *Angelica atropurpurea.*

Anise-root. See *Washingtonia longistylis.*

Antennaria margaritacea Hook. Same as *Anaphalis margaritacea.*

Anthemis cotula L. **Aster family (Asteraceae).**

Synonym.—Maruta cotula DC.

Mayweed; dog-fennel; fetid camomile (or chamomile).

Strong-scented, annual herb, naturalized from Europe; occurs in dry soil, fields, waste places, and along roadsides almost throughout North America, with the exception of the extreme North.

Part used.—Herb (nonofficial).

Aplectrum hyemale Nutt. Same as *Aplectrum spicatum*.

Aplectrum spicatum (Walt.) B. S. P. **Orchid family (Orchidaceae).**

Synonym.—Aplectrum hyemale Nutt.

Adam-and-Eve; putty-root.

Native herb, perennial, 1 to 2 feet high; in rich woods and swamps from Canada to Georgia and California.

Part used.—Root (nonofficial).

Apocynum. See *Apocynum cannabinum*.

Apocynum androsaemifolium L. **Dogbane family (Apocynaceae).**

Bitterroot; spreading dogbane; honeybloom.

Perennial herb, 1 to 4 feet high, native in fields and thickets from Canada south to Georgia and Arizona. The most common species in Canada and the Northeastern States.

Part used.—Root (nonofficial).

Apocynum cannabinum L. **Dogbane family (Apocynaceae).**

Apocynum; Canadian hemp; black Indian hemp; amy-root.

Perennial herb, 2 to 3 feet high, native in moist ground and borders of fields throughout the United States.

Part used.—Rhizome of this or of closely allied species of Apocynum (official).

Apple, custard-. See *Asimina triloba*.

Apple, May-. See *Podophyllum peltatum*.

Apple, thorn-. See *Datura stramonium*.

Apple-of-Peru. See *Datura stramonium*.

Aquilegia canadensis L. See under *Aquilegia vulgaris*.

Aquilegia vulgaris L. **Crowfoot family (Ranunculaceae).**

European columbine; garden-columbine.

Perennial herb, with showy flowers. Naturalized from Europe, and well known in cultivation; escaped from gardens into woods and fields; frequent in the Eastern and Middle States. The wild columbine (*Aquilegia canadensis* L.), occurring in rocky woods throughout Canada and the eastern United States, is said to possess properties similar to those of the European columbine.

Part used.—Herb (nonofficial).

Aralia hispida Vent. **Ginseng family (Araliaceae).**

Dwarf elder; wild elder; bristly sarsaparilla.

Erect, leafy perennial, 1 to 3 feet high, native in sandy woods and fields from Labrador south to North Carolina, west to Minnesota and Indiana.

Part used.—Root (nonofficial).

Aralia nudicaulis L. **Ginseng family (Araliaceae).**

American sarsaparilla; wild sarsaparilla; false sarsaparilla; Virginian sarsaparilla; small spikenard.

Herbaceous perennial, native, growing in moist woods from Newfoundland west to Manitoba and south to North Carolina and Missouri.

Part used.—Root (nonofficial).

Aralia racemosa L. **Ginseng family (Araliaceae).**

Indian-root; spikenard; American spikenard; spignet.

Herbaceous perennial, native, 3 to 6 feet high, growing in rich woods and rocky places from Canada to Georgia, west to Minnesota and Missouri.

Part used.—Root (nonofficial).

Arbor-vitae. See *Thuja occidentalis*.

Arbutus, trailing. See *Epigaea repens*.

Archangelica atropurpurea Hoffm. Same as *Angelica atropurpurea*.

Arctium lappa L. **Aster family (Asteraceae).**

Synonym.—Lappa major Gaertn.

Lappa; burdock; cockle-button; beggars'-buttons; bardane.

Coarse, biennial weed, 4 to 9 feet high, introduced from the Old World, and occurring along roadsides and in fields and waste places in the Eastern and Central States.

Parts used.—Root of this or of other species of Arctium collected from plants of first year's growth (official). The fresh leaves and the seeds are also used (nonofficial).

Arctostaphylos glauca Lindl. **Heath family (Ericaceae).**

Manzanita.

A shrub-like tree, 9 to 25 feet high, growing in California, in dry, rocky districts on the western slopes of the Sierras.

Part used.—Leaves (nonofficial).

Arctostaphylos uva-ursi (L.) Spreng. **Heath family (Ericaceae).**

Uva-ursi; bearberry; upland-cranberry.

Low, evergreen perennial, with trailing stems, native in rocky or dry, sandy soils from the Middle Atlantic States north to Labrador, westward to California and Alaska.

Part used.—Leaves (official).

Arisaema triphyllum (L.) Torr. **Arum family (Araceae).**

Synonym.—Arum triphyllum L.

Indian turnip; wild turnip; wake-robin; Jack-in-the-pulpit.

Native, perennial herb, 10 inches to 3 feet high, found in moist woods from Canada to Florida, west to Kansas and Minnesota.

Part used.—Partially dried corm (nonofficial).

Aristolochia reticulata Nutt. **Birthwort family (Aristolochiaceae).**

Serpentaria; Texas serpentaria; Texas snakeroot; Red River snakeroot.

Perennial herb, about 1½ feet in height, native in the Southwestern States, occurring on river banks from Arkansas to Louisiana.

Parts used.—Rhizome and roots (official).

Aristolochia serpentaria L. **Birthwort family (Aristolochiaceae).**

Serpentaria; Virginia serpentaria; Virginia snakeroot.

Native, perennial herb, 10 inches to 3 feet high, found in rich woods from Connecticut to Michigan and southward.

Parts used.—Rhizome and roots (official).

Arrowwood. See *Viburnum dentatum.*

Arrowwood, Indian. See *Euonymus atropurpureus.*

Artemisia abrotanum L. **Aster family (Asteraceae).**

Southernwood.

Shrubby, perennial herb, about 2 to 4 feet in height, occurring in waste places from Massachusetts to Nebraska. Adventive from Europe.

Part used.—Herb (nonofficial).

Artemisia absinthium L. **Aster family (Asteraceae).**

Absinthium; wormwood; absinth.

Shrubby, perennial herb, 2 to 3 feet high, naturalized from Europe, and occurring in waste places and along roadsides from Newfoundland to New York and westward.

Parts used.—Leaves and tops (official in U. S. P. 1890).

Artemisia vulgaris L. **Aster family (Asteraceae).**

Common mugwort.

Perennial herb, 1 to 3½ feet high, naturalized from Europe; found in waste places, Nova Scotia to the Middle States and westward to Michigan.

Part used.—Herb (nonofficial).

Arum triphyllum L. Same as *Arisaema triphyllum*.

Asarum canadense L. **Birthwort family (Aristolochiaceae).**
Canada snakeroot; wild ginger; Indian ginger.
Perennial herb, about 1 foot in height, native in rich woods from Canada to North Carolina and Kansas.
Parts used.—Rhizome and rootlets (nonofficial).

Asclepias. See *Asclepias tuberosa*.

Asclepias cornuti Dec. Same as *Asclepias syriaca*.

Asclepias incarnata L. **Milkweed family (Asclepiadaceae).**
White Indian hemp; swamp-milkweed; swamp-silkweed; rose-colored silkweed.
Perennial herb, 2 to 4 feet high, native in swamps from Canada to Tennessee and Kansas.
Part used.—Root (nonofficial).

Asclepias syriaca L. **Milkweed family (Asclepiadaceae).**
Synonym.—*Asclepias cornuti* Dec.
Common milkweed; silkweed.
Perennial herb, 3 to 5 feet high, native in fields and waste places from Canada to North Carolina and Kansas.
Part used.—Root (nonofficial).

Asclepias tuberosa L. **Milkweed family (Asclepiadaceae).**
Asclepias; pleurisy-root; butterfly-weed; Canada-root; whiteroot.
Native, perennial herb, 1 to 2 feet high, growing in dry fields from Canada to Florida and Arizona; most abundant southward.
Part used.—Root (official in U. S. P. 1890).

Ash, American mountain-. See *Sorbus americana*.

Ash, black. See *Fraxinus nigra*.

Ash, cane-. See *Fraxinus americana*.

Ash, hoop-. See *Fraxinus nigra*.

Ash, prickly. See *Fagara clava-herculis* and *Xanthoxylum americanum*.

Ash, wafer-. See *Ptelea trifoliata*.

Ash, white. See *Fraxinus americana*.

Asimina triloba (L.) Dunal. **Custard-apple family (Anonaceae).**
North American pawpaw; custard-apple.
Small, native tree, growing in rich soil along the banks of streams from New York to Michigan and southward. Most common in the Ohio Valley.
Part used.—Seed (nonofficial).

Aspen, American. See *Populus tremuloides*.

Aspen, quaking. See *Populus tremuloides*.

Aspidium. See *Dryopteris filix-mas* and *D. marginalis*.

Aspidium filix-mas Sw. Same as *Dryopteris filix-mas*.

Aspidium marginale Sw. Same as *Dryopteris marginalis*.

Asplenium filix-foemina (L.) Bernh. Same as *Athyrium filix-foemina*.

Aster puniceus L. **Aster family (Asteraceae).**
Red-stalked aster; cocash; meadow-scabish.
Perennial herb, with stout, reddish stem, 3 to 8 feet high, native; in swamps and on banks of streams, Nova Scotia to Minnesota, south to North Carolina, Ohio, and Michigan.
Part used.—Root (nonofficial).

Aster, red-stalked. See *Aster puniceus*.

Asthma-weed, Queensland. See *Euphorbia pilulifera*.

Athyrium filix-foemina (L.) Roth. **Fern family (Polypodiaceae).**

Synonym.—*Asplenium filix-foemina* (L.) Bernh.

Backache-brake; female-fern; lady-fern.

Native fern, with leaves 1 to 3 feet long; in woods and thickets, Canada to Alaska, southward to Florida and Arizona.

Part used.—Rhizome (nonofficial).

Avens, purple. See *Geum rivale.*

Avens, water-. See *Geum rivale.*

Backache-brake. See *Athyrium filix-foemina.*

Backache-root. See *Lacinaria spicata.*

Balm. See *Melissa officinalis.*

Balm, bee-. See *Monarda didyma.*

Balm, field-. See *Glecoma hederacea.*

Balm, garden-. See *Melissa officinalis.*

Balm, horse-. See *Collinsonia canadensis.*

Balm, lemon-. See *Melissa officinalis.*

Balm, mountain-. See *Eriodictyon californicum.*

Balm, scarlet. See *Monarda didyma.*

Balm, sweet. See *Melissa officinalis.*

Balm-of-Gilead. See *Populus candicans.*

Balmony. See *Chelone glabra.*

Balsam, sweet. See *Gnaphalium obtusifolium.*

Balsam tree, Canada. See *Abies balsamea.*

Balsam, white. See *Gnaphalium obtusifolium.*

Balsam-fir. See *Abies balsamea.*

Bamboo-brier. See *Smilax pseudo-china.*

Baneberry, red. See *Actaea rubra.*

Baneberry, white. See *Actaea alba.*

Baptisia tinctoria (L.) R. Br. **Pea family (Fabaceae).**

Wild indigo; yellow indigo; American indigo; indigo-weed; horsefly-weed.

Native, perennial herb, 2 to 3 feet high, growing in dry, poor soil from Maine to Minnesota, south to Florida and Louisiana.

Parts used.—Root and leaves (nonofficial).

Barberry, holly-leaved. See *Berberis aquifolium.*

Bardane. See *Arctium lappa.*

Basswood. See *Tilia americana.*

Bay, rose-. See *Rhododendron maximum.*

Bay, sweet. See *Magnolia virginiana.*

Bay, white. See *Magnolia virginiana.*

Bayberry. See *Myrica cerifera.*

Bean, bog-. See *Menyanthes trifoliata.*

Bean, buck-. See *Menyanthes trifoliata.*

Bean, hog's-. See *Hyoscyamus niger.*

Bearberry. See *Arctostaphylos uva-ursi.*

Bearberry-tree. See *Rhamnus purshiana.*

Bear's-foot, yellow. See *Polymnia uvedalia.*

Bear's-weed. See *Eriodictyon californicum.*

Beaver-poison. See *Cicuta maculata.*

Beaverroot. See *Nymphaea advena.*

Beaver-tree. See *Magnolia virginiana.*

Bedstraw. See *Galium aparine.*

Bee-balm. See *Monarda didyma.*

Beech, American. See *Fagus americana.*

Beechdrops. See *Leptamnium virginianum.*

Beechnut-tree. See *Fagus americana.*

Bee-plant. See *Scrophularia marilandica.*

Beggars'-buttons. See *Arctium lappa.*

Bellwort, perfoliate. See *Uvularia perfoliata.*

Benjamin-bush. See *Benzoin benzoin.*

Bennet. See *Pimpinella saxifraga.*

Benzoin benzoin (L.) Coulter. **Laurel family (Lauraceae).**

Synonyms.—*Laurus benzoin* L.; *Lindera benzoin* Meissn.; *Benzoin odoriferum* Nees.

Spicebush; feverbush; Benjamin-bush; wild allspice; spicewood.

Indigenous shrub, 5 to 12 feet high; in damp, shady woods, and along streams, Massachusetts to Michigan, south to North Carolina and Kansas.

Parts used.—Bark and berries (nonofficial).

Benzoin odoriferum Nees. Same as *Benzoin benzoin.*

Berberis. See *Berberis aquifolium.*

Berberis aquifolium Pursh. **Barberry family (Berberidaceae).**

Berberis; Oregon grape; holly-leaved barberry; Rocky Mountain grape.

A shrub, native in woods from Colorado to the Pacific Ocean; especially abundant in Oregon and northern California.

Parts used.—Rhizome and roots of this and of other species of Berberis (official).

Bergamot, wild. See *Monarda fistulosa.*

Bethroot, ill-scented. See *Trillium erectum.*

Betony, Paul's-. See *Veronica officinalis.*

Betula lenta L. **Birch family (Betulaceae).**

Sweet birch; black birch; cherry birch.

Large, indigenous forest tree; Newfoundland to Ontario, south to Florida and Tennessee.

Part used.—Bark (nonofficial). Oil of betula, obtained by maceration and distillation from the bark, is official.

Bikukulla canadensis (Goldie) Millsp. **Poppy family (Papaveraceae).**

Synonyms.—*Corydalis formosa* Pursh; *Corydalis canadensis* Goldie; *Dicentra canadensis* Walp.

Turkey-corn; squirrel-corn; turkey-pea; staggerweed.

Native, perennial plant, 6 to 12 inches high; in rich woods from Nova Scotia south along the mountains to Kentucky, and westward to Missouri and Minnesota.

Part used.—Tubers (nonofficial).

Birch, black. See *Betula lenta.*

Birch, cherry. See *Betula lenta.*

Birch, sweet. See *Betula lenta.*

Bird's-foot violet. See *Viola pedata.*

Birthroot. See *Trillium erectum.*

Bitterbloom. See *Sabbatia angularis.*

Bitter-buttons. See *Tanacetum vulgare.*

Bitterroot. See *Apocynum androsaemifolium.*

Bittersweet. See *Solanum dulcamara.*

Bittersweet, false. See *Celastrus scandens.*

Bitterweed. See *Erigeron canadensis.*

Blackberry, high-bush. See *Rubus nigrobaccus.*

Blackberry, knee-high. See *Rubus cuneifolius.*

Blackberry, low running. See *Rubus procumbens.*

Blackberry, low-bush. See *Rubus trivialis.*

Blackberry, sand-. See *Rubus cuneifolius.*

Blackcap. See *Rubus occidentalis.*

Blackroot. See *Veronica virginica.*

Blackroot, Indian. See *Pterocaulon undulatum.*

Blackwort. See *Symphytum officinale.*

Bladderpod. See *Lobelia inflata.*

Blazingstar. See *Chamaelirium luteum.*

Blazingstar, blue. See *Lacinaria scariosa.*

Blazingstar, scaly. See *Lacinaria squarrosa.*

Bloodroot. See *Sanguinaria canadensis.*

Bloodwort. See *Hieracium venosum.*

Bloodwort, striped. See *Hieracium venosum.*

Blowball. See *Taraxacum officinale.*

Blue-curls. See *Prunella vulgaris.*

Bog-bean. See *Menyanthes trifoliata.*

Bog-myrtle. See *Myrica gale.*

Boneset. See *Eupatorium perfoliatum.*

Boneset, deerwort-. See *Eupatorium ageratoides.*

Boneset, purple. See *Eupatorium purpureum.*

Bouncing-Bet. See *Saponaria officinalis.*

Bowman's-root. See *Porteranthus trifoliatus* and *Veronica virginica.*

Boxwood. See *Cornus florida.*

Brake, backache-. See *Athyrium filix-foemina.*

Brake, buckhorn-. See *Osmunda regalis.*

Brake, rock-. See *Polypodium vulgare.*

Brassica nigra (L.) Koch. **Mustard family (Brassicaceae).**

Synonym.—Sinapis nigra L.

Sinapis nigra; black mustard; brown mustard; red mustard.

Annual herb, introduced from Europe; found in fields and waste places almost throughout the United States.

Part used.—Seed (official); the volatile oil obtained from black mustard seed is also official.

Brauneria angustifolia (DC.) Heller. **Aster family (Asteraceae).**

Synonym.—Echinacea angustifolia DC.

Echinacea; pale-purple coneflower; Sampson-root; niggerhead (in Kansas).

Native, perennial, herbaceous plant, 2 to 3 feet high, occurring in rich prairie soil or sandy soil from Alabama to Texas and northwestward; most abundant in Kansas and Nebraska.

Part used.—Root (nonofficial).

Broom. See *Cytisus scoparius.*

Broom, green. See *Cytisus scoparius.*

Broom, Scotch. See *Cytisus scoparius.*

Brownwort. See *Prunella vulgaris.*

Bruisewort. See *Symphytum officinale.*

Buck-bean. See *Menyanthes trifoliata.*

Buckeye, fetid. See *Aesculus glabra.*

Buckeye, Ohio. See *Aesculus glabra.*

Buckeye, smooth. See *Aesculus glabra.*

Buckhorn-brake. See *Osmunda regalis.*

Buckthorn. See *Rhamnus cathartica.*

Bugle, sweet. See *Lycopus virginicus.*

Bugle, water-. See *Lycopus virginicus.*

Bugleweed. See *Lycopus virginicus.*

Bullbrier. See *Smilax pseudo-china.*

Bull-nettle. See *Solanum carolinense.*

Bulrush. See *Typha latifolia.*

Burdock. See *Arctium lappa.*

Burnet-saxifrage. See *Pimpinella saxifraga.*

Burningbush. See *Euonymus atropurpurea.*

Bursa bursa-pastoris (L.) Britton. **Mustard family (Brassicaceae).**

Synonym.—Capsella bursa-pastoris Medic.

Shepherd's-purse; cocowort; toywort.

Annual plant, about 1 foot in height, found in fields and waste places; widely distributed. Introduced from Europe.

Part used.—Herb (nonofficial).

Burseed, spiny. See *Xanthium spinosum.*

Burweed, thorny. See *Xanthium spinosum.*

Butneria florida (L.) Kearney. **Strawberry-shrub family (Calycanthaceae).**

Synonym.—Calycanthus floridus L.

Hairy strawberry-shrub; sweet-scented shrub; Carolina allspice; Florida allspice.

Native shrub, 4 to 8 feet high; in rich soil, Virginia to Mississippi.

Part used.—Bark (nonofficial).

Butterfly-weed. See *Asclepias tuberosa.*

Butternut. See *Juglans cinerea.*

Buttonbush. See *Cephalanthus occidentalis.*

Button-snakeroot. See *Eryngium yuccifolium.*

Button-snakeroot, dense. See *Lacinaria spicata.*

Button-snakeroot, large. See *Lacinaria scariosa.*

Button-tree. See *Cephalanthus occidentalis.*

Buttonwood-shrub. See *Cephalanthus occidentalis.*

Cabbage, skunk-. See *Spathyema foetida.*

Cabbage, swamp-. See *Spathyema foetida.*

Calamus. See *Acorus calamus.*

Calfkill. See *Kalmia angustifolia.*

Calico-bush. See *Kalmia latifolia.*

Calycanthus floridus L. Same as *Butneria florida.*

Camomile, fetid. See *Anthemis cotula.*

Canada balsam tree. See *Abies balsamea.*

Canada-root. See *Asclepias tuberosa.*

Cancerroot. See *Leptamnium virginianum.*

Candleberry. See *Myrica cerifera.*

Cane-ash. See *Fraxinus americana.*

Cankerroot. See *Coptis trifolia* and *Limonium carolinianum.*

Canker-weed. See *Nabalus serpentarius.*

Canker-weed, white. See *Nabalus albus.*

Cankerwort. See *Taraxacum officinale.*

Canoewood. See *Liriodendron tulipifera.*

Capsella bursa-pastoris Medic. Same as *Bursa bursa-pastoris.*

Cardinal, red. See *Lobelia cardinalis.*

Cardinal-flower. See *Lobelia cardinalis.*

Cardinal-flower, blue. See *Lobelia siphilitica.*

Carduus arvensis (L.) Robs. **Aster family (Asteraceae).**

Synonym.—Cirsium arvense Scop.

Canada thistle; creeping thistle; cursed thistle.

Perennial herb, 1 to 3 feet high; growing in cultivated fields, pastures, and waste places from Newfoundland to Virginia, west to Minnesota and Nebraska. A bad weed, introduced from Europe.

Part used.—Root (nonofficial).

Carduus benedictus Auct. Same as *Cnicus benedictus.*

Carpenter's-square. See *Scrophularia marilandica.*

Carrion-flower. See *Smilax herbacea.*

Carrot, wild. See *Daucus carota.*

Carya alba Nutt. Same as *Hicoria ovata.*

Cascara sagrada. See *Rhamnus purshiana.*

Cassia marilandica L. **Senna family (Caesalpiniaceae).**

American senna; wild senna; locust-plant.

Native, perennial herb; in swamps and wet soil, New England to Florida, west to Louisiana and Nebraska.

Part used.—Leaves (nonofficial).

Castalia odorata (Dryand.) Woodv. & Wood. **Water-lily family (Nymphaeaceae).**

Synonym.—Nymphaea odorata Dryand.

White pond-lily; water-lily; sweet-scented water-lily.

Indigenous, aquatic herb; perennial; in ponds, marshes, and sluggish streams, from Canada to Florida and Louisiana.

Part used.—Rhizome (nonofficial).

Castanea. See *Castanea dentata.*

Castanea dentata (Marsh.) Borkh. **Beech family (Fagaceae).**

Castanea; chestnut; American chestnut.

A large, spreading tree, occurring in rich woods from Maine to Michigan, south to Tennessee. Especially abundant in the Allegheny region. Native.

Part used.—Leaves (official in U. S. P. 1890).

Catchweed. See *Galium aparine.*

Catfoot. See *Glecoma hederacea.*

Catgut. See *Cracca virginiana.*

Catmint. See *Nepeta cataria.*

Catnip. See *Nepeta cataria.*

Cattail, broad-leaved. See *Typha latifolia.*

Cattail-flag. See *Typha latifolia.*

Caulophyllum. See *Caulophyllum thalictroides.*

Caulophyllum thalictroides (L.) Michx. **Barberry family (Berberidaceae).**

Caulophyllum; blue cohosh; squawroot; papoose-root.

Native, perennial herb, 1 to 3 feet high; found in rich, shady woods from New Brunswick to South Carolina, westward to Nebraska; abundant throughout the Allegheny Mountain region.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Ceanothus americanus L. **Buckthorn family (Rhamnaceae).**

Jersey tea; New Jersey tea; redroot.

A native shrub, growing in dry, open woods from Canada to Florida and Texas.

Parts used.—Root, root-bark, and leaves (nonofficial).

Cedar, red. See *Juniperus virginiana.*

Cedar, shrubby red. See *Juniperus sabina.*

Cedar, white. See *Thuja occidentalis.*

Cedar, yellow. See *Thuja occidentalis.*

Celandine. See *Chelidonium majus.*

Celandine, garden-. See *Chelidonium majus.*

Celandine, great. See *Chelidonium majus.*

Celandine, wild. See *Impatiens aurea.*

Celastrus scandens L. **Staff-tree family (Celastraceae).**

False bittersweet; staff-tree; waxwork; fevertwig.

An indigenous, twining, woody vine; in rich, damp soil, woods, and thickets, Ontario to Manitoba, south to North Carolina and New Mexico.

Part used.—Bark of plant and of root (nonofficial).

Centaurea benedicta L. Same as *Cnicus benedictus.*

Centaury, American. See *Sabbatia angularis.*

Centaury, ground-. See *Polygala nuttallii.*

Cephalanthus occidentalis L. **Madder family (Rubiaceae).**

Buttonbush; button-tree; buttonwood-shrub; globeflower.

Indigenous shrub, 6 to 12 feet high; in swamps and damp places, Canada to Florida and California.

Part used.—Bark (nonofficial).

Cercis canadensis L. **Senna family (Caesalpiniaceae).**

Judas-tree; redbud.

Small, native tree, growing in rich soil from New Jersey to Minnesota, south to Florida and Texas.

Part used.—Bark of root (nonofficial).

Chamaelirium luteum (L.) A. Gray. **Bunchflower family (Melanthiaceae).**

Synonym.—*Helonias dioica* Pursh.

True (not false) unicorn-root;[a] blazingstar; starwort; drooping starwort.

Slender, perennial herb, about 2 feet high; native in moist meadows and thickets from Massachusetts to Michigan, south to Florida and Arkansas.

Part used.—Rhizome (nonofficial).

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[a] The name "unicorn-root" was first applied to *Chamaelirium luteum*, and the designation "true unicorn-root" would seem to belong more properly to that species than to *Aletris farinosa*, to which the name unicorn-root was given later, and which may thus be called "false unicorn-root."

Chamaenerion angustifolium (L.) Scop. **Evening-primrose family (Onagraceae).**

Synonym.—Epilobium angustifolium L.

Great willow-herb; wickup.

Native, perennial herb, 2 to 8 feet high, found in dry soil from Canada to Alaska, south to North Carolina, Arizona, and California. Very common from Pennsylvania northward.

Parts used.—Leaves and root (nonofficial).

Chamomile, fetid. See *Anthemis cotula.*

Champion-oak. See *Quercus rubra.*

Checkerberry. See *Gaultheria procumbens* and *Mitchella repens.*

Cheeseflower. See *Malva sylvestris.*

Cheeses. See *Malva rotundifolia.*

Chelidonium. See *Chelidonium majus.*

Chelidonium majus L. **Poppy family (Papaveraceae).**

Chelidonium; celandine; garden-celandine; great celandine; tetterwort.

Perennial herb, 1 to 2 feet high, growing along fences, roadsides, and in waste places; common in the East. Naturalized from Europe.

Part used.—Entire plant (official in U. S. P. 1890).

Chelone glabra L. **Figwort family (Scrophulariaceae).**

Balmony; turtle-head; shellflower; snakehead; salt-rheum weed.

Native, perennial, herbaceous plant, 2 to 3 feet high; in swamps and along streams, Newfoundland to Manitoba, south to Florida and Kansas.

Part used.—Herb, and especially the leaves (nonofficial).

Chenopodium. See *Chenopodium ambrosioides* and *C. anthelminticum.*

Chenopodium ambrosioides L. **Goosefoot family (Chenopodiaceae).**

Chenopodium; Mexican tea; American wormseed; Jerusalem tea; Spanish tea.

Strong-scented herb, 2 to 3 feet high, annual; naturalized from tropical America, and occurring in waste places, meadows, and pastures from New England to Florida, west to California.

Part used.—Fruit (official in U. S. P. 1890).

Chenopodium anthelminticum L. **Goosefoot family (Chenopodiaceae).**

Chenopodium; wormseed; Jerusalem oak.

Annual, sometimes perennial, herb, usually taller than *C. ambrosioides*, naturalized from Europe, and found in waste places from southern New York to Wisconsin, south to Florida and Mexico.

Parts used.—Fruit (official in U. S. P. 1890). The oil of chenopodium, distilled from this plant, is official.

Chenopodium botrys L. **Goosefoot family (Chenopodiaceae).**

Jerusalem oak.

Annual herb, about 2 feet high, introduced from Europe; found in waste places from Nova Scotia to New York and Kentucky, westward to Oregon.

Parts used.—Herb and seeds (nonofficial).

Cherry birch. See *Betula lenta.*

Cherry, rum-. See *Prunus serotina.*

Cherry, wild. See *Prunus serotina.*

Chervil, sweet. See *Washingtonia longistylis.*

Chestnut. See *Castanea dentata.*

Chestnut, American. See *Castanea dentata.*

Chestnut, horse-. See *Aesculus hippocastanum.*

Chickentoe. See *Corallorhiza odontorhiza.*

Chickweed, common. See *Alsine media.*

Chickweed, red. See *Anagallis arvensis.*

Chicory. See *Cichorium intybus.*

Chimaphila. See *Chimaphila umbellata.*

Chimaphila umbellata (L.) Nutt. **Wintergreen family (Pyrolaceae).**

Chimaphila; pipsissewa; prince's-pine; bitter wintergreen; rheumatism-weed.

Small, perennial herb, native in dry, shady woods, especially in pine forests, from Nova Scotia to Georgia, west to California.

Part used.—Leaves (official).

China-root, American. See *Smilax pseudo-china.*

China-root, false. See *Smilax pseudo-china.*

Chionanthus virginica L. **Olive family (Oleaceae).**

Fringe-tree; old-man's-beard.

A shrub or small tree, native in moist thickets from Delaware to Florida and Texas.

Part used.—Bark of root (nonofficial).

Chittem-bark. See *Rhamnus purshiana.*

Chrysanthemum leucanthemum L. **Aster family (Asteraceae).**

Synonym.—*Leucanthemum vulgare* Lam.

Oxeye daisy; white daisy.

Perennial herb, 1 to 3 feet high, naturalized from Europe; occurring in pastures, meadows, and waste places in nearly every section of the country, but less abundantly in the South and rarely in the West.

Part used.—Herb (nonofficial).

Chrysanthemum parthenium (L.) Pers. **Aster family (Asteraceae).**

Synonym.—*Pyrethrum parthenium* Smith.

Common feverfew; featherfew; febrifuge-plant.

Perennial herb, naturalized from Europe. Mostly escaped from cultivation; in waste places, New Brunswick to New Jersey, and locally in the interior.

Part used.—Herb (nonofficial).

Cichorium intybus L. **Chicory family (Cichoriaceae).**

Chicory; succory.

Perennial herb, 1 to 3 feet high, growing in fields, waste places, and along roadsides from Nova Scotia to North Carolina, west to Nebraska. Abundant eastward. Naturalized from Europe.

Part used.—Root (nonofficial).

Cicuta maculata L. **Parsley family (Apiaceae).**

Water-hemlock; musquash-root; beaver-poison.

Native perennial, 3 to 6 feet high, stout, erect; poisonous. Found in swamps and low grounds from Canada south to Florida and New Mexico.

Part used.—Leaves (nonofficial).

Cimicifuga. See *Cimicifuga racemosa.*

Cimicifuga racemosa (L.) Nutt. **Crowfoot family (Ranunculaceae).**

Synonym.—*Actaea racemosa* L.

Cimicifuga; black snakeroot; black cohosh; squawroot; rattle-root.

Native, perennial herb, 3 to 8 feet high; in rich soil in shady woods, Maine to Georgia, west to Wisconsin and Missouri. Most abundant in the Ohio Valley.

Parts used.—Rhizome and roots (official).

Cinquefoil. See *Potentilla canadensis.*

Cirsium arvense Scop. Same as *Carduus arvensis.*

Cleavers. See *Galium aparine.*

Cleaverwort. See *Galium aparine.*

Clematis. See *Clematis virginiana.*

Clematis virginiana L. **Crowfoot family (Ranunculaceae).**

Virgin's-bower; clematis.

Shrubby, perennial vine; native; found along river banks in hedges and thickets from Canada to Georgia and Kansas.

Parts used.—Leaves and flowers (nonofficial).

Clotbur, spiny. See *Xanthium spinosum.*

Clotweed, thorny. See *Xanthium spinosum.*

Clover, bitter. See *Sabbatia angularis.*

Clover, meadow-. See *Trifolium pratense.*

Clover, purple. See *Trifolium pratense.*

Clover, red. See *Trifolium pratense.*

Clover, yellow sweet. See *Melilotus officinalis.*

Club-moss. See *Lycopodium clavatum.*

Cnicus benedictus L. **Aster family (Asteraceae).**

Synonyms.—*Carduus benedictus* Auct.; *Centaurea benedicta* L.

Blessed thistle; holy thistle; bitter thistle; spotted thistle; St. Benedict's-thistle.

Annual plant, 1 to 2 feet high; in waste places, Southern States, and in California and Utah; introduced from Europe.

Part used.—Herb (nonofficial).

Cocash. See *Aster puniceus.*

Cocash-weed. See *Senecio aureus.*

Cockle-button. See *Arctium lappa.*

Cocowort. See *Bursa bursa-pastoris.*

Cohosh, black. See *Cimicifuga racemosa.*

Cohosh, blue. See *Caulophyllum thalictroides.*

Cohosh, red. See *Actaea rubra.*

Cohosh, white. See *Actaea alba.*

Colic-root. See *Aletris farinosa*, *Dioscorea villosa*, *Lacinaria spicata*, and *L. squarrosa.*

Collinsonia canadensis L. **Mint family (Menthaceae).**

Stoneroot; richweed; knobroot; horse-balm.

Native, perennial herb, about 2 feet high, occurring in rich, moist woods from Maine to Wisconsin, south to Florida and Kansas.

Parts used.—Root and leaves (nonofficial).

Colt's-foot. See *Tussilago farfara.*

Colt's-tail. See *Erigeron canadensis.*

Columbine, European. See *Aquilegia vulgaris.*

Columbine, garden-. See *Aquilegia vulgaris.*

Columbine, wild. See under *Aquilegia vulgaris.*

Columbo, American. See *Frasera carolinensis.*

Comfrey. See *Symphytum officinale.*

Compass-plant. See *Silphium laciniatum.*

Comptonia asplenifolia Gaertn. Same as *Comptonia peregrina.*

Comptonia peregrina (L.) Coulter. **Bayberry family (Myricaceae).**

Synonyms.—*Comptonia asplenifolia* Gaertn.; *Myrica asplenifolia* L.

Sweet fern; spleenwortbush; meadow-fern.

Shrubby plant, about 2½ feet high, native; in thin sandy or stony woods and on hillsides, Canada to North Carolina, Indiana, and Michigan.

Parts used.—Leaves and tops (nonofficial).

Coneflower, pale-purple. See *Brauneria angustifolia.*

Coneflower, tall. See *Rudbeckia laciniata.*

Congo-root. See *Psoralea pedunculata.*

Conium. See *Conium maculatum.*

Conium maculatum L. **Parsley family (Apiaceae).**

Conium; poison-hemlock; spotted parsley; spotted cowbane.

Biennial herb, 2 to 6 feet high, naturalized from Europe; common in waste places, especially in the Eastern and Middle States. Poisonous.

Parts used.—Full-grown, but unripe, fruit, carefully dried and preserved (official); leaves (nonofficial).

Consumptive's-weed. See *Eriodictyon californicum.*

Convallaria. See *Convallaria majalis.*

Convallaria biflora Walt. Same as *Polygonatum biflorum.*

Convallaria majalis L. **Lily-of-the-valley family (Convallariaceae).**

Convallaria; lily-of-the-valley.

A low, perennial herb; indigenous; on the higher mountains from Virginia to the Carolinas.

Parts used.—Rhizome and roots (official); herb and flowers (nonofficial).

Convallaria racemosa L. Same as *Vagnera racemosa.*

Convolvulus panduratus L. Same as *Ipomoea pandurata.*

Coolwort. See *Tiarella cordifolia.*

Coptis trifolia (L.) Salisb. **Crowfoot family (Ranunculaceae).**

Goldthread; cankerroot; mouthroot; yellowroot.

Low, native, perennial herb, growing in damp mossy woods and bogs from Canada and Alaska south to Maryland and Minnesota; most common in the New England States, northern New York and Michigan, and in Canada.

Parts used.—Rhizome and rootlets (nonofficial).

Corallorhiza odontorhiza (Willd.) Nutt. **Orchid family (Orchidaceae).**

Crawley-root; coralroot; dragon's-claw; chickentoe.

Leafless plant, 6 to 15 inches high, found in rich woods from Maine to Florida, west to Michigan and Missouri. Native.

Part used.—Rhizome (nonofficial).

Coralroot. See *Corallorhiza odontorhiza.*

Corn, squirrel-. See *Bikukulla canadensis.*

Corn, turkey-. See *Bikukulla canadensis.*

Cornel, silky. See *Cornus amomum.*

Corn-snakeroot. See *Eryngium yuccifolium* and *Lacinaria spicata.*

Cornus amomum Mill. **Dogwood family (Cornaceae).**

Synonym.—*Cornus sericea* L.

Red osier; swamp-dogwood; silky cornel; rose-willow.

Native shrub, 3 to 10 feet high; in low woods and along streams, Canada to Florida, west to Texas and the Dakotas.

Part used.—Bark (nonofficial).

Cornus circinata L'Her. **Dogwood family (Cornaceae).**

Green osier; round-leaved dogwood.

Native shrub, 3 to 10 feet high; in shady places, Canada and the northeastern United States.

Part used.—Bark (nonofficial).

Cornus florida L. **Dogwood family (Cornaceae).**

Flowering dogwood; boxwood.

Small, native tree or large shrub, growing in woods from Canada to Florida, Texas and Missouri. Most abundant in the Middle States.

Parts used.—Bark of tree and of root, the latter preferred (nonofficial).

Cornus sericea L. Same as *Cornus amomum*.

Corydalis canadensis Goldie. Same as *Bikukulla canadensis*.

Corydalis formosa Pursh. Same as *Bikukulla canadensis*.

Cotton-gum. See *Nyssa aquatica*.

Cottonweed. See *Anaphalis margaritacea*.

Couch-grass. See *Agropyron repens*.

Coughweed. See *Senecio aureus*.

Coughwort. See *Tussilago farfara*.

Cowbane, spotted. See *Conium maculatum*.

Cow-lily. See *Nymphaea advena*.

Cow-parsnip. See *Heracleum lanatum*.

Cracca virginiana L. **Pea family (Fabaceae).**

Synonym.—Tephrosia virginiana Pers.

Devil's-shoestring; hoary pea; goat's-rue; catgut.

Hoary, perennial herb, 1 to 2 feet high, native; occurring in dry, sandy soil from New England to Florida, west to Texas and Minnesota.

Part used.—Root (nonofficial).

Cramp-bark. See *Viburnum opulus*.

Cranberry, high-bush. See *Viburnum opulus*.

Cranberry, upland-. See *Arctostaphylos uva-ursi*.

Crane's-bill, spotted. See *Geranium maculatum*.

Crane's-bill, wild. See *Geranium maculatum*.

Crataegus oxyacantha L. **Apple family (Malaceae).**

Hawthorn; hedgethorn; whitethorn; maythorn.

Shrub or tree, introduced from Europe, and sparingly escaped from cultivation.

Part used.—Berries (nonofficial).

Crawley-root. See *Corallorhiza odontorhiza*.

Crosswort. See *Eupatorium perfoliatum*.

Cucumber-tree. See *Magnolia acuminata* and *M. tripetala*.

Cudweed, low. See *Gnaphalium uliginosum*.

Cudweed, marsh-. See *Gnaphalium uliginosum*.

Culver's-physic. See *Veronica virginica*.

Culver's-root. See *Veronica virginica*.

Cunila mariana L. Same as *Cunila origanoides*.

Cunila origanoides (L.) Britton. **Mint family (Menthaceae).**

Synonym.—Cunila mariana L.

American dittany; stonemint.

Indigenous, perennial plant, found on dry hills and in dry woods from New York to Florida, west to Ohio.

Part used.—Herb (nonofficial).

Cup-plant. See *Silphium perfoliatum*.

Custard-apple. See *Asimina triloba*.

Cynoglossum officinale L. **Borage family (Boraginaceae).**

Hound's-tongue; gypsy-flower.

Biennial herb, about 3 feet high, naturalized from Europe, and occurring in waste places from Canada to North Carolina, west to Kansas and Minnesota.

Parts used.—Leaves and root (nonofficial).

Cypripedium. See *Cypripedium hirsutum* and *C. parviflorum*.

Cypripedium hirsutum Mill. **Orchid family (Orchidaceae).**

Synonym.—Cypripedium pubescens Willd.

Cypripedium; large yellow ladies-slipper; yellow moccasin-flower; American valerian.

Herb, 1 to 2 feet high, native in woods and thickets from Nova Scotia south to Alabama and west to Nebraska and Missouri.

Parts used.—Rhizome and roots (official).

Cypripedium parviflorum Salisb. **Orchid family (Orchidaceae).**

Cypripedium; small yellow ladies-slipper.

Herb, 1 to 2 feet high; native in woods and thickets from British America to Georgia, Missouri, and Oregon.

Parts used.—Rhizome and roots (official).

Cypripedium pubescens Willd. Same as *Cypripedium hirsutum.*

Cytisus scoparius (L.) Link. **Pea family (Fabaceae).**

Synonym.—Sarothamnus scoparius Wimm.

Scoparius; broom; green broom; Scotch broom.

Stiff, wiry plant, 3 to 5 feet high; naturalized from Europe; growing in dry, sandy soil from Massachusetts to Virginia and becoming common in many places in the northwestern United States.

Part used.—Tops (official).

Daisy, oxeye. See *Chrysanthemum leucanthemum.*

Daisy, white. See *Chrysanthemum leucanthemum.*

Daisy-fleabane. See *Erigeron philadelphicus.*

Damiana. See *Turnera microphylla.*

Dandelion. See *Taraxacum officinale.*

Daphne mezereum L. **Mezereon family (Daphnaceae).**

Synonym.—Mezereum officinarum C. A. Mey.

Mezereum; mezereon; spurge-laurel; paradise-plant; spurge-olive.

A very hardy shrub, introduced from Europe and escaped from cultivation in Canada and New England.

Part used.—Bark of this and of other European species of Daphne (official).

Datura stramonium L. **Potato family (Solanaceae).**

Stramonium; jimson-weed; Jamestown-weed; thorn-apple; apple-of-Peru.

Poisonous weed; annual, 2 to 5 feet high; introduced from the Tropics, and occurring in fields and waste places throughout the United States, with the exception of the North and West.

Parts used.—Leaves (official); seeds (official in U. S. P. 1890).

Daucus carota L. **Parsley family (Apiaceae).**

Wild carrot; Queen-Anne's-lace.

Biennial herb, 2 to 3 feet high; naturalized from Europe; common almost throughout the United States, growing in old fields and along roadsides.

Parts used.—Root, fruit, and leaves (nonofficial).

Deerberry. See *Gaultheria procumbens* and *Mitchella repens.*

Deer-laurel. See *Rhododendron maximum.*

Deer's-tongue. See *Trilisa odoratissima.*

Deerwood. See *Ostrya virginiana.*

Deerwort-boneset. See *Eupatorium ageratoides.*

Delphinium consolida L. **Crowfoot family (Ranunculaceae).**

Field-larkspur; knight's-spur; lark-heel.

An annual herb, about 2 feet high; naturalized from Europe, and found in waste places from southern New Jersey and Pennsylvania southward. The indig-

Delphinium consolida—Continued.

enous tall larkspur, *Delphinium urceolatum* Jacq. (*D. exaltatum* Ait.), is used for similar purposes. This is found in woods from Pennsylvania to Minnesota, south to Alabama and Nebraska.

Parts used.—Herb and seeds (nonofficial).

Delphinium exaltatum Ait. See under *Delphinium consolida.*

Delphinium urceolatum Jacq. See under *Delphinium consolida.*

Devil's-bit. See *Lacinaria scariosa.*

Devil's-shoestring. See *Cracca virginiana.*

Dewberry. See *Rubus procumbens.*

Dewberry, one-flowered. See *Rubus villosus.*

Dewberry, southern. See *Rubus trivialis.*

Dicentra canadensis Walp. Same as *Bikukulla canadensis.*

Digitalis. See *Digitalis purpurea.*

Digitalis purpurea L. **Figwort family (Scrophulariaceae).**

Digitalis; foxglove; fairy-fingers; thimbles; lady's-glove.

Very handsome biennial plant, 3 to 4 feet high; introduced from Europe as a garden plant, and now escaped from cultivation in parts of Oregon, Washington, and West Virginia.

Parts used.—Leaves from plants of second year's growth, gathered at commencement of flowering (official).

Dioscorea villosa L. **Yam family (Dioscoreaceae).**

Wild yam; colic-root; rheumatism-root.

Slender, herbaceous, native vine, growing in moist thickets from Rhode Island to Minnesota, south to Florida and Texas; more common in central and southern parts of the United States.

Part used.—Rhizome (nonofficial).

Diospyros virginiana L. **Ebony family (Diospyraceae).**

Persimmon.

Indigenous tree, 15 to 50 feet in height; in fields and woods, Rhode Island to Kansas, Florida, and Texas.

Parts used.—Bark and unripe fruit (nonofficial).

Dirca palustris L. **Mezereon family (Daphnaceae).**

Leatherwood; moosewood; American mezereon; wickopy; rope-bark.

A native shrub, occurring in woods and thickets, New Brunswick to Florida, west to Missouri and Minnesota; most common in the Northern and Eastern States.

Part used.—Bark (nonofficial).

Ditch-stonecrop. See *Penthorum sedoides.*

Dittany, American. See *Cunila origanoides.*

Dock, bitter. See *Rumex obtusifolius.*

Dock, blunt-leaved. See *Rumex obtusifolius.*

Dock, broad-leaved. See *Rumex obtusifolius.*

Dock, curled. See *Rumex crispus.*

Dock, narrow. See *Rumex crispus.*

Dock, sour. See *Rumex crispus.*

Dock, spatter-. See *Nymphaea advena.*

Dock, velvet. See *Verbascum thapsus.*

Dock, yellow. See *Rumex crispus.*

Dogbane, spreading. See *Apocynum androsaemifolium.*

Dogberry. See *Sorbus americana.*

Dog-fennel. See *Anthemis cotula.*

Dog-grass. See *Agropyron repens.*

Dog's-tooth violet. See *Erythronium americanum.*

Dogwood, flowering. See *Cornus florida.*

Dogwood, round-leaved. See *Cornus circinata.*

Dogwood, swamp-. See *Cornus amomum.*

Dooryard-plantain. See *Plantago major.*

Dracontium foetidum L. Same as *Spathyema foetida.*

Dragon's-claw. See *Corallorhiza odontorhiza.*

Dropwort, western. See *Porteranthus trifoliatus.*

Drosera rotundifolia L. **Sundew family (Droseraceae).**

Round-leaved sundew; youthwort.

Low, perennial herb, growing in bogs and muddy shores of rivers from Canada to Florida and California.

Part used.—Herb (nonofficial).

Dryopteris filix-mas (L.) Schott. **Fern family (Polypodiaceae).**

Synonyms.—*Aspidium filix-mas* Sw.; *Polypodium filix-mas* L.

Aspidium; male-fern.

Fern, with leaves 1 to 3 feet long; in rocky woods from Canada to northern Michigan, and in the Rocky Mountains to Arizona.

Part used.—Rhizome (official).

Dryopteris marginalis (L.) A. Gray. **Fern family (Polypodiaceae).**

Synonyms.—*Aspidium marginale* Sw.; *Polypodium marginale* L.

Aspidium; evergreen wood-fern; marginal-fruited shield-fern.

Fern, with leaves 6 inches to 2½ feet long; in rocky woods from Canada south to Alabama and Arkansas.

Part used.—Rhizome (official).

Dulcamara. See *Solanum dulcamara.*

Dysentery-weed. See *Gnaphalium uliginosum.*

Earth-smoke. See *Fumaria officinalis.*

Echinacea. See *Brauneria angustifolia.*

Echinacea angustifolia DC. Same as *Brauneria angustifolia.*

Elder. See *Sambucus canadensis.*

Elder, American. See *Sambucus canadensis.*

Elder, dwarf. See *Aralia hispida.*

Elder, sweet. See *Sambucus canadensis.*

Elder, wild. See *Aralia hispida.*

Elecampane. See *Inula helenium.*

Elk-tree. See *Oxydendrum arboreum.*

Elkwood. See *Magnolia tripetala.*

Elliott's-sabbatia. See *Sabbatia elliottii.*

Elm. See *Ulmus fulva.*

Elm, Indian. See *Ulmus fulva.*

Elm, moose-. See *Ulmus fulva.*

Elm, red. See *Ulmus fulva.*

Elm, slippery. See *Ulmus fulva.*

Emetic-root. See *Euphorbia corollata.*

Epigaea repens L. **Heath family (Ericaceae).**

Gravel-plant; trailing arbutus; mayflower.

Small, shrubby, native plant, spreading on the ground in sandy soil, especially under evergreen trees, from Florida to Michigan and northward.

Part used.—Leaves (nonofficial).

Epilobium angustifolium L. Same as *Chamaenerion angustifolium*.

Epilobium palustre L. **Evening-primrose family (Onagraceae).**

Swamp willow-herb; wickup.

Slender, erect, native herb, 6 to 18 inches high, found in swamps and marshes from Canada and the New England States west to Colorado and Washington.

Parts used.—Leaves and root (nonofficial).

Epiphegus virginiana Bart. Same as *Leptamnium virginianum*.

Equisetum hyemale L. **Horsetail family (Equisetaceae).**

Common scouring-rush; horsetail; shave-grass.

Rush-like perennial plant, growing in wet places along river banks and borders of woods throughout nearly the whole of North America.

Part used.—Plant (nonofficial).

Erechtites hieracifolia (L.) Raf. **Aster family (Asteraceae).**

Fireweed; pilewort.

Native, annual herb, 1 to 8 feet high, in woods, fields, and waste places, Canada to Florida, Louisiana, and Nebraska.

Part used.—Herb (nonofficial).

Erigeron canadensis L. **Aster family (Asteraceae).**

Synonym.—*Leptilon canadense* (L.) Britton.[a]

Canada fleabane; horseweed; colt's-tail; prideweed; bitterweed.

Native, annual weed, 3 inches to 10 feet in height; in fields and meadows, along roadsides, and in waste places, almost throughout North America.

Part used.—Herb (nonofficial); the oil of erigeron, distilled from the fresh, flowering herb, is official.

Erigeron philadelphicus L. **Aster family (Asteraceae).**

Philadelphia fleabane; sweet scabious; daisy-fleabane.

Native, perennial herb, 1 to 3 feet high, in fields and woods throughout North America, except extreme North.

Part used.—Herb (nonofficial).

Eriodictyon. See *Eriodictyon californicum*.

Eriodictyon californicum (H. & A.) Greene. **Waterleaf family (Hydrophyllaceae).**

Synonym.—*Eriodictyon glutinosum* Benth.

Eriodictyon; yerba santa; mountain-balm; consumptive's-weed; bear's-weed.

Shrubby plant, 2 to 4 feet high, native; grows in clumps in dry situations and among rocks throughout California and northern Mexico.

Part used.—Leaves (official).

Eriodictyon glutinosum Benth. Same as *Eriodictyon californicum*.

Eryngium yuccaefolium Michx. Same as *Eryngium yuccifolium*.

Eryngium yuccifolium Michx. **Parsley family (Apiaceae).**

Synonym.—*Eryngium yuccaefolium* Michx.

Water-eryngo; button-snakeroot; rattlesnake-weed; rattlesnake-master; corn-snakeroot.

Native, perennial herb, 1 to 5 feet high, growing in swamps and low wet ground from the pine barrens of New Jersey west to Minnesota, and south to Texas and Florida.

Part used.—Rhizome (nonofficial).

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[a] Some authors hold that this plant belongs to the genus *Leptilon* and that its name should be *Leptilon canadense* (L.) Britton. The Pharmacopœia is here followed.

Eryngo, water-. See *Eryngium yuccifolium.*

Erythronium americanum Ker. **Lily family (Liliaceae).**

Yellow adder's-tongue; dog's-tooth violet; yellow snowdrop; rattlesnake-violet; yellow snakeleaf.

Native, perennial herb, occurring in moist woods and thickets, Nova Scotia to Minnesota, south to Arkansas and Florida.

Parts used.—Leaves and root (nonofficial).

Euonymus. See *Euonymus atropurpureus.*

Euonymus atropurpureus Jacq. **Staff-tree family (Celastraceae).**

Euonymus; wahoo; burningbush; spindle-tree; Indian arrowwood.

Native shrub or small tree, growing in woods and thickets from Ontario and eastern United States west to Montana.

Part used.—Bark of root (official).

Eupatorium. See *Eupatorium perfoliatum.*

Eupatorium ageratoides L. f. **Aster family (Asteraceae).**

White snakeroot; white sanicle; Indian sanicle; deerwort-boneset; poolwort; poolroot; richweed; squaw-weed.

Erect, perennial herb, 1 to 4 feet high, native; in rich woods from Canada to Georgia, west to Nebraska and Louisiana.

Part used.—Root (nonofficial).

Eupatorium aromaticum L. **Aster family (Asteraceae).**

Smaller white snakeroot; poolwort; poolroot; wild hoarhound.

Native, perennial herb, 1 to 2 feet high; in dry soil from Massachusetts to Florida, especially throughout the Middle States.

Part used.—Root (nonofficial).

Eupatorium perfoliatum L. **Aster family (Asteraceae).**

Eupatorium; boneset; thoroughwort; Indian sage; agueweed; crosswort.

Native, perennial herb, 1 to 5 feet high; in low, wet places from Canada to Florida, west to Texas and Nebraska.

Parts used.—Leaves and flowering tops (official).

Eupatorium purpureum L. **Aster family (Asteraceae).**

Queen-of-the-meadow; gravelroot; Joe-Pye-weed; purple boneset; kidneyroot.

Native, perennial herb, 3 to 10 feet high; in low grounds from Canada to Florida and Texas.

Parts used.—Root and herb (nonofficial).

Euphorbia corollata L. **Spurge family (Euphorbiaceae).**

Flowering spurge; emetic-root; milk-ipecac; snakemilk; purging-root.

Native, perennial herb, about 3 feet in height, growing in dry fields and woods from Ontario to Florida and Minnesota to Texas.

Part used.—Root (nonofficial).

Euphorbia hypericifolia A. Gray. Same as *Euphorbia nutans.*

Euphorbia ipecacuanhae L. **Spurge family (Euphorbiaceae).**

Wild ipecac; ipecac-spurge; American ipecac; Carolina ipecac.

Native, perennial herb, 4 to 10 inches high; in dry, sandy soil, mostly near the coast, from Connecticut to Florida.

Part used.—Root (nonofficial).

Euphorbia nutans Lag. **Spurge family (Euphorbiaceae).**

Synonym.—*Euphorbia hypericifolia* A. Gray.

Large spotted spurge; black purslane; fluxweed; milk-purslane.

Native, annual plant, from ½ to 2 feet in height; in rich soils, fields, and thickets throughout eastern North America, except extreme north, and extending west to the Rocky Mountains.

Part used.—Herb (nonofficial).

Euphorbia pilulifera L. **Spurge family (Euphorbiaceae).**

Pill-bearing spurge; snakeweed; Queensland asthma-weed.

Herbaceous annual, 10 to 15 inches high, occurring from the Gulf States through Texas to New Mexico.

Part used.—Herb (nonofficial).

Evening-primrose. See *Oenothera biennis.*

Everlasting. See *Anaphalis margaritacea.*

Everlasting, large-flowered. See *Anaphalis margaritacea.*

Everlasting, pearly. See *Anaphalis margaritacea.*

Eve's-cup. See *Sarracenia flava.*

Fagara clava-herculis (L.) Small. **Rue family (Rutaceae).**

Synonym.—*Xanthoxylum clava-herculis* L.

Xanthoxylum; southern prickly ash; toothache-tree; yellowthorn; yellow-wood; Hercules-club.

Small, indigenous, very prickly tree, sometimes 45 feet in height, occurring along streams from southern Virginia to Florida, west to Texas and Arkansas.

Parts used.—Bark official under the name "Xanthoxylum"; berries (nonofficial).

Fagus americana Sweet. **Beech family (Fagaceae).**

Synonym.—*Fagus ferruginea* Ait.

American beech; beechnut-tree.

Large, native forest tree, growing in rich soil from Nova Scotia to Florida, west to Wisconsin and Texas.

Parts used.—Bark and leaves (nonofficial).

Fagus ferruginea Ait. Same as *Fagus americana.*

Fairy-fingers. See *Digitalis purpurea.*

Featherfew. See *Chrysanthemum parthenium.*

Febrifuge-plant. See *Chrysanthemum parthenium.*

Female-fern. See *Athyrium filix-foemina* and *Polypodium vulgare.*

Fennel, dog-. See *Anthemis cotula.*

Fern, evergreen wood-. See *Dryopteris marginalis.*

Fern, female-. See *Athyrium filix-foemina* and *Polypodium vulgare.*

Fern, lady-. See *Athyrium filix-foemina.*

Fern, maidenhair-. See *Adiantum pedatum.*

Fern, male-. See *Dryopteris filix-mas.*

Fern, marginal-fruited shield-. See *Dryopteris marginalis.*

Fern, meadow-. See *Comptonia peregrina.*

Fern, parsley-. See *Tanacetum vulgare.*

Fern, royal. See *Osmunda regalis.*

Fern, sweet. See *Comptonia peregrina.*

Fernroot. See *Polypodium vulgare.*

Feverbush. See *Benzoin benzoin* and *Ilex verticillata.*

Feverfew, common. See *Chrysanthemum parthenium.*

Feverroot. See *Triosteum perfoliatum.*

Fevertwig. See *Celastrus scandens.*

Field-balm. See *Glecoma hederacea.*

Field-larkspur. See *Delphinium consolida.*

Field-sorrel. See *Rumex acetosella.*

Figwort, Maryland. See *Scrophularia marilandica.*

Fir, balsam-. See *Abies balsamea.*

Fireweed. See *Erechtites hieracifolia.*

Fit-plant. See *Monotropa uniflora.*

Fitroot. See *Monotropa uniflora.*

Fivefinger. See *Potentilla canadensis.*

Flag, blue. See *Iris versicolor.*

Flag, cattail-. See *Typha latifolia.*

Flag, sweet-. See *Acorus calamus.*

Flag, water-. See *Iris versicolor.*

Flag-lily. See *Iris versicolor.*

Flannel-leaf. See *Verbascum thapsus.*

Fleabane, Canada. See *Erigeron canadensis.*

Fleabane, daisy-. See *Erigeron philadelphicus.*

Fleabane, Philadelphia. See *Erigeron philadelphicus.*

Fluxweed. See *Euphorbia nutans.*

Flytrap. See *Sarracenia purpurea.*

Foamflower. See *Tiarella cordifolia.*

Foxglove. See *Digitalis purpurea.*

Fragaria virginiana Duchesne. **Rose family (Rosaceae).**

Virginia strawberry; scarlet strawberry.

Native, perennial herb, occurring in dry soil from Canada to Georgia, west to Indian Territory and Minnesota.

Part used.—Leaves (nonofficial).

Frankenia grandifolia Cham. & Schlecht. **Frankenia family (Frankeniaceae).**

Yerba reuma.

Native, perennial herb, 8 to 13 inches high, common in salt marshes and sandy localities near the coast in California.

Part used.—Herb (nonofficial).

Frasera carolinensis Walt. **Gentian family (Gentianaceae).**

Synonym.—*Frasera walteri* Michx.

American columbo; Indian lettuce; meadowpride; pyramid-flower.

Smooth, perennial herb, 3 to 8 feet high, found in dry soil from New York to Wisconsin, south to Georgia and Kentucky.

Part used.—Root (nonofficial).

Frasera walteri Michx. Same as *Frasera carolinensis.*

Fraxinus acuminata Lam. Same as *Fraxinus americana.*

Fraxinus alba Marsh. Same as *Fraxinus americana.*

Fraxinus americana L. **Olive family (Oleaceae).**

Synonyms.—*Fraxinus alba* Marsh; *Fraxinus acuminata* Lam.

White ash; cane-ash.

Large, native forest tree, in rich woods from Nova Scotia to Minnesota, south to Florida and Texas. Occurs chiefly in the Northern States and Canada.

Part used.—Bark (nonofficial).

Fraxinus nigra Marsh. **Olive family (Oleaceae).**

Synonym.—*Fraxinus sambucifolia* Lam.

Black ash; hoop-ash.

Native tree, 40 to 70 feet in height, occurring in swamps and wet woods from Canada to Virginia and Arkansas.

Part used.—Bark (nonofficial).

Fraxinus sambucifolia Lam. Same as *Fraxinus nigra*.

Fringe-tree. See *Chionanthus virginica*.

Frost-plant. See *Helianthemum canadense*.

Frostweed. See *Helianthemum canadense*.

Frostwort. See *Helianthemum canadense*.

Fuller's-herb. See *Saponaria officinalis*.

Fumaria officinalis L. **Poppy family (Papaveraceae).**

Fumitory; hedge-fumitory; earth-smoke.

Annual plant, 10 to 15 inches high, adventive from Europe and found in waste places about dwellings, in cultivated land, and on ballast, Nova Scotia to the Gulf States.

Part used.—Herb (nonofficial).

Fumitory. See *Fumaria officinalis*.

Fumitory, hedge-. See *Fumaria officinalis*.

Gagroot. See *Lobelia inflata*.

Gale, sweet. See *Myrica gale*.

Galium aparine L. **Madder family (Rubiaceae).**

Cleavers; goose-grass; cleaverwort; bedstraw; catchweed.

Annual plant, with weak, procumbent stem, 2 to 6 feet long, growing in shady thickets and margins of woods, New Brunswick south to Florida and Texas. Naturalized from Europe.

Part used.—Herb of this and of other species of Galium (nonofficial).

Gallweed. See *Gentiana quinquefolia*.

Garden-balm. See *Melissa officinalis*.

Garden-celandine. See *Chelidonium majus*.

Garden-columbine. See *Aquilegia vulgaris*.

Garden-valerian. See *Valeriana officinalis*.

Garget. See *Phytolacca decandra*.

Gaultheria procumbens L. **Heath family (Ericaceae).**

Wintergreen; checkerberry; mountain-tea; teaberry; deerberry.

Small, native perennial, with evergreen leaves, found in sandy soils in cool, damp woods, especially under evergreen trees, in Canada and the northeastern United States.

Part used.—Leaves (nonofficial); the oil of gaultheria, distilled from the leaves, is official.

Gay-feather. See *Lacinaria scariosa* and *L. spicata*.

Gelsemium. See *Gelsemium sempervirens*.

Gelsemium sempervirens (L.) Ait. f. **Logania family (Loganiaceae).**

Gelsemium; yellow jasmine; Carolina jasmine; wild woodbine.

Twining, shrubby perennial, native, growing on low ground in woods and thickets from eastern Virginia to Florida and Texas, mostly near the coast.

Parts used.—Rhizome and roots (official).

Gemfruit. See *Tiarella cordifolia*.

Gentian, American. See *Gentiana saponaria*.

Gentian, blue. See *Gentiana saponaria*.

Gentian, five-flowered. See *Gentiana quinquefolia*.

Gentian, horse-. See *Triosteum perfoliatum*.

Gentian, marsh-. See *Gentiana villosa*.

Gentian, snake-. See *Nabalus serpentarius*.

Gentian, soapwort-. See *Gentiana saponaria.*

Gentian, stiff. See *Gentiana quinquefolia.*

Gentian, straw-colored. See *Gentiana villosa.*

Gentian, striped. See *Gentiana villosa.*

Gentian, white. See *Triosteum perfoliatum.*

Gentiana catesbaei Walt. Same as *Gentiana saponaria.*

Gentiana ochroleuca Froel. Same as *Gentiana villosa.*

Gentiana quinqueflora Lam. Same as *Gentiana quinquefolia.*

Gentiana quinquefolia L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana quinqueflora Lam.

Stiff gentian; five-flowered gentian; agueweed; gallweed.

Native, annual plant, 1 to 2 feet in height, growing in pastures and other open situations from Maine to Michigan, south to Florida and Missouri.

Parts used.—Root and herb (nonofficial).

Gentiana saponaria L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana catesbaei Walt.

American gentian; blue gentian; soapwort-gentian.

Native, perennial herb, 1 to 2½ feet high; in wet soil, Ontario to Minnesota, south to Louisiana and Florida.

Part used.—Root (nonofficial).

Gentiana villosa L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana ochroleuca Froel.

Striped gentian; straw-colored gentian; marsh-gentian; Sampson's-snakeroot.

Native, perennial herb, 6 to 18 inches high; in shaded places, Middle and Southern States.

Part used.—Root (nonofficial).

Geranium. See *Geranium maculatum.*

Geranium maculatum L. **Geranium family (Geraniaceae).**

Geranium; wild crane's-bill; spotted crane's-bill; wild geranium; spotted geranium; alum-root.

Native, perennial herb, 1 to 1½ feet high; found in low grounds and open woods from Canada south to Georgia and Missouri.

Part used.—Rhizome (official).

Geranium, spotted. See *Geranium maculatum.*

Geranium, wild. See *Geranium maculatum.*

Geum rivale L. **Rose family (Rosaceae).**

Water-avens; purple avens.

Native, perennial herb, 1 to 2 feet high, occurring in swamps and wet meadows from Canada to Pennsylvania and Colorado, especially in the Northern and Middle States.

Parts used.—Rhizome and rootlets (nonofficial).

Ghostflower. See *Monotropa uniflora.*

Gillenia trifoliata Moench. Same as *Porteranthus trifoliatus.*

Gill-over-the-ground. See *Glecoma hederacea.*

Ginger, Indian. See *Asarum canadense.*

Ginger, wild. See *Asarum canadense.*

Gingerroot. See *Tussilago farfara.*

Ginseng. See *Panax quinquefolium.*

Glecoma hederacea L. **Mint family (Menthaceae).**

Synonym.—Nepeta glechoma Benth.

Ground-ivy; gill-over-the-ground; catfoot; field-balm.

Low, perennial herb, with creeping stem. Naturalized from Europe and found in waste places, woods, and thickets from Newfoundland to Minnesota, south to Georgia and Kansas.

Part used.—Herb (nonofficial).

Globeflower. See *Cephalanthus occidentalis.*

Gnaphalium margaritaceum L. Same as *Anaphalis margaritacea.*

Gnaphalium obtusifolium L. **Aster family (Asteraceae).**

Synonym.—Gnaphalium polycephalum Michx.

Sweet balsam; life-everlasting; sweet life-everlasting; white balsam.

Native, herbaceous annual, 1 to 2 feet high; in dry, open places and old fields from Nova Scotia and Manitoba south to Florida and Texas.

Part used.—Herb (nonofficial).

Gnaphalium polycephalum Michx. Same as *Gnaphalium obtusifolium.*

Gnaphalium uliginosum L. **Aster family (Asteraceae).**

Mouse-ear; low cudweed; marsh-cudweed; wartwort; dysentery-weed.

Annual herb, 2 to 8 inches high, occurring in damp soil from Newfoundland to Minnesota, south to Indiana and Virginia; apparently naturalized from Europe.

Part used.—Herb (nonofficial).

Gnaphalium undulatum Walt. Same as *Pterocaulon undulatum.*

Goat's-rue. See *Cracca virginiana.*

Goldenrod, anise-scented. See *Solidago odora.*

Goldenrod, fragrant-leaved. See *Solidago odora.*

Goldenrod, sweet. See *Solidago odora.*

Goldenseal. See *Hydrastis canadensis.*

Goldthread. See *Coptis trifolia.*

Goodyera pubescens R. Br. Same as *Peramium pubescens.*

Goodyera repens R. Br. Same as *Peramium repens.*

Goose-grass. See *Galium aparine.*

Grape, Oregon. See *Berberis aquifolium.*

Grape, Rocky Mountain. See *Berberis aquifolium.*

Gravel-plant. See *Epigaea repens.*

Gravelroot. See *Eupatorium purpureum.*

Gravel-weed. See *Onosmodium virginianum.*

Greenbrier, long-stalked. See *Smilax pseudo-china.*

Grindelia. See *Grindelia robusta* and *G. squarrosa.*

Grindelia robusta Nutt. **Aster family (Asteraceae).**

Grindelia; gum-plant.

Perennial herb, about 1½ feet high, native in the States west of the Rocky Mountains.

Parts used.—Leaves and flowering tops (official).

Grindelia, scaly. See *Grindelia squarrosa.*

Grindelia squarrosa (Pursh) Dunal. **Aster family (Asteraceae).**

Grindelia; scaly grindelia; broad-leaved gum-plant.

Perennial herb, 1 to 2 feet high, native; occurring on the plains and prairies from the Saskatchewan to Minnesota, Texas, and California.

Parts used.—Leaves and flowering tops (official).

Gromwell, Virginia false. See *Onosmodium virginianum*

Ground-centaury. See *Polygala nuttallii.*

Ground-ivy. See *Glecoma hederacea.*

Ground-raspberry. See *Hydrastis canadensis.*

Ground-squirrel pea. See *Jeffersonia diphylla.*

Gum, cotton-. See *Nyssa aquatica.*

Gum, red. See *Liquidambar styraciflua.*

Gum, star-leaved. See *Liquidambar styraciflua.*

Gum, sweet-. See *Liquidambar styraciflua.*

Gum, tupelo. See *Nyssa aquatica.*

Gum-plant. See *Grindelia robusta.*

Gum-plant, broad-leaved. See *Grindelia squarrosa.*

Gypsy-flower. See *Cynoglossum officinale.*

Gypsy-weed. See *Lycopus virginicus.*

Hackmatack. See *Larix laricina.*

Haircap-moss. See *Polytrichum juniperinum.*

Hamamelis See *Hamamelis virginiana.*

Hamamelis virginiana L. **Witch-hazel family** (**Hamamelidaceae**).

Hamamelis; witch-hazel; winterbloom; snapping hazel.

Indigenous shrub, found in low, damp woods from New Brunswick to Minnesota, south to Florida and Texas.

Parts used.—Leaves (collected in autumn), bark, and twigs (official).

Hardhack. See *Spiraea tomentosa.*

Hart's-thorn. See *Rhamnus cathartica.*

Haw, black. See *Viburnum prunifolium.*

Hawkweed, early. See *Hieracium venosum.*

Hawthorn. See *Crataegus oxyacantha.*

Hazel, snapping. See *Hamamelis virginiana.*

Heal-all. See *Prunella vulgaris* and *Scrophularia marilandica.*

Healing-herb. See *Symphytum officinale.*

Heart-liverleaf. See *Hepatica acuta.*

Heartsease. See *Viola tricolor.*

Hedeoma. See *Hedeoma pulegioides.*

Hedeoma pulegioides (L.) Pers. **Mint family** (**Menthaceae**).

Hedeoma; American pennyroyal; tickweed; squawmint.

Low, native, annual plant, 6 to 12 inches high, growing in barren woods and dry fields, Nova Scotia to Minnesota, south to Nebraska and Florida.

Parts used.—Leaves and flowering tops, and the volatile oil distilled from these, are official.

Hedge-fumitory. See *Fumaria officinalis.*

Hedgethorn. See *Crataegus oxyacantha.*

Helenium autumnale L. **Aster family** (**Asteraceae**).

Sneezeweed; sneezewort; swamp-sunflower.

Native perennial, 2 to 3 feet high, growing in swamps, wet fields, and meadows, Canada to Florida and Arizona.

Part used.—Herb (nonofficial).

Helianthemum canadense (L.) Michx. **Rock-rose family** (**Cistaceae**).

Frostweed; frostwort; frost-plant; Canadian rock-rose.

Native, perennial herb, about one foot in height; in dry, sandy soil, Maine to Wisconsin, south to North Carolina and Kentucky.

Part used.—Herb (nonofficial).

Hellebore, American. See *Veratrum viride.*

Hellebore, green. See *Veratrum viride.*

Hellebore, swamp-. See *Veratrum viride.*

Helmetpod. See *Jeffersonia diphylla.*

Helonias dioica Pursh. Same as *Chamaelirium luteum.*

Hemlock. See *Tsuga canadensis.*

Hemlock, poison-. See *Conium maculatum.*

Hemlock, water-. See *Cicuta maculata.*

Hemlock-spruce. See *Tsuga canadensis.*

Hemp, black Indian. See *Apocynum cannabinum.*

Hemp, Canadian. See *Apocynum cannabinum.*

Hemp, white Indian. See *Asclepias incarnata.*

Henbane. See *Hyoscyamus niger.*

Hepatica acuta (Pursh) Britton. **Crowfoot family** (**Ranunculaceae**).

Synonym.—*Hepatica acutiloba* DC.

Heart-liverleaf; sharp-lobed liverleaf; liverwort.

Perennial herb, 4 to 9 inches high, found in woods from Quebec and Ontario, south to Georgia (but rare near the coast), west to Iowa and Minnesota.

Part used.—Leaves (nonofficial).

Hepatica acutiloba DC. Same as *Hepatica acuta.*

Hepatica hepatica (L.) Karst. **Crowfoot family** (**Ranunculaceae**).

Synonym.—*Hepatica triloba* Chaix.

Round-lobed liverleaf; kidney-liverleaf; liverwort.

Perennial herb, 4 to 6 inches high; in woods from Nova Scotia to northern Florida, west to Iowa and Missouri; less common than the heart-liverleaf.

Part used.—Leaves (nonofficial).

Hepatica triloba Chaix. Same as *Hepatica hepatica.*

Heracleum lanatum Michx. **Parsley family** (**Apiaceae**).

Masterwort; cow-parsnip; youthwort.

Native, perennial herb, 3 to 5 feet high, growing in moist meadows and cultivated ground from Canada south to North Carolina, Utah, and California.

Parts used.—Root, leaves, and seeds (nonofficial).

Hercules-club. See *Fagara clava-herculis.*

Heuchera americana L. **Saxifrage family** (**Saxifragaceae**).

Alum-root; American sanicle.

Native, perennial herb, 2 to 4 feet in height; in shady, rocky woodlands from Connecticut to Minnesota, south to Alabama and Louisiana.

Part used.—Root (nonofficial).

Hickory, shellbark-. See *Hicoria ovata.*

Hicoria ovata (Mill.) Britton. **Walnut family** (**Juglandaceae**).

Synonym.—*Carya alba* Nutt.

Shagbark, shellbark-hickory.

Large, native tree, sometimes 120 feet in height; in rich soil from Quebec to southern Ontario and Minnesota, south to Florida and Texas.

Parts used.—Bark and leaves (nonofficial).

Hieracium venosum L. **Chicory family** (**Cichoriaceae**).

Early hawkweed; rattlesnake-weed; bloodwort; striped bloodwort.

Perennial herb, 1 to 2 feet high, native; occurring in dry woods and thickets from Maine to Georgia, west to Nebraska; more common in the northern and eastern United States.

Parts used.—Leaves and root (nonofficial).

Highbelia. See *Lobelia siphilitica.*

Hive-vine. See *Mitchella repens.*

Hoarhound. See *Marrubium vulgare.*

Hoarhound, water-. See *Lycopus virginicus.*

Hoarhound, wild. See *Eupatorium aromaticum.*

Hog-potato. See *Ipomoea pandurata.*

Hog's-bean. See *Hyoscyamus niger.*

Hogweed. See *Ambrosia artemisiaefolia.*

Holly, American. See *Ilex opaca.*

Holly, white. See *Ilex opaca.*

Honeybloom. See *Apocynum androsaemifolium.*

Hoodwort. See *Scutellaria lateriflora.*

Hoop-ash. See *Fraxinus nigra.*

Hop-hornbeam. See *Ostrya virginiana.*

Hop-tree. See *Ptelea trifoliata.*

Hornbeam, hop-. See *Ostrya virginiana.*

Horse-balm. See *Collinsonia canadensis.*

Horse-chestnut. See *Aesculus hippocastanum.*

Horsefly-weed. See *Baptisia tinctoria.*

Horsefoot. See *Tussilago farfara.*

Horse-gentian. See *Triosteum perfoliatum.*

Horseheal. See *Inula helenium.*

Horsemint. See *Monarda fistulosa* and *M. punctata.*

Horse-nettle. See *Solanum carolinense.*

Horsetail. See *Equisetum hyemale.*

Horseweed. See *Erigeron canadensis.*

Hound's-tongue. See *Cynoglossum officinale.*

Hydrangea. See *Hydrangea arborescens.*

Hydrangea arborescens L. **Hydrangea family** (**Hydrangeaceae**).

Hydrangea; wild hydrangea; seven-barks.

Indigenous shrub, 5 or 6 feet in height; on rocky river banks from southern New York to Florida, west to Iowa and Missouri; very abundant in the valley of the Delaware.

Part used.—Root (nonofficial).

Hydrangea, wild. See *Hydrangea arborescens.*

Hydrastis. See *Hydrastis canadensis.*

Hydrastis canadensis L. **Crowfoot family** (**Ranunculaceae**).

Hydrastis; goldenseal; yellowroot; ground-raspberry; orangeroot; yellow puccoon.

Perennial herb, about 1 foot in height, native in rich soil in shady woods, southern New York to Minnesota, south to Georgia and Missouri, but principally in Ohio, Indiana, Kentucky, and West Virginia.

Parts used.—Rhizome and roots (official).

Hyoscyamus. See *Hyoscyamus niger.*

Hyoscyamus niger L. **Potato family (Solanaceae).**

Hyoscyamus; henbane; hog's-bean; insane-root.

Biennial herb, 6 inches to 2 feet high, sparingly naturalized from Europe, in waste places from Nova Scotia to Ontario, New York, and Michigan.

Parts used.—Leaves and flowering tops from plants of second year's growth (official); seeds are also used (nonofficial).

Hypericum perforatum L. **St. John's-wort family (Hypericaceae).**

John's-wort; common St. John's-wort.

Herbaceous perennial, 1 to 2 feet high, naturalized from Europe; common in fields and waste places throughout almost the entire United States, except the Southern States.

Part used.—Herb (nonofficial).

Hyssop. See *Hyssopus officinalis.*

Hyssop, wild. See *Verbena hastata.*

Hyssop-skullcap. See *Scutellaria integrifolia.*

Hyssopus officinalis L. **Mint family (Menthaceae).**

Hyssop.

Perennial herb, 1 to 3 feet high, naturalized from Europe, and found along roadsides and in waste places from Ontario and Maine to North Carolina, and on the Pacific coast.

Part used.—Herb (nonofficial).

Ilex opaca Ait. **Holly family (Aquifoliaceae).**

American holly; white holly.

Native tree, 20 to 40 feet in height, with evergreen leaves; in moist woodlands, Maine to Florida, and west to Missouri and Texas; most abundant in the Atlantic States.

Parts used.—Leaves and bark (nonofficial).

Ilex verticillata (L.) A. Gray. **Holly family (Aquifoliaceae).**

Synonym.—*Prinos verticillata* L.

Black alder; feverbush; Virginia winterberry.

A native shrub, growing in moist woods and along banks of streams from Nova Scotia to Florida, west to Wisconsin and Missouri.

Parts used.—Bark and berries (nonofficial).

Impatiens aurea Muhl. **Jewelweed family (Impatientaceae).**

Synonym.—*Impatiens pallida* Nutt.

Jewelweed; pale touch-me-not; snapweed; wild celandine.

Native, annual plant, 2 to 4 feet high, found in rich soil in moist, shady places from Quebec to Oregon, south to Georgia and Kansas.

Part used.—Herb (nonofficial).

Impatiens biflora Walt. **Jewelweed family (Impatientaceae).**

Synonym.—*Impatiens fulva* Nutt.

Jewelweed; spotted touch-me-not; snapweed; silverleaf.

Native, annual plant, 2 to 5 feet high, growing in rich soil in moist, shady places from Canada to Alaska and Oregon, south to Florida and Missouri; more common than the pale touch-me-not.

Part used.—Herb (nonofficial).

Impatiens fulva Nutt. Same as *Impatiens biflora.*

Impatiens pallida Nutt. Same as *Impatiens aurea.*

Indian-cup. See *Silphium perfoliatum.*

Indian-paint. See *Sanguinaria canadensis.*

Indian-physic. See *Porteranthus trifoliatus.*

Indian-pipe. See *Monotropa uniflora.*

Indian-root. See *Aralia racemosa.*

Indigo, American. See *Baptisia tinctoria.*

Indigo, wild. See *Baptisia tinctoria.*

Indigo, yellow. See *Baptisia tinctoria.*

Indigo-weed. See *Baptisia tinctoria.*

Inkberry. See *Phytolacca decandra.*

Inkroot. See *Limonium carolinianum.*

Insane-root. See *Hyoscyamus niger.*

Inula. See *Inula helenium.*

Inula helenium L. **Aster family (Asteraceae).**

Inula; elecampane; horseheal; scabwort.

Rough, perennial herb, 3 to 6 feet high, naturalized from Europe, and found along roadsides and in fields and pastures from Nova Scotia to North Carolina, westward to Missouri and Minnesota.

Part used.—Root (official in U. S. P. 1890).

Ipecac, American. See *Euphorbia ipecacuanhae.*

Ipecac, Carolina. See *Euphorbia ipecacuanhae.*

Ipecac, false. See *Porteranthus trifoliatus.*

Ipecac, milk-. See *Euphorbia corollata.*

Ipecac, wild. See *Euphorbia ipecacuanhae* and *Triosteum perfoliatum.*

Ipecac-spurge. See *Euphorbia ipecacuanhae.*

Ipomoea pandurata (L.) Meyer. **Morning-glory family (Convolvulaceae).**

Synonym.—*Convolvulus panduratus* L.

Manroot; man-of-the-earth; wild potato; hog-potato; wild jalap.

Native perennial, with trailing stems 2 to 12 feet long; in dry fields or on hills from Connecticut to Michigan, south to Florida and Texas.

Part used.—Root (nonofficial).

Iris. See *Iris versicolor.*

Iris versicolor L. **Iris family (Iridaceae).**

Iris; blue flag; flag-lily; liver-lily; water-flag; snake-lily.

Native, perennial plant, 2 to 3 feet high, found in wet, marshy localities from Newfoundland to Manitoba, south to Florida and Arkansas.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Ironwood. See *Ostrya virginiana.*

Ivy, American. See *Parthenocissus quinquefolia.*

Ivy, ground-. See *Glecoma hederacea.*

Ivy, poison-. See *Rhus radicans* and *R. toxicodendron.*

Jack-in-the-pulpit. See *Arisaema triphyllum.*

Jacob's-ladder. See *Polemonium reptans.*

Jacob's-ladder, American. See *Smilax herbacea.*

Jalap, wild. See *Ipomoea pandurata.*

James-tea. See *Ledum groenlandicum.*

Jamestown-weed. See *Datura stramonium.*

Jasmine, Carolina. See *Gelsemium sempervirens.*

Jasmine, yellow. See *Gelsemium sempervirens.*

Jeffersonia diphylla (L.) Pers. **Barberry family** (**Berberidaceae**).

Twinleaf; rheumatism-root; helmetpod; yellowroot; ground-squirrel pea.

Native, perennial plant, 8 to 14 inches in height, growing in woods and near streams from New York to Virginia, westward to Wisconsin.

Part used.—Rhizome (nonofficial).

Jewelweed. See *Impatiens aurea* and *I. biflora.*

Jimson-weed. See *Datura stramonium.*

Job's-tears, wild. See *Onosmodium virginianum.*

Joe-Pye-weed. See *Eupatorium purpureum.*

John's-wort. See *Hypericum perforatum.*

Judas-tree. See *Cercis canadensis.*

Juglans. See *Juglans cinerea.*

Juglans cinerea L. **Walnut family** (**Juglandaceae**).

Juglans; butternut; white walnut.

Indigenous tree, 20 to 50 feet in height, common in rich woods from New Brunswick to North Dakota, south to Georgia, Mississippi, and Arkansas.

Part used.—Bark of root, collected in autumn (official in U. S. P. 1890).

Juniper. See *Juniperus communis.*

Juniperus communis L. **Pine family** (**Pinaceae**).

Juniper.

Evergreen shrub or low tree, common on dry, sterile hills from Canada south to New Jersey, west to Nebraska, and in the Rocky Mountains to New Mexico.

Part used.—Fruit (nonofficial). The oil of juniper, distilled from the fruit, is official.

Juniperus sabina L. **Pine family** (**Pinaceae**).

Sabina; savin; shrubby red cedar.

A shrub, usually procumbent, seldom more than 4 feet in height, occurring in rocky places in the northern United States.

Part used.—Tops, and the oil of savin, distilled from the fresh tops, are official.

Juniperus virginiana L. **Pine family** (**Pinaceae**).

Red cedar; red savin.

A tree, sometimes 100 feet in height, common in dry soil from Canada to Florida and Arizona.

Parts used.—Leaves and "cedar apples" (nonofficial).

Kalmia angustifolia L. **Heath family** (**Ericaceae**).

Sheep-laurel; lambkill; calfkill; narrow-leaved laurel.

Native, evergreen shrub, about 3 feet high, growing in moist soil from Canada south to Georgia.

Part used.—Leaves (nonofficial).

Kalmia latifolia L. **Heath family** (**Ericaceae**).

Mountain-laurel; calico-bush; broad-leaved laurel; sheep-laurel.

Native, evergreen shrub, 10 to 20 feet high, growing in sandy or rocky soil from New Brunswick to Ohio, Florida, and Louisiana.

Part used.—Leaves (nonofficial).

Kidney-liverleaf. See *Hepatica hepatica.*

Kidneyroot. See *Eupatorium purpureum.*

Knight's-spur. See *Delphinium consolida.*

Knobroot. See *Collinsonia canadensis.*

Knotweed, biting. See *Polygonum hydropiper.*

Koellia montana (Michx.) Kuntze. **Mint family** (**Menthaceae**).

Synonym.—Pycnanthemum montanum Michx.

Thin-leaved mountain-mint.

Native perennial, 2 to 3 feet high, found in woods from southern Virginia to Georgia and Alabama.

Part used.—Herb (nonofficial).

Koellia pilosa (Nutt.) Britton. **Mint family** (**Menthaceae**).

Synonym.—Pycnanthemum pilosum Nutt.

Hairy mountain-mint.

Native perennial, 1 to 2½ feet high, occurring in prairies and dry woods from Ohio to Georgia, west to Missouri and Arkansas.

Part used.—Herb (nonofficial).

Lacinaria scariosa (L.) Hill. **Aster family** (**Asteraceae**).

Synonym.—Liatris scariosa Willd.

Blue blazingstar; large button-snakeroot; rattlesnake-master; gay-feather; devil's-bit.

Native, perennial herb, 4 to 5 feet high, found in dry woods and sandy fields from Maine to Florida, west to Texas and Nebraska.

Part used.—Root (nonofficial).

Lacinaria spicata (L.) Kuntze. **Aster family** (**Asteraceae**).

Synonym.—Liatris spicata Willd.

Dense button-snakeroot; colic-root; prairie-pine; gay-feather; rattlesnake-master; corn-snakeroot; backache-root.

Native, perennial herb, 2 to 5 feet high, in moist places from Massachusetts to Florida, west to Wisconsin and Arkansas.

Part used.—Root (nonofficial).

Lacinaria squarrosa (L.) Hill. **Aster family** (**Asteraceae**).

Synonym.—Liatris squarrosa Willd.

Scaly blazingstar; colic-root; rattlesnake-master (in the South).

Native, perennial herb, 2 to 3 feet high, in dry soil, Ontario to Florida, west to Nebraska and Texas.

Part used.—Root (nonofficial).

Lactuca canadensis L. **Chicory family** (**Cichoriaceae**).

Synonym.—Lactuca elongata Muhl.

Wild lettuce; tall lettuce; wild opium; trumpet-milkweed.

Annual or biennial plant, 3 to 10 feet in height, native in moist, open places, British America south to Georgia and Louisiana.

Part used.—Herb (nonofficial).

Lactuca elongata Muhl. Same as *Lactuca canadensis.*

Ladies-slipper, large yellow. See *Cypripedium hirsutum.*

Ladies-slipper, small yellow. See *Cypripedium parviflorum.*

Lady-fern. See *Athyrium filix-foemina.*

Lady's-glove. See *Digitalis purpurea.*

Lambkill. See *Kalmia angustifolia.*

Lappa. See *Arctium lappa.*

Lappa major Gaertn. Same as *Arctium lappa.*

Larch, American. See *Larix laricina.*

Larch, black. See *Larix laricina.*

Larix americana Michx. Same as *Larix laricina.*

Larix laricina (Du Roi) Koch. **Pine family (Pinaceae).**

Synonym.—Larix americana Michx.

Tamarack; American larch; hackmatack; black larch.

A tall, slender tree, native in swampy woods and moist places from Canada south to New Jersey, Indiana, and Minnesota.

Part used.—Bark (nonofficial).

Lark-heel. See *Delphinium consolida.*

Larkspur, field-. See *Delphinium consolida.*

Larkspur, tall. See under *Delphinium consolida.*

Laurel, broad-leaved. See *Kalmia latifolia.*

Laurel, deer-. See *Rhododendron maximum.*

Laurel, great. See *Rhododendron maximum.*

Laurel, mountain-. See *Kalmia latifolia.*

Laurel, narrow-leaved. See *Kalmia angustifolia.*

Laurel, rose-. See *Rhododendron maximum.*

Laurel, sheep-. See *Kalmia angustifolia* and *K. latifolia.*

Laurel, spurge-. See *Daphne mezereum.*

Laurel, swamp-. See *Magnolia virginiana.*

Laurus benzoin L. Same as *Benzoin benzoin.*

Lavender, sea-. See *Limonium carolinianum.*

Leafcup, yellow. See *Polymnia uvedalia.*

Leatherwood. See *Dirca palustris.*

Ledum groenlandicum Oeder. **Heath family (Ericaceae).**

Synonym.—Ledum latifolium Ait.

Labrador tea; continental tea; James-tea.

Evergreen shrub, 1 to 4 feet high, native in cold bogs and damp mountain woods, northern part of the United States and in Canada.

Part used.—Leaves (nonofficial).

Ledum latifolium Ait. Same as *Ledum groenlandicum.*

Lemon, wild. See *Podophyllum peltatum.*

Lemon-balm. See *Melissa officinalis.*

Leonurus cardiaca L. **Mint family (Menthaceae).**

Motherwort; lion's-tail; throwwort.

Perennial plant, 2 to 5 feet high, naturalized from Europe, and occurring in fields and waste places from Nova Scotia to North Carolina westward to Nebraska.

Part used.—Herb (nonofficial).

Leptamnium virginianum (L.) Raf. **Broomrape family (Orobanchaceae).**

Synonyms.—Epiphegus virginiana Bart.; *Orobanche virginiana* L.

Beechdrops; cancerroot.

Plant 6 inches to 2 feet in height, parasitic upon the roots of beech trees from New Brunswick to Florida, west to Michigan and Louisiana.

Part used.—Whole plant (nonofficial).

Leptandra. See *Veronica virginica.*

Leptandra virginica (L.) Nutt. Same as *Veronica virginica.*

Leptilon canadense (L.) Britton. Same as *Erigeron canadensis.*

Lettuce, Indian. See *Frasera carolinensis.*

Lettuce, tall. See *Lactuca canadensis.*

Lettuce, white. See *Nabalus albus* and *N. serpentarius.*

Lettuce, wild. See *Lactuca canadensis.*

Leucanthemum vulgare Lam. Same as *Chrysanthemum leucanthemum.*

Leverwood. See *Ostrya virginiana.*

Liatris odoratissima Michx. Same as *Trilisa odoratissima.*

Liatris scariosa Willd. Same as *Lacinaria scariosa.*

Liatris spicata Willd. Same as *Lacinaria spicata.*

Liatris squarrosa Willd. Same as *Lacinaria squarrosa.*

Life-everlasting. See *Anaphalis margaritacea* and *Gnaphalium obtusifolium.*

Life-everlasting, sweet. See *Gnaphalium obtusifolium.*

Liferoot. See *Senecio aureus.*

Ligustrum vulgare L. **Olive family** (**Oleaceae**).

Privet; primwort; prim.

A shrub, 5 or 6 feet high, introduced from Europe; escaped from cultivation and grows wild in woods and along roadsides from Ontario to Pennsylvania and North Carolina.

Part used.—Leaves (nonofficial).

Lily, cow-. See *Nymphaea advena.*

Lily, flag-. See *Iris versicolor.*

Lily, large yellow pond-. See *Nymphaea advena.*

Lily, liver-. See *Iris versicolor.*

Lily, snake-. See *Iris versicolor.*

Lily, sweet-scented water-. See *Castalia odorata.*

Lily, water-. See *Castalia odorata.*

Lily, white pond-. See *Castalia odorata.*

Lily-of-the-valley. See *Convallaria majalis.*

Lime, Ogeechee. See *Nyssa ogeche.*

Limonium carolinianum (Walt.) Britton.

Plumbago family (**Plumbaginaceae**).

Synonym.—*Statice caroliniana* Walt.

Marsh-rosemary; inkroot; sea-lavender; cankerroot.

Native, perennial herb, 1 to 2 feet high, in salt meadows on the Atlantic and Gulf coasts.

Part used.—Root (nonofficial).

Linden, American. See *Tilia americana.*

Lindera benzoin Meissn. Same as *Benzoin benzoin.*

Lion's-foot. See *Nabalus albus* and *N. serpentarius.*

Lion's-tail. See *Leonurus cardiaca.*

Liquidambar styraciflua L. **Witch-hazel family** (**Hamamelidaceae**).

Sweet-gum; star-leaved gum; red gum.

Large, native tree, 80 to 140 feet high, in moist woods from Connecticut to Florida, Illinois, and Missouri. Most common near the coast in the Middle and Southern States.

Parts used.—Bark and resin (nonofficial).

Liriodendron tulipifera L. **Magnolia family** (**Magnoliaceae**).

Tulip-tree; yellow poplar; whitewood; tulip-poplar; canoewood.

An indigenous tree, 60 to 190 feet in height, growing in rich woods from New England to Florida, west to Michigan and Arkansas; reaches greatest size in the Middle and Southern States.

Part used.—Bark of trunk and of root (nonofficial).

Lithospermum virginianum L. Same as *Onosmodium virginianum.*

Liverleaf, heart-. See *Hepatica acuta.*

Liverleaf, kidney-. See *Hepatica hepatica.*

Liverleaf, round-lobed. See *Hepatica hepatica.*

Liverleaf, sharp-lobed. See *Hepatica acuta.*

Liver-lily. See *Iris versicolor.*

Liverwort. See *Hepatica acuta* and *H. hepatica.*

Lobelia. See *Lobelia inflata.*

Lobelia, blue. See *Lobelia siphilitica.*

Lobelia cardinalis L. **Bellflower family (Campanulaceae).**

Cardinal-flower; red cardinal; red lobelia.

Native, perennial herb, 2 to 4 feet high, with showy scarlet flowers; in moist soil from British America south to Florida and Texas.

Part used.—Herb (nonofficial).

Lobelia, great. See *Lobelia siphilitica.*

Lobelia inflata L. **Bellflower family (Campanulaceae).**

Lobelia; Indian tobacco; gagroot; vomitwort; bladderpod.

Native, annual, herbaceous plant, 1 to 3 feet high, poisonous; in dry soil, fields, old pastures, and along roadsides from Canada to Georgia, Nebraska, and Arkansas.

Parts used.—Leaves and tops, collected after a portion of the capsules have become inflated (official). The seeds are also used (nonofficial).

Lobelia, red. See *Lobelia cardinalis.*

Lobelia siphilitica L. **Bellflower family (Campanulaceae).**

Blue cardinal-flower; great lobelia; blue lobelia; highbelia.

Native, perennial herb, about 1 to 3 feet high, growing in moist soil from Ontario to Georgia, west to Louisiana and the Dakotas.

Part used.—Herb (nonofficial).

Locust, black. See *Robinia pseudacacia.*

Locust, yellow. See *Robinia pseudacacia.*

Locust-plant. See *Cassia marilandica.*

Locust-tree. See *Robinia pseudacacia.*

Lycopodium. See *Lycopodium clavatum.*

Lycopodium clavatum L. **Club-moss family (Lycopodiaceae).**

Lycopodium; club-moss; stag's-horn.

Native perennial, with trailing stem, growing in dry situations in woods from Canada to North Carolina, Michigan, and Washington.

Part used.—Spores of this or of other species of Lycopodium (official).

Lycopus virginicus L. **Mint family (Menthaceae).**

Bugleweed; sweet bugle; water-bugle; gypsy-weed; water-hoarhound.

Indigenous, perennial herb, 10 to 20 inches in height; in wet, shady places from Canada to Florida, Missouri, and Nebraska.

Part used.—Herb (nonofficial).

Madweed. See *Scutellaria lateriflora.*

Magnolia acuminata L. **Magnolia family (Magnoliaceae).**

Cucumber-tree; mountain-magnolia; blue magnolia.

Native tree, 60 to 80 feet in height, occurring in the mountainous regions from New York to Georgia. More abundant in the Southern States.

Part used.—Bark (nonofficial).

Magnolia, blue. See *Magnolia acuminata.*

Magnolia glauca L. Same as *Magnolia virginiana*.

Magnolia, mountain-. See *Magnolia acuminata*.

Magnolia, sweet. See *Magnolia virginiana*.

Magnolia tripetala L. **Magnolia family (Magnoliaceae).**

Synonym.—Magnolia umbrella Lam.

Cucumber-tree; umbrella-tree; elkwood.

A small native tree, not more than 40 feet high, growing in rather moist, rich soil; widely distributed in the Appalachian Mountain region, but nowhere very common.

Part used.—Bark (nonofficial).

Magnolia umbrella Lam. Same as *Magnolia tripetala*.

Magnolia virginiana L. **Magnolia family (Magnoliaceae).**

Synonym.—Magnolia glauca L.

White bay; sweet bay; sweet magnolia; beaver-tree; swamp-sassafras; swamp-laurel.

A native tree, averaging about 25 feet in height, growing in swamps and morasses, Massachusetts to the Gulf of Mexico.

Part used.—Bark (nonofficial).

Maidenhair-fern. See *Adiantum pedatum*.

Male-fern. See *Dryopteris filix-mas*.

Mallow, common. See *Malva sylvestris*.

Mallow, dwarf. See *Malva rotundifolia*.

Mallow, high. See *Malva sylvestris*.

Mallow, low. See *Malva rotundifolia*.

Mallow, running. See *Malva rotundifolia*.

Malva rotundifolia L. **Mallow family (Malvaceae).**

Low mallow; running mallow; cheeses; dwarf mallow.

Annual or biennial procumbent plant, naturalized from Europe, and widely distributed as a weed in waste places.

Parts used.—Leaves and flowers (nonofficial).

Malva sylvestris L. **Mallow family (Malvaceae).**

High mallow; common mallow; cheeseflower.

Biennial herb, adventive from Europe; sparingly distributed in the United States and Canada, growing in waste places and along roadsides.

Part used.—Flowers (nonofficial).

Mandrake, American. See *Podophyllum peltatum*.

Mandrake, wild. See *Podophyllum peltatum*.

Man-of-the-earth. See *Ipomoea pandurata*.

Manroot. See *Ipomoea pandurata*.

Manzanita. See *Arctostaphylos glauca*.

Maple, red. See *Acer rubrum*.

Maple, swamp-. See *Acer rubrum*.

Maple, vine-. See *Menispermum canadense*.

Marrubium. See *Marrubium vulgare*.

Marrubium vulgare L. **Mint family (Menthaceae).**

Marrubium; hoarhound.

Bushy, perennial herb, 1 to 3 feet high, naturalized from Europe, and growing in dry, sandy soil, in fields and waste places, from Maine southward to Texas and westward to California and Oregon.

Parts used.—Leaves and flowering tops (official).

Marsh-cudweed. See *Gnaphalium uliginosum*.

Marsh-gentian. See *Gentiana villosa.*

Marshmallow. See *Althaea officinalis.*

Marsh-rosemary. See *Limonium carolinianum.*

Marsh-trefoil. See *Menyanthes trifoliata.*

Maruta cotula DC. Same as *Anthemis cotula.*

Masterwort. See *Angelica atropurpurea* and *Heracleum lanatum.*

May-apple. See *Podophyllum peltatum.*

Mayflower. See *Epigaea repens.*

May-pops. See *Passiflora incarnata.*

Maythorn. See *Crataegus oxyacantha.*

Mayweed. See *Anthemis cotula.*

Meadow-clover. See *Trifolium pratense.*

Meadow-fern. See *Comptonia peregrina.*

Meadowpride. See *Frasera carolinensis.*

Meadow-scabish. See *Aster puniceus.*

Meadowsweet, pink. See *Spiraea tomentosa.*

Mealy-tree. See *Viburnum dentatum.*

Melilot, yellow. See *Melilotus officinalis.*

Melilotus officinalis (L.) Lam. **Pea family (Fabaceae).**

Yellow melilot; yellow sweet clover.

Annual or biennial herb, 1 to 3 feet high, introduced from Europe, and occurring in waste places throughout the eastern United States.

Parts used.—Leaves and flowering tops (nonofficial).

Melissa. See *Melissa officinalis.*

Melissa officinalis L. **Mint family (Menthaceae).**

Melissa; balm; lemon-balm; garden-balm; sweet balm.

Perennial herb, 10 to 20 inches high, naturalized from Europe, and growing in waste places, fields, and woods from Maine to Georgia.

Parts used.—Leaves and tops (official in U. S. P. 1890).

Menispermum. See *Menispermum canadense.*

Menispermum canadense L. **Moonseed family (Menispermaceae).**

Menispermum; yellow parilla; Canada moonseed; Texas sarsaparilla; vine-maple.

Native, perennial, woody climber, found in woods along streams from Canada to Georgia and Arkansas.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Mentha piperita. See *Mentha piperita* L.

Mentha piperita L. **Mint family (Menthaceae).**

Mentha piperita; peppermint.

Aromatic, perennial herb, 1 to 2 feet high, naturalized from Europe, and occurring in damp places from Nova Scotia to Minnesota, south to Florida and Tennessee. Cultivated principally in Michigan and New York.

Parts used.—Leaves and flowering tops, and the oil of peppermint distilled from these, are official.

Mentha spicata L. **Mint family (Menthaceae).**

Synonym.—*Mentha viridis* L.

Mentha viridis; spearmint.

Aromatic, perennial herb, 1 to 2 feet high, naturalized from Europe, and growing in moist fields and waste places from Nova Scotia to Utah, south to Florida and Kansas. Also cultivated.

Parts used.—Leaves and flowering tops, and the oil of spearmint distilled from these, are official.

Mentha viridis. See *Mentha spicata.*

Mentha viridis L. Same as *Mentha spicata.*

Menyanthes trifoliata L. **Buck-bean family (Menyanthaceae).**

Buck-bean; bog-bean; marsh-trefoil; water-shamrock.

Indigenous, perennial plant, about 1 foot in height, found in spongy, boggy soils and swamps from Canada and Alaska south to Pennsylvania, Minnesota, and California.

Parts used.—Rhizome and leaves (nonofficial).

Mezereon. See *Daphne mezereum.*

Mezereon, American. See *Dirca palustris.*

Mezereum. See *Daphne mezereum.*

Mezereum officinarum C. A. Mey. Same as *Daphne mezereum.*

Micromeria chamissonis (Benth.) Greene. **Mint family (Menthaceae).**

Synonym.—*Micromeria douglasii* Benth.

Yerba buena.

A trailing, perennial herb, common in woods along the Pacific coast of the United States.

Part used.—Plant (nonofficial).

Micromeria douglasii Benth. Same as *Micromeria chamissonis.*

Milfoil. See *Achillea millefolium.*

Milk-ipecac. See *Euphorbia corollata.*

Milk-purslane. See *Euphorbia nutans.*

Milkweed, common. See *Asclepias syriaca.*

Milkweed, swamp-. See *Asclepias incarnata.*

Milkweed, trumpet-. See *Lactuca canadensis.*

Milkwort, Nuttall's-. See *Polygala nuttallii.*

Mint, hairy mountain-. See *Koellia pilosa.*

Mint, mountain-. See *Monarda didyma.*

Mint, thin-leaved mountain-. See *Koellia montana.*

Mistletoe. See *Phoradendron flavescens.*

Mistletoe, American. See *Phoradendron flavescens.*

Mitchella repens L. **Madder family (Rubiaceae).**

Squaw-vine; checkerberry; partridgeberry; deerberry; hive-vine; squawberry.

Small, creeping, evergreen herb, common in moist woods from Nova Scotia to Minnesota, south to Florida and Arkansas.

Part used.—Plant (nonofficial).

Miterwort, false. See *Tiarella cordifolia.*

Moccasin-flower, yellow. See *Cypripedium hirsutum.*

Mohawk-weed. See *Uvularia perfoliata.*

Monarda didyma L. **Mint family (Menthaceae).**

Bee-balm; Oswego tea; mountain-mint; scarlet balm.

Native perennial, 2 to 3 feet high, growing in moist soil, especially along streams, from New Brunswick to Michigan and south to Georgia.

Part used.—Herb (nonofficial).

Monarda fistulosa L. **Mint family (Menthaceae).**

Wild bergamot; horsemint.

Native perennial, 2 to 3 feet high, found on dry hills and in thickets from Ontario south to Florida and Louisiana.

Part used.—Herb (nonofficial).

Monarda punctata L. **Mint family (Menthaceae).**

Horsemint.

Native, perennial herb, 2 to 3 feet high, found in dry, sandy fields from New York to Florida, west to Wisconsin and Texas.

Part used.—Herb (nonofficial).

Monotropa uniflora L. **Indian-pipe family (Monotropaceae).**

Indian-pipe; fit-plant; fitroot; ghostflower; pipe-plant.

A curious plant, white in all its parts, growing in rich, moist woods from Canada to Florida, westward to Washington and California.

Part used.—Root (nonofficial).

Moonseed, Canada. See *Menispermum canadense.*

Moose-elm. See *Ulmus fulva.*

Moosewood. See *Dirca palustris.*

Mortification-root. See *Althaea officinalis.*

Moss, club-. See *Lycopodium clavatum.*

Moss, haircap-. See *Polytrichum juniperinum.*

Motherwort. See *Leonurus cardiaca.*

Mountain-ash, American. See *Sorbus americana.*

Mountain-balm. See *Eriodictyon californicum.*

Mountain-laurel. See *Kalmia latifolia.*

Mountain-magnolia. See *Magnolia acuminata.*

Mountain-mint. See *Monarda didyma.*

Mountain-mint, hairy. See *Koellia pilosa.*

Mountain-mint, thin-leaved. See *Koellia montana.*

Mountain-sumac. See *Sorbus americana.*

Mountain-tea. See *Gaultheria procumbens.*

Mouse-ear. See *Gnaphalium uliginosum.*

Mouthroot. See *Coptis trifolia.*

Mugwort, common. See *Artemisia vulgaris.*

Mullein. See *Verbascum thapsus.*

Musquash-root. See *Cicuta maculata.*

Mustard, black. See *Brassica nigra.*

Mustard, brown. See *Brassica nigra.*

Mustard, rēd. See *Brassica nigra.*

Mustard, white. See *Sinapis alba.*

Mustard, yellow. See *Sinapis alba.*

Myrica asplenifolia L. Same as *Comptonia peregrina.*

Myrica cerifera L. **Bayberry family (Myricaceae).**

Bayberry; wax-myrtle; candleberry; waxberry.

Grows in sandy swamps or wet woods from Florida and Texas northward to Maryland. In the South it is a small evergreen tree, becoming in its northward range a tall, semi-deciduous shrub, or a dwarfed and deciduous shrub.

Parts used.—Bark of root, leaves, and berries (nonofficial).

Myrica gale L. **Bayberry family (Myricaceae).**

Sweet gale; Dutch myrtle; bog-myrtle; golden osier.

Indigenous shrub, growing in swamps and along streams from Canada and Alaska to Virginia and Washington.

Parts used.—Leaves and buds (nonofficial).

Myrtle, bog-. See *Myrica gale.*

Myrtle, Dutch. See *Myrica gale.*

Myrtle, wax-. See *Myrica cerifera.*

Nabalus albus (L.) Hook. **Chicory family (Cichoriaceae).**

Synonym.—Prenanthes alba L.

Lion's-foot; rattlesnake-root; white lettuce; white canker-weed.

Native, perennial herb, 2 to 4 feet high, common in rich, moist woods from Canada to Georgia and Kentucky.

Part used.—Plant (nonofficial).

Nabalus serpentarius (Pursh) Hook. **Chicory family (Cichoriaceae).**

Synonym.—Prenanthes serpentaria Pursh.

Lion's-foot; canker-weed; white lettuce; rattlesnake-root; snake-gentian.

Native, perennial herb, about 2 feet high, growing in dry, sandy soil in fields and thickets from Ontario to Florida and Alabama.

Part used.—Plant (nonofficial).

Nannybush. See *Viburnum lentago.*

Necklace-weed. See *Actaea alba* and *Onosmodium virginianum.*

Nepeta cataria L. **Mint family (Menthaceae).**

Catnip; catmint.

Common, perennial weed, 2 to 3 feet high, naturalized from Europe; found in waste places and cultivated land from Canada to Minnesota, south to Virginia and Arkansas.

Part used.—Herb (nonofficial).

Nepeta glechoma Benth. Same as *Glecoma hederacea.*

Netleaf-plantain. See *Peramium pubescens.*

Netleaf-plantain, smaller. See *Peramium repens.*

Nettle, bull-. See *Solanum carolinense.*

Nettle, great. See *Urtica dioica.*

Nettle, horse-. See *Solanum carolinense.*

Nettle, stinging. See *Urtica dioica.*

Niggerhead. See *Brauneria angustifolia.*

Nightshade, woody. See *Solanum dulcamara.*

Nuphar advena R. Br. Same as *Nymphaea advena.*

Nuttall's-milkwort. See *Polygala nuttallii.*

Nymphaea advena Soland. **Water-lily family (Nymphaeaceae).**

Synonym.—Nuphar advena R. Br.

Large yellow pond-lily; cow-lily; spatter-dock; beaverroot.

An aquatic plant, found in ponds and slow streams from Canada to Florida, and westward to the Rocky Mountains.

Part used.—Rhizome (nonofficial).

Nymphaea odorata Dryand. Same as *Castalia odorata.*

Nyssa aquatica L. **Dogwood family (Cornaceae).**

Synonym.—Nyssa uniflora Wang.

Large tupelo; cotton-gum; tupelo gum.

A large, native tree, occurring in swamps from southern Virginia to Florida, west to Texas and Missouri.

Part used.—Root wood (nonofficial).

Nyssa capitata Walt. Same as *Nyssa ogeche.*

Nyssa ogeche Marsh. **Dogwood family (Cornaceae).**

Synonym.—Nyssa capitata Walt.

Sour tupelo; Ogeechee lime.

A small tree, growing in swamps near the seacoast from southern South Carolina to Florida.

Part used.—Root wood (nonofficial).

Nyssa uniflora Wang. Same as *Nyssa aquatica*.

Oak, champion-. See *Quercus rubra*.

Oak, Jerusalem. See *Chenopodium anthelminticum* and *C. botrys*.

Oak, poison-. See *Rhus radicans* and *R. toxicodendron*.

Oak, red. See *Quercus rubra*.

Oak, Spanish. See *Quercus rubra*.

Oak, stone-. See *Quercus alba*.

Oak, white. See *Quercus alba*.

Oenothera biennis L. **Evening-primrose family (Onagraceae).**

Synonym.—Onagra biennis (L.) Scop.

Evening-primrose; tree-primrose; night willow-herb.

Annual or biennial plant, 2 to 5 feet high, common in fields and waste places from Labrador to Florida, west to the Rocky Mountains. Native.

Part used.—Plant (nonofficial).

Old-man's-beard. See *Chionanthus virginica*.

Olive, spurge-. See *Daphne mezereum*.

Onagra biennis (L.) Scop. Same as *Oenothera biennis*.

Onosmodium virginianum (L.) DC. **Borage family (Boraginaceae).**

Synonym.—Lithospermum virginianum L.

Virginia false gromwell; gravel-weed; necklace-weed; pearl-plant; wild Job's-tears.

Rough-hairy, native, perennial herb, 1 to 2 feet high; in dry, hilly grounds from the New England States to Florida, Kansas, and Texas.

Parts used.—Root and seeds (nonofficial).

Opium, wild. See *Lactuca canadensis*.

Orangeroot. See *Hydrastis canadensis*.

Orobanche virginiana L. Same as *Leptamnium virginianum*.

Osier, golden. See *Myrica gale*.

Osier, green. See *Cornus circinata*.

Osier, red. See *Cornus amomum*.

Osmorrhiza longistylis DC. Same as *Washingtonia longistylis*.

Osmunda regalis L. **Royal fern family (Osmundaceae).**

Royal fern; buckhorn-brake.

A tall, native fern, with fronds 3 to 4 feet high, occurring in swamps and marshes from Canada to Florida and Mississippi.

Part used.—Rhizome (nonofficial).

Ostrya virginiana (Mill.) Willd. **Birch family (Betulaceae).**

Hop-hornbeam; ironwood; deerwood; leverwood.

Native tree, 25 to 30 feet in height, growing in rich woods, Canada and eastern United States.

Part used.—Bark (nonofficial).

Oxalis acetosella L. **Wood-sorrel family (Oxalidaceae).**

White wood-sorrel; shamrock; sour trefoil.

Small, native, perennial herb, found in cold, damp woods, Canada south to Michigan and North Carolina.

Part used.—Herb (nonofficial).

Oxeye daisy. See *Chrysanthemum leucanthemum.*

Oxydendrum arboreum (L.) DC. **Heath family (Ericaceae).**

Synonym.—*Andromeda arborea* L.

Sourwood; sorrel-tree; elk-tree.

Native tree, sometimes 40 to 50 feet in height, growing in rich woods from Ohio to Maryland, south to Alabama and Florida.

Parts used.—Leaves and bark (nonofficial)

Palmetto, saw-. See *Serenoa serrulata.*

Panax quinquefolium L. **Ginseng family (Araliaceae).**

Ginseng.

Native, perennial herb, about 1 foot in height, found in rich, shady woods from the Middle and Northern States south to Alabama and Georgia.

Part used.—Root (nonofficial).

Pansy. See *Viola tricolor.*

Papoose-root. See *Caulophyllum thalictroides.*

Paradise-plant. See *Daphne mezereum.*

Parilla, yellow. See *Menispermum canadense.*

Parsley, spotted. See *Conium maculatum.*

Parsley-fern. See *Tanacetum vulgare.*

Parsnip, cow-. See *Heracleum lanatum.*

Parthenocissus quinquefolia (L.) Planch. **Grape family (Vitaceae).**

Synonym.—*Ampelopsis quinquefolia* Michx.

American ivy; Virginia creeper.

A common, woody vine, native in woods and thickets from Canada to Florida and Texas.

Parts used.—Bark and young twigs (nonofficial).

Partridgeberry. See *Mitchella repens.*

Pasqueflower, American. See *Pulsatilla hirsutissima.*

Passiflora incarnata L. **Passion-flower family (Passifloraceae).**

Passion-flower; passion-vine; may-pops.

Climbing, perennial plant, native in dry soil from Virginia to Florida, westward to Missouri and Arkansas.

Parts used.—Root and stem base (nonofficial).

Passion-flower. See *Passiflora incarnata.*

Passion-vine. See *Passiflora incarnata.*

Paul's-betony. See *Veronica officinalis.*

Pawpaw, North American. See *Asimina triloba.*

Pea, ground-squirrel. See *Jeffersonia diphylla.*

Pea, hoary. See *Cracca virginiana.*

Pea, turkey-. See *Bikukulla canadensis.*

Pearl-plant. See *Onosmodium virginianum.*

Pencil-flower. See *Stylosanthes biflora.*

Pennyroyal, American. See *Hedeoma pulegioides.*

Penthorum sedoides L. **Virginia stonecrop family (Penthoraceae).**

Virginia stonecrop; ditch-stonecrop.

Native, perennial herb, about 1 foot in height, growing in ditches and swamps from New Brunswick to Minnesota, south to Florida and Texas.

Part used.—Herb (nonofficial.)

Pepper, water-. See *Polygonum hydropiper.*

Peppermint. See *Mentha piperita.*

Pepper-plant. See *Polygonum hydropiper.*

Peramium pubescens (Willd.) MacM. **Orchid family (Orchidaceae).**

Synonym.—*Goodyera pubescens* R. Br.

Downy rattlesnake-plantain; rattlesnake-weed; netleaf-plantain; scrofula-weed.

Native, perennial herb, 8 to 12 inches in height, occurring in rich woods from Newfoundland to Minnesota, south to Florida and Tennessee. Most common southward.

Part used.—Plant (nonofficial).

Peramium repens (L.) Salisb. **Orchid family (Orchidaceae).**

Synonym.—*Goodyera repens* R. Br.

White plantain; lesser rattlesnake-plantain; smaller netleaf-plantain; squirrel-ear.

A smaller plant than *P. pubescens*, but very similar to it and more common northward.

Part used.—Plant (nonofficial).

Persimmon. See *Diospyros virginiana.*

Phoradendron flavescens (Pursh) Nutt. **Mistletoe family (Loranthaceae).**

Synonym.—*Viscum flavescens* Pursh.

Mistletoe; American mistletoe.

Parasitic shrub, found on deciduous-leaved trees from New Jersey to Missouri, south to Florida and Texas.

Parts used.—Leaves and branches (nonofficial).

Phytolacca. See *Phytolacca decandra.*

Phytolacca americana L. Same as *Phytolacca decandra.*

Phytolacca decandra L.[a] **Pokeweed family (Phytolaccaceae).**

Synonym.—*Phytolacca americana* L.[a]

Phytolacca; poke; pokeweed; garget; scoke; inkberry.

Native, perennial herb, with large and branching stem, 6 to 10 feet high; in rich, moist soil, Maine to Minnesota, south to Florida and Texas.

Parts used.—Root collected in autumn (official); fruit (official in U. S. P. 1890); leaves (nonofficial).

Picea mariana (Mill.) B. S. P. **Pine family (Pinaceae).**

Synonym.—*Abies nigra* Desf.

Black spruce; spruce-gum tree.

Indigenous, evergreen tree, 40 to 80 feet in height, growing on elevated situations and in cold bogs from Canada south along the mountains to North Carolina, and to Minnesota.

Parts used.—Branches, and the essence obtained from the same (nonofficial).

Pilewort. See *Erechtites hieracifolia* and *Scrophularia marilandica.*

Pilotweed. See *Silphium laciniatum.*

Pimpernel. See *Pimpinella saxifraga.*

Pimpernel, red. See *Anagallis arvensis.*

Pimpernel, scarlet. See *Anagallis arvensis.*

[a] *Phytolacca americana* L. by right of priority should be accepted, but *P. decandra* L. is used in conformity with the Pharmacopœia.

Pimpinella saxifraga L. **Parsley family** (**Apiaceae**).

Burnet-saxifrage; bennet; pimpernel.

Erect, perennial herb, 1 to 2 feet high, adventive from Europe, and found in waste places in eastern Pennsylvania, at several localities in the valley of the Delaware, and in Ohio.

Part used.—Root (nonofficial).

Pine, northern. See *Pinus strobus.*

Pine, prairie-. See *Lacinaria spicata.*

Pine, prince's-. See *Chimaphila umbellata*

Pine, Weymouth. See *Pinus strobus.*

Pine, white. See *Pinus strobus.*

Pink, rose-. See *Sabbatia angularis.*

Pinkroot. See *Spigelia marilandica.*

Pinkroot, Indian. See *Spigelia marilandica.*

Pinkroot, Maryland. See *Spigelia marilandica.*

Pinus strobus L. **Pine family** (**Pinaceae**).

White pine; northern pine; Weymouth pine.

Large, indigenous forest tree, sometimes 175 feet in height, growing in woods from Canada south to Georgia and Iowa.

Part used.—Bark (nonofficial).

Pipe-plant. See *Monotropa uniflora.*

Pipsissewa. See *Chimaphila umbellata.*

Pitcher-plant. See *Sarracenia purpurea.*

Plantago major L. **Plantain family** (**Plantaginaceae**).

Common plantain; dooryard-plantain; greater plantain.

Perennial herb, 1 to 3 feet high, naturalized from Europe; common in fields and waste places and along roadsides nearly throughout North America.

Parts used.—Root and leaves (nonofficial).

Plantain, common. See *Plantago major.*

Plantain, dooryard-. See *Plantago major.*

Plantain, downy rattlesnake-. See *Peramium pubescens.*

Plantain, greater. See *Plantago major.*

Plantain, lesser rattlesnake-. See *Peramium repens.*

Plantain, netleaf-. See *Peramium pubescens.*

Plantain, smaller netleaf-. See *Peramium repens.*

Plantain, white. See *Peramium repens.*

Pleurisy-root. See *Asclepias tuberosa.*

Podophyllum. See *Podophyllum peltatum.*

Podophyllum peltatum L. **Barberry family** (**Berberidaceae**).

Podophyllum; May-apple; wild mandrake; American mandrake; wild lemon.

Native, perennial herb, 1 to 1½ feet high, found in low, rich woods from Canada to Minnesota, south to Florida and Texas.

Part used.—Rhizome (official).

Poison-hemlock. See *Conium maculatum.*

Poison-ivy. See *Rhus radicans* and *R. toxicodendron.*

Poison-oak. See *Rhus radicans* and *R. toxicodendron.*

Poison-vine. See *Rhus radicans.*

Poke. See *Phytolacca decandra.*

Pokeweed. See *Phytolacca decandra.*

Polar-plant. See *Silphium laciniatum.*

Polecat-weed. See *Spathyema foetida.*

Polemonium reptans L. **Phlox family (Polemoniaceae).**

American Greek valerian; abscess-root; sweetroot; Jacob's-ladder.

Native, perennial herb, 12 to 20 inches high, growing in woods and damp ground from New York to Minnesota, south to Georgia and Missouri.

Part used.—Root (nonofficial).

Polygala nuttallii T. & G. **Milkwort family (Polygalaceae).**

Nuttall's-milkwort; ground-centaury.

Slender, erect, annual herb, 6 to 12 inches high, native in dry, sandy soil from Massachusetts to North Carolina, west to Alabama and Missouri.

Part used.—Herb (nonofficial).

Polygala senega L. **Milkwort family (Polygalaceae).**

Senega; Seneca snakeroot.

Native, perennial herb, 8 to 12 inches high, found in rocky woods and on hillsides from New Brunswick and western New England to Minnesota, south to North Carolina and Missouri.

Part used.—Root (official).

Polygonatum biflorum (Walt.) Ell. **Lily-of-the-valley family (Convallariaceae).**

Synonyms.—*Convallaria biflora* Walt.; *Salomonia biflora* (Walt.) Britton.

Hairy Solomon's-seal; smaller Solomon's-seal.

Native, perennial herb, 8 inches to 3 feet high, found in woods and thickets from Canada south to Florida and Michigan.

Part used.—Rhizome (nonofficial).

Polygonatum commutatum (Roem. & Schult.) Dietr. **Lily-of-the-valley family (Convallariaceae).**

Synonyms.—*Polygonatum giganteum* Dietr.; *Salomonia commutata* (Roem. & Schult.) Britton.

Giant Solomon's-seal; great Solomon's-seal; smooth Solomon's-seal.

Native, perennial herb, 1 to 8 feet high, occurring in moist woods and along streams from Canada to Georgia, west to Louisiana and Utah.

Part used.—Rhizome (nonofficial).

Polygonatum giganteum Dietr. Same as *Polygonatum commutatum.*

Polygonum hydropiper L. **Buckwheat family (Polygonaceae).**

Smartweed; water-pepper; biting knotweed; pepper-plant.

Smooth, annual plant, 8 inches to 2 feet high, naturalized from Europe; common in moist waste places almost throughout North America.

Part used.—Herb (nonofficial).

Polygonum punctatum Ell. **Buckwheat family (Polygonaceae).**

Dotted smartweed; water-smartweed.

Native, annual or perennial herb, found in swamps and other wet places throughout most of North America.

Part used.—Herb (nonofficial).

Polymnia uvedalia L. **Aster family (Asteraceae).**

Yellow bear's-foot; yellow leafcup; uvedalia.

Large, native, perennial plant, 3 to 6 feet high; in ravines and edges of woods from New York to Michigan, south to Florida and Texas.

Part used.—Root (nonofficial).

Polypodium filix-mas L. Same as *Dryopteris filix-mas.*

Polypodium marginale L. Same as *Dryopteris marginalis.*

Polypodium vulgare L. **Fern family (Polypodiaceae).**

Common polypody; fernroot; rock-brake; female-fern.

Native fern, 3 to 10 inches in height, with a perennial, creeping rhizome; on shady, rocky banks, in woods and mountains almost throughout North America.

Parts used.—Rhizome and tops (nonofficial).

Polypody, common. See *Polypodium vulgare.*

Polytrichum juniperinum Hedw. **Haircap-moss family (Polytrichaceae).**

Haircap-moss; robin's-rye.

Native moss, 4 to 7 inches in height, growing along margins of dry woods and exposed places, mostly on poor, sandy soil.

Part used.—Whole plant (nonofficial).

Pond-lily, large yellow. See *Nymphaea advena.*

Pond-lily, white. See *Castalia odorata.*

Poolroot. See *Eupatorium ageratoides, E. aromaticum,* and *Sanicula marilandica.*

Poolwort. See *Eupatorium ageratoides* and *E. aromaticum.*

Poplar, silver. See *Populus alba.*

Poplar, silverleaf-. See *Populus alba.*

Poplar, trembling. See *Populus tremuloides.*

Poplar, tulip-. See *Liriodendron tulipifera.*

Poplar, white. See *Populus alba* and *P. tremuloides.*

Poplar, yellow. See *Liriodendron tulipifera.*

Populus alba L. **Willow family (Salicaceae).**

White poplar; silverleaf-poplar; silver poplar; white-bark.

A large tree, sometimes 120 feet in height, naturalized in the United States; occurs along roadsides from New Brunswick to Virginia.

Part used.—Bark, collected in spring (nonofficial).

Populus balsamifera candicans A. Gray. Same as *Populus candicans.*

Populus candicans Ait. **Willow family (Salicaceae).**

Synonym.—*Populus balsamifera candicans* A. Gray.

Balm-of-Gilead.

A large tree, about 80 feet in height, mostly escaped from cultivation, New Brunswick to New Jersey, west to Minnesota.

Parts used.—Leafbuds and bark (nonofficial).

Populus tremuloides Michx. **Willow family (Salicaceae).**

Quaking aspen; American aspen; white poplar; trembling poplar; quiverleaf.

A slender, indigenous tree, growing in dry or moist soil from lower Canada south to Kentucky and in the Rocky Mountains to Lower California.

Part used.—Bark, collected in spring (nonofficial).

Porteranthus trifoliatus (L.) Britton. **Rose family (Rosaceae).**

Synonym.—*Gillenia trifoliata* Moench.

Indian-physic; Bowman's-root; false ipecac; western dropwort.

Native, perennial herb, 2 to 3 feet high, found in moist, shady places in rich woods from New York to Michigan, south to Georgia and Missouri; more common in the Atlantic States than in the Western States.

Part used.—Root (nonofficial).

Potato, hog-. See *Ipomoea pandurata.*

Potato, wild. See *Ipomoea pandurata.*

Potentilla canadensis L. **Rose family (Rosaceae).**

Fivefinger; cinquefoil.

A small, annual or biennial plant, with creeping stems, growing in dry soil from Quebec to Georgia, west to Minnesota and the Indian Territory.

Part used.—Plant (nonofficial).

Prairie-pine. See *Lacinaria spicata.*

Prenanthes alba L. Same as *Nabalus albus.*

Prenanthes serpentaria Pursh. Same as *Nabalus serpentarius.*

Prickly ash, northern. See *Xanthoxylum americanum.*

Prickly ash, southern. See *Fagara clava-herculis.*

Prideweed. See *Erigeron canadensis.*

Prim. See *Ligustrum vulgare.*

Primrose, evening-. See *Oenothera biennis.*

Primrose, tree-. See *Oenothera biennis.*

Primwort. See *Ligustrum vulgare.*

Prince's-pine. See *Chimaphila umbellata.*

Prinos verticillatus L. Same as *Ilex verticillata.*

Privet. See *Ligustrum vulgare.*

Prunella vulgaris L. **Mint family (Menthaceae).**

Self-heal; heal-all; brownwort; sicklewort; blue-curls.

Perennial plant, 2 inches to 2 feet high, naturalized from Europe, and found in fields, woods, and waste places throughout nearly the whole of North America.

Part used.—Herb (nonofficial).

Prunus serotina Ehrh. **Plum family (Amygdalaceae).**

Synonym.—*Prunus virginiana* Mill., not of Linnaeus.

Prunus virginiana; wild cherry; rum-cherry.

A large, indigenous tree, 50 to 80 feet high, growing in woods or open places from Ontario to Florida, west to Texas and Dakota. Most abundant in the Southwestern States.

Part used.—Bark, which should be collected in autumn and carefully dried and preserved (official).

Prunus virginiana. See *Prunus serotina.*

Prunus virginiana Mill., not L. Same as *Prunus serotina.*

Psoralea. See *Psoralea pedunculata.*

Psoralea melilotoides Michx. Same as *Psoralea pedunculata.*

Psoralea pedunculata (Mill.) Vail. **Pea family (Fabaceae).**

Synonym.—*Psoralea melilotoides* Michx.

Psoralea; Samson's-snakeroot; Congo-root.

Slender, herbaceous perennial, 1 to 2½ feet high, native in dry soil in open woods from Ohio and Kentucky southward.

Parts used.—Root and leaves (nonofficial).

Ptelea trifoliata L. **Rue family (Rutaceae).**

Wafer-ash; wingseed; hop-tree; shrubby trefoil.

Native shrub, 6 to 8 feet high; in shady woods from New York to Florida, west to Minnesota and Texas; grows more abundantly west of the Alleghenies.

Parts used.—Bark of root, fruit, and leaves (nonofficial).

Pterocaulon undulatum (Walt.) Mohr. **Aster family (Asteraceae).**

Synonym.—*Gnaphalium undulatum* Walt.

Indian blackroot.

Native, perennial herb, growing in sandy pine lands from North Carolina to Florida and Mississippi.

Part used.—Root (nonofficial).

Puccoon, red. See *Sanguinaria canadensis.*

Puccoon, yellow. See *Hydrastis canadensis.*

Pulsatilla, American. See *Pulsatilla hirsutissima.*

Pulsatilla hirsutissima (Pursh) Britton. **Crowfoot family (Ranunculaceae).**

Synonym.—*Anemone patens* var. *nuttalliana* A. Gray.

American pasqueflower; American pulsatilla.

Native, perennial herb, 6 to 16 inches high, found in the prairie regions of Illinois, west to the Rocky Mountains and the Northwest.

Part used.—Flowering herb (nonofficial).

Purging-root. See *Euphorbia corollata.*

Purslane, black. See *Euphorbia nutans.*

Purslane, milk-. See *Euphorbia nutans.*

Pussy-willow. See *Salix nigra.*

Putty-root. See *Aplectrum spicatum.*

Pycnanthemum montanum Michx. Same as *Koellia montana.*

Pycnanthemum pilosum Nutt. Same as *Koellia pilosa.*

Pyramid-flower. See *Frasera caroliniensis.*

Pyrethrum parthenium Smith. Same as *Chrysanthemum parthenium.*

Pyrus americana DC. Same as *Sorbus americana.*

Quack-grass. See *Agropyron repens.*

Queen-Anne's-lace. See *Daucus carota.*

Queen-of-the-meadow. See *Eupatorium purpureum.*

Queen's-delight. See *Stillingia sylvatica.*

Queensland asthma-weed. See *Euphorbia pilulifera.*

Queen's-root. See *Stillingia sylvatica.*

Quercus. See *Quercus alba.*

Quercus alba L. **Beech family (Fagaceae).**

Quercus; white oak; stone-oak.

Large, indigenous forest tree, 50 to 100 feet in height, in woods from Maine to Minnesota, south to Florida and Texas. More abundant in the Middle States.

Part used.—Bark, "collected from trunks or branches 10 to 25 years of age, and deprived of the periderm" (official).

Quercus rubra L. **Beech family (Fagaceae).**

Red oak; champion-oak; Spanish oak.

Large, wide-spreading, indigenous forest tree, about 70 feet in height, from Nova Scotia to Minnesota, south to Florida and Texas. More common in the Northern States and in Canada.

Part used.—Bark (nonofficial).

Quinine-flower. See *Sabbatia elliottii.*

Quinine-herb. See *Sabbatia elliottii.*

Quinine-plant. See *Sabbatia elliottii.*

Quiverleaf. See *Populus tremuloides.*

Ragged-cup. See *Silphium perfoliatum.*

Ragweed. See *Ambrosia artemisiaefolia.*

Ragwort, golden. See *Senecio aureus.*

Raspberry, black. See *Rubus occidentalis.*

Raspberry, ground-. See *Hydrastis canadensis.*

Raspberry, wild red. See *Rubus strigosus.*

Rattle-root. See *Cimicifuga racemosa.*

Rattlesnake-herb. See *Actaea alba* and *A. rubra.*

Rattlesnake-master. See *Eryngium yuccifolium*, *Lacinaria scariosa*, *L. spicata*, and *L. squarrosa*.

Rattlesnake-plantain, downy. See *Peramium pubescens*.

Rattlesnake-plantain, lesser. See *Peramium repens*.

Rattlesnake-root. See *Nabalus albus* and *N. serpentarius*.

Rattlesnake-violet. See *Erythronium americanum*.

Rattlesnake-weed. See *Eryngium yuccifolium*, *Hieracium venosum*, and *Peramium pubescens*.

Redbud. See *Cercis canadensis*.

Redroot. See *Ceanothus americanus*.

Rhamnus cathartica L. **Buckthorn family (Rhamnaceae).**

Buckthorn; hart's-thorn; waythorn.

A shrub 6 to 15 feet high, introduced from Europe; escaped from hedges and growing in dry soil in the New England and Middle States.

Part used.—Berries (nonofficial).

Rhamnus purshiana. See *Rhamnus purshiana* DC.

Rhamnus purshiana DC. **Buckthorn family (Rhamnaceae).**

Rhamnus purshiana; cascara sagrada; chittem-bark; sacred-bark; bearberry-tree.

Small, indigenous tree, 15 to 20 feet in height, found on the sides and bottoms of canyons, Rocky Mountains west to the Pacific Ocean, and extending north into British America.

Part used.—Bark, collected at least one year before being used (official).

Rheumatism-root. See *Dioscorea villosa* and *Jeffersonia diphylla*.

Rheumatism-weed. See *Chimaphila umbellata*.

Rhododendron maximum L. **Heath family (Ericaceae).**

Great laurel; rose-bay; deer-laurel; rose-laurel.

Tall, native, evergreen shrub or small tree, found in low woods and along streams from Canada to Georgia.

Part used.—Leaves (nonofficial).

Rhus aromatica Ait. **Sumac family (Anacardiaceae).**

Fragrant sumac; sweet-scented sumac.

Indigenous shrub, 2 to 6 feet high, growing in woods and rocky situations, Canada to Florida, especially along the mountains, west to Minnesota and Arkansas.

Part used.—Bark of root (nonofficial).

Rhus glabra. See *Rhus glabra* L.

Rhus glabra L. **Sumac family (Anacardiaceae).**

Rhus glabra; smooth sumac; scarlet sumac.

Indigenous, branching shrub, from 4 to 12 feet high; in dry soil, thickets, and waste grounds nearly throughout the United States and Canada.

Parts used.—Fruit (official); bark and leaves (nonofficial).

Rhus radicans L.[a] **Sumac family (Anacardiaceae).**

Rhus toxicodendron (pharmacopœial name, 1890); poison-ivy; poison-oak; poison-vine.

Native, woody vine, clinging to trees and fence rows; Canada to Florida, west to Nebraska and Arkansas. Very poisonous to the touch.

Part used.—Fresh leaves (official in U. S. P. 1890).

Rhus toxicodendron. See *Rhus radicans*.

[a] *Rhus radicans* L. was formerly believed to be a variety of *Rhus toxicodendron* L., but the two are now regarded as distinct species, and the leaves from both have been used under the pharmacopœial name (U. S. P. 1890) Rhus toxicodendron.

Rhus toxicodendron L. **Sumac family (Anacardiaceae).**

Poison-ivy; poison-oak.

Low, erect, and finely pubescent plant, more shrubby than *Rhus radicans*, and found in dry soil in more southern localities from Virginia to Georgia. Very poisonous to the touch.

Part used.—Fresh leaves, collected with those of *Rhus radicans*.

Richweed. See *Collinsonia canadensis* and *Eupatorium ageratoides*.

Robinia pseudacacia L. **Pea family (Fabaceae).**

Locust-tree; black locust; yellow locust; false acacia.

A large, indigenous tree, sometimes 80 feet in height, growing in woods from Pennsylvania south along the western slope of the Allegheny Mountains to Georgia, west to the Indian Territory. Most abundant in the Middle and Eastern States.

Part used.—Bark of root (nonofficial).

Robin's-rye. See *Polytrichum juniperinum*.

Rock-brake. See *Polypodium vulgare*.

Rock-rose, Canadian. See *Helianthemum canadense*.

Rope-bark. See *Dirca palustris*.

Rose, Canadian rock-. See *Helianthemum canadense*.

Rose-bay. See *Rhododendron maximum*.

Rose-laurel. See *Rhododendron maximum*.

Rosemary, marsh-. See *Limonium carolinianum*.

Rose-pink. See *Sabbatia angularis*.

Rose-willow. See *Cornus amomum*.

Rosinweed. See *Silphium laciniatum*.

Roundwood. See *Sorbus americana*.

Rubus. See *Rubus cuneifolius*, *R. nigrobaccus*, *R. procumbens*, *R. trivialis*, and *R. villosus*.

Rubus canadensis T. & G., not L. Same as *Rubus procumbens*.

Rubus cuneifolius Pursh. **Rose family (Rosaceae).**

Rubus; sand-blackberry; knee-high blackberry.

Shrubby plant, 1 to 3 feet high; in sandy soil from Connecticut to Florida, west to Missouri and Louisiana.

Part used.—Bark of rhizome (official).

Rubus idaeus var. *americanus* Torr. Same as *Rubus occidentalis*.

Rubus nigrobaccus Bailey. **Rose family (Rosaceae).**

Synonym.—*Rubus villosus* A. Gray, not Ait.

Rubus; high-bush blackberry.

Slender shrub, 3 to 7 feet high, growing in dry fields and along roadsides, New England States to Florida, and west to Arkansas.

Part used.—Bark of rhizome (official).

Rubus occidentalis L. **Rose family (Rosaceae).**

Synonym.—*Rubus idaeus* var. *americanus* Torr.

Black raspberry; thimbleberry; blackcap.

A straggling shrub, growing along the borders of woods and in rocky thickets from Canada south to Georgia and Missouri.

Parts used.—Fruit and leaves (nonofficial).

Rubus procumbens Muhl. **Rose family (Rosaceae).**

Synonym.—Rubus canadensis T. & G., not L.

Rubus; low running blackberry; dewberry.

Shrubby, trailing plant, found in dry soil from Newfoundland to Lake Superior, south to Virginia and the Indian Territory.

Part used.—Bark of root (official in U. S. P. 1890).

Rubus strigosus Michx. **Rose family (Rosaceae).**

Wild red raspberry.

Shrubby plant, found in dry or rocky situations from Canada to North Carolina and New Mexico.

Parts used.—Fruit and leaves (nonofficial).

Rubus trivialis Michx. **Rose family (Rosaceae).**

Rubus; southern dewberry; low-bush blackberry.

Shrubby, procumbent plant, found in sandy soils, Virginia to Florida, west to Missouri and Texas.

Part used.—Bark of root (official in U. S. P. 1890).

Rubus villosus A. Gray, not Ait. Same as *Rubus nigrobaccus.*

Rubus villosus Ait. **Rose family (Rosaceae).**

Rubus; one-flowered dewberry.

Trailing plant, with slender branches, growing in sandy or dry soil near the coast from Maine to South Carolina.

Part used.—Bark of rhizome (official)

Rudbeckia laciniata L. **Aster family (Asteraceae).**

Thimbleweed; tall coneflower.

Much-branched, native perennial, 3 to 12 feet high; in moist thickets, Canada and Montana, south to Florida and New Mexico.

Part used.—Herb (nonofficial).

Rum-cherry. See *Prunus serotina.*

Rumex. See *Rumex crispus.*

Rumex acetosella L. **Buckwheat family (Polygonaceae).**

Sheep-sorrel; field-sorrel; sour-grass; common sorrel.

Annual or perennial herb, abundant in dry fields, pastures, and waste ground throughout the United States.

Part used.—Leaves (nonofficial).

Rumex crispus L. **Buckwheat family (Polygonaceae).**

Rumex; yellow dock; curled dock; narrow dock; sour dock.

A weed introduced from Europe, and common in cultivated and waste ground throughout the United States. Perennial plant, 2 to 4 feet high.

Part used.—Root of this and some other species of Rumex (official in U. S. P. 1890).

Rumex obtusifolius L. **Buckwheat family (Polygonaceae).**

Bitter dock; blunt-leaved dock; broad-leaved dock.

A perennial weed, 2 to 4 feet high, naturalized from Europe, and found in waste places from New England to Florida, west to Texas and Oregon.

Part used.—Root, collected with that of *Rumex crispus.*

Sabal. See *Serenoa serrulata.*

Sabbatia angularis (L.) Pursh. **Gentian family (Gentianaceae).**

American centaury; rose-pink; bitterbloom; bitter clover.

Native, biennial plant, 1 to 2 feet high, growing in damp, rich soil, in meadows and among high grass, from New York to Michigan, south to Florida and the Indian Territory.

Part used.—Herb (nonofficial).

Sabbatia elliottii Steud. **Gentian family (Gentianaceae).**

Synonym.—Sabbatia paniculata Ell.

Quinine-flower; quinine-plant; quinine-herb; Elliott's-sabbatia.

An erect, native herb, about one foot in height, growing in pine barrens from North Carolina to Florida.

Part used.—Herb (nonofficial).

Sabbatia, Elliott's-. See *Sabbatia elliottii.*

Sabbatia paniculata Ell. Same as *Sabbatia elliottii.*

Sabina. See *Juniperus sabina.*

Sacred-bark. See *Rhamnus purshiana.*

Sage, Indian. See *Eupatorium perfoliatum.*

Saint-Benedict's thistle. See *Cnicus benedictus.*

Saint-John's wort, common. See *Hypericum perforatum.*

Salix alba L. **Willow family (Salicaceae).**

White willow; European willow.

A large tree, sometimes 90 feet in height, introduced from Europe; occurs in moist soil along streams from Pennsylvania northward to New Brunswick and Ontario, sparingly escaped from cultivation.

Part used.—Bark (nonofficial).

Salix nigra Marsh. **Willow family (Salicaceae).**

Black willow; pussy-willow; swamp-willow.

Tall, indigenous tree, growing on banks of rivers from Canada to Florida and California.

Parts used.—Bark, and fresh aments gathered early in May (nonofficial).

Salomonia biflora (Walt.) Britton. Same as *Polygonatum biflorum.*

Salomonia commutata (Roem. & Schult.) Dietr. Same as *Polygonatum commutatum.*

Salt-rheum weed. See *Chelone glabra.*

Sambucus. See *Sambucus canadensis.*

Sambucus canadensis L. **Honeysuckle family (Caprifoliaceae).**

Sambucus; elder; American elder; sweet elder.

Indigenous shrub, 6 to 10 feet high, growing in low, damp ground from Canada to Florida and Arizona.

Parts used.—Flowers (official in U. S. P. 1890); bark and berries (nonofficial).

Sampson-root. See *Brauneria angustifolia.*

Sampson's-snakeroot. See *Gentiana villosa.*

Samson's-snakeroot. See *Psoralea pedunculata.*

Sand-blackberry. See *Rubus cuneifolius.*

Sandbrier. See *Solanum carolinense.*

Sanguinaria. See *Sanguinaria canadensis.*

Sanguinaria canadensis L. **Poppy family (Papaveraceae).**

Sanguinaria; bloodroot; red puccoon; Indian-paint; tetterwort.

Native, perennial herb, about 6 inches high, found in rich, open woods from Nova Scotia to Nebraska, south to Florida and Arkansas.

Part used.—Rhizome, "collected after the death of the foliage" (official).

Sanicle, American. See *Heuchera americana* and *Sanicula marilandica.*

Sanicle, black. See *Sanicula marilandica.*

Sanicle, Indian. See *Eupatorium ageratoides.*

Sanicle, white. See *Eupatorium ageratoides.*

Sanicula marilandica L. — **Parsley family (Apiaceae).**

Black sanicle; black snakeroot; American sanicle; poolroot.

Native, perennial herb, 1 to 3 feet high; in rich woods, Canada to Georgia.

Part used.—Root (nonofficial).

Saponaria officinalis L. — **Pink family (Silenaceae).**

Soapwort; soaproot; bouncing-Bet; fuller's-herb.

Stout, perennial herb, 1 to 2 feet high, naturalized from Europe and found along roadsides and waste places; common almost everywhere.

Parts used.—Root and herb (nonofficial).

Sarothamnus scoparius Wimm. Same as *Cytisus scoparius.*

Sarracenia flava L. — **Pitcher-plant family (Sarraceniaceae).**

Trumpetleaf; trumpets; Eve's-cup; watercup; yellow-flowered watercup.

Curious, indigenous perennial, about 1 to 3 feet high, found in low, wet pine barrens in the southeastern United States.

Parts used.—Root and sometimes the leaves (nonofficial).

Sarracenia purpurea L. — **Pitcher-plant family (Sarraceniaceae).**

Pitcher-plant; flytrap; sidesaddle-flower; watercup; smallpox-plant.

Indigenous perennial, 1 to 2 feet high, growing in wet, boggy places and marshes, from Canada to Minnesota and Florida.

Parts used.—Root and sometimes the leaves (nonofficial).

Sarsaparilla, American. See *Aralia nudicaulis.*

Sarsaparilla, bristly. See *Aralia hispida.*

Sarsaparilla, false. See *Aralia nudicaulis.*

Sarsaparilla, Texas. See *Menispermum canadense.*

Sarsaparilla, Virginian. See *Aralia nudicaulis.*

Sarsaparilla, wild. See *Aralia nudicaulis.*

Sassafras. See *Sassafras variifolium.*

Sassafras officinale Nees & Eberm. Same as *Sassafras variifolium.*

Sassafras sassafras (L.) Karst. Same as *Sassafras variifolium.*

Sassafras, swamp-. See *Magnolia virginiana.*

Sassafras variifolium (Salisb.) O. Kuntze.[a] — **Laurel family (Lauraceae).**

Synonyms.—*Sassafras officinale* Nees & Eberm.; *Sassafras sassafras* (L.) Karst.[a]

Sassafras; ague-tree.

Native tree, sometimes reaching a height of 125 feet; in rich woods, Massachusetts to Ontario and Michigan, south to Florida and Texas.

Parts used.—Bark of root, collected in early spring or autumn and deprived of the periderm (official); pith (official); and the oil of sassafras distilled from the root, especially the root bark (official).

Satureia hortensis L. — **Mint family (Menthaceae).**

Summer-savory.

Hairy, aromatic, annual herb, adventive from Europe and occurring in waste places from Canada to Pennsylvania and Nevada.

Part used.—Herb (nonofficial).

Savin. See *Juniperus sabina.*

Savin, red. See *Juniperus virginiana.*

Savory, summer-. See *Satureia hortensis.*

Saw-palmetto. See *Serenoa serrulata.*

Saxifrage, burnet-. See *Pimpinella saxifraga.*

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[a] Although the combination *Sassafras sassafras* (L.) Karst. should be accepted by strict right of priority, the usage of the Pharmacopœia is followed.

Scabious, sweet. See *Erigeron philadelphicus.*

Scabish, meadow-. See *Aster puniceus.*

Scabwort. See *Inula helenium.*

Scarletberry. See *Solanum dulcamara.*

Scoke. See *Phytolacca decandra.*

Scoparius. See *Cytisus scoparius.*

Scouring-rush, common. See *Equisetum hyemale.*

Scrofula-plant. See *Scrophularia marilandica.*

Scrofula-weed. See *Peramium pubescens.*

Scrophularia marilandica L. **Figwort family (Scrophulariaceae).**

Synonym.—Scrophularia nodosa var. *marilandica* A. Gray.

Maryland figwort; scrofula-plant; carpenter's-square; heal-all; bee-plant; pilewort.

Smooth, native perennial, 3 to 5 feet high; moist, shady ground in woods and thickets, New York to North Carolina and Kansas.

Parts used.—Herb and root (nonofficial).

Scrophularia nodosa var. *marilandica* A. Gray. Same as *Scrophularia marilandica.*

Scutellaria. See *Scutellaria lateriflora.*

Scutellaria hyssopifolia L. Same as *Scutellaria integrifolia.*

Scutellaria integrifolia L. **Mint family (Menthaceae).**

Synonym.—Scutellaria hyssopifolia L.

Larger skullcap; hyssop-skullcap.

Native, perennial herb, 6 inches to 2 feet high, found in fields and woods from Connecticut south to Florida and Texas.

Part used.—Herb (nonofficial).

Scutellaria lateriflora L. **Mint family (Menthaceae).**

Scutellaria; skullcap; madweed; hoodwort.

Smooth, branching perennial, 1 to 2 feet high, native in damp places along banks of streams from Canada south to Florida, New Mexico, and Washington.

Part used.—Plant (official).

Sea-lavender. See *Limonium carolinianum.*

Self-heal. See *Prunella vulgaris.*

Senecio aureus L. **Aster family (Asteraceae).**

Liferoot; swamp squaw-weed; golden ragwort; cocash-weed; coughweed.

Indigenous, perennial herb, 1 to 2½ feet high, growing in swamps and wet meadows, Newfoundland to Ontario, south to Florida, Missouri, and Texas.

Parts used.—Root and herb (nonofficial).

Senega. See *Polygala senega.*

Senna, American. See *Cassia marilandica.*

Senna, wild. See *Cassia marilandica.*

Serenoa serrulata (Roem. & Schult.) Hook. f. **Palm family (Phoenicaceae).**

Sabal; saw-palmetto.

A palm, 3 to 7 feet in height, found in sandy soil from North Carolina and Arkansas to Florida and Texas.

Part used.—Partially dried ripe fruit (official).

Serpentaria. See *Aristolochia reticulata* and *A. serpentaria*

Serpentaria, Texas. See *Aristolochia reticulata.*

Serpentaria, Virginia. See *Aristolochia serpentaria.*

Service-tree, American. See *Sorbus americana.*

Seven-barks. See *Hydrangea arborescens*.

Shagbark. See *Hicoria ovata*.

Shamrock. See *Oxalis acetosella*.

Shamrock, water-. See *Menyanthes trifoliata*.

Shave-grass. See *Equisetum hyemale*.

Sheepberry. See *Viburnum lentago*.

Sheep-laurel. See *Kalmia angustifolia* and *K. latifolia*.

Sheep-sorrel. See *Rumex acetosella*.

Shellbark-hickory. See *Hicoria ovata*.

Shellflower. See *Chelone glabra*.

Shepherd's-purse. See *Bursa bursa-pastoris*.

Shepherd's-weatherglass. See *Anagallis arvensis*.

Shield-fern, marginal-fruited. See *Dryopteris marginalis*.

Shrub, sweet-scented. See *Butneria florida*.

Shrub yellowroot. See *Xanthorrhiza apiifolia*.

Sicklewort. See *Prunella vulgaris*.

Sidesaddle-flower. See *Sarracenia purpurea*.

Silkweed. See *Asclepias syriaca*.

Silkweed, rose-colored. See *Asclepias incarnata*.

Silkweed, swamp-. See *Asclepias incarnata*.

Silphium laciniatum L. **Aster family** (**Asteraceae**).

Rosinweed; compass-plant; pilotweed; polar-plant.

Coarse, native perennial, 3 to 12 feet high, growing on prairies from Ohio to Alabama, west to Texas and South Dakota.

Part used.—Herb (nonofficial).

Silphium perfoliatum L. **Aster family** (**Asteraceae**).

Cup-plant; Indian-cup; ragged-cup.

Stout, perennial herb, 4 to 8 feet high, native in moist soil and low ground from Ontario and the eastern United States west to Louisiana and Nebraska.

Part used.—Root (nonofficial).

Silverleaf. See *Impatiens biflora*, *Spiraea tomentosa*, and *Stillingia sylvatica*.

Silverleaf-poplar. See *Populus alba*.

Simpler's-joy. See *Verbena hastata*.

Sinapis alba. See *Sinapis alba* L.

Sinapis alba L. **Mustard family** (**Brassicaceae**).

Sinapis alba; white mustard; yellow mustard.

Annual herb, about 2 feet in height, naturalized from Europe, and found in fields and waste places, but not so widely distributed as the black mustard.

Part used.—Seed (official).

Sinapis nigra. See *Brassica nigra*.

Sinapis nigra L. Same as *Brassica nigra*.

Skullcap. See *Scutellaria lateriflora*.

Skullcap, hyssop-. See *Scutellaria integrifolia*.

Skullcap, larger. See *Scutellaria integrifolia*.

Skunk-cabbage. See *Spathyema foetida*.

Skunkweed. See *Spathyema foetida*.

Sloe. See *Viburnum prunifolium*.

Smallpox-plant. See *Sarracenia purpurea*.

Smartweed. See *Polygonum hydropiper.*

Smartweed, dotted. See *Polygonum punctatum.*

Smartweed, water-. See *Polygonum punctatum.*

Smilacina racemosa Desf. Same as *Vagnera racemosa.*

Smilax herbacea L. **Smilax family (Smilacaceae).**

Carrion-flower; American Jacob's-ladder.

Native, herbaceous perennial, occurring in woods and thickets in Canada and the eastern United States.

Part used.—Herb (nonofficial).

Smilax pseudo-china L. **Smilax family (Smilacaceae).**

Bamboo-brier; long-stalked greenbrier; American China-root; false China-root; bullbrier.

Perennial vine, native, growing in dry or sandy thickets, Maryland to Florida, west to Texas and Nebraska.

Part used.—Rhizome (nonofficial).

Snake-gentian. See *Nabalus serpentarius.*

Snakehead. See *Chelone glabra.*

Snakeleaf, yellow. See *Erythronium americanum.*

Snake-lily. See *Iris versicolor.*

Snakemilk. See *Euphorbia corollata.*

Snakeroot, black. See *Cimicifuga racemosa* and *Sanicula marilandica.*

Snakeroot, button-. See *Eryngium yuccifolium.*

Snakeroot, Canada. See *Asarum canadense.*

Snakeroot, corn-. See *Eryngium yuccifolium* and *Lacinaria spicata.*

Snakeroot, dense button-. See *Lacinaria spicata.*

Snakeroot, large button-. See *Lacinaria scariosa.*

Snakeroot, Red River. See *Aristolochia reticulata.*

Snakeroot, Sampson's- See *Gentiana villosa.*

Snakeroot, Samson's-. See *Psoralea pedunculata.*

Snakeroot, Seneca. See *Polygala senega.*

Snakeroot, smaller white. See *Eupatorium aromaticum.*

Snakeroot, Texas. See *Aristolochia reticulata.*

Snakeroot, Virginia. See *Aristolochia serpentaria.*

Snakeroot, white. See *Eupatorium ageratoides.*

Snake-violet. See *Viola pedata.*

Snakeweed. See *Euphorbia pilulifera.*

Snapweed. See *Impatiens aurea* and *I. biflora.*

Sneezeweed. See *Helenium autumnale.*

Sneezewort. See *Helenium autumnale.*

Snowdrop, yellow. See *Erythronium americanum.*

Soaproot. See *Saponaria officinalis.*

Soapwort. See *Saponaria officinalis.*

Soapwort-gentian. See *Gentiana saponaria.*

Solanum carolinense L. **Potato family (Solanaceae).**

Horse-nettle; bull-nettle; sandbrier.

Rough-hairy, native, perennial herb, common in dry fields and on sandy or gravelly banks from the eastern United States west to Texas and Nebraska.

Parts used.—Root, leaves, and berries (nonofficial).

Solanum dulcamara L. **Potato family (Solanaceae).**

Dulcamara; bittersweet; woody nightshade; violet-bloom; scarletberry.

Climbing, shrubby perennial, naturalized from Europe; found in low, damp grounds and moist banks, New Brunswick to Minnesota, south to New Jersey and Kansas.

Part used.—Young branches (official in U. S. P. 1890).

Solidago odora Ait. **Aster family (Asteraceae).**

Sweet goldenrod; fragrant-leaved goldenrod; anise-scented goldenrod.

Slender, perennial herb, 2 to 3 feet high, native; in dry soil from Maine to Texas.

Parts used.—Leaves and tops (nonofficial).

Solomon's-seal, false. See *Vagnera racemosa.*

Solomon's-seal, giant. See *Polygonatum commutatum.*

Solomon's-seal, great. See *Polygonatum commutatum.*

Solomon's-seal, hairy. See *Polygonatum biflorum.*

Solomon's-seal, small. See *Vagnera racemosa.*

Solomon's-seal, smaller. See *Polygonatum biflorum.*

Solomon's-seal, smooth. See *Polygonatum commutatum.*

Sorbus americana Marsh. **Apple family (Malaceae).**

Synonym.—*Pyrus americana* DC.

American mountain-ash; roundwood; dogberry; mountain-sumac; American service-tree.

Indigenous tree or tall shrub, growing in low woods or moist ground from Newfoundland south along the mountains to North Carolina, and to Michigan.

Parts used.—Bark and berries (nonofficial).

Sorrel, common. See *Rumex acetosella.*

Sorrel, field-. See *Rumex acetosella.*

Sorrel, sheep-. See *Rumex acetosella.*

Sorrel, white wood-. See *Oxalis acetosella.*

Sorrel-tree. See *Oxydendrum arboreum.*

Sour-grass. See *Rumex acetosella.*

Sourwood. See *Oxydendrum arboreum.*

Southernwood. See *Artemisia abrotanum.*

Spathyema foetida (L.) Raf. **Arum family (Araceae).**

Synonyms.—*Dracontium foetidum* L.; *Symplocarpus foetidus* Nutt.

Skunk-cabbage; skunkweed; polecat-weed; swamp-cabbage.

Indigenous, perennial herb, about 1 to 2 feet high, found in swamps and wet soil from Canada south to Florida, Iowa, and Minnesota. Appears very early in spring.

Parts used.—Rhizome and roots (nonofficial).

Spatter-dock. See *Nymphaea advena.*

Spearmint. See *Mentha spicata.*

Speedwell, common. See *Veronica officinalis.*

Speedwell, tall. See *Veronica virginica.*

Spicebush. See *Benzoin benzoin.*

Spicewood. See *Benzoin benzoin.*

Spigelia. See *Spigelia marilandica.*

Spigelia marilandica L. **Logania family** (**Loganiaceae**).

Spigelia; pinkroot; Maryland pinkroot; Indian pinkroot; worm-grass.

Erect, native, perennial herb, 6 inches to 1½ feet high, found in rich woods, New Jersey to Florida, west to Texas and Wisconsin. Occurs principally in the Southern States.

Parts used.—Rhizome and roots (official).

Spignet. See *Aralia racemosa.*

Spikenard. See *Aralia racemosa.*

Spikenard, American. See *Aralia racemosa.*

Spikenard, false. See *Vagnera racemosa.*

Spikenard, small. See *Aralia nudicaulis.*

Spikenard, wild. See *Vagnera racemosa.*

Spindle-tree. See *Euonymus atropurpureus.*

Spiraea. See *Spiraea tomentosa.*

Spiraea tomentosa L. **Rose family** (**Rosaceae**).

Spiraea; hardhack; steeplebush; pink meadowsweet; silverleaf.

Native shrub, occurring in low grounds and moist meadows from Nova Scotia south to Georgia, west to Kansas and Manitoba.

Parts used.—Leaves and root (nonofficial).

Spleenwortbush. See *Comptonia peregrina.*

Spruce, black. See *Picea mariana.*

Spruce, hemlock-. See *Tsuga canadensis.*

Spruce, weeping. See *Tsuga canadensis.*

Spruce-gum tree. See *Picea mariana.*

Spurge, flowering. See *Euphorbia corollata.*

Spurge, ipecac-. See *Euphorbia ipecacuanhae.*

Spurge, large spotted. See *Euphorbia nutans.*

Spurge, pill-bearing. See *Euphorbia pilulifera.*

Spurge-laurel. See *Daphne mezereum*

Spurge-olive. See *Daphne mezereum.*

Squawberry. See *Mitchella repens.*

Squawbush. See *Viburnum opulus.*

Squawflower. See *Trillium erectum.*

Squawmint. See *Hedeoma pulegioides.*

Squawroot. See *Caulophyllum thalictroides* and *Cimicifuga racemosa.*

Squaw-vine. See *Mitchella repens.*

Squaw-weed. See *Eupatorium ageratoides.*

Squaw-weed, swamp. See *Senecio aureus.*

Squirrel-corn. See *Bikukulla canadensis.*

Squirrel-ear. See *Peramium repens.*

Staff-tree. See *Celastrus scandens.*

Stagbush. See *Viburnum prunifolium.*

Staggerweed. See *Bikukulla canadensis.*

Stag's-horn. See *Lycopodium clavatum.*

Stammerwort. See *Ambrosia artemisiaefolia.*

Star-grass. See *Aletris farinosa.*

Starwort. See *Chamaelirium luteum.*

Starwort, drooping. See *Chamaelirium luteum.*

Statice caroliniana Walt. Same as *Limonium carolinianum.*

Steeplebush. See *Spiraea tomentosa.*

Stellaria media Cyr. Same as *Alsine media.*

Stillingia. See *Stillingia sylvatica.*

Stillingia sylvatica L. **Spurge family (Euphorbiaceae).**

Stillingia; queen's-root; queen's-delight; silverleaf.

Native, herbaceous perennial, 1 to 3 feet in height, occurring in dry, sandy soil, and pine barrens from Maryland to Florida, west to Kansas and Texas.

Part used.—Root (official).

Stonecrop, ditch-. See *Penthorum sedoides.*

Stonecrop, Virginia. See *Penthorum sedoides.*

Stonemint. See *Cunila origanoides.*

Stone-oak. See *Quercus alba.*

Stoneroot. See *Collinsonia canadensis.*

Stramonium. See *Datura stramonium.*

Strawberry, scarlet. See *Fragaria virginiana.*

Strawberry, Virginia. See *Fragaria virginiana.*

Strawberry-shrub, hairy. See *Butneria florida.*

Stylosanthes biflora (L.) B. S. P. **Pea family (Fabaceae).**

Synonym.—*Stylosanthes elatior* Sw.

Pencil-flower; afterbirth-weed.

Wiry, perennial herb, 6 inches to 2 feet in height, native; occurring in dry soil from New York to Florida, west to the Indian Territory.

Part used.—Herb (nonofficial).

Stylosanthes elatior Sw. Same as *Stylosanthes biflora.*

Succory. See *Cichorium intybus.*

Sumac, fragrant. See *Rhus aromatica.*

Sumac, mountain-. See *Sorbus americana.*

Sumac, scarlet. See *Rhus glabra.*

Sumac, smooth. See *Rhus glabra.*

Sumac, sweet-scented. See *Rhus aromatica.*

Summer-savory. See *Satureia hortensis.*

Sundew, round-leaved. See *Drosera rotundifolia.*

Sunflower, swamp-. See *Helenium autumnale.*

Swamp squaw-weed. See *Senecio aureus.*

Swamp willow-herb. See *Epilobium palustre.*

Swamp-cabbage. See *Spathyema foetida.*

Swamp-dogwood. See *Cornus amomum.*

Swamp-hellebore. See *Veratrum viride.*

Swamp-laurel. See *Magnolia virginiana.*

Swamp-maple. See *Acer rubrum.*

Swamp-milkweed. See *Asclepias incarnata.*

Swamp-sassafras. See *Magnolia virginiana.*

Swamp-silkweed. See *Asclepias incarnata.*

Swamp-sunflower. See *Helenium autumnale.*

Swamp-willow. See *Salix nigra.*

Sweatweed. See *Althaea officinalis.*

Sweet-cicely. See *Washingtonia longistylis.*

Sweet-flag. See *Acorus calamus.*

Sweet-gum. See *Liquidambar styraciflua.*

Sweetroot. See *Polemonium reptans.*

Symphytum officinale L. **Borage family (Boraginaceae).**

Comfrey; healing-herb; blackwort; bruisewort.

Erect, perennial herb, 2 to 3 feet high, naturalized from Europe; found in waste places, Newfoundland to Minnesota, south to Maryland.

Part used.—Root (nonofficial).

Symplocarpus foetidus Nutt. Same as *Spathyema foetida.*

Tag-alder. See *Alnus rugosa.*

Tamarack. See *Larix laricina.*

Tanacetum. See *Tanacetum vulgare.*

Tanacetum vulgare L. **Aster family (Asteraceae).**

Tanacetum; tansy; double tansy; bitter-buttons; parsley-fern.

Strong-scented, perennial herb, $1\frac{1}{2}$ to 3 feet high, introduced from Europe; escaped from cultivation and found along roadsides from Nova Scotia to Minnesota, south to North Carolina and Missouri.

Parts used.—Leaves and flowering tops (official in U. S. P. 1890).

Tanbark-tree. See *Tsuga canadensis.*

Tansy. See *Tanacetum vulgare.*

Tansy, double. See *Tanacetum vulgare.*

Taraxacum. See *Taraxacum officinale.*

Taraxacum officinale Weber.[a] **Chicory family (Cichoriaceae).**

Synonym.—Taraxacum taraxacum (L.) Karst.[a]

Taraxacum; dandelion; blowball; cankerwort.

Low, perennial weed, 5 to 10 inches high, naturalized from Europe; very abundant in lawns, meadows, and waste places throughout the United States, with the exception of the South.

Part used.—Root, collected in autumn (official).

Taraxacum taraxacum (L.) Karst. Same as *Taraxacum officinale.*

Tea, continental. See *Ledum groenlandicum.*

Tea, James-. See *Ledum groenlandicum.*

Tea, Jersey. See *Ceanothus americanus.*

Tea, Jerusalem. See *Chenopodium ambrosioides.*

Tea, Labrador. See *Ledum groenlandicum.*

Tea, Mexican. See *Chenopodium ambrosioides.*

Tea, mountain-. See *Gaultheria procumbens.*

Tea, New Jersey. See *Ceanothus americanus.*

Tea, Oswego. See *Monarda didyma.*

Tea, Spanish. See *Chenopodium ambrosioides.*

Teaberry. See *Gaultheria procumbens.*

Tephrosia virginiana Pers. Same as *Cracca virginiana.*

Tetterwort. See *Chelidonium majus* and *Sanguinaria canadensis.*

Thimbleberry. See *Rubus occidentalis.*

[a] Although the combination *Taraxacum taraxacum* (L.) Karst. should be accepted by right of priority, the usage of the Pharmacopœia is followed.

Thimbles. See *Digitalis purpurea.*

Thimbleweed. See *Rudbeckia laciniata.*

Thistle, bitter. See *Cnicus benedictus.*

Thistle, blessed. See *Cnicus benedictus.*

Thistle, Canada. See *Carduus arvensis.*

Thistle, creeping. See *Carduus arvensis.*

Thistle, cursed. See *Carduus arvensis.*

Thistle, holy. See *Cnicus benedictus.*

Thistle, St. Benedict's-. See *Cnicus benedictus.*

Thistle, spotted. See *Cnicus benedictus.*

Thorn-apple. See *Datura stramonium.*

Thoroughwort. See *Eupatorium perfoliatum.*

Thousandleaf. See *Achillea millefolium.*

Throwwort. See *Leonurus cardiaca.*

Thuja occidentalis L. Pine family (**Pinaceae**).

Arbor-vitae; white cedar; yellow cedar.

Indigenous, evergreen tree, 20 to 50 feet in height; in wet soil and along banks of streams, Canada to North Carolina, Illinois, and Minnesota. Especially abundant in Canada and the Northern States.

Parts used.—Branchlets and leaves (nonofficial).

Tiarella cordifolia L. Saxifrage family (**Saxifragaceae**).

Coolwort; false miterwort; foamflower; gemfruit.

Slender, indigenous perennial, 6 to 12 inches high, found in rich, moist woods, Nova Scotia to Minnesota, south, especially along the mountains, to Georgia and Indiana.

Part used.—Herb (nonofficial).

Tickweed. See *Hedeoma pulegioides.*

Tilia americana L. Linden family (**Tiliaceae**).

Synonym.—*Tilia glabra* Vent.

Basswood; American linden; whitewood.

Large, indigenous forest tree, 60 to 125 feet in height; in rich woods, especially along the mountains, from Canada to Georgia, west to Texas and Nebraska.

Part used.—Inflorescence of this and of other species of Tilia (nonofficial).

Tilia glabra Vent. Same as *Tilia americana.*

Tinker's-weed. See *Triosteum perfoliatum.*

Tobacco, Indian. See *Lobelia inflata.*

Toothache-tree. See *Fagara clava-herculis* and *Xanthoxylum americanum.*

Touch-me-not, pale. See *Impatiens aurea.*

Touch-me-not, spotted. See *Impatiens biflora.*

Toywort. See *Bursa bursa-pastoris.*

Tree-primrose. See *Oenothera biennis.*

Trefoil, marsh-. See *Menyanthes trifoliata.*

Trefoil, shrubby. See *Ptelea trifoliata.*

Trefoil, sour. See *Oxalis acetosella.*

Trifolium pratense L. Pea family (**Fabaceae**).

Red clover; meadow-clover; purple clover.

Perennial herb, 6 inches to 2 feet high; common in fields and meadows throughout the eastern United States; naturalized from Europe, and widely cultivated.

Part used.—Blossoms (nonofficial).

Trilisa odoratissima (Walt.) Cass. **Aster family (Asteraceae).**

Synonym.—Liatris odoratissima Michx.

Vanilla-plant; deer's-tongue; vanilla-leaf; Carolina vanilla.

Rather stout, native, perennial herb, 2 to 3 feet high, with fragrant leaves; in pine barrens from Virginia south to Florida and Louisiana.

Part used.—Leaves (nonofficial).

Trillium erectum L. **Lily-of-the-valley family (Convallariaceae).**

Wake-robin; ill-scented bethroot; birthroot; squawflower.

Stout, native perennial, 8 to 16 inches high, growing in rich soil in damp, shady woods from Canada south to Tennessee and Missouri.

Part used.—Rhizome of this and of several other species of Trillium (nonofficial).

Triosteum perfoliatum L. **Honeysuckle family (Caprifoliaceae).**

Feverroot; horse-gentian; tinker's-weed; white gentian; wild ipecac.

Indigenous, perennial herb, 2 to 4 feet high; in rich soil in shady locations, Quebec to Minnesota, south to Alabama and Kansas.

Part used.—Root (nonofficial).

Triticum. See *Agropyron repens.*

Triticum repens Beauv. Same as *Agropyron repens.*

Trumpetleaf. See *Sarracenia flava.*

Trumpet-milkweed. See *Lactuca canadensis.*

Trumpets. See *Sarracenia flava.*

Tsuga canadensis (L.) Carr. **Pine family (Pinaceae).**

Synonym.—Abies canadensis Michx.

Hemlock; hemlock-spruce; weeping spruce; tanbark-tree.

Indigenous tree, about 75 feet in height, in forests from Canada south to Alabama and Wisconsin.

Parts used.—Bark and prepared resinous exudate (nonofficial).

Tulip-poplar. See *Liriodendron tulipifera.*

Tulip-tree. See *Liriodendron tulipifera.*

Tupelo gum. See *Nyssa aquatica.*

Tupelo, large. See *Nyssa aquatica.*

Tupelo, sour. See *Nyssa ogeche.*

Turkey-corn. See *Bikukulla canadensis.*

Turkey-pea. See *Bikukulla canadensis.*

Turnera aphrodisiaca Ward. Same as *Turnera microphylla.*

Turnera microphylla Desv. **Turnera family (Turneraceae).**

Synonym.—Turnera aphrodisiaca Ward.

Damiana.

A small, shrubby plant, native of Lower California, Texas, and northern Mexico, growing in dry soil.

Part used.—Leaves (nonofficial).

Turnip, Indian. See *Arisaema triphyllum.*

Turnip, wild. See *Arisaema triphyllum.*

Turtle-head. See *Chelone glabra.*

Tussilago farfara L. **Aster family (Asteraceae).**

Colt's-foot; coughwort; horsefoot; gingerroot.

Perennial herb, 3 to 18 inches high, naturalized from Europe; in moist places along roadsides and brooks, northeastern United States and Minnesota to Canada.

Parts used.—Leaves and root (nonofficial).

Twinleaf. See *Jeffersonia diphylla.*

Typha latifolia L. **Cattail family (Typhaceae).**

Broad-leaved cattail; cattail-flag; bulrush.

Native marsh plant, perennial, 4 to 8 feet high; found in marshes, ditches, muddy pools, and other wet places throughout North America, except extreme northern part.

Part used.—Root (nonofficial).

Ulmus. See *Ulmus fulva.*

Ulmus fulva Michx. **Elm family (Ulmaceae).**

Synonym.—*Ulmus pubescens* Walt.

Ulmus; elm; slippery elm; red elm; moose-elm; Indian elm.

Indigenous tree, 50 to 60 feet high, growing on hills, along streams and in woods from Quebec to North Dakota, south to Florida and Texas. More common in the western part of its range.

Part used.—Bark deprived of its periderm (official).

Ulmus pubescens Walt. Same as *Ulmus fulva.*

Umbrella-tree. See *Magnolia tripetala.*

Unicorn-root, false. See *Aletris farinosa.*

Unicorn-root, true. See *Chamaelirium luteum.*

Upland-cranberry. See *Arctostaphylos uva-ursi.*

Urtica dioica L. **Nettle family (Urticaceae).**

Stinging nettle; great nettle.

Herbaceous, perennial plant, 2 to 4 feet high, with stinging hairs; naturalized from Europe and found in waste places from Canada and Minnesota south to South Carolina and Missouri.

Parts used.—Flowers, leaves, and root (nonofficial).

Uva-ursi. See *Arctostaphylos uva-ursi.*

Uvedalia. See *Polymnia uvedalia.*

Uvularia perfoliata L. **Bunchflower family (Melanthiaceae).**

Perfoliate bellwort; Mohawk-weed.

Native, perennial herb, 6 to 20 inches high; in moist woods and thickets, Quebec to Florida and Mississippi.

Part used.—Root (nonofficial).

Vagnera racemosa (L.) Morong. **Lily-of-the-valley family (Convallariaceae).**

Synonyms.—*Convallaria racemosa* L.; *Smilacina racemosa* Desf.

False Solomon's-seal; small Solomon's-seal; wild spikenard; false spikenard.

Indigenous, perennial herb, 1 to 3 feet high, found in moist woods and thickets from Canada south to Georgia and Arizona.

Part used.—Root (nonofficial).

Valerian. See *Valeriana officinalis.*

Valerian, American. See *Cypripedium hirsutum.*

Valerian, American Greek. See *Polemonium reptans.*

Valerian, garden-. See *Valeriana officinalis.*

Valeriana. See *Valeriana officinalis.*

Valeriana officinalis L. **Valerian family (Valerianaceae).**

Valeriana; valerian; garden-valerian; vandal-root.

Perennial herb, 2 to 5 feet high, native of Europe; escaped from gardens to roadsides in New York and New Jersey.

Parts used.—Rhizome and roots (official).

Vandal-root. See *Valeriana officinalis.*

Vanilla, Carolina. See *Trilisa odoratissima.*

Vanilla-leaf. See *Trilisa odoratissima.*

Vanilla-plant. See *Trilisa odoratissima.*

Velvet-plant. See *Verbascum thapsus.*

Veratrum. See *Veratrum viride.*

Veratrum viride Ait. **Bunchflower family (Melanthiaceae).**

Veratrum; American hellebore; swamp-hellebore; green hellebore.

Native, perennial herb, 2 to 7 feet high, growing in swamps, wet woods, and meadows, Canada and Alaska, Minnesota south to Georgia.

Parts used.—Rhizome and roots of this or *V. album* (official).

Verbascum thapsus L. **Figwort family (Scrophulariaceae).**

Mullein; velvet dock; velvet-plant; flannel-leaf.

Tall, erect, biennial weed, sometimes 7 feet in height; naturalized from Europe and growing in fields, pastures, and waste places, Nova Scotia to Minnesota, southward to Florida.

Parts used.—Leaves and flowers (nonofficial).

Verbena hastata L. **Vervain family (Verbenaceae).**

Vervain; simpler's-joy; wild hyssop.

Erect, indigenous perennial, 3 to 4 feet high, found in fields, meadows, and waste places, Canada to Nebraska, New Mexico, and Florida.

Parts used.—Root and herb (nonofficial).

Veronica officinalis L. **Figwort family (Scrophulariaceae).**

Common speedwell; Paul's-betony.

Perennial herb, 3 to 10 inches high; in dry fields and woods, Nova Scotia to Michigan, south to North Carolina and Tennessee.

Part used.—Herb (nonofficial).

Veronica, tall. See *Veronica virginica.*

Veronica virginica L.[a] **Figwort family (Scrophulariaceae).**

Synonym.—*Leptandra virginica* (L.) Nutt.[a]

Leptandra; Culver's-root; Culver's-physic; blackroot; Bowman's-root; tall speedwell; tall veronica.

Indigenous, perennial plant, 2 to 5 feet high, in moist, rich ground in woods, meadows, and thickets from Canada to Alabama and Nebraska.

Parts used.—Rhizome and roots (official).

Vervain. See *Verbena hastata.*

Viburnum dentatum L. **Honeysuckle family (Caprifoliaceae).**

Arrowwood; mealy-tree.

Smooth, indigenous shrub, about 15 feet in height, growing on low ground and in damp woods and thickets from New Brunswick and Ontario south along the mountains to Georgia, and westward to Minnesota.

Part used.—Bark (nonofficial).

Viburnum lentago L. **Honeysuckle family (Caprifoliaceae).**

Nannybush; sheepberry; sweet viburnum.

An indigenous shrub, sometimes a small tree; in rich soil from Canada to Georgia and Missouri.

Part used.—Bark of the root of this species or of *V. prunifolium* official under the name "Viburnum prunifolium."

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[a] Some authors hold that this plant belongs to the genus Leptandra and that its name should be *Leptandra virginica* (L.) Nutt. The Pharmacopœia is here followed.

Viburnum opulus. See *Viburnum opulus* L.

Viburnum opulus L. **Honeysuckle family** (**Caprifoliaceae**).

Viburnum opulus; cramp-bark; high-bush cranberry; squawbush.

Indigenous shrub, 4 to 10 feet in height, found in low, rich woods and borders of fields from New Jersey, Michigan, and Oregon, northward.

Part used.—Bark (official).

Viburnum prunifolium. See *Viburnum lentago* and *V. prunifolium* L.

Viburnum prunifolium L. **Honeysuckle family** (**Caprifoliaceae**).

Black haw; sloe; stagbush.

Indigenous shrub or small tree, growing in dry woods and thickets and on rocky hillsides, Connecticut to Florida, west to Michigan and Texas. Most abundant in the South.

Part used.—Bark of the root of this species or of *V. lentago* official under the name "Viburnum prunifolium."

Viburnum, sweet. See *Viburnum lentago.*

Vine-maple. See *Menispermum canadense.*

Viola odorata L. **Violet family** (**Violaceae**).

English violet; sweet violet; March violet.

Low herb, native of Europe; escaped from gardens, Nova Scotia to New York and New Jersey, and on the Pacific coast.

Part used.—Flowers (nonofficial).

Viola pedata L. **Violet family** (**Violaceae**).

Bird's-foot violet; wood-violet; snake-violet.

Native plant, perennial, 3 to 10 inches high, occurring in dry fields and on hillsides from Maine to Minnesota, south to Florida and Missouri.

Parts used.—Herb and root (nonofficial).

Viola tricolor L. **Violet family** (**Violaceae**).

Pansy; heartsease.

Small herb, 4 to 12 inches high, introduced from Europe; found in waste places, sparingly escaped from gardens.

Part used.—Flowering herb (nonofficial).

Violet, bird's-foot. See *Viola pedata.*

Violet, dog's-tooth. See *Erythronium americanum.*

Violet, English. See *Viola odorata.*

Violet, March. See *Viola odorata.*

Violet, rattlesnake-. See *Erythronium americanum.*

Violet, snake-. See *Viola pedata.*

Violet, sweet. See *Viola odorata.*

Violet, wood-. See *Viola pedata.*

Violet-bloom. See *Solanum dulcamara.*

Virginia creeper. See *Parthenocissus quinquefolia.*

Virgin's-bower. See *Clematis virginiana.*

Viscum flavescens Pursh. Same as *Phoradendron flavescens.*

Vomitwort. See *Lobelia inflata.*

Wafer-ash. See *Ptelea trifoliata.*

Wahoo. See *Euonymus atropurpureus.*

Wake-robin. See *Arisaema triphyllum* and *Trillium erectum.*

Walnut, white. See *Juglans cinerea.*

Wartwort. See *Gnaphalium uliginosum.*

Washingtonia longistylis (Torr.) Britton. **Parsley family (Apiaceae).**

Synonym.—*Osmorrhiza longistylis* DC.

Sweet-cicely; anise-root; sweet chervil.

Erect, rather stout, perennial herb, 2 to 3 feet high, native; in rich, moist woods and banks of streams from Canada to Alabama and Texas.

Part used.—Root (nonofficial).

Water-avens. See *Geum rivale.*

Water-bugle. See *Lycopus virginicus.*

Watercup. See *Sarracenia flava* and *S. purpurea.*

Watercup, yellow-flowered. See *Sarracenia flava.*

Water-eryngo. See *Eryngium yuccifolium.*

Water-flag. See *Iris versicolor.*

Water-hemlock. See *Cicuta maculata.*

Water-hoarhound. See *Lycopus virginicus.*

Water-lily. See *Castalia odorata.*

Water-lily, sweet-scented. See *Castalia odorata.*

Water-pepper. See *Polygonum hydropiper.*

Water-shamrock. See *Menyanthes trifoliata.*

Water-smartweed. See *Polygonum punctatum.*

Waxberry. See *Myrica cerifera.*

Wax-myrtle. See *Myrica cerifera.*

Waxwork. See *Celastrus scandens.*

Waythorn. See *Rhamnus cathartica.*

White-bark. See *Populus alba.*

Whiteroot. See *Asclepias tuberosa.*

Whitethorn. See *Crataegus oxyacantha.*

Whitewood. See *Liriodendron tulipifera* and *Tilia americana.*

Wickopy. See *Dirca palustris.*

Wickup. See *Chamaenerion angustifolium* and *Epilobium palustre.*

Willow, black. See *Salix nigra.*

Willow, European. See *Salix alba.*

Willow, pussy-. See *Salix nigra.*

Willow, rose-. See *Cornus amomum.*

Willow, swamp-. See *Salix nigra.*

Willow, white. See *Salix alba.*

Willow-herb, great. See *Chamaenerion angustifolium.*

Willow-herb, night. See *Oenothera biennis.*

Willow-herb, swamp. See *Epilobium palustre.*

Wingseed. See *Ptelea trifoliata.*

Winterberry, Virginia. See *Ilex verticillata.*

Winterbloom. See *Hamamelis virginiana.*

Wintergreen. See *Gaultheria procumbens.*

Wintergreen, bitter. See *Chimaphila umbellata.*

Witch-hazel. See *Hamamelis virginiana.*

Woodbine, wild. See *Gelsemium sempervirens.*

Wood-fern, evergreen. See *Dryopteris marginalis.*

Wood-sorrel, white. See *Oxalis acetosella.*

Wood-violet. See *Viola pedata.*

Worm-grass. See *Spigelia marilandica.*

Wormseed. See *Chenopodium anthelminticum.*

Wormseed, American. See *Chenopodium ambrosioides.*

Wormwood. See *Artemisia absinthium.*

Wormwood, Roman. See *Ambrosia artemisiaefolia.*

Xanthium spinosum L. **Ragweed family (Ambrosiaceae).**

Spiny clotbur; spiny burseed; thorny clotweed; thorny burweed.

An annual weed, 1 to 3 feet high, naturalized from Europe or Asia; in waste ground, Ontario to Florida, westward to Missouri and Texas.

Part used.—Leaves (nonofficial).

Xanthorrhiza apiifolia L'Her. **Crowfoot family (Ranunculaceae).**

Shrub yellowroot; southern yellowroot.

Low, shrubby, indigenous perennial, 1 to 2 feet high, growing in woods and along river banks, southwestern New York to Florida, chiefly in the mountains.

Parts used.—Rhizome and roots (nonofficial).

Xanthoxylum. See *Fagara clava-herculis* and *Xanthoxylum americanum.*

Xanthoxylum americanum Mill. **Rue family (Rutaceae).**

Synonym.—*Xanthoxylum fraxineum* Willd.

Xanthoxylum; northern prickly ash; toothache-tree.

Indigenous shrub or small tree, maximum height about 25 feet; common in woods and thickets and along river banks from Virginia, Missouri, and Nebraska northward to Canada.

Parts used.—Bark of this or of *Fagara clava-herculis* official under the name "Xanthoxylum." Berries (nonofficial).

Xanthoxylum clava-herculis L. Same as *Fagara clava-herculis.*

Xanthoxylum fraxineum Willd. Same as *Xanthoxylum americanum.*

Yam, wild. See *Dioscorea villosa.*

Yarrow. See *Achillea millefolium.*

Yellowroot. See *Coptis trifolia, Hydrastis canadensis,* and *Jeffersonia diphylla.*

Yellowroot, shrub. See *Xanthorrhiza apiifolia.*

Yellowroot, southern. See *Xanthorrhiza apiifolia.*

Yellowthorn. See *Fagara clava-herculis.*

Yellowwood. See *Fagara clava-herculis.*

Yerba buena. See *Micromeria chamissonis.*

Yerba reuma. See *Frankenia grandifolia.*

Yerba santa. See *Eriodictyon californicum.*

Youthwort. See *Drosera rotundifolia* and *Heracleum lanatum.*

O

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART I.

B. T. GALLOWAY, *Chief of Bureau.*

THE STORAGE AND GERMINATION OF WILD RICE SEED.

BY

J. W. T. DUVEL,

ASSISTANT IN THE SEED LABORATORY.

ISSUED SEPTEMBER 7, 1905.

WASHINGTON:

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1905.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY OF THE UNIT[ED] STATES DEPARTMENT OF AGRICULTURE.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate Divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug, Tea, and Poisonous Plant Investigations; the Seed Laboratory; and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

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[W]ASHINGTON, D. C., *September 8, 1905.*

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THE STORAGE AND GERMINATION OF WILD RICE SEED.[a]

INTRODUCTION.

The seed of wild rice, sometimes called Indian rice or water oats (*Zizania aquatica* L.), has always been a very valuable food among the Indians, especially those of the upper Mississippi Valley. Of recent years wild rice has found a place on the menu cards of some of our best American hotels. The rich and highly nutritious grains, together with the slightly smoky flavor it has when properly prepared, make it an extremely palatable article of diet. If it were not for the difficulties of harvesting the seed and preparing the finished product for market it is probable that wild rice would find a place in many American homes.

At present, however, the greatest interest in wild rice is created by the value of the seed as a food for wild waterfowl, particularly wild ducks. As a result of this interest the propagation of wild rice from seed has become a question of considerable importance, especially to the members of the gunning clubs throughout the United States and Canada.

DISTRIBUTION.

The distribution of wild rice is now reported from New Brunswick and Assiniboia south to Florida, Louisiana, and Texas. There are, however, comparatively few localities in which it grows abundantly.

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[a] Wild rice is considered one of the most important foods for wild ducks and other waterfowl, and a large number of inquiries have been received from members of gunning clubs throughout the United States asking where good, germinable seed can be secured. It is quite generally recognized that wild rice seed loses its vitality if allowed to become dry, and better methods of storing the seed during the winter have long since been demanded.

The results of investigations begun two years ago show that wild rice seed can be handled without any deterioration in vitality if it is harvested and stored according to methods outlined in the present paper.

J. W. T. Duvel, *Acting Botanist in Charge of Seed Laboratory.*

Seed Laboratory,
Washington, D. C., July 20, 1905.

Good reasons exist for assuming that this area can be extended to include all fresh-water lakes, as well as swamps and river bogs, where the water does not become stagnant, throughout the whole of North America south of latitude 55° north. Wild rice also grows luxuriantly along the lower parts of many of the rivers of the Atlantic Coast States, the waters of which are affected by the action of the tide to a considerable degree, and consequently contain an appreciable quantity of salt. It has been shown[a] that the maximum degree of concentration of salt water in which wild rice plants can grow successfully is equivalent to a 0.03 normal solution of sodium chlorid. This concentration corresponds to 0.1755 per cent by weight of sodium chlorid, which is sufficient to give a slight salty taste to the water.

HABITAT.

While it is well recognized that the habitat of the wild rice plant is in shallow fresh water, it is now known that it will grow luxuriantly in water containing little less than two-tenths of 1 per cent of sodium chlorid. Occasional plants have been found growing in water which contained, for short periods at least, nearly double that amount of salt. These facts indicate the possibility of a much wider range of conditions to which this plant may be subjected without hindering its development. It is not beyond the range of possibility—indeed, it is quite probable—that by careful selection plants may be obtained which will thrive on soil that is comparatively dry, at least in places in which the water can be drawn off gradually during the latter part of the growing season.

In September, 1904, Mr. G. C. Worthen, of the Bureau of Plant Industry, collected a cluster of wild rice plants which were growing on the Potomac Flats, near Washington, D. C., in soil which was sufficiently dry to permit the use of a 2-horse mowing machine for cutting down the rank growth of vegetation. This was newly made land, and in all probability the seed giving rise to this cluster of plants was pumped in with the dirt from the Potomac River the year previous.

This amphibious type once established, it will undoubtedly carry with it a strain of seed which can withstand considerable drying without any marked injury to its vitality. Such being true, the methods and difficulties of propagation from seed would be greatly simplified.

Simultaneous with establishing an amphibious type should come the selection of seed plants which are capable of retaining their seed until the larger part of it has reached maturity. These two steps once made, the future of wild rice as a cereal will be assured.

[a] The Salt Water Limits of Wild Rice. Bulletin No. 72, Part II, Bureau of Plant Industry, United States Department of Agriculture, 1905.

GERMINATION OF THE SEED.

The greatest difficulty to be overcome in extending the area for growing wild rice is the poor germination of the commercial seed. Inasmuch as wild rice constitutes one of the most important foods of wild ducks and other wild waterfowl, many individuals and most of the gunning clubs east of the Rocky Mountains have been asking the question, How can we propagate wild rice from seed in order to establish better feeding and fattening grounds for our game birds?

The many failures in the propagation of wild rice from seed have been due to the use of seed that had become dry before sowing, or to the fact that the seed when sown fresh in the autumn had been eaten by ducks or other animals or was carried away by heavy floods before germination took place.

It is now very generally known that the seed of wild rice, if once allowed to become dry, will not germinate, save possibly an occasional grain. In its natural habitat the seed, as soon as mature, falls into the water and sinks into the mud beneath, where it remains during the winter months, germinating the following spring if conditions are favorable.

Heretofore the plan generally followed, and the one usually recommended by those who have given some attention to the propagation of wild rice, was practically that of natural seeding; that is, to gather the seed in the autumn, as soon as thoroughly mature, and, while still fresh, to sow it in 1 to 3 feet of water.

FALL SEEDING VERSUS SPRING SEEDING.

It must be remembered that the bulk of the seed remains dormant during the winter, germinating first the spring after maturing; consequently, with but few exceptions, fall seeding is unsatisfactory and unreliable. Fall seeding is likely to prove a failure for three reasons: (1) Wild ducks and other animals of various kinds eat or destroy the seed in considerable quantity before it has had time to germinate the following spring; (2) much of the seed is frequently covered so deeply with mud that washes in from the shore during the winter that the young plants die of suffocation and starvation before they reach the surface; (3) in some cases a large quantity of the seed is carried away from the place where sown by the high waters and floating ice prevalent during the latter part of the winter and early spring.

In exceptional cases these difficulties can be overcome; under which circumstances autumn sowing may be preferable to spring sowing. In the majority of cases, however, much better results will be obtained if the seed is properly stored and sown in the early spring, as soon as the danger of heavy floods is passed and the water level approaches normal.

In sowing the seed considerable care must be exercised in selecting a suitable place, securing the proper depth of water, etc. Good results can be expected if the seed is sown in from 1 to 3 feet of water which is not too stagnant or too swiftly moving, with a thick layer of soft mud underneath.[a] It is useless to sow wild rice seed on a gravelly bottom or in water where the seed will be constantly disturbed by strong currents.

Previous to this time, save in a few reported cases, the seed which was allowed to dry during the winter and was sown the following spring gave only negative results. It is now definitely known that wild rice, if properly handled, can be stored during the winter without impairing the quality of germination to any appreciable degree, and that it can be sown the following spring or summer with good success.

DIRECTIONS FOR STORING THE SEED.

The vitality of wild rice seed is preserved almost perfectly if kept wet in cold storage—Nature's method of preservation. This method of storage implies that the seed has been properly harvested and cared for up to the time of storage. The seed should be gathered as soon as mature, put loosely into sacks (preferably burlap), and sent at once to the cold-storage rooms. If the wild rice fields are some distance from the cold-storage plant the sacks of seed should be sent by express, and unless prompt delivery can be guaranteed it is not advisable to send by freight even for comparatively short distances. It is very important that the period between the time of harvesting and the time when the seed is put into cold storage be as short as possible. If this time is prolonged to such an extent as to admit of much fermentation or to allow the seed near the outside of the bags to become dry during transit, its vitality will be greatly lowered.

It is not practicable to give any definite length of time which may elapse between harvesting and storing, inasmuch as the temperature, humidity, and general weather conditions, as well as the methods of handling the seed, must be taken into consideration. Let it suffice to say, however, that the vitality of the seed will be the stronger the sooner it is put into cold storage after harvesting.

As soon as the seed is received at the cold-storage plant, while it is still fresh and before fermentation has taken place, it should be put into buckets, open barrels, or vats, covered with fresh water, and placed at once in cold storage. If there is present a considerable quantity of light immature seed or straw, broken sticks, etc., it will be profitable to separate this from the good seed by floating in water

[a] Wild Rice: Its Uses and Propagation. Bulletin No. 50, Bureau of Plant Industry, United States Department of Agriculture, 1903.

preparatory to storing. The storage room should be maintained at a temperature just above freezing—what the storage men usually designate as the "chill room."

When taken from cold storage in the spring the seed must not be allowed to dry out before planting, as a few days' drying will destroy every embryo.

Seed which was stored under the foregoing conditions from October 19, 1903, to November 15, 1904, 393 days, germinated from 80 to 88 per cent. Another lot of seed, which was stored on October 6, 1904, and tested for vitality on April 17, 1905, germinated 79.8 per cent.

Plate I shows the luxuriant growth made by the seed which was kept wet and stored at a temperature of 32° to 34° F. for 393 days.

DETAILED CONDITIONS AND RESULTS OF STORAGE EXPERIMENTS.

The foregoing conclusions are based on the results obtained from two series of experiments, as follows:

In October, 1903, a box of wild rice seed was received from Ontario, Canada. This seed, as soon as gathered, was loosely packed in moist sphagnum and sent by express to the Seed Laboratory of the United States Department of Agriculture. After a few days, while it was yet moist and before any fermentation had taken place, the seed was divided into four lots for special treatment, as follows:

(1) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F.

(2) Seed submerged in water and placed in cold storage at a temperature of 12° F. The seed was soon embedded in a solid mass of ice and remained so until samples were taken for test.

(3) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 32° to 34° F.

(4) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 12° F.

In October, 1904, a second consignment of seed was received from Minnesota, and the following additional storage experiments were made by Mr. C. S. Scofield, of the Bureau of Plant Industry.

(5) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F., as in No. 1.

(6) Seed submerged in water and placed in cold storage at a temperature of 12° F., as in No. 2.

(7) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building. The water was changed daily when not frozen.

(8) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building, as in No. 7. In this case the water was not changed save to replace the loss due to evaporation.

(9) The conditions for No. 9 were the same as those for No. 8, except that air was forced into the water daily when not frozen solid.

Samples of seed were taken from the different lots and tested for vitality at irregular intervals throughout the time of storage, which, in the former series, extended over a period approximately thirteen months and in the latter series over a period of little more than six months.

Experiments Nos. 1 and 5.—The seed which was submerged in water and stored in the "chill room" showed no deterioration in vitality. The results of the final tests gave a germination varying from 79.8 to 88 per cent. This is practically Nature's method of preserving the vitality of the seed during the winter.

Experiments Nos. 2 and 6.—The seed which was submerged in water and stored at a temperature of 12° F. was all killed before the spring following the date of storage. Soon after being placed in storage the water was frozen solid and the seeds were embedded in a mass of ice, in which condition they remained throughout the experiment, a portion being cut out from time to time for germination tests. The complete loss of vitality in these two lots of seed is attributed not to the freezing directly, but to the thorough desiccation as a result of the continuous low temperature.

Experiments Nos. 3 and 4.—The samples of seed which were stored in cloth bags at the temperatures of 32° to 34° F. and of 12° F. had, for all economic purposes, entirely lost their vitality. The average percentage of germination, as shown by the 37 tests made from each of the two lots, was less than five-tenths of 1 per cent.

Experiment No. 7.—The seed which was submerged in water and stored on the roof of the laboratory building, the water being changed daily, showed a good percentage of germination when the last vitality tests were made. If only a small quantity of seed is desired for the spring planting and cold storage can not be readily secured, good results may be obtained by this treatment; but it is much less certain and probably more expensive than keeping the seed in cold storage, and for this reason is not recommended. The success of this method will likewise depend largely on the temperature of the water.

Experiments Nos. 8 and 9.—On April 22, 1905, samples taken from each of these two lots of seed showed a marked deterioration in vitality. Thoroughly mixed samples from No. 8 showed a vitality of only 58 per cent, while No. 9 had deteriorated to 14.3 per cent.

PACKING FOR TRANSPORTATION.

Too much care can not be given to the matter of packing the seed for transportation, for unless the packing is properly done the vitality of the seed will be destroyed during transit. What is here said applies to fresh seed which is to be sown in the autumn, as well as to seed which has been kept in cold storage during the winter. It must not be forgotten, however, that the vitality of cold-storage seed is more quickly destroyed on drying than that of fresh seed.

For transportation the seed should be carefully packed, with moist sphagnum, cocoanut fiber, or fine excelsior, in a loosely slatted box. If the time of transportation does not exceed five or six days no special precautions need be taken as to the temperature. During the period of transportation it is quite probable that some of the seed will germinate, but if sown at once growth will not be retarded and the roots will soon penetrate the soil and anchor the young plants.

If the time of transportation is necessarily long, it is recommended, if the best results are desired, that some provision be made for a reduced temperature. The nearer the temperature approaches that of freezing the better. It has been demonstrated, however, that a fair percentage of seed will remain germinable for a considerable time if packed as above described.

On October 10, 1904, Mr. C. S. Scofield sent a small quantity of wild rice, packed in moist sphagnum moss in a well-ventilated box, to Doctor De Vries, of Amsterdam, Holland. On October 14 or 15 this box was placed in cold storage on the steamer in New York Harbor. The box of seed was received by Doctor De Vries in good condition on November 2, twenty-one days after the seed was packed for shipment.

METHODS OF MAKING GERMINATION TESTS.

The samples were tested (1) between folds of blotting paper—our regular method for testing the germination of most seeds—and (2) in water, Nature's method of sowing wild rice seed. The latter method gave much better results and was the one finally adopted for the laboratory tests. The seed should be covered with water, the water in the dishes to be changed daily.

Plate I shows the importance of making the germination tests in water, as described in the foregoing paragraph. The seed was covered with water and placed in a germinating chamber maintained at an alternating temperature of 20° C. (68° F.) for eighteen hours, and 30° C. (84° F.) for six hours, until the majority of the seeds had germinated. At this stage the dish containing the seeds was transferred to the worktable, which was exposed to the temperature of the laboratory—approximately that of a living-room. The water in the dish was changed daily during the period of germination, and water was afterwards added at irregular intervals to replace the loss by evaporation.

Plate II shows somewhat in detail the different stages in the germination of wild rice seeds. The seeds and seedlings are shown in natural size. In *b* and *c* the first sheath has just burst through the seed coats, taking a position at right angles to the seed proper. The lateral roots begin to emerge when the first sheath leaf has attained a length of ½ to 1½ inches. From this time growth continues rapidly, and by the time the seedlings are 2 or 3 inches long the root system is very well developed (*f* and *g*). At this stage under favorable conditions the plants have a good hold in the soil and will not be washed away by an ordinary freshet. The relative position of the actively growing seedling is always at right angles to that of the old seed, as shown in *f* and *g*.

EFFECT OF TEMPERATURE ON GERMINATION.

Germination tests were made at constant and alternating temperatures, ranging from 15° to 35° C. (59° to 95° F.). While no effort was made to show the minimum and maximum temperatures of germination, the percentage was somewhat reduced at a constant temperature of 35° C., and the maximum is not much above that. All of the other temperatures gave good results. The lower temperatures, however, were slightly more favorable than the higher. These facts are valuable to show that the wild rice plant can thrive in either warm or cold water, but better, perhaps, in northern than in southern latitudes.

SUMMARY.

(1) Under no circumstances should wild rice seed which is intended for planting be allowed to dry. Dried seed will germinate but rarely and should never be sown.

(2) Wild rice seed can be stored without deterioration if it is gathered as soon as matured, put into barrels or tanks, covered with fresh water, and, before fermentation has set in, stored at a temperature of 32–34° F. Seed treated in this way germinated as high as 88 per cent after being in storage 393 days. Fresh seed seldom germinates better, and usually not so well.

(3) After the seed is taken from cold storage it should not be allowed to dry. The vitality of cold-storage seed is destroyed on drying even more quickly than that of fresh seed.

(4) For transportation the seed should be packed in moist sphagnum, cocoanut fiber, or fine excelsior. If not more than five or six days are required for transit, no special precautions need be taken for controlling the temperature; but if the time for transportation exceeds

six days, provision should be made for a temperature sufficiently low to prevent marked fermentation. A temperature approximately freezing will give the most satisfactory results.

(5) Wild rice can be sown either in the autumn or in the spring. Spring sowing is preferable, thus avoiding the danger of having the seed eaten or destroyed by wild ducks or other animals during the fall or winter, or of its being buried or washed away by the heavy floods of late winter or early spring.

(6) Wild rice should be sown in the spring in from 1 to 3 feet of water which is neither too stagnant nor too swiftly moving, as soon as the danger of heavy floods is passed.

(7) Wild rice is of the greatest importance as a food for wild waterfowl, likewise a delicious breakfast food for man, and the area in which it is extensively grown should be extended. It will grow luxuriantly in either warm or cold water; furthermore, it can be grown successfully in water which is slightly salty to the taste.

(8) In determining the vitality of any sample of wild rice seed the germination tests should be made in water—the condition under which the self-sown seed germinates.

(9) The seed will germinate well at temperatures ranging from 15° to 30° C. The maximum temperature of germination is above 35° C. (95° F.), but better results are obtained at lower temperatures.

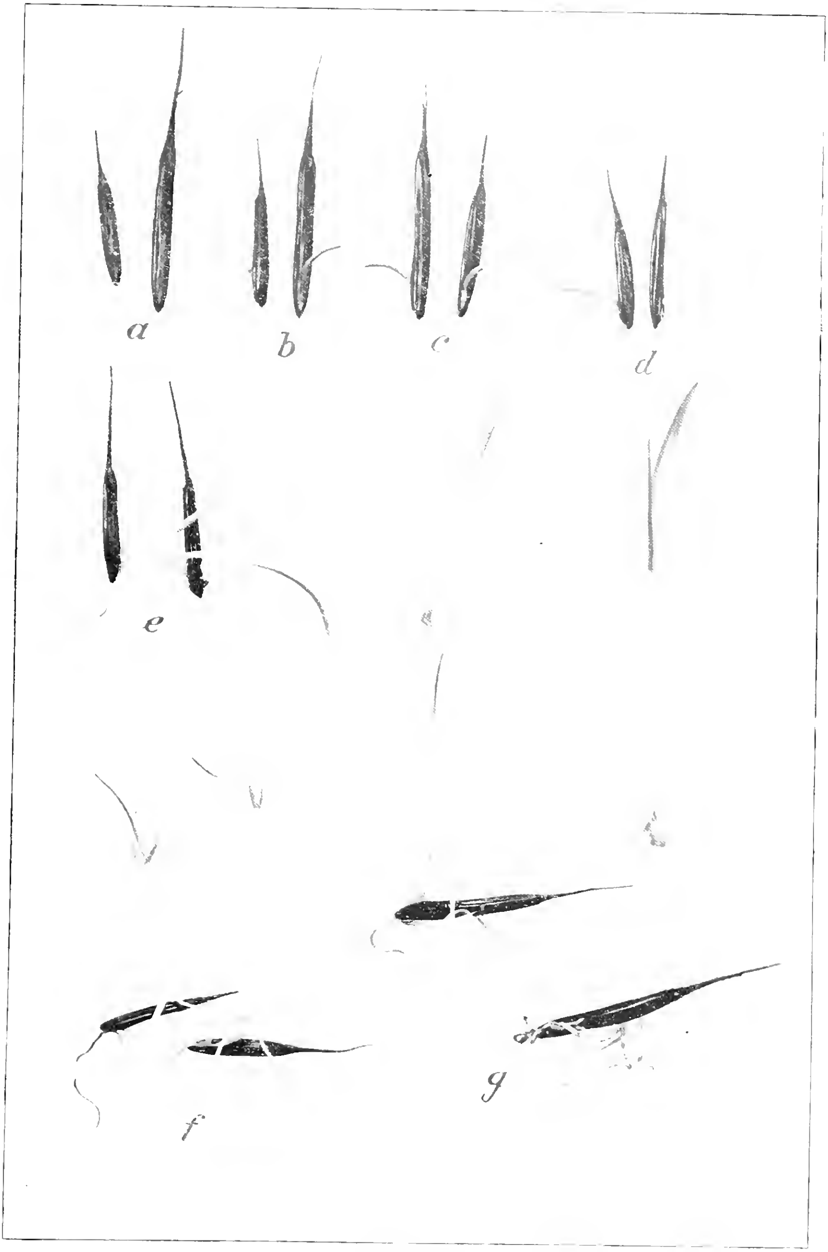
PLATES.

DESCRIPTION OF PLATES.

PLATE I. Wild rice growing in water. This seed was submerged at a temperature of 32–34° F. for approximately thirteen months. In making the germination test the seed was covered with water and placed in a germinating chamber maintained at a temperature of 20° C. (68° F.) for eighteen hours, and at 30° C. (86° F.) for six hours. After the majority of the seeds had germinated the dish was transferred to the worktable of the Seed Laboratory.

PLATE II. Progressive stages in the development of wild rice seedlings; *f* and *g*, seedlings showing the relative position of the growing seedlings and the parent seed, which take a position at right angles to each other when grown normally in water. (Natural size.)

WILD RICE GROWING IN WATER AFTER BEING KEPT WET IN COLD STORAGE AT A TEMPERATURE OF 32-34° F., FROM OCTOBER 19, 1903, TO NOVEMBER 15, 1904.



STAGES OF GERMINATION OF WILD RICE, SHOWING THE DEVELOPMENT OF THE ROOT SYSTEM AND THE RELATIVE POSITION OF THE SEEDLING AND THE PARENT SEED. NATURAL SIZE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART II.

B. T. GALLOWAY, *Chief of Bureau.*

THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.

BY

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VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

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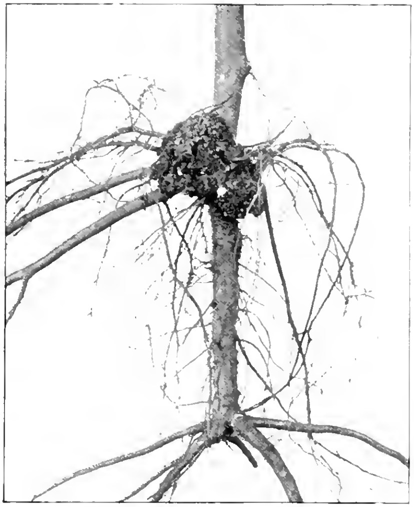

FIG. 1.—APPLE CROWN-GALL ON GRAFTED TREE.

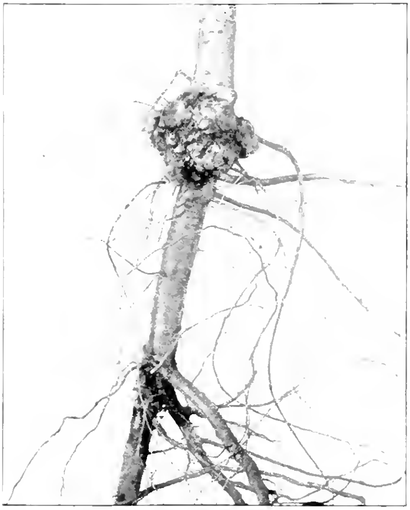

FIG. 2.—APPLE CROWN-GALL ON TRANSPLANTED SEEDLING.

FIG. 3.—HAIRY-ROOT DISEASE ON GRAFTED APPLE TREE.

FIG. 4.—HAIRY-ROOT DISEASE ON GRAFTED APPLE TREE.

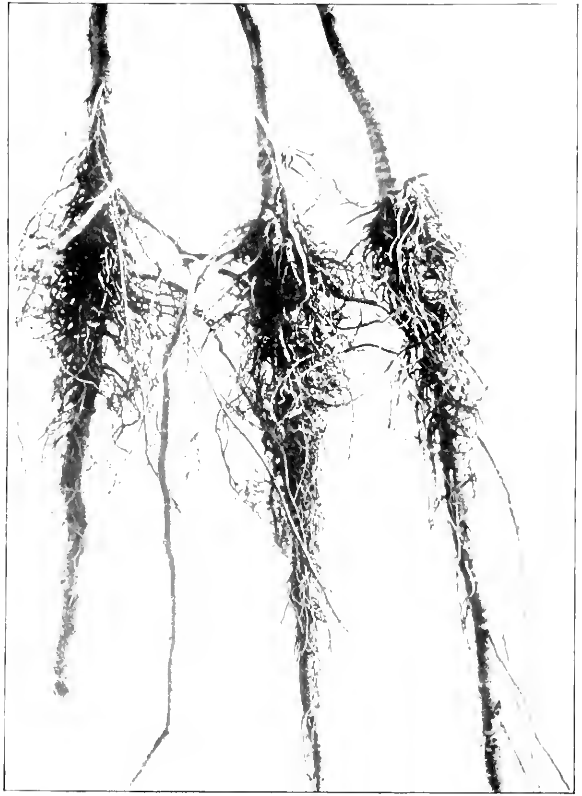

FIG. 1.—APPLE SEEDLINGS DISEASED WITH HAIRY-ROOT.

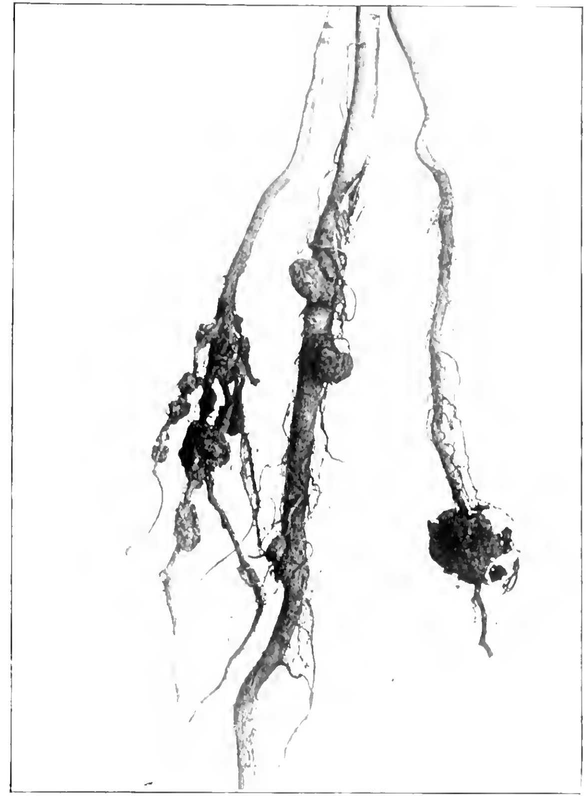

FIG. 2.—APPLE SEEDLINGS DISEASED WITH SOFT CROWN-GALL.

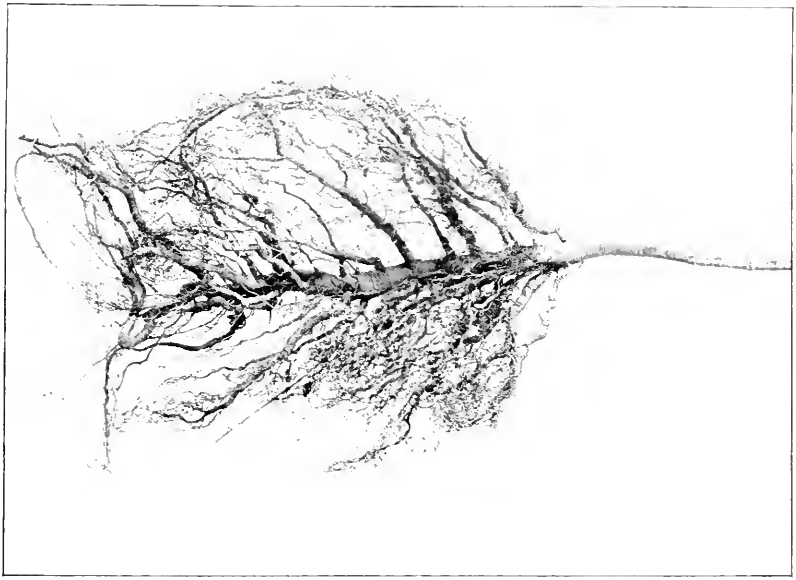

FIG. 1.—HEALTHY FIBROUS-ROOTED APPLE TREE, POT GROWN.

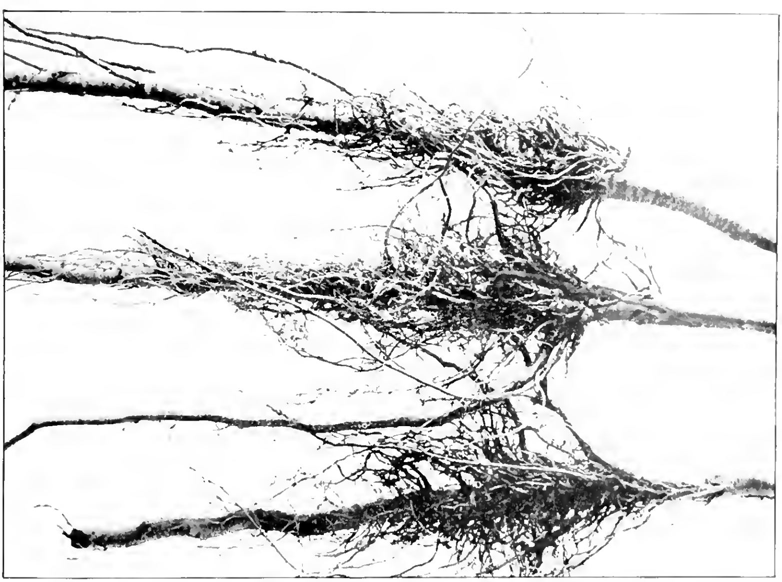

FIG. 2.—APPLE SEEDLINGS DISEASED WITH HAIRY-ROOT.

THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.

INTRODUCTION.

The diseases of the apple which have been classed under the name crown-gall have, during the last few years, attracted much attention, due partly to an increase of these diseases and partly to the enacting of more stringent State laws governing the shipment and inspection of trees.

A series of investigations into the nature of crown-gall upon the apple, pear, raspberry, peach, almond, grape, rose, and other plants has been in progress for some time in the Mississippi Valley Laboratory of the Bureau of Plant Industry at St. Louis, Mo., and also at other points in the Mississippi Valley. It is not to be assumed, however, that such diseases are more common in this locality than in some other portions of the United States. Apple crown-gall and hairy-root have been found in all nurseries that have been examined in various portions of the country.

This preliminary report is sent out, not with the intention of giving the results of all our investigations, but for the purpose of calling the attention of apple-tree growers to the different diseases hitherto known as apple crown-gall, and to endeavor to interest them in the collection of data regarding the predisposition of varieties to these diseases.

TWO DISTINCT DISEASES, CROWN-GALL AND HAIRY-ROOT.

Our investigations have resulted first in separating apple crown-gall into two diseases, which are considered distinct. The disease now designated as crown-gall is a callous-like gall growth of hypertrophied tissue following wounds on some portion of the root system of the tree, which rarely occurs above the ground on parts of the trunk or limbs. (See Pl. I, figs. 1 and 2.)

The malady now called the hairy-root disease is evidently the same as the one first given this name by Stewart, Rolfs, and Hall in Bulletin 191 of the New York State Experiment Station. It is characterized both in seedlings (Pl. II, fig. 1, and Pl. III, fig. 2) and in grafted or budded trees (Pl. I, figs. 3 and 4) by a stunted root system, accompanied with an excessive production of small fibrous roots, often originating in clusters from the main root, or taproot. Galls often occur in connection with hairy-root, but these are a result of wounds rather than a form of this disease. Seedlings of the hairy-root type, unless wounded, remain free from galls.

TYPES OF APPLE CROWN-GALL.

Apple crown-gall is of two types. A hard callous form is common on grafted trees at the union of the root and scion, and at any other point of the root system where wounds occur in either the cultivation or transplanting of trees (Pl. I, fig. 1). The results of extensive inoculations with this type have failed to prove that this disease is of a contagious nature.

A second type is a soft form more common on seedlings (Pl. II, fig. 2), occurring more rarely on grafted trees (Pl. I, fig. 2). These softer galls resemble those of the raspberry and peach, in that they are soft and often rot off. It is not certain, however, that they, like the latter, are replaced the following year by a new gall growth from the adjacent live tissues of the host, nor is there proof yet that they are of a contagious nature.

EFFECT UPON THE LENGTH OF LIFE OF THE APPLE TREE.

Careful data are being collected from orchards and nurseries as to the effect of these diseases upon the life and fruitfulness of trees. Any information as to the locality of orchards in which diseased trees have been planted will be highly appreciated. In our crown-gall orchard there are more than 200 trees diseased with the hard type of crown-gall, and 200 healthy trees of the same grade planted under similar conditions. After two years' growth six of the crown-gall trees and nine of the healthy ones have died. No difference in the growth of the trees is noticeable. However, it can not be assumed from the results so far that, on the one hand, the disease may not yet shorten the life of the trees, or, on the other, that the trees may not entirely overcome its effects. A tree having crown-gall on its roots, however, can never be correctly graded with a smooth-rooted tree. The root system of a healthy fibrous-rooted apple tree is shown in Plate III, figure 1.

SUGGESTIONS TO NURSERYMEN.

Nurserymen are advised to be careful in the selection of seedlings for grafting and budding. All rough, warty, or galled seedlings should be thrown out, for most of them will form rough-rooted trees. Seedlings with tufted or hairy roots should also be rejected, for these, as shown by our experiments, develop into hairy-rooted trees with a very deficient root system. The hairy-root disease, as it appears from the results of two years' experiments, is not contagious. It is hoped in the near future to be able to offer some practical means of reducing the percentage of trees affected with these diseases in the nursery.

DATA DESIRED.

The hearty cooperation of nurserymen and orchardists in securing data is desired. It is hoped to secure the help of the leading nurserymen of this country in getting an accurate count from each nursery of the number of diseased trees in at least one row of every variety in all fields where the trees are all dug in one season. Such data are desired from every locality where apple trees are grown. Printed blanks with directions for tabulating such data have been provided and these will be sent to all who request them. Address the Mississippi Valley Laboratory, St. Louis, Mo.

O

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART III.

B. T. GALLOWAY, *Chief of Bureau.*

PEPPERMINT.

BY

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ASSISTANT, DRUG-PLANT INVESTIGATIONS.

ISSUED DECEMBER 28, 1905.

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B. P. I—189.

PEPPERMINT.[a]

DESCRIPTION.

One of the most important essential oils produced in the United States is distilled from the peppermint plant and its varieties. The three kinds of mint grown in this country for the distillation of peppermint oil are the so-called American mint (*Mentha piperita* L.), the black mint (*Mentha piperita vulgaris* Sole), and the white mint (*Mentha piperita officinalis* Sole), the two last named being varieties of the American mint.

The American mint, although introduced from England many years ago, is so called from the fact that it has long been cultivated in this country, and the name "State mint" has been applied to it in the State of New York for the same reason.

The peppermint, or American mint, is now naturalized in many parts of the eastern United States, occurring in wet soil from the New England States to Minnesota, south to Florida and Tennessee. It is an aromatic perennial belonging to the mint family (Menthaceæ), and propagates by means of its long, running roots (fig. 1). The smooth, square stems are erect and branching, from 1 to 3 feet in height, bearing dark-green, lance-shaped leaves, which are from 1 to 2 inches long, and from one-half to 1 inch wide. The leaves are pointed at the apex, rounded or narrowed at the base, sharply toothed, smooth on both sides, or with hairy veins on the lower surface. The flowers are borne in whorls in dense, terminal spikes; they are purplish, with a tubular, five-toothed calyx, and a four-lobed corolla. (Fig. 2.)

[a] In response to a steady demand for information relating to the peppermint industry, Miss Alice Henkel, Assistant in Drug-Plant Investigations, has been requested to bring together the most important facts regarding the history, culture, and utilization of the peppermint plant. The information here presented has been obtained in large part from scattered articles on the subject, and in part from experience with the plant in the Testing Gardens of the Department of Agriculture.

RODNEY H. TRUE, *Physiologist in Charge.*

OFFICE OF DRUG-PLANT INVESTIGATIONS,

Washington, D. C., October 14, 1905.

The two varieties mentioned are closely related botanically, although in general appearance they are quite different. The variety known as black mint (*Mentha piperita vulgaris*) has purple stems and slightly toothed, dark-green leaves, while the white mint (*Mentha piperita officinalis*) has green stems, with brighter green leaves, which are more lance-shaped and more deeply toothed. Black mint is much more hardy and productive than either the American mint or the white mint, and is grown on nearly all peppermint farms in this country. The white mint, which produces a fine grade of oil, is rarely cultivated on a commercial scale in this country on account of its inability to withstand the climate and its smaller yield of essential oil.

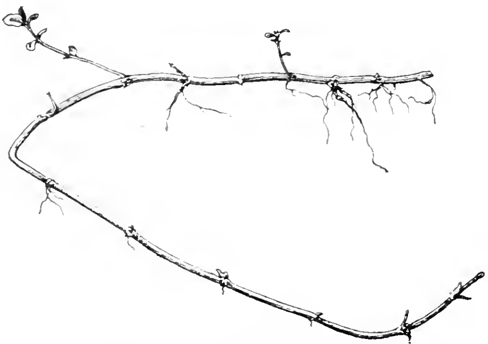

FIG. 1.—Peppermint "runners," showing method of propagation.

The oils spoken of as Japanese and Chinese "peppermint" oils are not obtained from the true peppermint plant, but are distilled from entirely different species, namely, *Mentha arvensis piperascens* Malinvaud and *Mentha arvensis glabrata* Holmes, respectively.

COUNTRIES WHERE GROWN.

The most important peppermint-producing countries are the United States, England, and Japan. Peppermint is grown on a smaller scale in Germany, France, Italy, Russia, China, and southern India.

In Japan, peppermint cultivation is said to have been undertaken before the Christian era. The plant grown there is not, as already stated, the peppermint cultivated in our country, but *Mentha arvensis piperascens*, which is entirely dis-

FIG. 2.—Leaves and flowering top of peppermint.

tinct from the true peppermint, not only botanically but also in taste and odor.

Peppermint is cultivated on many drug farms in England, especially at Mitcham, the middle of the eighteenth century marking the beginning of peppermint cultivation in that country. Up to 1805, however, there were no stills at Mitcham, and the crops obtained there were sent to London for distillation. About 1850, at which time the peppermint industry in England was at its height, the effect of American competition began to be felt, and caused a decided check in the production.

PEPPERMINT CULTIVATION IN THE UNITED STATES.

Wayne County, N. Y., in 1816, was the first locality in this country to distill peppermint on a commercial scale. The supply of rootstocks was obtained from the wild plants found growing along the banks of streams and brooks. Adjacent counties soon undertook the cultivation of peppermint, but Wayne County was then, and is now, the principal peppermint district in New York.

The cultivation of peppermint was extended to Ashtabula, Geauga, and Cuyahoga counties in Ohio, and also to northern Indiana. Roots were taken from Ohio into St. Joseph County, Mich., the first plantation being made on Pigeon prairie in 1835. Other plantations in St. Joseph County were established the following years, and adjoining counties soon took up the cultivation of peppermint, and southwestern Michigan has been for thirty-five years or more the greatest peppermint-producing section in the United States.

About 1844 an interesting peppermint-oil monopoly [a] was undertaken by a New York firm, which seems to have put an end to peppermint cultivation in Ohio, for none of the counties just mentioned has since been heard from as a peppermint-producing section.

The first step taken by this New York firm in its efforts to control the peppermint-oil market was to send a representative to Liverpool, England, to ascertain the amount annually demanded by that market, which was found to be about 12,000 pounds. This done, another agent was sent West to determine the amount produced annually, with the result that it was found that the farms in New York did not produce enough oil for their purposes, the plantations in Ohio too much, while those in Michigan seemed to produce just about the right amount to satisfy the Liverpool demand. A contract was then entered into by this agent with the producers in New York and Ohio "whereby he bound them under heavy penalties to plow up their mint fields and destroy the roots, and not plant any more mint, or sell or give away any roots, or produce or sell any mint oil for the

[a] Proc. Amer. Pharm. Assoc., 7: 449–459 (1858).

period of five years." For this wholesale destruction of their mint fields the producers received a bonus of $1.50 per acre. Next a contract was made by the agent with the producers of St. Joseph County, Mich., agreeing to pay them $2.50 a pound for their mint oil, every ounce of the mint oil to be delivered for a period of five years to the agents named in the contract. They also were prohibited during this period from extending their plantations and from selling roots to anyone. The producers held to these contracts for about three years, after which period the New York firm was not so anxious to enforce them, having, in the meantime, acquired a large fortune through its peppermint-oil monopoly.

Since that period the area devoted to peppermint cultivation in Michigan has steadily increased, and northern Indiana, with its principal centers of production in St. Joseph, Steuben, and La Grange counties, continues to place on the market a considerable quantity of oil. Ohio seems to have abandoned peppermint cultivation, at least on a commercial scale, and New York, for a number of years and until very recently, had greatly reduced the area under peppermint, thousands of acres formerly devoted to this crop having been given over to sugar beets, onions, and celery. In 1889 Wayne County, N. Y., had 3,325 acres of peppermint, whereas in 1899 there were only 300 acres. In 1905, about 933 acres were under cultivation.

Special canvassers appointed by the State of Michigan[a] made a canvass of 299 growers in the peppermint district in that State, covering 39 townships in nine counties (Allegan, Berrien, Branch, Cass, Kalamazoo, Oakland, St. Joseph, St. Clair, and Van Buren), and the total number of acres under peppermint cultivation, the number of pounds of oil distilled, and the average number of pounds per acre, as ascertained by this canvass, for the years 1900, 1901, and 1902, are as follows:

Items.	1900.	1901.	1902.
Total number of acres grown	2,112	$2,782\frac{1}{2}$	$6,400\frac{2}{5}$
Total number of pounds distilled	$47,628\frac{1}{2}$	$63,718\frac{3}{4}$	$82,420\frac{1}{4}$
Average number of pounds per acre	22.5	23.9	12.8

CULTIVATION.

Peppermint cultivation is most profitable on muck lands, such as are now used in Michigan for this crop and for celery and cranberry culture. These muck lands were formerly marshes and swamps, which have been reclaimed by draining, plowing, and cultivating, the swamp vegetation having been thus subdued, and the decayed

[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

vegetable matter resulting in a very black soil which is most admirably adapted to mint cultivation. Formerly peppermint was grown exclusively on upland soil in Michigan, but it is a very exhausting crop on such land. Only two crops can be obtained from upland plantations, and after the second year's harvest the land is plowed and a rotation of clover, corn, etc., is practiced for five years before peppermint is again planted. But on the rich muck land peppermint can be grown year after year for six or seven years, the land being plowed up after each crop is harvested, and the runners turned under to form a new growth the succeeding year. The ground is harrowed in autumn and again in spring, and carefully weeded. Peppermint will grow, however, on any land that will produce good crops of corn, the ground being prepared by deep plowing and harrowing.

In Michigan[a] the land is plowed in the autumn, and early in spring it is harrowed and marked with furrows about 3 feet apart. The roots selected for planting are from one-eighth to one-quarter of an inch thick, and from 1 to 3 feet long; and the workmen engaged in "setting mint," as the process is called, carry these roots in sacks across their shoulders and place them in the furrows by hand, covering the roots with one foot and stepping on them with the other. The roots are planted so close together in the furrow as to form a continuous line. An expert workman can plant about an acre in a day.

In about two weeks the young plants will make their appearance, and are carefully hoed and cultivated until July and August, when the plants have usually sent out so many runners as to make further cultivation difficult. The crop is cultivated with horse cultivators, but if the land was very weedy in the first place, the weeds will have to be pulled by hand. It is very necessary that the land be free from weeds, as any collected with the peppermint crop will seriously injure the quality of the oil.

It may be interesting to note here that on muck lands, when necessary, the horses are usually provided with mud shoes to prevent their sinking into the soft, wet ground, these mud shoes consisting of wide pieces of iron or wood about 9 by 10 inches, fastened to the hoofs and ordinary shoes by means of bolts and straps.

CONDITIONS INJURIOUS TO CROP.

Cold and wet weather or extremely dry periods have a very unfavorable effect on the mint crop. Insect enemies also tend to cut down the mint harvest—grasshoppers, crickets, and cutworms sometimes doing considerable damage. A rust, causing the foliage to drop off

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[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

and leaving the stems almost bare, is apt to follow if very moist weather occurs toward the latter part of the season. Weeds are especially to be avoided in a mint field, since, as stated, the quality of the oil will be seriously impaired if these are harvested with the peppermint. The weeds generally found in a peppermint field are Canada fleabane (*Leptilon canadense*), fireweed (*Erechtites hieracifolia*), giant ragweed (*Ambrosia trifida*), pennyroyal (*Hedeoma pulegioides*), Eaton's grass (*Eatonia pennsylvanica*), June grass (*Poa pratensis*), and other low grasses.

HARVESTING AND DISTILLATION.

The first crop of mint is harvested in the latter part of August, when the plants are in full flower, and the gathering continues until about the middle of September, the stills running night and day until all the mint is disposed of. The first crop is usually cut with a scythe, as mowing machines do not work well on soft cultivated land. The succeeding crops are cut with a mowing machine or sweep-rake reaper. The highest yield per acre and the best quality of oil are obtained from the first year's crop. Sometimes, if the weather conditions have been very favorable, a second cutting is made. The yield of oil from peppermint obtained from the same field sometimes varies very much, the condition of the atmosphere seeming to exert an influence upon it, as it is said that mint cut after a warm and humid night will yield more oil than that cut after a cool and dry night. It requires about 330 pounds of dried peppermint to produce 1 pound of oil, and the yield of oil from an acre ranges from 12 to 50 pounds.

If the mint crop has been grown on muck land, all that is necessary after the crop has been harvested is to plow up the land and turn the runners under for a new crop. If grown on upland, after the second year's crop is in, or, at the most, after the third year's harvest, the land is plowed and then given up to other crops. Peppermint exhausts the land, and it is necessary to practice rotation of crops for about five years in order to put the land in condition if it is desired to use it again for peppermint cultivation.

After the plants are cut they are usually placed in windrows until they are dried, but are not allowed to become so dry as to permit the leaves to shatter off, and are then taken to the distillery. Some growers believe that if the plants are allowed to dry there will be a smaller oil content owing to the escape of some of the oil into the atmosphere, and so have the plants brought to the distillery in the green state; but Mr. A. M. Todd[a] is of the opinion that no loss of oil will result

[a] Amer. Jour. Pharm., 60: 328–332 (1888).

from drying, his experiments along this line showing that the dry plants can be distilled three times as rapidly as the green plants, and that a larger quantity of oil may be obtained. He states that—

To obtain the best results, both as to quality of essential oil and economy of transportation and distillation, the plants should be dried as thoroughly as possible without endangering the loss of the leaves in handling. Distillation should then take place as soon as convenient to prevent the oxidation of the oil in the leaf by atmospheric action.

The smaller producers, who have no stills of their own, have their mint crop hauled to the nearest peppermint distillery, where it is distilled for them at a cost of 25 cents per pound of oil.

DESCRIPTION OF STILL.

The apparatus used in peppermint distillation in the early years of the industry in this country consisted of a copper kettle, from the top of which a pipe connected with a condensing "worm." Water was placed in the kettle and the plants were immersed in it, and direct heat was applied to the bottom from a furnace. With such a still only about 15 pounds of oil could be obtained from a charge. In 1846, large wooden vats were substituted for the copper kettles, and the plants were distilled by steam passing through them. The kettle formerly used as the still was now employed to generate steam, a long pipe conveying the steam to the bottom of the vats. With this method of distillation from 75 to 100 pounds of oil could be obtained from a charge without much additional expense.

A modern peppermint still (fig. 3) may be briefly described as follows: The apparatus required consists of a boiler, a pair of large circular wooden vats, a condenser, and a receiver. The boiler, of course, is used for the generation of steam.

Two wooden vats are used in order that they may be filled and emptied alternately. These vats are about 6 feet high and about 5 feet in diameter, with tight-fitting removable covers and perforated false bottoms. Steam pipes are led from the boiler into the bottom of the vats.

The condenser consists of a series of pipes of block tin, either immersed in tanks of cold water or over which cold water is kept running, the condenser being connected with the top of the distilling vats. The condensed steam, together with the oil, flows into a metallic receiver, in which the oil, being lighter than the water, rises to the top and can be drawn off.

The perforated false bottoms with which the vats are supplied permit the passage of steam. A strong iron hoop is placed about this false bottom, and two pairs of stout chains, which meet at the top of the vat in a pair of rings, are attached to it. After the charge has been distilled it is drawn from the vats by means of this arrangement.

The plants are thrown into the vats and are closely packed by two or three men tramping upon them, and as the vat becomes about one-third full the packing is still further assisted by turning in a small supply of steam, which softens the plants. When the vat is filled the tight cover is replaced and a full head of steam turned on. In the largest distilleries the vats have a capacity of from 2,000 to 3,000 pounds of dried plants each.

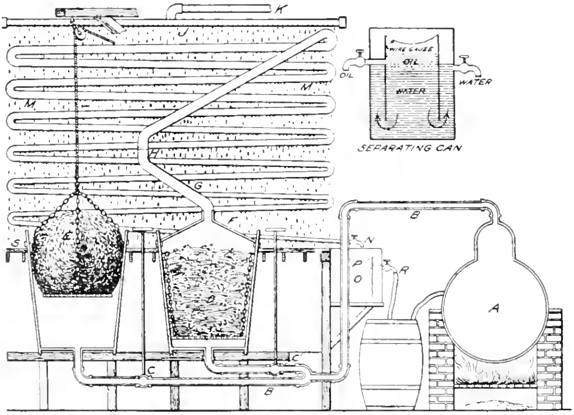

FIG. 3.- Peppermint still. (After Dewey, in Bailey's Cyclopedia of American Horticulture.)

A, boiler; *B*, steam pipes leading to vats; *C*, valves for shutting off steam; *D*, mint packed in vat ready for distilling; *E*, mint being lowered into vat; *F*, tight-fitting cover used alternately for both vats; *G*, pipe from top of vat, joined at *H* so as to swing to other vat; *J*, perforated pipe, from which cold water drops over condensing tubes; *K*, supply pipe for cold water; *M*, condensing pipes; *N*, outlet for condensed oil and water; *O* and *P*, water and oil in separating can; *R*, outlet for water; *S*, floor of distilling room.

Large tanks are used for storing the oil, and cans holding 20 pounds each are employed for shipping, three of these cans being placed in a wooden case.

The peppermint hay which remains after distillation is used as a fertilizer or is fed to stock.

PEPPERMINT OIL AND MENTHOL.

Peppermint leaves and flowering tops are official in the Eighth Decennial Revision of the United States Pharmacopœia, as are likewise the following products and preparations derived from these parts: Oil of peppermint, menthol, spirit of peppermint, and peppermint water.

The United States Pharmacopœia describes oil of peppermint as "a colorless liquid, having the characteristic strong odor of peppermint and a strongly aromatic pungent taste, followed by a sensation of cold when air is drawn into the mouth." It is largely used in medicine, internally as a stimulant and carminative, and externally to relieve neuralgic and rheumatic conditions. It is also used for flavoring and scenting confectionery, cordials, and cosmetics. There is a slight difference in the odor of white and black peppermint oil, the black being more pungent and less agreeable in fragrance than the white, which has a much finer odor, but, as already indicated, the white mint is less hardy than the black and yields a smaller quantity of oil.

The Japanese oil of peppermint, which, as pointed out elsewhere in these pages, is obtained from a different species of mint than that which produces the true oil of peppermint, is very inferior to the last named. It has a very unpleasant odor and a bitter, disagreeable taste, but it is a heavy oil and contains a higher percentage of menthol and, being a very much cheaper oil, it is liable to be used as an adulterant of true peppermint oil.

Menthol, formerly known as peppermint camphor, is the solid constituent of oil of peppermint, obtained by subjecting the distilled oil to an exceedingly low temperature by means of a freezing mixture. Its properties are about the same as those of oil of peppermint, only somewhat intensified. It is very largely made up into cones or pencils, which furnish a popular remedy, to be applied externally or inhaled, for the relief of headache, neuralgia, catarrh, asthma, and kindred affections. It is also largely employed in other forms of medication. The name "pipmenthol" has been applied to the menthol obtained from the American oil, to distinguish it from the Japanese menthol. Pipmenthol is said to have a distinct odor of peppermint, while the Japanese menthol has but a slight peppermint odor.

EXPORT OF PEPPERMINT OIL.

The exports of peppermint oil during the fiscal year ended June 30, 1904, amounted to 42,939 pounds, valued at $124,728. Germany and the United Kingdom were the largest consumers, the former receiving 22,372 pounds, valued at $65,505, and the latter 11,558 pounds, worth $31,798.

The following tables show the export of peppermint oil, by countries, for the fiscal year ended June 30, 1904, and the quantities and values of peppermint oil exported for a period of ten years, from July 1, 1894, to June 30, 1904, inclusive:

Exports of peppermint oil, by countries, for the fiscal year ended June 30, 1904.[a]

Country.	Quantity.	Value.
	Pounds.	
Belgium	473	$1,585
France	3,054	10,059
Germany	22,372	65,505
Italy	826	2,471
Netherlands	590	1,934
United Kingdom	11,558	31,798
Dominion of Canada:		
Nova Scotia, New Brunswick, etc	85	234
Quebec, Ontario, Manitoba, etc	1,165	3,306
Newfoundland and Labrador	94	204
West Indies:		
British	183	700
Cuba	29	87
Danish	17	55
Dutch	20	61
Argentina	1,237	3,504
British Guiana	10	31
Peru	50	175
British Australasia	1,176	3,019
Total	42,939	124,728

[a] The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 531, Bureau of Statistics, Department of Commerce and Labor.

Quantities and values of peppermint oil exported during the fiscal years 1895 to 1904, inclusive.[a]

Fiscal year.	Quantity.	Value.	Fiscal year.	Quantity.	Value.
	Pounds.			*Pounds.*	
1895	87,633	$194,616	1900	89,558	$90,298
1896	85,290	174,810	1901	60,166	63,672
1897	162,492	257,484	1902	36,301	54,898
1898	145,375	180,811	1903	13,033	34,943
1899	117,462	118,227	1904	42,939	124,728

[a] From The Foreign Commerce and Navigation of the United States for the year ending June 30, 1902, vol. 2, p. 309, Bureau of Statistics, Treasury Department; and The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 192, Bureau of Statistics, Department of Commerce and Labor.

PRICES OF PEPPERMINT OIL.

The price of peppermint oil was very low for a few years prior to 1900, the enormous production of 1897 resulting in a great drop in price. The lowest price paid for it was in 1899, when it brought only 75 cents per pound. As a result of the low price a great many mint farmers restricted the area of their mint plantations or altogether abandoned peppermint cultivation. The smaller output of the following seasons again sent prices up, and in 1902 the oil sold as high as $4.75 a pound, which price was maintained until early in 1903, when it gradually declined, until toward the end of that year it reached $2.20 per pound.

The following table[a] gives the highest and lowest prices of peppermint oil in bulk from 1873 to September 16, 1905:

Year.	Highest.	Lowest.	Year.	Highest.	Lowest.	Year.	Highest.	Lowest.
1873	$3.15	$3.15	1884	$3.00	$2.50	1895	$2.00	$1.70
1874	5.25	3.75	1885	4.37	2.75	1896	1.85	1.20
1875	5.50	3.20	1886	3.60	2.75	1897	1.25	.90
1876	3.75	2.40	1887	2.75	1.90	1898	.90	.80
1877	3.00	1.75	1888	2.40	1.75	1899	.90	.75
1878	2.00	1.50	1889	2.30	1.80	1900	1.10	.80
1879	2.65	1.45	1890	2.40	1.80	1901	1.80	1.10
1880	2.87	2.60	1891	2.50	2.45	1902	4.75	1.70
1881	2.85	2.35	1892	2.50	2.15	1903	4.75	2.20
1882	2.50	2.25	1893	2.45	2.15	1904	3.75	2.65
1883	2.60	2.20	1894	2.45	1.70	1905*	3.45	2.25

* To September 16.

The good prices of the past few years have caused many farmers to look again to peppermint as a profitable crop, as noted in increased areas under cultivation in many localities. This is the case not only in Michigan and Indiana, but also in New York, where for many years the peppermint industry has been declining. Thus, if favorable conditions of growth prevail, an increased production may be looked for within the next few years, which will have the effect of again depressing prices.

As is the case with other products the prices of which are subject to great fluctuations, the condition of the market for peppermint oil needs to be closely observed. The cost of cultivation per acre has been stated at from $12 to $14, and, with a charge of 25 cents per pound of oil for distillation, the market price may easily fall below the cost of production.

[a] From Oil, Paint, and Drug Reporter, September 18, 1905, p. 7.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN No. 90, PART IV.
B. T. GALLOWAY, *Chief of Bureau*.

THE POISONOUS ACTION OF JOHNSON GRASS.

BY

ALBERT C. CRAWFORD,
PHARMACOLOGIST, POISONOUS PLANT INVESTIGATIONS.

ISSUED JANUARY 17, 1906.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

B. P. I.—191.

THE POISONOUS ACTION OF JOHNSON GRASS.[1]

Johnson grass, which was introduced from Turkey into this country about 1830,[2] has spread so that in many places it is considered as a weed and pest.[3] Some farmers, however, have utilized the dried grass as hay with advantage, either alone or combined with other food material,[4] and chemical analyses have proved its value as feed. Recently reports have come to this office from California of the death of cattle under such circumstances as to point to Johnson grass as the causative agent—the cattle dying in thirty minutes after eating the grass. Johnson grass belongs to the same genus of the Gramineae as sorghum. This group has been partially investigated chemically, and it has been found that the fresh green plants of various members yield hydrocyanic

[1] This office has from time to time received communications from stockmen, especially in the lower part of California, Arizona, and adjacent territory, expressing a suspicion that the eating of Johnson grass had caused the death of stock with rather sudden and violent symptoms. There has seemed to be little ground in poisonous-plant literature to support such an explanation. Last summer, however, convincing observations were reported from California by a stockman who had lost heavily, and a supply of the grass in question was obtained. The result of the study of this material was so positive, and the possibility of damage due to this unsuspected forage plant so clear, that this preliminary notice is put out in the hope of getting observations and material for study from many sources, in order, if possible, to determine the conditions under which the poisonous properties are developed and over how wide an area they are likely to appear.

RODNEY H. TRUE, *Physiologist.*

OFFICE OF POISONOUS PLANT INVESTIGATIONS,
Washington, D. C., December 11, 1905.

[2] Ball, C. R. Johnson Grass. Bul. No. 11, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1902.

[3] Spillman, W. J. Extermination of Johnson Grass. Bul. No. 72, Part III, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905.

[4] North Carolina Agr. Expt. Sta. Bul. 97, p. 92.

Vasey, G. Grasses of the South. Bul. No. 3, Division of Botany, U. S. Dept. of Agriculture, 1887.

Report of the Commissioner of Agriculture for 1881, pp. 231, 232, 239, 241; Report of the Secretary of Agriculture, 1890, p. 381.

acid as a result of the action of enzymes on more highly complex bodies.[1]

Ball[2] in 1902 stated that at that time there had been no official reports to his office of cases of poisoning by Johnson grass, but that there were some newspaper statements to that effect. He thought these accounts were probably not authentic, but stated that "since Johnson grass is closely related to sorghum, which is known to be poisonous under some circumstances, it would not be surprising if Johnson grass should also be poisonous under like conditions. * * * In comparison with the great number of cattle fed or pastured in Johnson grass, the reported cases of poisoning are extremely rare."

The first report of the poisonous action of Johnson grass which reached the Department came from Miles City, Mont. Mr. William Story reported that he and a neighbor had lost several head of cattle after they had eaten small quantities of the grass, and that they had died very suddenly. Mr. Story suggested that there was "something peculiarly poisonous about the grass." The Commissioner of Agriculture in publishing this report stated that "although the grass has been cultivated in the South for forty or fifty years, no similar charges have been made against it."[3]

In India this plant is widely used as a fodder for cattle,[4] and the natives make use of the seeds for food. It has been noted there that deaths in cattle frequently occur when, on account of the failure of rain, the plants which have reached a certain size become stunted and withered. The toxic principle appears simultaneously over a wide area, but soon disappears if a rainfall occurs.[5] The deaths of cattle have been attributed by some to an insect living upon the plant, and in Australia it is the belief that *Sorghum vulgare*, which also yields hydrocyanic acid, becomes more poisonous when attacked by an insect during a drought. A similar observation has been made with *Sorghum vulgare* in the Sudan. Balfour[6] found that one specimen of the plant

[1] Dunstan, W. R., and Henry, T. A. The Nature and Origin of the Poison of Lotus Arabicus. Phil. Trans. Roy. Soc. London, 1901, vol. 194, B., p. 515.

Dunstan, W. R., and Henry, T. A. Cyanogenesis in Plants. Phil. Trans. Roy. Soc. London, 1902, vol. 199, A., p. 399.

Slade, Henry B. Prussic Acid in Sorghum. Jour. Amer. Chem. Soc., 1903, vol. 25, pp. 55–59.

Slade, Henry B. Study of the Enzymes of Green Sorghum. Fifteenth Ann. Report, Agr. Expt. Sta. of Nebraska, 1902, pp. 55–62.

Brünnich, J. C. Hydrocyanic Acid in Fodder-plants. Jour. Chem. Soc., 1903, vol. 83, part 2, pp. 788–796.

[2] Loc. cit., p. 23.

[3] Report of the Commissioner of Agriculture, 1885, p. 74.

[4] Duthie, J. F. Fodder Grasses of Northern India, 1888, p. 41.

[5] Pease, H. T. Poisoning of Cattle by Andropogon Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 18, 1897, p. 679. See also Agr. Ledger, 1896, No. 24.

[6] Balfour, Andrew. Cyanogenesis in Sorghum Vulgare. First Report, Wellcome Research Laboratory, at Gordon Mem. College, Khartum, 1904, p. 47.

which harbored aphids yielded more hydrocyanic acid than a second one without parasites. Pease has lately claimed that the deaths from Johnson grass in India were really cases of nitrate poisoning, as he found 25 per cent of nitrate of potassium in the stem of the plant and was able to produce somewhat similar symptoms in animals by feeding them this salt. Johnson grass is being introduced into Australia as a fodder plant, but as yet no reports of its poisonous action there have been noted by the writer.[1]

There has been some chemical study of Johnson grass, but not with reference to any poisonous principle.[2]

A fresh, green, mature, nonflowering specimen of Johnson grass, moistened with a little water and preserved with chloroform, was sent from Santa Rosa, Cal., in sealed glass vessels, to this laboratory. This was botanically identified here as Johnson grass. This specimen was not immediately worked up, but remained in the jars for about a month. At that time on opening the jars a marked odor of hydrocyanic acid, together with that of chloroform, was detected. The ground-up plant, with the water in which it came, was distilled, and the distillate was caught in sodium hydrate solution. This distillate, on mixing with ferrous sulphate and acidulation with hydrochloric acid, gave a heavy blue precipitate with ferric chlorid. Yellow ammonium sulphid was added to the same filtrate, and the mixture was evaporated to dryness on the bath. The dried residue was then taken in hydrochloric acid water, and on the addition of ferric chlorid the fluid gave the characteristic red reaction for hydrocyanic acid. The nitro-prussid, picric acid, and silver nitrate reactions were all positive for hydrocyanic acid. The aqueous fluid in which the plant was shipped was filtered off from the plant and gave on distillation all the above reactions for hydrocyanic acid.

According to our California correspondent, this plant is poisonous when grown on irrigated as well as on nonirrigated lands, but especially so when grown on irrigated soil and the growth has become rank.

Recently Dunstan[3] has shown that Lima beans (*Phaseolus lunatus*), which when grown wild in Mauritius yield sufficient hydrocyanic acid to produce poisoning, when cultivated in Burma lose this toxicity almost entirely, although it may return most unexpectedly.[4] He was unable, however, to determine the condition which increased its poisonous properties.

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[1] Maiden, J. H. Useful Australian Plants. Dept. Agr. New South Wales, Misc. Pub. No. 22, 1896.

[2] Annual Report of the Commissioner of Agriculture, 1878, p. 168.

[3] Dunstan, W. R. Phaseolus Lunatus. Agr. Ledger, 1905, No. 2.

[4] Church, A. H. Food-Grains of India. 1886, p. 155.

Watt, George. Dictionary of the Economic Products of India, vol. 6, part 1, 1892, p. 187.

It is interesting to note, besides this production of hydrocyanic acid from complex glucosids, that proteids, when subjected to oxidation under certain conditions, also yield it.[1] In fact, hydrocyanic acid may exist in plants in two forms, either as the acid or as one of its salts, or in the form of complex glucosids.[2] Under the circumstances, the conclusions of Brünnich[3] should be held in mind, viz. that "all fodder plants related to sorghum must be used with discretion in either the green or the dried state, and should not be given in large amounts to animals which have fasted for some time."

In reference to other forage plants, Avery[4] says that "Kafir-corn leaves also contain this poison, but other forage plants—clover, alfalfa, grasses, and corn—give no test for prussic acid," and Brünnich also found it in Guinea grass or *Panicum maximum* and *P. muticum.* Many facts have been collected relative to the distribution of hydrocyanic acid in plants, yet its exact significance in their metabolism is unknown.[5] The question as to the relationship of parasites[6] to the production of hydrocyanic acid remains to be solved.

Later investigations will be carried on to determine the nature of this cyanogenetic compound, to determine whether hydrocyanic acid is present in all stages of its growth, but disappears on drying the plant, whether the hydrocyanic acid production occurs under all conditions or only when grown on certain soils, and the amount produced. Hydrocyanic acid will also be looked for in other members of this genus.

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[1] Plummer, R. H. A. The Formation of Prussic Acid by the Oxidation of Albumins. Jour. Physiol., vol. 31, 1904, p. 65; vol. 32, 1904, p. 50.

[2] Les Nouveaux Remèdes, vol. 14, 1898, p. 272.

[3] Loc. cit., p. 792.

[4] Avery, S. Laboratory Notes on Poison in Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 23, 1902, p. 705.

[5] Czapek, F. Biochemie d. Pflanzen, 1905, vol. 2, p. 259.

[6] Literature on some parasites of the sorghum family can be found in Bot. Gaz., vol. 28, 1899, p. 65. Also in Busse, W., Untersuch. u. d. Krank. der Sorghum Hirse, Arb. a. d. biol. Abtheil. f. Land u. Forstw. am kaiserl. Gesundheitsamt, 1904, vol. 4.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90.

B. T. GALLOWAY, *Chief of Bureau.*

MISCELLANEOUS PAPERS.

I. THE STORAGE AND GERMINATION OF WILD RICE SEED.
By J. W. T. DUVEL, *Assistant.*

II. THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.
By GEORGE G. HEDGCOCK, *Assistant.*

III. PEPPERMINT.
By ALICE HENKEL, *Assistant.*

IV. THE POISONOUS ACTION OF JOHNSON GRASS.
By A. C. CRAWFORD, *Pharmacologist.*

ISSUED FEBRUARY 21, 1906.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate Divisions, and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm, Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory, and Dry Land Agriculture and Western Agricultural Extension.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Government Printing Office, Washington, D. C.

No. 1. The Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.
2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.
3. Macaroni Wheats. 1901. Price, 20 cents.
4. Range Improvement in Arizona. 1902. Price, 10 cents.
5. Seeds and Plants Imported. Inventory No. 9. 1902. Price, 10 cents.
6. A List of American Varieties of Peppers. 1902. Price, 10 cents.
7. The Algerian Durum Wheats. 1902. Price, 15 cents.
8. A Collection of Fungi Prepared for Distribution. 1902. Price, 10 cents.
9. The North American Species of Spartina. 1902. Price, 10 cents.
10. Records of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902. Price, 10 cents.
11. Johnson Grass. 1902. Price, 10 cents.
12. Stock Ranges of Northwestern California. 1902. Price, 15 cents.
13. Range Improvement in Central Texas. 1902. Price, 10 cents.
14. The Decay of Timber and Methods of Preventing It. 1902. Price, 55 cents.
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16. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and Other Basidiomycetous Fungi. 1902. Price, 10 cents.
17. Some Diseases of the Cowpea. 1902. Price, 10 cents.
18. Observations on the Mosaic Disease of Tobacco. 1902. Price, 15 cents.
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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90.

B. T. GALLOWAY, *Chief of Bureau.*

MISCELLANEOUS PAPERS.

I. THE STORAGE AND GERMINATION OF WILD RICE SEED.
By J. W. T. DUVEL, *Assistant.*

II. THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.
By GEORGE G. HEDGCOCK, *Assistant.*

III. PEPPERMINT.
By ALICE HENKEL, *Assistant.*

IV. THE POISONOUS ACTION OF JOHNSON GRASS.
By A. C. CRAWFORD, *Pharmacologist.*

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,

Pathologist and Physiologist, and Chief of Bureau.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ALBERT F. WOODS, *Pathologist and Physiologist in Charge, Acting Chief of Bureau in Absence of Chief.*

BOTANICAL INVESTIGATIONS.

FREDERICK V. COVILLE, *Botanist in Charge.*

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SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

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ARLINGTON EXPERIMENTAL FARM.

L. C. CORBETT, *Horticulturist in Charge.*

INVESTIGATIONS IN THE AGRICULTURAL ECONOMY OF TROPICAL AND SUBTROPICAL PLANTS.

O. F. COOK, *Bionomist in Charge.*

DRUG AND POISONOUS PLANT INVESTIGATIONS, AND TEA CULTURE INVESTIGATIONS.

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DRY LAND AGRICULTURE AND WESTERN AGRICULTURAL EXTENSION.

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EXPERIMENTAL GARDENS AND GROUNDS.

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J. E. ROCKWELL, *Editor.*

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[a] The four papers constituting this Bulletin were issued in separate form on September 7, November 17, December 28, 1905, and January 17, 1906, respectively.

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MISCELLANEOUS PAPERS.

B. P. I.—178.

I.—THE STORAGE AND GERMINATION OF WILD RICE SEED.[a]

By J. W. T. Duvel, *Assistant in the Seed Laboratory.*

INTRODUCTION.

The seed of wild rice, sometimes called Indian rice or water oats (*Zizania aquatica* L.), has always been a very valuable food among the Indians, especially those of the upper Mississippi Valley. Of recent years wild rice has found a place on the menu cards of some of our best American hotels. The rich and highly nutritious grains, together with the slightly smoky flavor it has when properly prepared, make it an extremely palatable article of diet. If it were not for the difficulties of harvesting the seed and preparing the finished product for market it is probable that wild rice would find a place in many American homes.

At present, however, the greatest interest in wild rice is created by the value of the seed as a food for wild waterfowl, particularly wild ducks. As a result of this interest the propagation of wild rice from seed has become a question of considerable importance, especially to the members of the gunning clubs throughout the United States and Canada.

DISTRIBUTION.

The distribution of wild rice is now reported from New Brunswick and Assiniboia south to Florida, Louisiana, and Texas. There are, however, comparatively few localities in which it grows abundantly.

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[a] Wild rice is considered one of the most important foods for wild ducks and other waterfowl, and a large number of inquiries have been received from members of gunning clubs throughout the United States asking where good, germinable seed can be secured. It is quite generally recognized that wild rice seed loses its vitality if allowed to become dry, and better methods of storing the seed during the winter have long since been demanded.

The results of investigations begun two years ago show that wild rice seed can be handled without any deterioration in vitality if it is harvested and stored according to methods outlined in the present paper.

J. W. T. Duvel, *Acting Botanist in Charge of Seed Laboratory.*

Seed Laboratory,
Washington, D. C., July 20, 1905.

Good reasons exist for assuming that this area can be extended to include all fresh-water lakes, as well as swamps and river bogs, where the water does not become stagnant, throughout the whole of North America south of latitude 55° north. Wild rice also grows luxuriantly along the lower parts of many of the rivers of the Atlantic Coast States, the waters of which are affected by the action of the tide to a considerable degree, and consequently contain an appreciable quantity of salt. It has been shown[a] that the maximum degree of concentration of salt water in which wild rice plants can grow successfully is equivalent to a 0.03 normal solution of sodium chlorid. This concentration corresponds to 0.1755 per cent by weight of sodium chlorid, which is sufficient to give a slight salty taste to the water.

HABITAT.

While it is well recognized that the habitat of the wild rice plant is in shallow fresh water, it is now known that it will grow luxuriantly in water containing little less than two-tenths of 1 per cent of sodium chlorid. Occasional plants have been found growing in water which contained, for short periods at least, nearly double that amount of salt. These facts indicate the possibility of a much wider range of conditions to which this plant may be subjected without hindering its development. It is not beyond the range of possibility—indeed, it is quite probable—that by careful selection plants may be obtained which will thrive on soil that is comparatively dry, at least in places in which the water can be drawn off gradually during the latter part of the growing season.

In September, 1904, Mr. G. C. Worthen, of the Bureau of Plant Industry, collected a cluster of wild rice plants which were growing on the Potomac Flats, near Washington, D. C., in soil which was sufficiently dry to permit the use of a 2-horse mowing machine for cutting down the rank growth of vegetation. This was newly made land, and in all probability the seed giving rise to this cluster of plants was pumped in with the dirt from the Potomac River the year previous.

This amphibious type once established, it will undoubtedly carry with it a strain of seed which can withstand considerable drying without any marked injury to its vitality. Such being true, the methods and difficulties of propagation from seed would be greatly simplified.

Simultaneous with establishing an amphibious type should come the selection of seed plants which are capable of retaining their seed until the larger part of it has reached maturity. These two steps once made, the future of wild rice as a cereal will be assured.

---

[a] The Salt Water Limits of Wild Rice. Bulletin No. 72, Part II, Bureau of Plant Industry, United States Department of Agriculture, 1905.

GERMINATION OF THE SEED.

The greatest difficulty to be overcome in extending the area for growing wild rice is the poor germination of the commercial seed. Inasmuch as wild rice constitutes one of the most important foods of wild ducks and other wild waterfowl, many individuals and most of the gunning clubs east of the Rocky Mountains have been asking the question, How can we propagate wild rice from seed in order to establish better feeding and fattening grounds for our game birds?

The many failures in the propagation of wild rice from seed have been due to the use of seed that had become dry before sowing, or to the fact that the seed when sown fresh in the autumn had been eaten by ducks or other animals or was carried away by heavy floods before germination took place.

It is now very generally known that the seed of wild rice, if once allowed to become dry, will not germinate, save possibly an occasional grain. In its natural habitat the seed, as soon as mature, falls into the water and sinks into the mud beneath, where it remains during the winter months, germinating the following spring if conditions are favorable.

Heretofore the plan generally followed, and the one usually recommended by those who have given some attention to the propagation of wild rice, was practically that of natural seeding; that is, to gather the seed in the autumn, as soon as thoroughly mature, and, while still fresh, to sow it in 1 to 3 feet of water.

FALL SEEDING VERSUS SPRING SEEDING.

It must be remembered that the bulk of the seed remains dormant during the winter, germinating first the spring after maturing; consequently, with but few exceptions, fall seeding is unsatisfactory and unreliable. Fall seeding is likely to prove a failure for three reasons: (1) Wild ducks and other animals of various kinds eat or destroy the seed in considerable quantity before it has had time to germinate the following spring; (2) much of the seed is frequently covered so deeply with mud that washes in from the shore during the winter that the young plants die of suffocation and starvation before they reach the surface; (3) in some cases a large quantity of the seed is carried away from the place where sown by the high waters and floating ice prevalent during the latter part of the winter and early spring.

In exceptional cases these difficulties can be overcome; under which circumstances autumn sowing may be preferable to spring sowing. In the majority of cases, however, much better results will be obtained if the seed is properly stored and sown in the early spring, as soon as the danger of heavy floods is passed and the water level approaches normal.

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In sowing the seed considerable care must be exercised in selecting a suitable place, securing the proper depth of water, etc. Good results can be expected if the seed is sown in from 1 to 3 feet of water which is not too stagnant or too swiftly moving, with a thick layer of soft mud underneath.[a] It is useless to sow wild rice seed on a gravelly bottom or in water where the seed will be constantly disturbed by strong currents.

Previous to this time, save in a few reported cases, the seed which was allowed to dry during the winter and was sown the following spring gave only negative results. It is now definitely known that wild rice, if properly handled, can be stored during the winter without impairing the quality of germination to any appreciable degree, and that it can be sown the following spring or summer with good success.

DIRECTIONS FOR STORING THE SEED.

The vitality of wild rice seed is preserved almost perfectly if kept wet in cold storage—Nature's method of preservation. This method of storage implies that the seed has been properly harvested and cared for up to the time of storage. The seed should be gathered as soon as mature, put loosely into sacks (preferably burlap), and sent at once to the cold-storage rooms. If the wild rice fields are some distance from the cold-storage plant the sacks of seed should be sent by express, and unless prompt delivery can be guaranteed it is not advisable to send by freight even for comparatively short distances. It is very important that the period between the time of harvesting and the time when the seed is put into cold storage be as short as possible. If this time is prolonged to such an extent as to admit of much fermentation or to allow the seed near the outside of the bags to become dry during transit, its vitality will be greatly lowered.

It is not practicable to give any definite length of time which may elapse between harvesting and storing, inasmuch as the temperature, humidity, and general weather conditions, as well as the methods of handling the seed, must be taken into consideration. Let it suffice to say, however, that the vitality of the seed will be the stronger the sooner it is put into cold storage after harvesting.

As soon as the seed is received at the cold-storage plant, while it is still fresh and before fermentation has taken place, it should be put into buckets, open barrels, or vats, covered with fresh water, and placed at once in cold storage. If there is present a considerable quantity of light immature seed or straw, broken sticks, etc., it will be profitable to separate this from the good seed by floating in water

[a] Wild Rice: Its Uses and Propagation. Bulletin No. 50, Bureau of Plant Industry, United States Department of Agriculture, 1903.

preparatory to storing. The storage room should be maintained at a temperature just above freezing—what the storage men usually designate as the "chill room."

When taken from cold storage in the spring the seed must not be allowed to dry out before planting, as a few days' drying will destroy every embryo.

Seed which was stored under the foregoing conditions from October 19, 1903, to November 15, 1904, 393 days, germinated from 80 to 88 per cent. Another lot of seed, which was stored on October 6, 1904, and tested for vitality on April 17, 1905, germinated 79.8 per cent.

Plate I shows the luxuriant growth made by the seed which was kept wet and stored at a temperature of 32° to 34° F. for 393 days.

DETAILED CONDITIONS AND RESULTS OF STORAGE EXPERIMENTS.

The foregoing conclusions are based on the results obtained from two series of experiments, as follows:

In October, 1903, a box of wild rice seed was received from Ontario, Canada. This seed, as soon as gathered, was loosely packed in moist sphagnum and sent by express to the Seed Laboratory of the United States Department of Agriculture. After a few days, while it was yet moist and before any fermentation had taken place, the seed was divided into four lots for special treatment, as follows:

(1) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F.

(2) Seed submerged in water and placed in cold storage at a temperature of 12° F. The seed was soon embedded in a solid mass of ice and remained so until samples were taken for test.

(3) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 32° to 34° F.

(4) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 12° F.

In October, 1904, a second consignment of seed was received from Minnesota, and the following additional storage experiments were made by Mr. C. S. Scofield, of the Bureau of Plant Industry.

(5) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F., as in No. 1.

(6) Seed submerged in water and placed in cold storage at a temperature of 12° F., as in No. 2.

(7) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building. The water was changed daily when not frozen.

(8) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building, as in No. 7. In this case the water was not changed save to replace the loss due to evaporation.

(9) The conditions for No. 9 were the same as those for No. 8, except that air was forced into the water daily when not frozen solid.

Samples of seed were taken from the different lots and tested for vitality at irregular intervals throughout the time of storage, which, in the former series, extended over a period of approximately thirteen months and in the latter series over a period of little more than six months.

Experiments Nos. 1 and 5.—The seed which was submerged in water and stored in the "chill room" showed no deterioration in vitality. The results of the final tests gave a germination varying from 79.8 to 88 per cent. This is practically Nature's method of preserving the vitality of the seed during the winter.

Experiments Nos. 2 and 6.—The seed which was submerged in water and stored at a temperature of 12° F. was all killed before the spring following the date of storage. Soon after being placed in storage the water was frozen solid and the seeds were embedded in a mass of ice, in which condition they remained throughout the experiment, a portion being cut out from time to time for germination tests. The complete loss of vitality in these two lots of seed is attributed not to the freezing directly, but to the thorough desiccation as a result of the continuous low temperature.

Experiments Nos. 3 and 4.—The samples of seed which were stored in cloth bags at the temperatures of 32° to 34° F. and of 12° F. had, for all economic purposes, entirely lost their vitality. The average percentage of germination, as shown by the 37 tests made from each of the two lots, was less than five-tenths of 1 per cent.

Experiment No. 7.—The seed which was submerged in water and stored on the roof of the laboratory building, the water being changed daily, showed a good percentage of germination when the last vitality tests were made. If only a small quantity of seed is desired for the spring planting and cold storage can not be readily secured, good results may be obtained by this treatment; but it is much less certain and probably more expensive than keeping the seed in cold storage, and for this reason is not recommended. The success of this method will likewise depend largely on the temperature of the water.

Experiments Nos. 8 and 9.—On April 22, 1905, samples taken from each of these two lots of seed showed a marked deterioration in vitality. Thoroughly mixed samples from No. 8 showed a vitality of only 58 per cent, while No. 9 had deteriorated to 14.3 per cent.

PACKING FOR TRANSPORTATION.

Too much care can not be given to the matter of packing the seed for transportation, for unless the packing is properly done the vitality of the seed will be destroyed during transit. What is here said applies to fresh seed which is to be sown in the autumn, as well as to seed which has been kept in cold storage during the winter. It must not be forgotten, however, that the vitality of cold-storage seed is more quickly destroyed on drying than that of fresh seed.

For transportation the seed should be carefully packed, with moist sphagnum, cocoanut fiber, or fine excelsior, in a loosely slatted box. If the time of transportation does not exceed five or six days no special precautions need be taken as to the temperature. During the period of transportation it is quite probable that some of the seed will germinate, but if sown at once growth will not be retarded and the roots will soon penetrate the soil and anchor the young plants.

If the time of transportation is necessarily long, it is recommended, if the best results are desired, that some provision be made for a reduced temperature. The nearer the temperature approaches that of freezing the better. It has been demonstrated, however, that a fair percentage of seed will remain germinable for a considerable time if packed as above described.

On October 10, 1904, Mr. C. S. Scofield sent a small quantity of wild rice, packed in moist sphagnum moss in a well-ventilated box, to Doctor De Vries, of Amsterdam, Holland. On October 14 or 15 this box was placed in cold storage on the steamer in New York Harbor. The box of seed was received by Doctor De Vries in good condition on November 2, twenty-one days after the seed was packed for shipment.

METHODS OF MAKING GERMINATION TESTS.

The samples were tested (1) between folds of blotting paper—our regular method for testing the germination of most seeds—and (2) in water, Nature's method of sowing wild rice seed. The latter method gave much better results and was the one finally adopted for the laboratory tests. The seed should be covered with water, the water in the dishes to be changed daily.

Plate I shows the importance of making the germination tests in water, as described in the foregoing paragraph. The seed was covered with water and placed in a germinating chamber maintained at an alternating temperature of 20° C. (68° F.) for eighteen hours, and 30° C. (84° F.) for six hours, until the majority of the seeds had germinated. At this stage the dish containing the seeds was transferred to the worktable, which was exposed to the temperature of the laboratory—approximately that of a living-room. The water in the dish was changed daily during the period of germination, and water was afterwards added at irregular intervals to replace the loss by evaporation.

Plate II shows somewhat in detail the different stages in the germination of wild rice seeds. The seeds and seedlings are shown in natural size. In *b* and *c* the first sheath has just burst through the seed coats, taking a position at right angles to the seed proper. The lateral roots begin to emerge when the first sheath leaf has attained a length of ½ to 1½ inches. From this time growth continues rapidly, and by the time the seedlings are 2 or 3 inches long the root system is very well developed (*f* and *g*). At this stage under favorable conditions the plants have a good hold in the soil and will not be washed away by an ordinary freshet. The relative position of the actively growing seedling is always at right angles to that of the old seed, as shown in *f* and *g*.

EFFECT OF TEMPERATURE ON GERMINATION.

Germination tests were made at constant and alternating temperatures, ranging from 15° to 35° C. (59° to 95° F.). While no effort was made to show the minimum and maximum temperatures of germination, the percentage was somewhat reduced at a constant temperature of 35° C., and the maximum is not much above that. All of the other temperatures gave good results. The lower temperatures, however, were slightly more favorable than the higher. These facts are valuable to show that the wild rice plant can thrive in either warm or cold water, but better, perhaps, in northern than in southern latitudes.

SUMMARY.

(1) Under no circumstances should wild rice seed which is intended for planting be allowed to dry. Dried seed will germinate but rarely and should never be sown.

(2) Wild rice seed can be stored without deterioration if it is gathered as soon as matured, put into barrels or tanks, covered with fresh water, and, before fermentation has set in, stored at a temperature of 32–34° F. Seed treated in this way germinated as high as 88 per cent after being in storage 393 days. Fresh seed seldom germinates better, and usually not so well.

(3) After the seed is taken from cold storage it should not be allowed to dry. The vitality of cold-storage seed is destroyed on drying even more quickly than that of fresh seed.

(4) For transportation the seed should be packed in moist sphagnum, cocoanut fiber, or fine excelsior. If not more than five or six days are required for transit, no special precautions need be taken for controlling the temperature; but if the time for transportation exceeds

six days, provision should be made for a temperature sufficiently low to prevent marked fermentation. A temperature approximately freezing will give the most satisfactory results.

(5) Wild rice can be sown either in the autumn or in the spring. Spring sowing is preferable, thus avoiding the danger of having the seed eaten or destroyed by wild ducks or other animals during the fall or winter, or of its being buried or washed away by the heavy floods of late winter or early spring.

(6) Wild rice should be sown in the spring in from 1 to 3 feet of water which is neither too stagnant nor too swiftly moving, as soon as the danger of heavy floods is passed.

(7) Wild rice is of the greatest importance as a food for wild water-fowl, likewise a delicious breakfast food for man, and the area in which it is extensively grown should be extended. It will grow luxuriantly in either warm or cold water; furthermore, it can be grown successfully in water which is slightly salty to the taste.

(8) In determining the vitality of any sample of wild rice seed the germination tests should be made in water—the condition under which the self-sown seed germinates.

(9) The seed will germinate well at temperatures ranging from 15° to 30° C. The maximum temperature of germination is above 35° C. (95° F.), but better results are obtained at lower temperatures.

DESCRIPTION OF PLATES I AND II.

Plate I. Wild rice growing in water. This seed was submerged at a temperature of 32–34° F. for approximately thirteen months. In making the germination test the seed was covered with water and placed in a germinating chamber maintained at a temperature of 20° C. (68° F.) for eighteen hours, and at 30° C. (86° F.) for six hours. After the majority of the seeds had germinated the dish was transferred to the worktable of the Seed Laboratory.

Plate II. Progressive stages in the development of wild rice seedlings; *f* and *g*, seedlings showing the relative position of the growing seedlings and the parent seed, which take a position at right angles to each other when grown normally in water. (Natural size.)

WILD RICE GROWING IN WATER AFTER BEING KEPT WET IN COLD STORAGE AT A TEMPERATURE OF 32-34° F., FROM OCTOBER 19, 1903, TO NOVEMBER 15, 1904.

STAGES OF GERMINATION OF WILD RICE, SHOWING THE DEVELOPMENT OF THE ROOT SYSTEM AND THE RELATIVE POSITION OF THE SEEDLING AND THE PARENT SEED. NATURAL SIZE.

II.—THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.

By George G. Hedgcock, *Assistant in Pathology, Vegetable Pathological and Physiological Investigations.*

INTRODUCTION.

The diseases of the apple which have been classed under the name crown-gall have, during the last few years, attracted much attention, due partly to an increase of these diseases and partly to the enacting of more stringent State laws governing the shipment and inspection of trees.

A series of investigations into the nature of crown-gall upon the apple, pear, raspberry, peach, almond, grape, rose, and other plants has been in progress for some time in the Mississippi Valley Laboratory of the Bureau of Plant Industry at St. Louis, Mo., and also at other points in the Mississippi Valley. It is not to be assumed, however, that such diseases are more common in this locality than in some other portions of the United States. Apple crown-gall and hairy-root have been found in all nurseries that have been examined in various portions of the country.

This preliminary report is sent out, not with the intention of giving the results of all our investigations, but for the purpose of calling the attention of apple-tree growers to the different diseases hitherto known as apple crown-gall, and to endeavor to interest them in the collection of data regarding the predisposition of varieties to these diseases.

TWO DISTINCT DISEASES, CROWN-GALL AND HAIRY-ROOT.

Our investigations have resulted first in separating apple crown-gall into two diseases, which are considered distinct. The disease now designated as crown-gall is a callous-like gall growth of hypertrophied tissue following wounds on some portion of the root system of the tree, which rarely occurs above the ground on parts of the trunk or limbs. (See Pl. III, figs. 1 and 2.)

The malady now called the hairy-root disease is evidently the same as the one first given this name by Stewart, Rolfs, and Hall in Bulletin 191 of the New York State Experiment Station. It is characterized both in seedlings (Pl. IV, fig. 1, and Pl. V, fig. 2) and in grafted or budded trees (Pl. III, figs. 3 and 4) by a stunted root system, accompanied with an excessive production of small fibrous roots, often originating in clusters from the main root, or taproot. Galls often occur in connection with hairy-root, but these are a result of wounds rather than a form of this disease. Seedlings of the hairy-root type, unless wounded, remain free from galls.

TYPES OF APPLE CROWN-GALL.

Apple crown-gall is of two types. A hard callous form is common on grafted trees at the union of the root and scion, and at any other point of the root system where wounds occur in either the cultivation or transplanting of trees (Pl. III, fig. 1). The results of extensive inoculations with this type have failed to prove that this disease is of a contagious nature.

A second type is a soft form more common on seedlings (Pl. IV, fig. 2), occurring more rarely on grafted trees (Pl. III, fig. 2). These softer galls resemble those of the raspberry and peach, in that they are soft and often rot off. It is not certain, however, that they, like the latter, are replaced the following year by a new gall growth from the adjacent live tissues of the host, nor is there proof yet that they are of a contagious nature.

EFFECT UPON THE LENGTH OF LIFE OF THE APPLE TREE.

Careful data are being collected from orchards and nurseries as to the effect of these diseases upon the life and fruitfulness of trees. Any information as to the locality of orchards in which diseased trees have been planted will be highly appreciated. In our crown-gall orchard there are more than 200 trees diseased with the hard type of crown-gall, and 200 healthy trees of the same grade planted under similar conditions. After two years' growth six of the crown-gall trees and nine of the healthy ones have died. No difference in the growth of the trees is noticeable. However, it can not be assumed from the results so far that, on the one hand, the disease may not yet shorten the life of the trees, or, on the other, that the trees may not entirely overcome its effects. A tree having crown-gall on its roots, however, can never be correctly graded with a smooth-rooted tree. The root system of a healthy fibrous-rooted apple tree is shown in Plate V, figure 1.

SUGGESTIONS TO NURSERYMEN.

Nurserymen are advised to be careful in the selection of seedlings for grafting and budding. All rough, warty, or galled seedlings should be thrown out, for most of them will form rough-rooted trees. Seedlings with tufted or hairy roots should also be rejected, for these,

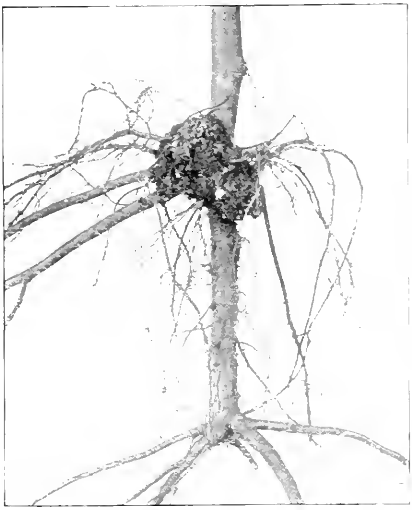

FIG. 1.—APPLE CROWN-GALL ON GRAFTED TREE.

FIG. 2.—APPLE CROWN-GALL ON TRANSPLANTED SEEDLING.

FIG. 3.—HAIRY-ROOT DISEASE ON GRAFTED APPLE TREE.

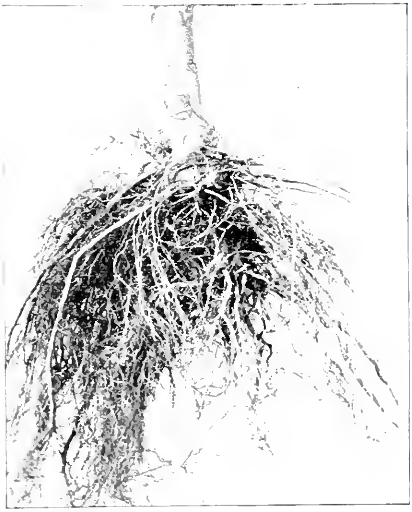

FIG. 4.—HAIRY-ROOT DISEASE ON GRAFTED APPLE TREE.

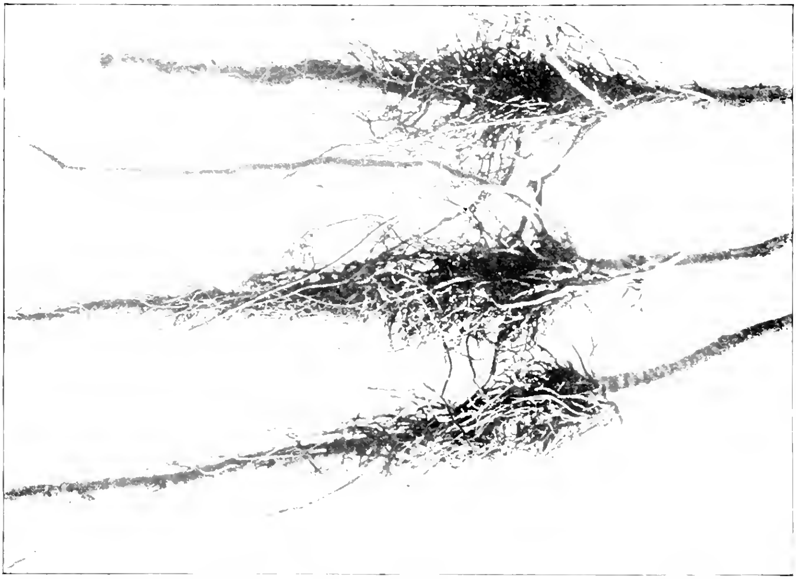

FIG. 1.—APPLE SEEDLINGS DISEASED WITH HAIRY-ROOT.

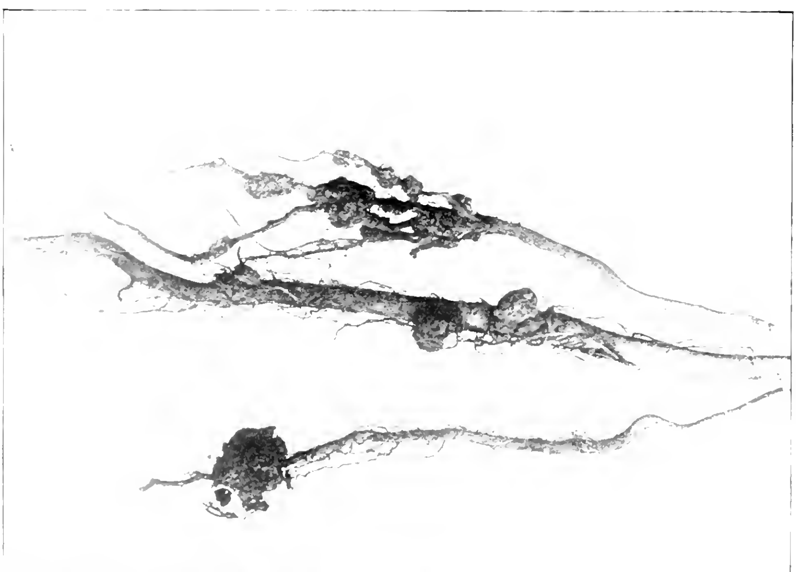

FIG. 2.—APPLE SEEDLINGS DISEASED WITH SOFT CROWN-GALL.

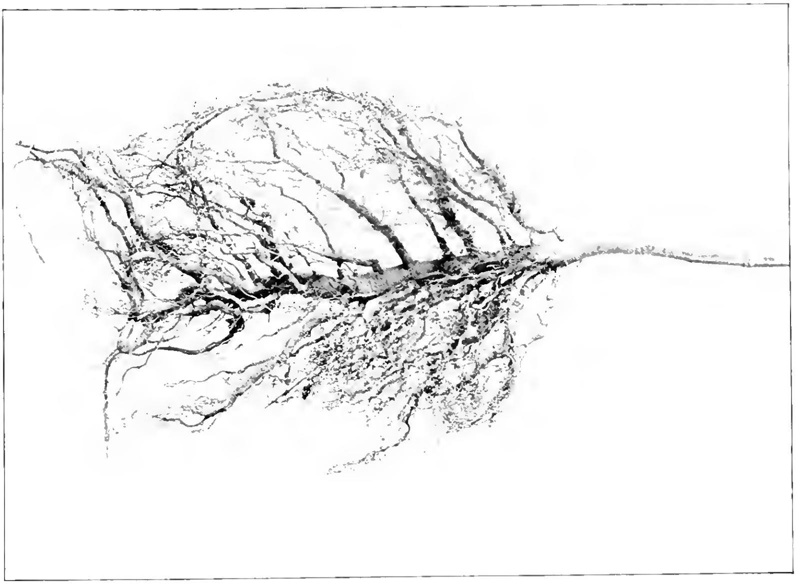

Fig. 1.—Healthy Fibrous-Rooted Apple Tree, Pot Grown.

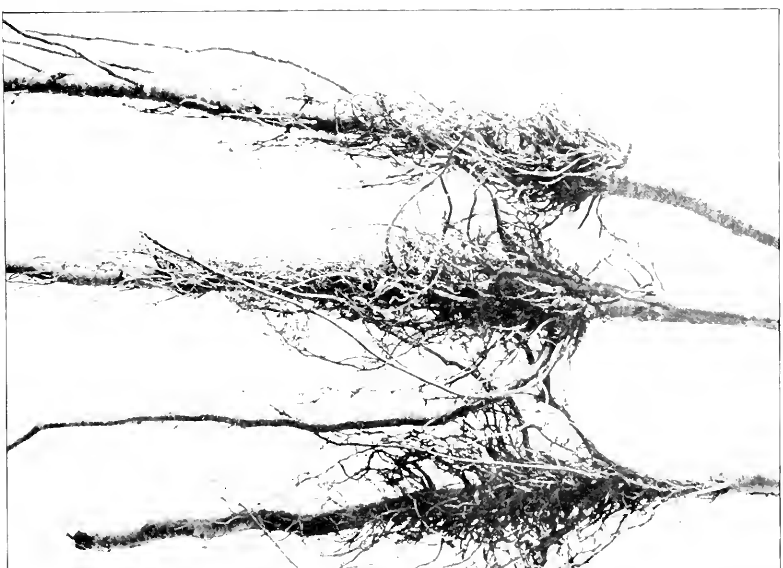

Fig. 2.—Apple Seedlings Diseased with Hairy-Root.

as shown by our experiments, develop into hairy-rooted trees with a very deficient root system. The hairy-root disease, as it appears from the results of two years' experiments, is not contagious. It is hoped in the near future to be able to offer some practical means of reducing the percentage of trees affected with these diseases in the nursery.

DATA DESIRED.

The hearty cooperation of nurserymen and orchardists in securing data is desired. It is hoped to secure the help of the leading nurserymen of this country in getting an accurate count from each nursery of the number of diseased trees in at least one row of every variety in all fields where the trees are all dug in one season. Such data are desired from every locality where apple trees are grown. Printed blanks with directions for tabulating such data have been provided and these will be sent to all who request them. Address the Mississippi Valley Laboratory, St. Louis, Mo.

B. P. I.—189.

III.—PEPPERMINT.[a]

By Alice Henkel, *Assistant, Drug-Plant Investigations.*

DESCRIPTION.

One of the most important essential oils produced in the United States is distilled from the peppermint plant and its varieties. The three kinds of mint grown in this country for the distillation of peppermint oil are the so-called American mint (*Mentha piperita* L.), the black mint (*Mentha piperita vulgaris* Sole), and the white mint (*Mentha piperita officinalis* Sole), the two last named being varieties of the American mint.

The American mint, although introduced from England many years ago, is so called from the fact that it has long been cultivated in this country, and the name "State mint" has been applied to it in the State of New York for the same reason.

The peppermint, or American mint, is now naturalized in many parts of the eastern United States, occurring in wet soil from the New England States to Minnesota, south to Florida and Tennessee. It is an aromatic perennial belonging to the mint family (Menthaceae), and propagates by means of its long, running roots (fig. 1). The smooth, square stems are erect and branching, from 1 to 3 feet in height, bearing dark-green, lance-shaped leaves, which are from 1 to 2 inches long, and from one-half to 1 inch wide. The leaves are pointed at the apex, rounded or narrowed at the base, sharply toothed, smooth on both sides, or with hairy veins on the lower surface. The flowers are borne in whorls in dense, terminal spikes; they are purplish, with a tubular, five-toothed calyx, and a four-lobed corolla. (Fig. 2.)

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[a] In response to a steady demand for information relating to the peppermint industry, Miss Alice Henkel, Assistant in Drug-Plant Investigations, has been requested to bring together the most important facts regarding the history, culture, and utilization of the peppermint plant. The information here presented has been obtained in large part from scattered articles on the subject, and in part from experience with the plant in the Testing Gardens of the Department of Agriculture.

Rodney H. True, *Physiologist in Charge.*

Office of Drug-Plant Investigations,
Washington, D. C., October 14, 1905.

The two varieties mentioned are closely related botanically, although in general appearance they are quite different. The variety known as black mint (*Mentha piperita vulgaris*) has purple stems and slightly toothed, dark-green leaves, while the white mint (*Mentha piperita officinalis*) has green stems, with brighter green leaves, which are more lance-shaped and more deeply toothed. Black mint is much more hardy and productive than either the American mint or the white mint, and is grown on nearly all peppermint farms in this country. The white mint, which produces a fine grade of oil, is rarely cultivated on a commercial scale in this country on account of its inability to withstand the climate and its smaller yield of essential oil.

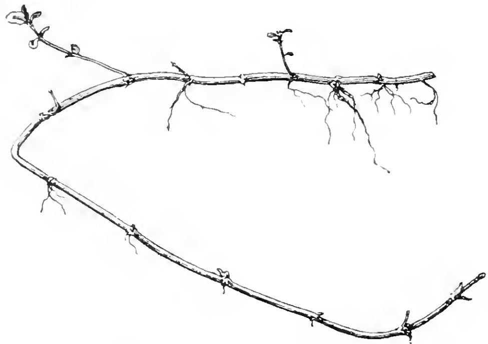

FIG. 1.—Peppermint "runners," showing method of propagation.

The oils spoken of as Japanese and Chinese "peppermint" oils are not obtained from the true peppermint plant, but are distilled from entirely different species, namely, *Mentha arvensis piperascens* Malinvaud and *Mentha arvensis glabrata* Holmes, respectively.

FIG. 2.—Leaves and flowering top of peppermint.

COUNTRIES WHERE GROWN.

The most important peppermint-producing countries are the United States, England, and Japan. Peppermint is grown on a smaller scale in Germany, France, Italy, Russia, China, and southern India.

In Japan, peppermint cultivation is said to have been undertaken before the Christian era. The plant grown there is not, as already stated, the peppermint cultivated in our country, but *Mentha arvensis piperascens*, which is entirely distinct from the true peppermint, not only botanically but also in taste and odor.

Peppermint is cultivated on many drug farms in England, especially at Mitcham, the middle of the eighteenth century marking the beginning of peppermint cultivation in that country. Up to 1805, however, there were no stills at Mitcham, and the crops obtained there were sent to London for distillation. About 1850, at which time the peppermint industry in England was at its height, the effect of American competition began to be felt, and caused a decided check in the production.

PEPPERMINT CULTIVATION IN THE UNITED STATES.

Wayne County, N. Y., in 1816, was the first locality in this country to distill peppermint on a commercial scale. The supply of rootstocks was obtained from the wild plants found growing along the banks of streams and brooks. Adjacent counties soon undertook the cultivation of peppermint, but Wayne County was then, and is now, the principal peppermint district in New York.

The cultivation of peppermint was extended to Ashtabula, Geauga, and Cuyahoga counties in Ohio, and also to northern Indiana. Roots were taken from Ohio into St. Joseph County, Mich., the first plantation being made on Pigeon prairie in 1835. Other plantations in St. Joseph County were established the following years, and adjoining counties soon took up the cultivation of peppermint, and southwestern Michigan has been for thirty-five years or more the greatest peppermint-producing section in the United States.

About 1844 an interesting peppermint-oil monopoly[a] was undertaken by a New York firm, which seems to have put an end to peppermint cultivation in Ohio, for none of the counties just mentioned has since been heard from as a peppermint-producing section.

The first step taken by this New York firm in its efforts to control the peppermint-oil market was to send a representative to Liverpool, England, to ascertain the amount annually demanded by that market, which was found to be about 12,000 pounds. This done, another agent was sent West to determine the amount produced annually, with the result that it was found that the farms in New York did not produce enough oil for their purposes, the plantations in Ohio too much, while those in Michigan seemed to produce just about the right amount to satisfy the Liverpool demand. A contract was then entered into by this agent with the producers in New York and Ohio "whereby he bound them under heavy penalties to plow up their mint fields and destroy the roots, and not plant any more mint, or sell or give away any roots, or produce or sell any mint oil for the

[a] Proc. Amer. Pharm. Assoc., 7: 449–459 (1858).

period of five years." For this wholesale destruction of their mint fields the producers received a bonus of $1.50 per acre. Next a contract was made by the agent with the producers of St. Joseph County, Mich., agreeing to pay them $2.50 a pound for their mint oil, every ounce of the mint oil to be delivered for a period of five years to the agents named in the contract. They also were prohibited during this period from extending their plantations and from selling roots to anyone. The producers held to these contracts for about three years, after which period the New York firm was not so anxious to enforce them, having, in the meantime, acquired a large fortune through its peppermint-oil monopoly.

Since that period the area devoted to peppermint cultivation in Michigan has steadily increased, and northern Indiana, with its principal centers of production in St. Joseph, Steuben, and La Grange counties, continues to place on the market a considerable quantity of oil. Ohio seems to have abandoned peppermint cultivation, at least on a commercial scale, and New York, for a number of years and until very recently, had greatly reduced the area under peppermint, thousands of acres formerly devoted to this crop having been given over to sugar beets, onions, and celery. In 1889 Wayne County, N. Y., had 3,325 acres of peppermint, whereas in 1899 there were only 300 acres. In 1905, about 933 acres were under cultivation.

Special canvassers appointed by the State of Michigan[a] made a canvass of 299 growers in the peppermint district in that State, covering 39 townships in nine counties (Allegan, Berrien, Branch, Cass, Kalamazoo, Oakland, St. Joseph, St. Clair, and Van Buren), and the total number of acres under peppermint cultivation, the number of pounds of oil distilled, and the average number of pounds per acre, as ascertained by this canvass, for the years 1900, 1901, and 1902, are as follows:

Items.	1900.	1901.	1902.
Total number of acres grown	2,112	2,782½	6,400⅔
Total number of pounds distilled	47,628½	63,718¾	82,420¼
Average number of pounds per acre	22.5	23.9	12.8

CULTIVATION.

Peppermint cultivation is most profitable on muck lands, such as are now used in Michigan for this crop and for celery and cranberry culture. These muck lands were formerly marshes and swamps, which have been reclaimed by draining, plowing, and cultivating, the swamp vegetation having been thus subdued, and the decayed

[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

vegetable matter resulting in a very black soil which is most admirably adapted to mint cultivation. Formerly peppermint was grown exclusively on upland soil in Michigan, but it is a very exhausting crop on such land. Only two crops can be obtained from upland plantations, and after the second year's harvest the land is plowed and a rotation of clover, corn, etc., is practiced for five years before peppermint is again planted. But on the rich muck land peppermint can be grown year after year for six or seven years, the land being plowed up after each crop is harvested, and the runners turned under to form a new growth the succeeding year. The ground is harrowed in autumn and again in spring, and carefully weeded. Peppermint will grow, however, on any land that will produce good crops of corn, the ground being prepared by deep plowing and harrowing.

In Michigan[a] the land is plowed in the autumn, and early in spring it is harrowed and marked with furrows about 3 feet apart. The roots selected for planting are from one-eighth to one-quarter of an inch thick, and from 1 to 3 feet long; and the workmen engaged in "setting mint," as the process is called, carry these roots in sacks across their shoulders and place them in the furrows by hand, covering the roots with one foot and stepping on them with the other. The roots are planted so close together in the furrow as to form a continuous line. An expert workman can plant about an acre in a day.

In about two weeks the young plants will make their appearance, and are carefully hoed and cultivated until July and August, when the plants have usually sent out so many runners as to make further cultivation difficult. The crop is cultivated with horse cultivators, but if the land was very weedy in the first place, the weeds will have to be pulled by hand. It is very necessary that the land be free from weeds, as any collected with the peppermint crop will seriously injure the quality of the oil.

It may be interesting to note here that on muck lands, when necessary, the horses are usually provided with mud shoes to prevent their sinking into the soft, wet ground, these mud shoes consisting of wide pieces of iron or wood about 9 by 10 inches, fastened to the hoofs and ordinary shoes by means of bolts and straps.

CONDITIONS INJURIOUS TO CROP.

Cold and wet weather or extremely dry periods have a very unfavorable effect on the mint crop. Insect enemies also tend to cut down the mint harvest—grasshoppers, crickets, and cutworms sometimes doing considerable damage. A rust, causing the foliage to drop off

[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

and leaving the stems almost bare, is apt to follow if very moist weather occurs toward the latter part of the season. Weeds are especially to be avoided in a mint field, since, as stated, the quality of the oil will be seriously impaired if these are harvested with the peppermint. The weeds generally found in a peppermint field are Canada fleabane (*Leptilon canadense*), fireweed (*Erechtites hieracifolia*), giant ragweed (*Ambrosia trifida*), pennyroyal (*Hedeoma pulegioides*), Eaton's grass (*Eatonia pennsylvanica*), June grass (*Poa pratensis*), and other low grasses.

HARVESTING AND DISTILLATION.

The first crop of mint is harvested in the latter part of August, when the plants are in full flower, and the gathering continues until about the middle of September, the stills running night and day until all the mint is disposed of. The first crop is usually cut with a scythe, as mowing machines do not work well on soft cultivated land. The succeeding crops are cut with a mowing machine or sweep-rake reaper. The highest yield per acre and the best quality of oil are obtained from the first year's crop. Sometimes, if the weather conditions have been very favorable, a second cutting is made. The yield of oil from peppermint obtained from the same field sometimes varies very much, the condition of the atmosphere seeming to exert an influence upon it, as it is said that mint cut after a warm and humid night will yield more oil than that cut after a cool and dry night. It requires about 330 pounds of dried peppermint to produce 1 pound of oil, and the yield of oil from an acre ranges from 12 to 50 pounds.

If the mint crop has been grown on muck land, all that is necessary after the crop has been harvested is to plow up the land and turn the runners under for a new crop. If grown on upland, after the second year's crop is in, or, at the most, after the third year's harvest, the land is plowed and then given up to other crops. Peppermint exhausts the land, and it is necessary to practice rotation of crops for about five years in order to put the land in condition if it is desired to use it again for peppermint cultivation.

After the plants are cut they are usually placed in windrows until they are dried, but are not allowed to become so dry as to permit the leaves to shatter off, and are then taken to the distillery. Some growers believe that if the plants are allowed to dry there will be a smaller oil content owing to the escape of some of the oil into the atmosphere, and so have the plants brought to the distillery in the green state; but Mr. A. M. Todd[a] is of the opinion that no loss of oil will result

[a] Amer. Jour. Pharm., 60: 328–332 (1888).

from drying, his experiments along this line showing that the dry plants can be distilled three times as rapidly as the green plants, and that a larger quantity of oil may be obtained. He states that—

To obtain the best results, both as to quality of essential oil and economy of transportation and distillation, the plants should be dried as thoroughly as possible without endangering the loss of the leaves in handling. Distillation should then take place as soon as convenient to prevent the oxidation of the oil in the leaf by atmospheric action.

The smaller producers, who have no stills of their own, have their mint crop hauled to the nearest peppermint distillery, where it is distilled for them at a cost of 25 cents per pound of oil.

DESCRIPTION OF STILL.

The apparatus used in peppermint distillation in the early years of the industry in this country consisted of a copper kettle, from the top of which a pipe connected with a condensing "worm." Water was placed in the kettle and the plants were immersed in it, and direct heat was applied to the bottom from a furnace. With such a still only about 15 pounds of oil could be obtained from a charge. In 1846, large wooden vats were substituted for the copper kettles, and the plants were distilled by steam passing through them. The kettle formerly used as the still was now employed to generate steam, a long pipe conveying the steam to the bottom of the vats. With this method of distillation from 75 to 100 pounds of oil could be obtained from a charge without much additional expense.

A modern peppermint still (fig. 3) may be briefly described as follows: The apparatus required consists of a boiler, a pair of large circular wooden vats, a condenser, and a receiver. The boiler, of course, is used for the generation of steam.

Two wooden vats are used in order that they may be filled and emptied alternately. These vats are about 6 feet high and about 5 feet in diameter, with tight-fitting removable covers and perforated false bottoms. Steam pipes are led from the boiler into the bottom of the vats.

The condenser consists of a series of pipes of block tin, either immersed in tanks of cold water or over which cold water is kept running, the condenser being connected with the top of the distilling vats. The condensed steam, together with the oil, flows into a metallic receiver, in which the oil, being lighter than the water, rises to the top and can be drawn off.

The perforated false bottoms with which the vats are supplied permit the passage of steam. A strong iron hoop is placed about this false bottom, and two pairs of stout chains, which meet at the top of the vat in a pair of rings, are attached to it. After the charge has been distilled it is drawn from the vats by means of this arrangement.

The plants are thrown into the vats and are closely packed by two or three men tramping upon them, and as the vat becomes about one-third full the packing is still further assisted by turning in a small supply of steam, which softens the plants. When the vat is filled the tight cover is replaced and a full head of steam turned on. In the largest distilleries the vats have a capacity of from 2,000 to 3,000 pounds of dried plants each.

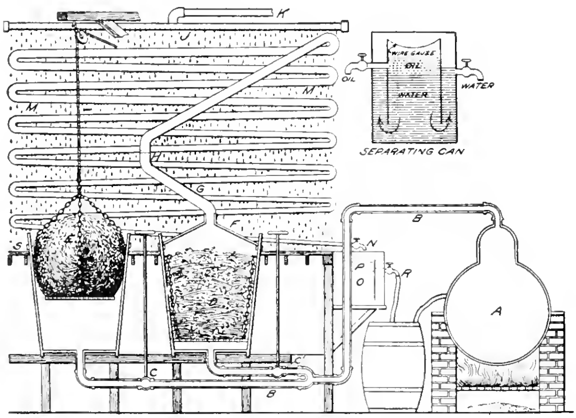

FIG. 3.—Peppermint still. (After Dewey, in Bailey's Cyclopedia of American Horticulture.)

A, boiler; *B*, steam pipes leading to vats; *C*, valves for shutting off steam; *D*, mint packed in vat ready for distilling; *E*, mint being lowered into vat; *F*, tight-fitting cover used alternately for both vats; *G*, pipe from top of vat, joined at *H* so as to swing to other vat; *J*, perforated pipe, from which cold water drops over condensing tubes; *K*, supply pipe for cold water; *M*, condensing pipes; *N*, outlet for condensed oil and water; *O* and *P*, water and oil in separating can; *R*, outlet for water; *S*, floor of distilling room.

Large tanks are used for storing the oil, and cans holding 20 pounds each are employed for shipping, three of these cans being placed in a wooden case.

The peppermint hay which remains after distillation is used as a fertilizer or is fed to stock.

PEPPERMINT OIL AND MENTHOL.

Peppermint leaves and flowering tops are official in the Eighth Decennial Revision of the United States Pharmacopœia, as are likewise the following products and preparations derived from these parts: Oil of peppermint, menthol, spirit of peppermint, and peppermint water.

The United States Pharmacopœia describes oil of peppermint as "a colorless liquid, having the characteristic strong odor of peppermint and a strongly aromatic pungent taste, followed by a sensation of cold when air is drawn into the mouth." It is largely used in medicine, internally as a stimulant and carminative, and externally to relieve neuralgic and rheumatic conditions. It is also used for flavoring and scenting confectionery, cordials, and cosmetics. There is a slight difference in the odor of white and black peppermint oil, the black being more pungent and less agreeable in fragrance than the white, which has a much finer odor, but, as already indicated, the white mint is less hardy than the black and yields a smaller quantity of oil.

The Japanese oil of peppermint, which, as pointed out elsewhere in these pages, is obtained from a different species of mint than that which produces the true oil of peppermint, is very inferior to the last named. It has a very unpleasant odor and a bitter, disagreeable taste, but it is a heavy oil and contains a higher percentage of menthol and, being a very much cheaper oil, it is liable to be used as an adulterant of true peppermint oil.

Menthol, formerly known as peppermint camphor, is the solid constituent of oil of peppermint, obtained by subjecting the distilled oil to an exceedingly low temperature by means of a freezing mixture. Its properties are about the same as those of oil of peppermint, only somewhat intensified. It is very largely made up into cones or pencils, which furnish a popular remedy, to be applied externally or inhaled, for the relief of headache, neuralgia, catarrh, asthma, and kindred affections. It is also largely employed in other forms of medication. The name "pipmenthol" has been applied to the menthol obtained from the American oil, to distinguish it from the Japanese menthol. Pipmenthol is said to have a distinct odor of peppermint, while the Japanese menthol has but a slight peppermint odor.

EXPORT OF PEPPERMINT OIL.

The exports of peppermint oil during the fiscal year ended June 30, 1904, amounted to 42,939 pounds, valued at $124,728. Germany and the United Kingdom were the largest consumers, the former receiving 22,372 pounds, valued at $65,505, and the latter 11,558 pounds, worth $31,798.

The following tables show the export of peppermint oil, by countries, for the fiscal year ended June 30, 1904, and the quantities and values of peppermint oil exported for a period of ten years, from July 1, 1894, to June 30, 1904, inclusive:

Exports of peppermint oil, by countries, for the fiscal year ended June 30, 1904.[a]

Country.	Quantity.	Value.
	Pounds.	
Belgium	473	$1,585
France	3,054	10,059
Germany	22,372	65,505
Italy	826	2,471
Netherlands	590	1,934
United Kingdom	11,558	31,798
Dominion of Canada:		
Nova Scotia, New Brunswick, etc	85	234
Quebec, Ontario, Manitoba, etc	1,165	3,306
Newfoundland and Labrador	94	204
West Indies:		
British	183	700
Cuba	29	87
Danish	17	55
Dutch	20	61
Argentina	1,237	3,504
British Guiana	10	31
Peru	50	175
British Australasia	1,176	3,019
Total	42,939	124,728

[a] The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 531, Bureau of Statistics, Department of Commerce and Labor.

Quantities and values of peppermint oil exported during the fiscal years 1895 to 1904, inclusive.[a]

Fiscal year.	Quantity.	Value.	Fiscal year.	Quantity.	Value.
	Pounds.			*Pounds.*	
1895	87,633	$194,616	1900	89,558	$90,298
1896	85,290	174,810	1901	60,166	63,672
1897	162,492	257,484	1902	36,301	54,898
1898	145,375	180,811	1903	13,033	34,943
1899	117,462	118,227	1904	42,939	124,728

[a] From The Foreign Commerce and Navigation of the United States for the year ending June 30, 1902, vol. 2, p. 309, Bureau of Statistics, Treasury Department; and The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 192, Bureau of Statistics, Department of Commerce and Labor.

PRICES OF PEPPERMINT OIL.

The price of peppermint oil was very low for a few years prior to 1900, the enormous production of 1897 resulting in a great drop in price. The lowest price paid for it was in 1899, when it brought only 75 cents per pound. As a result of the low price a great many mint farmers restricted the area of their mint plantations or altogether abandoned peppermint cultivation. The smaller output of the following seasons again sent prices up, and in 1902 the oil sold as high as $4.75 a pound, which price was maintained until early in 1903, when it gradually declined, until toward the end of that year it reached $2.20 per pound.

The following table[a] gives the highest and lowest prices of peppermint oil in bulk from 1873 to September 16, 1905:

Year.	Highest.	Lowest.	Year.	Highest.	Lowest.	Year.	Highest.	Lowest.
1873	$3.15	$3.15	1884	$3.00	$2.50	1895	$2.00	$1.70
1874	5.25	3.75	1885	4.37	2.75	1896	1.85	1.20
1875	5.50	3.20	1886	3.60	2.75	1897	1.25	.90
1876	3.75	2.40	1887	2.75	1.90	1898	.90	.80
1877	3.00	1.75	1888	2.40	1.75	1899	.90	.75
1878	2.00	1.50	1889	2.30	1.80	1900	1.10	.80
1879	2.65	1.45	1890	2.40	1.80	1901	1.80	1.10
1880	2.87	2.60	1891	2.50	2.45	1902	4.75	1.70
1881	2.85	2.35	1892	2.50	2.15	1903	4.75	2.20
1882	2.50	2.25	1893	2.45	2.15	1904	3.75	2.65
1883	2.60	2.20	1894	2.45	1.70	1905*	3.45	2.25

* To September 16.

The good prices of the past few years have caused many farmers to look again to peppermint as a profitable crop, as noted in increased areas under cultivation in many localities. This is the case not only in Michigan and Indiana, but also in New York, where for many years the peppermint industry has been declining. Thus, if favorable conditions of growth prevail, an increased production may be looked for within the next few years, which will have the effect of again depressing prices.

As is the case with other products the prices of which are subject to great fluctuations, the condition of the market for peppermint oil needs to be closely observed. The cost of cultivation per acre has been stated at from $12 to $14, and, with a charge of 25 cents per pound of oil for distillation, the market price may easily fall below the cost of production.

[a] From Oil, Paint, and Drug Reporter, September 18, 1905, p. 7.

B. P. I.—194.

IV.—THE POISONOUS ACTION OF JOHNSON GRASS.[a]

By A. C. Crawford, *Pharmacologist, Poisonous-Plant Investigations.*

Johnson grass, which was introduced from Turkey into this country about 1830,[b] has spread so that in many places it is considered as a weed and pest.[c] Some farmers, however, have utilized the dried grass as hay with advantage, either alone or combined with other food material,[d] and chemical analyses have proved its value as feed. Recently reports have come to this office from California of the death of cattle under such circumstances as to point to Johnson grass as the causative agent—the cattle dying in thirty minutes after eating the grass. Johnson grass belongs to the same genus of the Gramineae as sorghum. This group has been partially investigated chemically, and it has been found that the fresh green plants of various members yield

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[a] This office has from time to time received communications from stockmen, especially in the lower part of California, Arizona, and adjacent territory, expressing a suspicion that the eating of Johnson grass had caused the death of stock with rather sudden and violent symptoms. There has seemed to be little ground in poisonous-plant literature to support such an explanation. Last summer, however, convincing observations were reported from California by a stockman who had lost heavily, and a supply of the grass in question was obtained. The result of the study of this material was so positive, and the possibility of damage due to this unsuspected forage plant so clear, that this preliminary notice is put out in the hope of getting observations and material for study from many sources, in order, if possible, to determine the conditions under which the poisonous properties are developed and over how wide an area they are likely to appear.

Rodney H. True, *Physiologist.*

Office of Poisonous-Plant Investigations,
Washington, D. C., December 11, 1905.

[b] Ball, C. R. Johnson Grass. Bul. No. 11, Bureau of Plant Industry, United States Department of Agriculture, 1902.

[c] Spillman, W. J. Extermination of Johnson Grass. Bul. No. 72, Part III, Bureau of Plant Industry, United States Department of Agriculture, 1905.

[d] North Carolina Agricultural Experiment Station, Bul. 97, p. 92; Vasey, G., Grasses of the South, Bul. No. 3, Division of Botany, United States Department of Agriculture, 1887; Report of the Commissioner of Agriculture for 1881, pp. 231, 232, 239, 241; Report of the Secretary of Agriculture, 1890, p. 381.

hydrocyanic acid as a result of the action of enzymes on more highly complex bodies.[a]

Ball[b] in 1902 stated that at that time there had been no official reports to his office of cases of poisoning by Johnson grass, but that there were some newspaper statements to that effect. He thought these accounts were probably not authentic, but stated that "since Johnson grass is closely related to sorghum, which is known to be poisonous under some circumstances, it would not be surprising if Johnson grass should also be poisonous under like conditions. * * * In comparison with the great number of cattle fed or pastured in Johnson grass, the reported cases of poisoning are extremely rare."

The first report of the poisonous action of Johnson grass which reached the Department came from Miles City, Mont. Mr. William Story reported that he and a neighbor had lost several head of cattle after they had eaten small quantities of the grass, and that they had died very suddenly. Mr. Story suggested that there was "something peculiarly poisonous about the grass." The Commissioner of Agriculture in publishing this report stated that "although the grass has been cultivated in the South for forty or fifty years, no similar charges have been made against it."[c]

In India this plant is widely used as a fodder for cattle,[d] and the natives make use of the seeds for food. It has been noted there that deaths in cattle frequently occur when, on account of the failure of rain, the plants which have reached a certain size become stunted and withered. The toxic principle appears simultaneously over a wide area, but soon disappears if a rainfall occurs.[e] The deaths of cattle have been attributed by some to an insect living upon the plant, and in Australia it is the belief that *Sorghum vulgare*, which also yields hydrocyanic acid, becomes more poisonous when attacked by an insect during a drought. A similar observation has been made with *Sorghum vulgare* in the Sudan. Balfour[f] found that one specimen of the plant which harbored aphids yielded more hydrocyanic acid than a

[a] Dunstan, W. R., and Henry, T. A., The Nature and Origin of the Poison of Lotus Arabicus, Phil. Trans. Roy. Soc. London, 1901, vol. 194, B., p. 515; Dunstan, W. R., and Henry, T. A., Cyanogenesis in Plants, Phil. Trans. Roy. Soc. London, 1902, vol. 199, A., p. 399; Slade, Henry B., Prussic Acid in Sorghum, Jour. Amer. Chem. Soc., 1903, vol. 25, pp. 55–59; Slade, Henry B., Study of the Enzymes of Green Sorghum, Fifteenth Annual Report, Agricultural Experiment Station of Nebraska, 1902, pp. 55–62; Brünnich, J. C., Hydrocyanic Acid in Fodder-plants, Jour. Chem. Soc., 1903, vol. 83, part 2, pp. 788–796.

[b] Bul. No. 11, Bureau of Plant Industry, United States Department of Agriculture, p. 23.

[c] Report of the Commissioner of Agriculture, 1885, p. 74.

[d] Duthie, J. F. Fodder Grasses of Northern India, 1888, p. 41.

[e] Pease, H. T. Poisoning of Cattle by Andropogon Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 18, 1897, p. 679. See also Agr. Ledger, 1896, No. 24.

[f] Balfour, Andrew. Cyanogenesis in Sorghum Vulgare. First Report, Wellcome Research Laboratory, at Gordon Mem. College, Khartum, 1904, p. 47.

second one without parasites. Pease has lately claimed that the deaths from Johnson grass in India were really cases of nitrate poisoning, as he found 25 per cent of nitrate of potassium in the stem of the plant and was able to produce somewhat similar symptoms in animals by feeding them this salt. Johnson grass is being introduced into Australia as a fodder plant, but as yet no reports of its poisonous action there have been noted by the writer.[a]

There has been some chemical study of Johnson grass, but not with reference to any poisonous principle.[b]

A fresh, green, mature, nonflowering specimen of Johnson grass, moistened with a little water and preserved with chloroform, was sent from Santa Rosa, Cal., in sealed glass vessels, to this laboratory. This was botanically identified here as Johnson grass. This specimen was not immediately worked up, but remained in the jars for about a month. At that time on opening the jars a marked odor of hydrocyanic acid, together with that of chloroform, was detected. The ground-up plant, with the water in which it came, was distilled, and the distillate was caught in sodium hydrate solution. This distillate, on mixing with ferrous sulphate and acidulation with hydrochloric acid, gave a heavy blue precipitate with ferric chlorid. Yellow ammonium sulphid was added to the same filtrate, and the mixture was evaporated to dryness on the bath. The dried residue was then taken in hydrochloric acid water, and on the addition of ferric chlorid the fluid gave the characteristic red reaction for hydrocyanic acid. The nitro-prussid, picric acid, and silver nitrate reactions were all positive for hydrocyanic acid. The aqueous fluid in which the plant was shipped was filtered off from the plant and gave on distillation all the above reactions for hydrocyanic acid.

According to our California correspondent, this plant is poisonous when grown on irrigated as well as on nonirrigated lands, but especially so when grown on irrigated soil and the growth has become rank.

Recently Dunstan[c] has shown that lima beans (*Phaseolus lunatus*), which when grown wild in Mauritius yield sufficient hydrocyanic acid to produce poisoning, when cultivated in Burma lose this toxicity almost entirely, although it may return most unexpectedly.[d] He was unable, however, to determine the condition which increased its poisonous properties.

It is interesting to note, besides this production of hydrocyanic acid from complex glucosids, that proteids, when subjected to oxidation

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[a] Maiden, J. H. Useful Australian Plants. Department of Agriculture New South Wales, Misc. Pub. No. 22, 1896.

[b] Annual Report of the Commissioner of Agriculture, 1878, p. 168.

[c] Dunstan, W. R. Phaseolus Lunatus. Agricultural Ledger, 1905, No. 2.

[d] Church, A. H., Food-Grains of India, 1886, p. 155; Watt, George, Dictionary of the Economic Products of India, vol. 6, part 1, 1892, p. 187.

under certain conditions, also yield it.[a] In fact, hydrocyanic acid may exist in plants in two forms, either as the acid or as one of its salts, or in the form of complex glucosids.[b] Under the circumstances, the conclusions of Brünnich[c] should be held in mind, viz; that "all fodder plants related to sorghum must be used with discretion in either the green or the dried state, and should not be given in large amounts to animals which have fasted for some time."

In reference to other forage plants, Avery[d] says that "Kafir-corn leaves also contain this poison, but other forage plants—clover, alfalfa, grasses, and corn—give no test for prussic acid," and Brünnich also found it in Guinea grass or *Panicum maximum* and *P. muticum*. Many facts have been collected relative to the distribution of hydrocyanic acid in plants, yet its exact significance in their metabolism is unknown.[e] The question as to the relationship of parasites[f] to the production of hydrocyanic acid remains to be solved.

Later investigations will be carried on to determine the nature of this cyanogenetic compound, to determine whether hydrocyanic acid is present in all stages of its growth, but disappears on drying the plant, whether the hydrocyanic acid production occurs under all conditions or only when grown on certain soils, and the amount produced. Hydrocyanic acid will also be looked for in other members of this genus.

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[a] Plummer, R. H. A. The Formation of Prussic Acid by the Oxidation of Albumins. Jour. Physiol., vol. 31, 1904, p. 65; vol. 32, 1904, p. 50.

[b] Les Nouveaux Remèdes, vol. 14, 1898, p. 272.

[c] Jour. Chem. Soc., 1903, vol. 83, part 2, p. 792.

[d] Avery, S. Laboratory Notes on Poison in Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 23, 1902, p. 705.

[e] Czapek, F. Biochemie d. Pflanzen, 1905, vol. 2, p. 259.

[f] Literature on some parasites of the sorghum family can be found in Bot. Gaz., vol. 28, 1899, p. 65. Also in Busse, W., Untersuch. u. d. Krank. der Sorghum Hirse, Arb. a. d. biol. Abtheil. f. Land u. Forstw. am kaiserl. Gesundheitsamt, 1904, vol. 4.

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