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MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Practical Results from Studies on Egg Production

By H. D. GOODALE

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
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BULLETIN No. 191.

DEPARTMENT OF POULTRY HUSBANDRY.

PRACTICAL RESULTS FROM STUDIES ON EGG PRODUCTION.

H. D. GOODALE.

Introduction.

A series of short papers, dealing with phases of egg production from the purely practical standpoint, has been planned. They will be published from time to time as circumstances admit. Their aim is to present as definite information on the subject of each as the evidence warrants. The detailed data on which these practical papers are based are in process of being published elsewhere. Those already published are —

Internal Factors Influencing Egg Production in the Rhode Island Red Breed of Domestic Fowl. American Naturalist, Vol. LII, No. 614, 1918, 3 parts, pp. 65–94, 209–232, 301–321.

Winter Cycle of Egg Production in the Rhode Island Red Breed of Domestic Fowl. Journal of Agricultural Research, Vol. XII, No. 9, 1918, pp. 547–574.

The Bearing of Ratios on Theories of the Inheritance of Winter Egg Production. Journal of Experimental Zoölogy, Vol. 28, No. 1, 1919, pp. 83–124.

I. Inbreeding.

The poultryman often is in a quandary regarding inbreeding. On the one hand it is advocated, and on the other just as strongly condemned. What, then, are the facts?

Inbreeding may be defined as the mating of relatives, and just as there are degrees of relationship so there are degrees of inbreeding. Line breeding involves inbreeding, so designed, however, as to keep its amount at a minimum.

In the work at this station close matings of various sorts have been made as well as unrelated matings. The results afford a *practical* answer to the question, shall I inbreed? The answer is found in a paraphrase of an old saying, which is applicable to all breeding, "Handsome is that handsome breeds," that is, inbreeding is to be judged by its results. This is a special application of the well-known progeny test. Now experience shows that the results of some inbred matings are very good, while others are poor. But, contrariwise, sometimes the results of matings between unrelated birds are poor, while others are good. Nevertheless, matings between unrelated birds are almost universally approved, while inbreeding is often condemned.

In this bulletin no attempt will be made to answer most of the questions that arise concerning inbreeding, but evidence that inbreeding may be highly advantageous will be presented.

The Evidence.

1. Male No. 8097 produced 10 daughters, by his sister, that averaged 155.7 eggs each. The father of this pair also came from a brother-sister mating. On the other hand, male No. 8097 by a half first cousin produced 14 pullets that averaged 156.7 eggs each. There is no relation here between the degree of kinship (or inbreeding) and egg production.

2. The offspring of male No. 8147 by 4 females furnish interesting comparisons, as shown in the table, and are selected because the whole situation appears here in a nutshell. Eleven daughters by female No. 9420, which laid 221 eggs, averaged 190.1 eggs each. Female No. 9420 is distantly related to male No. 8147 five generations back through a single bird. By female No. 8652, laying 196 eggs, with a much inbred and tangled line of descent and closely related to himself (see figure), there were 9 daughters, with an average of 181.5 eggs. Moreover, the highest producing individual in the two families, viz., B2088, with a record of 237 eggs, was a daughter of female No. 8652. On the other hand, female No. 8418, laying 139 eggs, also closely related to male No. 8147 (see figure), produced 11 pullets sired by him that averaged only 156 eggs each. Finally, there is the mating of female No. 8185 with male No. 8147. This female is related to male No. 8147 in exactly the same degree as female No. 9420 (though otherwise unrelated to No. 9420) and through the same great, great grandparent. Unfortunately her 11 daughters were not all trapnested through the year, as they would have been if there had been any inkling of their importance. We are obliged to fall back on their winter records. Their average for the winter was 42.9 eggs each (which gives an estimated annual average of 142.9 eggs), while the daughters of female No. 9420 averaged 75.3 each; those of female No. 8652 averaged 62.4 each, and of female No. 8418, 50.5 each. These averages refer to the number of eggs laid before March 1 of the pullet year. Female No. 8185 was a good winter layer herself with a record of 85 eggs and a 365-day record of 185 eggs, but came from a mediocre family.

Details relating to the Egg Records of the Progeny of one Male.

Father No. 8147.

Number.	Date hatched.	Age at First Egg (Days).	Date of First Egg.	Eggs to March 1.	Annual Production.	Remarks.
Mother.	1916.					
8185, . .	Apr. 16	195	Oct. 28	85	186	
Daughters.	1917.					
B 830, . .	Apr. 8	229	Nov. 23	77	-	Did not complete year.
B1147, . .	Apr. 15	261	Jan. 1	29	-	Did not complete year.
B 1150, . .	Apr. 15	208	Nov. 9	61	-	Did not complete year.
B 1372, . .	Apr. 22	213	Nov. 21	48	-	Did not complete year.
B 1541, . .	Apr. 29	217	Dec. 2	64	142	
B 1990, . .	May 6	253	Jan. 14	35	-	Did not complete year.
B 2206, . .	May 13	213	Dec. 12	9	-	Did not complete year.
B 2208, . .	May 13	212	Dec. 11	38	-	Did not complete year.
B 2209, . .	May 13	198	Nov. 27	29	114	
B 2210, . .	May 13	229	Dec. 28	39	-	Did not complete year.
Average, .	Apr. 30	233.3	Dec. 9	42.9	142.9[1]	
Mother.	1916.					
9420, . .	May 28	169	Nov. 13	75	221	
Daughters.	1917.					
B 83, . .	Mar. 18	227	Oct. 31	106	223	
B 242, . .	Mar. 25	182	Sept. 23	120	202	
B 243, . .	Mar. 25	197	Oct. 8	77	198	
B 244, . .	Mar. 25	180	Sept. 21	67	137	
B 557, . .	Apr. 1	224	Nov. 11	66	213	
B 558, . .	Apr. 1	208	Oct. 26	53	171	
B 845, . .	Apr. 8	168	Sept. 23	93	207	
B 1125, . .	Apr. 15	202	Nov. 3	80	199	
B 1126, . .	Apr. 15	182	Oct. 14	81	181	
B 1127, . .	Apr. 15	178	Oct. 10	86	174	
B 1679, . .	Apr. 29	247	Jan. 2	29	-	Failed to complete year.
B 1986, . .	May 6	201	Nov. 23	55	-	Failed to complete year.
B 2065, . .	May 13	191	Nov. 20	66	186	
Average, .	Apr. 10	199	Oct. 26	75.3	190.1	

[1] Estimated.

Details relating to the Egg Records of the Progeny of one Male — Con.

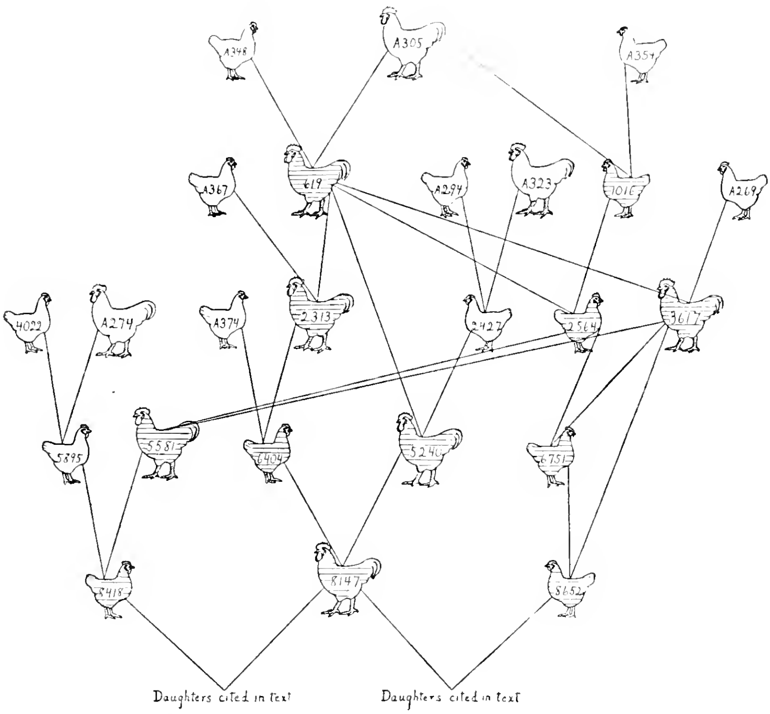
Father No. 8147 — Con.

Number.	Date hatched.	Age at First Egg (Days).	Date of First Egg.	Eggs to March 1.	Annual Production.	Remarks.
Mother.	**1916.**					
8418, . .	Apr. 23	213	Nov. 22	76	139	
Daughters.	**1917.**					
B 168, . .	Mar. 18	201	Oct. 5	88	-	Failed to complete year.
B 172, . .	Mar. 18	234	Nov. 7	48	162	
B 252, . .	Mar. 25	195	Oct. 6	57	132	
B 254, . .	Mar. 25	241	Nov. 21	59	176	
B 255, . .	Mar. 25	229	Nov. 9	53	136	
B 454, . .	Apr. 1	205	Oct. 23	74	209	
B 876, . .	Apr. 15	244	Dec. 15	28	138	
B 877, . .	Apr. 15	203	Nov. 4	80	181	
B 879, . .	Apr. 15	214	Nov. 15	32	84	
B 1290, . .	Apr. 22	224	Dec. 2	61	165	
B 1832, . .	May 6	235	Jan. 3	21	147	
B 1835, . .	May 6	226	Dec. 18	51	-	Failed to complete year.
B 2172, . .	May 13	218	Dec. 17	49	173	
B 2173,[1] . .	May 13	197	Nov. 26	8	78	Nester.
B 2174, . .	May 13	218	Dec. 17	48	169	
Average, .	Apr. 13	220.5	Nov. 20	53.5	156.0	
Mother.	**1916.**					
8652, . .	Apr. 30	204	Nov. 20	78	196	
Daughters.	**1917.**					
B 156, . .	Mar. 18	189	Sept. 23	73	198	
B 192, . .	Mar. 25	181	Sept. 22	89	-	Failed to complete year.
B 194, . .	Mar. 25	180	Sept. 21	62	154	
B 722, . .	Apr. 8	197	Oct. 22	65	169	
B 988, . .	Apr. 15	219	Nov. 20	31	123	
B 1361, . .	Apr. 22	192	Oct. 31	82	205	
B 1362, . .	Apr. 22	225	Dec. 3	67	215	
B 1646, . .	Apr. 29	216	Dec. 1	52	194	
B 1824, . .	May 6	213	Dec. 5	55	139	
B 2088, . .	May 13	225	Dec. 24	48	237	
Average, .	Apr. 15	203.7	Nov. 5	62.4	181.5	

[1] Not included in averages.

It may be of interest to note that the difference in average winter production of these groups of half sisters is closely related to average date of first egg. Thus, the average date of first egg of the daughters of female No. 9420 was October 26; of female No. 8652, November 5; of female No. 8418, November 17; and of female No. 8185, December 12.

Thus, of 4 females mated with a single male, 2 were inbred and 2 were unrelated to the male. The offspring of one inbred female were good layers, while those of the other were relatively poor. The offspring of one unrelated female were good layers, and of the other relatively poor. The results of inbreeding, therefore, must be judged by the quality of the offspring. If it is good, utilize those particular inbred matings. If not good, try other inbred matings.



Description of Figure. — The line of descent of two inbred families. A pair of divergent lines extend from the *back* of each bird whose pedigree is known, one going to the father, the other to the mother, and ending on the under side. From this figure the various inter-relationships may be made out. Thus 8147's sire is 5240 and his dam 6404. The sire of 5240 is 619, who is also the grandsire of 6404 as well as the sire of 2564 and 3617; 619 is therefore the great, great grandsire of the daughters of 8147, through some lines of descent, but only the great grandsire through others. No. 3617 is equally a half great, great uncle, grandsire and great grandsire of 8652's daughters. The birds with backs free of lines are foundation stock of unknown ancestry. The inbred lines of descent are indicated by the shaded birds.

3. A few instances may be added to show that the results of matings between unrelated birds may be very inferior to matings between closely related birds such as those just described, unless special attention is paid to egg production. Thus, female No. 6982 had 10 daughters, by an unrelated male, that averaged 101 eggs each, exactly their mother's record. The same male by female No. 5832, also unrelated, and laying 160 eggs, produced 7 daughters that averaged 151.7 eggs each. Another male, by an unrelated hen that laid 234 eggs, had 9 daughters that averaged 139.1 eggs each.

In these experiments good, strong, healthy stock has been used. The families from which the males were to be chosen were selected on the basis of their sisters' performance, and the strongest, most virile male in each family selected for breeding.

There is one thing more to be said on the subject. In our experience the very best results have come from outmatings, while the very poorest have come from close matings. *It is clear, then, that very great care must be used when inbreeding, lest disaster overtake the breeder unawares.* Very careful and accurate pedigrees and other records must be kept. Further, the provisional conclusion appears justified that the very best results are most likely to be obtained by crossing two distinct lines, each of which is inbred and which is doing well. Very likely the best way to renew the commercial egg flock is through the crossing of strong, high-producing, inbred lines, which will, of course, be maintained intact by inbreeding, and making the cross anew each season.

II. Is the Influence of the Male or of the Female the more Important?

The view that high fecundity does not descend from mother to daughter but does descend from mother to son, or from father to both sons and daughters is now generally accepted. This, then, leads to the belief that the use of the sons of high layers insures high production in the progeny sired by such sons. The male is regarded as all important, the female of importance only as a producer of good males. This situation has arisen apparently from the attempt to describe certain modes of inheritance in every-day language. The scientific foundation, *i.e.*, sex-linked inheritance of fecundity, on which the view mentioned is based does not warrant the popular interpretation which it has received. However this may be, evidence is now available which indicates that high fecundity is not sex-linked in some breeds, at any rate.

In speaking of fecundity the use of the terms high and low are not very precise for they are relative; we may, however, use them with this understanding of their limitation. In this bulletin winter production only is considered, because it is a fairly good index of a hen's inborn capacity to lay.

The important question to be answered is: Is it possible for high-egg production to descend from mother to daughter? An experiment was made in which a male from a low line was mated with several high producers belonging to a high line and at the same time to several low producers. Of course careful individual pedigrees were kept. The offspring of the high producers averaged 49.2 winter eggs against an average of the mothers and their sisters of 52.5 eggs. Nearly all were high producers. On the other hand, the offspring of the poor layers averaged only 11.6 winter eggs. In this experiment high production clearly descended from mothers to daughters.

In another experiment a male was used that came from a high-producing mother, but on the father's side production was poor. Some of his mates were good producers, some were poor. A few daughters were good layers, but most of them, regardless of whether their mother was a high or low producer, were mediocre to poor. In this experiment the influence of the male was more pronounced.

In other experiments males derived from high lines have been bred to low producers. For example, male B137, a high-line male, was bred to two low birds of low lines. The average winter production of the daughters was high, viz., 54.5 eggs. On the other hand, in the table of the section on inbreeding is shown a case where the production of the offspring of a male belonging to a high line, bred to a high-producing female, viz., No. 8185, of a mediocre line, was relatively poor compared with that obtained from the offspring of females belonging to high lines.

In still another experiment a male belonging to a low line was mated with a female belonging to another low line. Most of the offspring were *high* producers.

These experiments show that we are dealing with a situation that is complicated in many ways. It appears, however, to be perfectly clear that both male and female play a part in determining the egg production of their daughters. Whether one is more important than the other depends upon the particular individuals that are mated. In breeding for high production the influence of either must be judged by the production of the offspring. The aim of the breeder should be to produce a line that will give high average production and that will reproduce itself generation after generation. To this end the contribution of both father and mother must be made. Any male or any female, or a particular combination of a certain male with one or more females that give high production consistently, may well be used as breeders as long as they live, or till something better has been secured.

III. The Exclusion of Parasites.

The investigations on the inheritance of fecundity have led in several unexpected directions. If an analysis of the hereditary basis of fecundity is to be made, it is evident that the problem must be reduced to its simplest form. Disturbances introduced by the surroundings must be avoided. For example, the date at which a pullet lays her first egg influences her record. This date is determined in part by the date she was hatched and in part by the age at which she matures, and this in turn is influenced by various growth factors, some hereditary, some environmental. Of the latter, parasites, visible or invisible to the naked eye, especially those that are concerned in causing disease, must be under control. It is a biological law that just as a chicken or a dog requires parents so all life arises from pre-existing life. As far as is known with certainty, with the exception of the parasite that causes bacillary white diarrhœa, the chick enters the world free from parasites. If, therefore, a means can be found to keep such parasites away, the chick will never have them, and will not suffer from them. The means is found in a quarantine of the chicks, and in an extension of the rotation method introduced by the Maine Agricultural Experiment Station.

A suitable quarantine, which presupposes the use of artificial methods of hatching and rearing, is a very efficient method of keeping out parasites and disease resulting therefrom, and in many circumstances is the simplest and least laborious method of securing the desired end. In the work at the Massachusetts Agricultural Experiment Station a plot of ground was selected that had not had a chicken or chicken manure on it for several years. All buildings, appliances and utensils were either new or were scrubbed clean enough to eat from. Then everything not new was drenched outside and inside with 5 per cent coal tar disinfectant. One spraying was made before the buildings were moved, another after their removal to the clean ground. The chicks were hatched in carefully disinfected incubators. A separate attendant did the brooding and was quarantined from all other poultry. At the entrance to the rearing ground he changed his foot gear for a set reserved for use on the rearing ground, and, after changing, walked through a pan of strong disinfectant. Every loop-hole by which parasites might gain entrance was closed if at all possible. The result is that the parasite problem has been largely solved as long as the chicks remain quarantined.

The quarantine method of rearing chicks should be of particular advantage to any one who is starting a new poultry plant, because by purchasing eggs of stock free from bacillary white diarrhœa, and using only artificial methods for hatching and rearing, the proverbial good luck of the beginner should endure.

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MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Seventh Report of the Cranberry Substation

By H. J. FRANKLIN

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BULLETIN No. 192.

DEPARTMENT OF AGRICULTURE.

REPORT OF THE CRANBERRY SUBSTATION FROM 1917 TO 1919.

BY H. J. FRANKLIN.

The 1915 and 1916 lines of work were followed closely in 1917, but a collection of cranberry bog weeds was started and a long and searching study was made of the weather records, bearing on frost conditions, taken at the station from 1913 to 1917, inclusive. Storage tests with the fruit were continued as an important part of the work, with interesting results.

The 1918 work followed the general plan of other years. Special attention was given to frost predicting, the methods being much perfected. The storage tests were largely suspended, as the handling of the unusually large station crop left little room in the screenhouse for them. About 60 species of cranberry bog weeds were collected by the writer and identified, with the help of Prof. A. V. Osmun of the Massachusetts Agricultural College, and Dr. H. F. Bergman of the Bureau of Plant Industry. By agreement between the Massachusetts Agricultural Experiment Station and the Cape Cod Cranberry Growers' Association, the writer gave much time to developing a cranberry harvester, fair progress apparently being made. With the help of a special appropriation of the Legislature the iron roof of the screenhouse was replaced with boards and shingles, and the roof frame strengthened.

Fungous Diseases.

The co-operative investigation of diseases and of handling, storing and shipping the fruit was conducted in 1917 much as in 1916, Dr. C. L. Shear of the Bureau of Plant Industry and his assistant, Mr. B. A. Rudolph, making the more technical studies, and Dr. N. E. Stevens giving valuable aid in the planning and performing of practical experiments carried out in the cranberry section where he spent most of the fall months, a large part of his work being done at the station.

Copper sulfate put in the June flowage as a means of controlling diseases was tried in 1917 as in previous years, but without positive results.

Tables 1 and 2 show the results of spraying with "Corona" arsenate of lead. In the 1917 treatments this insecticide was used at the rate of 4 pounds to 50 gallons of water, with 2 pounds of Good's caustic potash fish-oil soap No. 3 added. The plots were sprayed three times, — June 26 and 27, July 25 and 26 and July 30. The third application followed the second so closely because a severe storm washed the latter severely soon after it was made. In 1918 the plots were sprayed four times, — June 11, June 27, July 19 and 20 and August 3. In the first two applications 3 pounds of the arsenate to 50 gallons of water were used, and the last two treatments were the same except that soap was added as in 1917. The 1918 plots A. L. 1 to A. L. 4, inclusive, were the same areas, respectively, so numbered in 1917. In both years the checks were laid out on different sides of and adjacent to the plot in each case. All the plots and checks were of the Early Black variety. The berries were all picked with scoops. The fruit was stored in bushel picking crates as it came from the bog, and was placed in storage the day it was picked. The quantity stored in 1917 varied from 1 to 6 bushels for the different plots and checks, while in 1918, 8 bushels from each plot and check were used.

The crates were examined by the "seven-sample" method to determine the percentages of berries showing decay. In this method seven samples from each crate are examined, one being taken from the surface berries of each half of the crate halfway between the middle and end; one from each half of the crate halfway between the top and bottom and halfway between the center and end; one from the very center; and one from the very bottom of each half of the crate halfway between the middle and end. This seems a most satisfactory way to sample in inspecting the crated fruit.

Both years all the plots but A. L. 2 yielded fruit of much better quality than that from the check areas, the improvement being most marked in 1918, when more treatments were applied. These tests and those of 1916 [1] show that arsenate of lead has a distinct fungicidal value as a treatment for the Early Black variety. What fungi are affected by it, however, has not been determined.

[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 189–192.

TABLE 1. — *Spraying Plots (Fungous Diseases) treated with Arsenate of Lead, 1917.*

Plots and Checks.	Area (Square Rods).	Yield per Square Rod (Bushels).	Period of Storage.	Percentage of Berries showing Decay at End of Storage.
A. L. 1,	9	.35	Sept. 14 to Dec. 19	48.54
A. L. 1 (check 1),	9	.22	Sept. 14 to Dec. 19	62.27
A. L. 1 (check 2),	6	.31	Sept. 14 to Dec. 19	56 07
A. L. 2,	9	.61	Sept. 14 to Dec. 20	65.26
A. L. 2 (check 1),	9	.28	Sept. 14 to Dec. 19	78.89
A. L. 2 (check 2),	6	.45	Sept. 14 to Dec. 20	62.81
A. L. 2 (check 3),	6	.61	Sept. 14 to Dec. 20	53.68
A. L. 3,	9	1 15	Sept. 20 to Dec. 18	37.33
A. L. 3 (check 1),	9	1 15	Sept. 20 to Dec. 18	49.58
A. L. 3 (check 2),	4½	.86	Sept. 20 to Dec. 17	47.42
A. L. 3 (check 3),	9	1.02	Sept. 20 to Dec. 17	45.39
A. L. 4,	8	1.08	Sept. 20 to Dec. 18	35 84
A. L. 4 (check 1),	8	.81	Sept. 20 to Dec. 19	41.81
A. L. 4 (check 2),	6	1.13	Sept. 20 to Dec. 18	49.08

TABLE 2. — *Spraying Plots (Fungous Diseases) treated with Arsenate of Lead, 1918.*

Plots and Checks.	Area (Square Rods).	Yield per Square Rod (Bushels).	Period of Storage.	Percentage of Berries showing Decay at End of Storage.
A. L. 1,	9	1.48	Sept. 25 to Jan. 2	56.09
A. L. 1 (check 1),	6	1.39	Sept. 25 to Jan. 2	62.23
A. L. 1 (check 2),	6	1.61	Sept. 25 to Jan. 2	75.62
A. L. 1 (check 3),	6	2.13	Sept. 25 to Jan. 2	69.05
A. L. 2,	9	1.91	Sept. 25 to Jan. 6	64.43
A. L. 2 (check 1),	6	2 00	Sept. 25 to Jan. 2	82.58
A. L. 2 (check 2),	6	1.80	Sept. 25 to Jan. 6	64.71
A. L. 2 (check 3),	6	2.61	Sept. 25 to Jan. 7	58.67
A. L. 3,	9	2.14	Sept. 11 to Dec. 27	12.07
A. L. 3 (check 1),	6	2.45	Sept. 11 to Dec. 27	42.04
A. L. 3 (check 2),	6	2.33	Sept. 11 to Dec. 27	35.99
A. L. 4,	8	2.18	Sept. 11 to Dec. 27	13 01
A. L. 4 (check 1),	8	2.59	Sept. 11 to Dec. 27	39.94
A. L. 4 (check 2),	8	2.53	Sept. 11 to Dec. 26	39.25
A. L. 5,	9	2.15	Sept. 17 to Dec. 26	17.60
A. L. 5 (check 1),	6	2.00	Sept. 17 to Dec. 26	26.50
A. L. 5 (check 2),	6	1.89	Sept. 17 to Dec. 26	30.18
A. L. 5 (check 3),	6	2.11	Sept. 17 to Dec. 26	32.71
A. L. 6,	8	1.81	Sept. 16 to Dec. 30	20.43
A. L. 6 (check 1),	8	2.06	Sept. 16 to Dec. 30	39.83
A. L. 6 (check 2),	8	2.08	Sept. 16 to Dec. 30	36.60
A. L. 7,	8	2.25	Sept. 22 to Dec. 30	17.84
A. L. 7 (check 1),	8	2.25	Sept. 22 to Dec. 30	42.18
A. L. 7 (check 2),	4	2.25	Sept. 22 to Dec. 30	41.79
A. L. 7 (check 3),	8	2.38	Sept. 22 to Dec. 30	47.64

Tests were made in both 1917 and 1918 to determine the effect of Black-Leaf 40 on cranberry diseases. This was used at the rate of 1 part to 400 parts of water, and 2 pounds of resin fish-oil soap to 50 gallons were added. The fruit was picked, stored and examined in the same way as that from the arsenate of lead plots. No positive effect of this treatment on the quality of the fruit was shown by the experiments.

The "rose bloom" disease caused by *Exobasidium oxycocci* Rostr. was prevalent, and deformed many of the blossoms on several bogs in both 1917 and 1918, doing more harm than in any year since 1907, and greatly reducing the crop wherever abundant. It affected late varieties mostly, harming Early Black vines on only a few bogs. In 1917 nearly all the new shoots on large portions of the Howes sections of the station bog showed the abnormal enlargement caused by the disease. These growths were first seen the latter part of May, and were present in full development and abundance until the bog was flowed for worms the night of June 22. When the bog was examined again at 6 P.M. on June 25 (after the water was let off), all the "rose blooms" had turned black and shriveled so much they could hardly be found. The forty-six-hour flooding and the subsequent drying of the vines by strong sunlight had killed the diseased shoots on all parts of the bog.

The station bog was flowed from Sept. 29 to Oct. 13, 1917, and was flowed for the winter on December 13. The winter water was let off April 4, 1918. In 1918 the "rose bloom" growths were somewhat less abundant on this bog than in 1917, but the disease destroyed most of the crop on two sections. The 1918 growing season was quite dry, but the disease deformed many blossoms.

In 1918 spraying tests with Scalecide and resin fish-oil soap to kill the "rose bloom" shoots were tried, as follows: —

1. One gallon to 25 of water with one-half pound of soap applied May 29. This killed most of the "rose bloom" shoots, but left a considerable percentage. It destroyed most of the prospective cranberry bloom, but did not kill the tips of the growing uprights.
2. One gallon to 37½ of water with three-fourths pound of soap applied May 29. This failed to kill a large percentage of the diseased shoots. It destroyed most of the prospective cranberry bloom, but did not kill the tips of the growing uprights.
3. One gallon to 50 of water with 1 pound of soap applied May 29. This failed to kill a large proportion of the diseased shoots. It destroyed most of the prospective bloom.
4. One gallon to 100 of water with 2 pounds of soap applied May 29. This affected the buds and diseased shoots but little.

On the whole, these tests were of little value.

Spraying with iron sulfate to kill the diseased growths was also tried in 1918, as follows: —

1. Three pounds in 12 gallons of water applied June 1. This killed the diseased shoots fairly well and injured the cranberry uprights but little.

2. Five pounds in 10 gallons of water applied June 1. This killed all the diseased shoots and hurt the uprights little.

3. Five pounds in 10 gallons of water applied May 31. This killed all the diseased shoots and reduced the prospective crop more than 50 per cent.

4. Ten pounds in 10 gallons of water applied May 29. This killed all the "rose bloom" shoots and hurt the uprights but little.

5. Twenty pounds in 10 gallons of water applied May 29. This killed all the diseased shoots and injured the uprights severely.

These experiments suggest that the sulfate may be used to combat the disease successfully if applied at a right strength often enough to prevent the infected shoots from developing to the condition in which they give off spores. To be thorough enough this treatment might necessitate the sacrifice of the crop of the season in which it was used, and also, by destroying the bud-bearing tips of the new growth, that of the next year. As fresh spores were found on the diseased growths on May 20, 1918, the spraying, if tried, should be begun fairly early in the season.

The station bog was completely flooded June 3, 1918, and the water was held forty-four hours. The "rose bloom" shoots turned dark and shriveled soon after the water was let off, just as they did after the 1917 flooding. It seems from this that such submergence can be relied on to destroy these growths.

The diseased shoots were well developed and plentiful on the station bog on May 18, 1918, but they did not seem to be giving off spores then. The winter buds in the tips of the cranberry uprights were enlarged but not opened at all at the time, and therefore probably were not in condition to receive a new infection from the spores of the disease. The infected axillary buds apparently develop earlier than the healthy terminal buds.

These observations and the effect of the June floodings on the "rose bloom" growths suggest that where water supplies are adequate the disease may be controlled by letting off the winter water about May 20 and flooding again for from two to three days when the terminal buds are developed to the point of breaking open. This treatment would allow the diseased, spore-producing shoots to grow, but would destroy them before the new cranberry growth developed enough to become susceptible to infection.

The writer has never yet found "rose bloom" very prevalent on a bog that was regularly reflowed after picking.

Table 3 compares the experience had with Early Black and with Howes cranberries which were left unpicked and subjected to the long (September 29 to October 13) after-picking flooding in 1917 with that had with berries of the same varieties picked before the flowing from vines near those bearing the submerged fruit. The Early Black berries decayed remarkably in the water, the main fungus causing the rot, as determined by Dr. Shear, being *Sporonema oxycocci* Shear. The Howes fruit picked after the flooding, however, showed less decay than that gathered and stored before it, this probably being due to a considerable development of "end-rot" (caused by *Fusicoccum putrefaciens* Shear) in the stored fruit. A few of the flooded berries of this variety showed small spots of rot caused by Sporonema, but no "end-rot."

It seemed impossible to get the flooded berries dry for picking after the water was let off, chiefly because the many shells left by fruit worms were full of water and would dry out but slowly; therefore the fruit finally was picked and stored wet.

The berries were stored in picking crates, two bushels being used in each lot. They were examined for rot when placed in storage, October 25, and again at the end of the storage period, December 27.

TABLE 3. — *Effect of a Long Fall Flooding on Ripe Early Black and Howes Berries.*

VARIETY.	Lot No.	Picked before or after Flooding.	Date picked.	Condition when picked and stored.	PERCENTAGE OF BERRIES SHOWING DECAY.	
					Before Storage.	At End of Storage.
Early Black,	1	Before	Sept. 27	Dry	13.50	40.26
	2	After	Oct. 17	Wet	63.35	88.08
Howes,	1	Before	Sept. 27	Dry	17.45	36.23
	2	After	Oct. 17	Wet	14.68	56.85

A like test made at the station in 1914 gave much the same results as this one, the flowage promoting rapid decay among Early Black berries, but not doing so among Howes.

The fact that the submerged Howes berries showed less rot than those picked before the flooding confirms the opinion given in a previous report,[1] that fruit of this variety should never be picked before the end of the first week in October. If left until then it not only will have better size and color, but also will include less rot when prepared for shipment. Late picking of Howes berries is especially desirable where this variety usually develops much "end-rot" (Fusicoccum) in storage.

Although unpicked ripe Howes berries evidently endure rather long submergence without appreciable deterioration, this is not advisable, especially if they have been much infested with fruit worms, because they are so hard to get dry afterward.

Table 3 confirms the comparative results of storing cranberries wet or dry shown elsewhere (page 122) in this report and in a former one.[2]

The McFarlin vines on the station bog usually bear sound berries. In both 1916 and 1917 this fruit was of exceptional quality for the variety in spite of the unusual wetness of those seasons, keeping nearly as well as the Howes berries. The season of 1918 was much drier than those of 1916 and 1917, but fully half the station McFarlin berries rotted on the

[1] Bul. No. 168, Mass. Agr. Expt. Sta., 1916, p. 19.

[2] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 201-204.

vines, the fungus mainly responsible being found by Dr. Shear to be that of bitter-rot, *Glomerella cingulata vaccinii* Shear. The Howes berries on the same part of the bog also showed much more rot than usual when picked, and they looked as though they were affected by the same fungus, but this was not definitely determined. The bitter-rot had affected the Early Black variety on this bog considerably in previous years, but its sudden severe infection of the later varieties is remarkable.

The holding of winter flowage until midsummer, thus sacrificing one season's crop, is practiced often in New Jersey, and occasionally on the Cape, as a means of reducing pests.[1] The New Jersey growers who have had most experience with this treatment claim that the year after its application a large crop of berries of unusual size and excellent keeping quality is obtained. "The benefits, both in the reduction of field rot and in the improvement of keeping quality, are frequently said to persist for several years."[2] One grower of large experience told the writer he had failed to improve the keeping quality of Howes berries from New Jersey bogs so treated the year before by spraying with Bordeaux mixture.

Two valuable papers on cranberry diseases have been published recently, — one by Dr. C. L. Shear on "end-rot" (*Fusicoccum putrefaciens* Shear),[3] and the other by Dr. N. E. Stevens on the relation of regional temperatures to the growth of cranberry fungi,[4] both being quite technical.

Storage Tests.

The descriptions of these experiments are arranged in numbered groups below. Nos. 1, 2, 5, 7, 10 and 12 were planned by Drs. Shear and Stevens, and conducted by the latter. Nos. 4, 6, 8 and 9 were planned and carried out by the writer. Nos. 3 and 11 were planned and conducted by Dr. Stevens and the writer. All these experiments were carried out in 1917. A large crop so filled the station screenhouse in 1918 that it was impossible to do much storage work.

The fruit in the tests of groups 3, 4, 6, 8 and 9 was examined by cup samples by the screeners employed at the station during the fall under the writer's supervision, the inspectors' cup of the New England Cranberry Sales Company being used for sampling. The Sales Company's hand grader was used to facilitate the work.

The "seven-sample" method (described elsewhere in this report, page 106) was used in examining all the fruit spoken of as being stored in crates.

All the tests but those of groups 1, 10, 11 and 12 were conducted in the basement of the station screenhouse, this providing fairly even temperatures.

The groups of storage experiments conducted are as follows: —

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[1] Bul. No. 168, Mass. Agr. Expt. Sta., 1916, p. 46.

[2] Bul. No. 714, U. S. Dept. Agr., 1918, p. 7.

[3] Shear, C. L.: End-rot of cranberries. In Journal of Agricultural Research, Vol. 11, No. 2, pp. 35-42, Pl. A, 1917.

[4] Stevens, Neil E.: Temperatures of the cranberry regions of the United States in relation to the growth of certain fungi. In Journal of Agricultural Research, Vol. 11, No. 10, pp. 521-529, 1917.

1. *The Effect of Temperature on Cranberry Keeping.*

Table 4 shows the amounts of rot that developed among different lots of sprayed and unsprayed Early Black berries kept at different temperatures, some in open and some in closed one-quart cans. All the berries seemed sound when put in the cans. These tests were carried out in Washington, with Brooks and Cooley's temperature apparatus.[1] The softening among the fruit was in all cases greater with the higher temperatures. Table 4 shows like results in tests with Howes berries.

TABLE 4. — *Storage Temperature Tests with Cranberries.*

EARLY BLACK BERRIES FROM HARWICH BOG, STORED SEPT. 28, EXAMINED NOV. 27, 1917.

Temperature at which the Fruit was stored (°C.).	Stored in Open Cans.			Stored in Closed Cans.		
	Number of Sound Berries at End of Test.	Berries showing Decay at End of Test.		Number of Sound Berries at End of Test.	Berries showing Decay at End of Test.	
		Number.	Per Cent.		Number.	Per Cent.
Sprayed.						
0, ...	467	94	16.76	334	175	34.38
5, ...	401	147	26.82	369	213	36.60
15, ...	323	299	48.07	211	345	62.05
20, ...	149	393	72.51	172	356	67.42
Unsprayed.						
0, ...	498	131	20.83	523	139	21.00
5, ...	475	174	26.81	406	248	37.92
15, ...	290	311	51.75	276	393	58.74
20, ...	219	411	65.24	280	326	53.80
HOWES BERRIES FROM THE STATION BOG, STORED OCT. 9, EXAMINED DEC. 17, 1917.						
0, ...	515	44	7.87	452	74	14.07
5, ...	411	150	26.74	291	219	42.90
15, ...	291	272	48.31	301	210	41.10
20, ...	112	322	74.19	111	450	80.21

[1] Brooks, Charles, and Cooley, J. S.: Temperature Relations of Apple-rot Fungi. In Jour. Agr. Research, Vol. 8, No. 4, pp. 141, 142, 1917.

2. *The Relation of Air Humidity to Cranberry Keeping.*

Table 5 describes three series of humidity tests with cranberries conducted at the station, in Hempel desiccators, in which the air was kept at known humidities by exposure to sulfuric acid of various specific gravities.[1] In the first two series ventilation was supplied the berries every other day by removing the covers of the desiccators and pumping fresh air into their chambers with a bellows. No ventilating was done in the last series. The fruit was all from the station bog and was hand sorted. Five ounces of berries were used in each test in the second series, and four in the third series.

The results of these experiments and of others carried out by Dr. Stevens show no definite relation between the air humidity and the rate of decay among the fruit. Berries kept as well in very moist air as in dryer air, unless they were actually wet. The last column of the table, however, shows that the loss of the berries in weight increased with the decrease in the air humidity. Evidently considerable humidity in the air is needed to prevent drying of the fruit. Under the conditions usually prevailing in Cape screenhouses, however, the humidity is probably sufficient to prevent much loss from drying.

TABLE 5. — *Air Humidity and Cranberry Keeping.*

Variety.	Tests began.	Tests ended.	Humidity (Per Cent).	Number of Sound Berries at End of Test.	Berries showing Decay at End of Test. Number.	Berries showing Decay at End of Test. Per Cent.	Loss in Weight during the Test (Per Cent).
Early Black,	Sept. 13	Oct. 8	100	147	33	18.33	-
			35	173	17	8.95	-
			Varied: 100, 80, 65, 35, 0, in rotation, every other day.	192	13	6.34	-
				167	9	5.11	-
				198	5	2.46	-
				180	12	6.25	-
				156	13	7.69	-
Howes, . .	Oct. 8	Nov. 13	100	141	10	6.62	.0
			80	153	13	7.83	3.7
			65	128	19	12.93	5.0
			35	134	11	7.59	6.0
			0	132	22	14.29	7.5
			Alternated, 100 and 35, every other day.	121	19	13.57	3.7
				119	21	15.00	3.7
Howes, . .	Nov. 18	Dec. 19	100	116	13	10.08	.0
			100	112	18	13.85	.0
			80	106	16	13.11	1.5
			65	117	14	10.69	3.0
			35	115	9	7.26	5.0
			35	111	9	7.50	4.5
			0	106	13	10.92	6.0

3. *Ventilation and Cranberry Keeping.*

On September 17 three lots, of two bushels each, of uncleaned, freshly picked cranberries from the same area of the station bog were stored in

[1] The method is fully described by Dr. Stevens in Phytopathology, 1916, Vol. 6, No. 6, pp. 428–432.

picking crates under different conditions of ventilation. Lot 1 was placed in a tightly closed trunk; lot 2 was unenclosed in the basement of the screenhouse; and lot 3 was left outdoors every clear, cold night, and kept in the basement the rest of the time. The last lot was much wetted by dews, this probably largely offsetting the benefits of the lower temperatures obtained by the night exposure.

Considerably more spoilage took place among the fruit in the trunk than in the other lots, confirming the findings concerning ventilation given in previous reports. The percentages of berries showing decay at the end of the experiment — November 13 — follow: —

Lot 1,	35.85
Lot 2,	27.88
Lot 3,	28.58

4. *Losses from Decay and from Size Shrinkage of Sound Berries in Closed and in Open Containers compared.*

Table 6 shows the results in this connection with the Howes fruit of grading tests 3 and 4 of group 6. There was almost no shrinkage in the size of the sound berries in the closed crates, while those in the open ones shrunk on an average over 4 per cent. This difference in shrinkage, being due to the difference in ventilation, is probably a fair measure of it. If so, the Beaton crate has practically no ventilation when packed for shipment.

The table shows that the average increase in loss due to decay in the closed crates was less than half the average increase in loss from size shrinkage in the open ones. This is surprising and needs further investigation. The fact that the berries of test 3 were picked in a different place from those in test 4 makes the result especially questionable, for those of test 4 may have been inferior keepers anyway.

An experienced observer [1] has estimated that Early Black berries held in common storage at a bog for late trade shrink as much as 10 per cent aside from any decay. The difference between the averages of the cup-counts taken at the beginning and at the end of the storage in grading test 1 (Table 9) shows a size shrinkage of about 10 per cent for this variety between October 10 and January 14. This fruit was picked September 20, and its total size shrinkage must have been much more than 10 per cent, for cranberries lose weight in ordinary storage considerably more than twice as fast in early fall as in winter.[2]

The loss from size shrinkage under conditions of free ventilation is evidently so large, especially in the early fall, that the advisability of making special provisions for ventilating, except where this may aid in maintaining low temperatures, is much reduced. In the writer's opinion, shipping in crates instead of in barrels is, except with poorly colored fruit, desirable more because it reduces mass bruising than because it allows freer ventilation.

[1] Griffith, H. S.: In Ann. Rept. New Eng. Cranberry Sales Co., 1913, p. 20.
[2] Bul. No. 168, Mass. Agr. Expt. Sta., 1916, p. 16.

TABLE 6. — *Losses from Shrinkage in Size and from Decay in Closed and Open Containers compared.*

Test. No.	Container.	Graded or not.	Cup-count of Sound Berries.		Percentage of Loss from Shrinkage in Size of Sound Berries.		Percentage of Berries showing Decay.		Percentage of Loss from Decay.	
			At Beginning of Test.	At End of Test.			At Beginning of Test.	At End of Test.		
3	Closed Beaton half-barrel crates,	Graded,	112½	113	.44	.22	5.68	30.26	26.05	24.79
		Not graded,	132	132	.00		7.12	28.90	23.52	
4	Open bushel picking crates,	Graded,	112	116	3.57	4.19	7.44	30.45	24.85	23.22
		Not graded,	125	131	4.80		6.29	26.47	21.59	
Differences in average percentages of losses,						—3.97				+1.57

5. *Water Storage.*

Storing cranberries in water has been recommended often as a way to keep them a long time. When thus stored they soon soften from smothering.[1]

Table 7 describes several tests in which water storage in stoppered bottles was compared with dry storage in tight and in ventilated containers. All the Early Black fruit stored in water softened, while only a part of that stored dry did so. The Howes berries softened less in water than did the Early Black, probably partly because they were picked later, and, as compared with the first two lots, partly because they were stored later, the temperature of the screenhouse basement and therefore that of the water being lower. The berries of the third Early Black lot were probably partly smothered in ordinary storage before they were put in the water. The berries used in the tests were all hand-sorted.

The fruit softened by water storage had much the same peculiar character, described by Dr. Shear and his associates,[2] that cranberries smothered in dry storage have. They lacked the bitter taste of the fruit smothered dry, however, and were therefore suitable for cooking when taken from the water. Among the berries stored dry, much more softening occurred in the tight containers than in the open ones. This result supports conclusions given in previous reports.

The berries used in the first two series of these tests were only partly colored when stored. Those put in shipping crates were subject to the same temperatures, and were less exposed to the light than those without ventilation, but they colored up very much during the storage, while the color of the others changed little. This shows that ventilation is essential to the coloring of berries picked green. Therefore green or partly colored fruit in particular, should be stored and shipped in ventilated containers.

Table 8 describes water storage experiments with Dill[3] cranberries in three different degrees of maturity. Most of the berries in all the different lots softened in the water, somewhat more spoilage occurring among the green than among the ripe fruit.

Unpicked Howes berries at the station bog were kept from freezing with planks and leaves until the bog was winter-flowed on Dec. 13, 1917. Some of this fruit was examined January 1 through a hole cut in the ice, and was then found fresh and crisp. The berries were picked by hand April 1, 1918, before the water was let off, and were all soft then. The writer cut some of them open and found their flesh reddened throughout, their appearance being that of smothered berries.

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[1] This name was given by Dr. Shear and his associates to the spoilage of cranberries caused by insufficient ventilation. See Bul. No. 714, U. S. Dept. Agr., August, 1918, p. 4.

[2] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 237.

[3] This variety is grown solely by Mr. Bion Wing of Philips, Me.

TABLE 7. — *Keeping of Ripe Cranberries when stored in Water.*

Berries used.	Test began.	Test ended.	Water Stored.				Dry Stored.			
			Kind of Water.	Condition of berries at end of test.			Container.	Condition of berries at end of test.		
				Sound.	Soft.			Sound.	Soft.	
					Number.	Per Cent.			Number.	Per Cent.
Early Black, fresh-picked, ...	Sept. 13	Oct. 17	Well water, .	None	All	100	Stoppered bottle, .	571	474	45.36
							Peck shipping crate,	999	291	22.56
							Peck shipping crate,[1]	1,009	242	19.34
Early Black, cooled after picking, . .	Sept. 15	Oct. 17	Well water, .	None	All	100	Stoppered bottle, .	680	427	38.57
							Peck shipping crate,	1,027	141	12.08
Howes, ...	Oct. 13	Nov. 16	Boiled water, .	635	346	35.27	Bottle, ...	710	304	29.98
			Unboiled water,	346[2]	159[2]	31.49	Peck shipping crate,	704	207	22.72
Early Black, ...	Nov. -	Dec. 19	Boiled water, .	None	All	100	Stoppered bottle, .	277	777	73.72
			Unboiled water,	None	All	100	Peck shipping crate,	982	382	28.01

[1] Fruit wetted from time to time.

[2] Part of the berries in this test were lost by accident and not counted.

TABLE 8. — *Effect of Water Storage on the Keeping of Dill Cranberries of Different Degrees of Ripeness. Period of Storage, September 29 to November 22.*

Degree of Ripeness.	Kind of Water used.	Condition of Berries at End of Test.		
		Sound.	Soft.	
			Number.	Per Cent.
Ripe,	Boiled,	57	226	79.86
Ripe,	Unboiled,	82	223	73.11
Half ripe,	Boiled,	57	302	84.12
Half ripe,	Unboiled,	84	259	75.51
Green,	Boiled,	47	431	90.17
Green,	Unboiled,	47	388	89.20

6. *The Relative Keeping of Graded and Ungraded Cranberries.*

Table 9 describes five experiments in this connection. In each of these the two lots of fruit were obtained by dividing the contents of picking crates by alternate dipping with a quart measure. Only berries coming from the separator spout were used, those going into the boxes of the machine not being included. The spacing of the grader was fifteen thirty-seconds of an inch. A board seven-sixteenths of an inch thick was in the grader frame in place of the grader when the second lot of each test was run through the machine. Further information about the tests follows: —

Test 1. — All this fruit was picked on September 20 in the same location on the station bog. Both lots were put through a Hayden separator October 2, and run into boxes placed close up to the separator spouts instead of barrels. The grader took out about 30 per cent of the quantity of fruit in the first lot. Both lots were screened October 6, and run from the screens into bushel picking crates, all of which were of the same size and construction, and were placed close up to the mouths of the screen. The screeners were exchanged between the two screens when the two lots were about half looked over, so as to have the cleaning of the lots as uniform as possible. The crates were left open during the storage, four crates of the graded and five of the ungraded fruit being used.

Test 2. — All this fruit was gathered in the same place on the station bog on September 27. On October 25 both lots were put through a separator, being run from the spouts of the machine into boxes placed close up to them. The grader took out about 30 per cent of the first lot. When the fruit was screened, October 26, both lots were run into barrels from the mouths of the screen as usual, no easers [1] being used. The writer

[1] "Easer" is a term applied to any device for preventing the bruising of berries by breaking their fall.

packed both lots in barrels, measurements being taken to heap them exactly alike before they were headed up. Two barrels of each lot were used in the test.

Test 3. — These berries were picked on one of Dr. Charles R. Rogers' bogs at East Wareham on October 3. They were kept in the basement of the station screenhouse just as they came from the bog from October 3 until November 25, when they were run through a separator, the grader taking out about 27 per cent of the fruit in the first lot. Both lots were run into bushel picking crates placed up close to the spouts of the separator. When the berries were screened, November 26, they were run from the mouths of the screen into the Beaton crates placed close up to them. The fruit of each lot was taken into the warm screening room a crateful at a time, and each crate was taken out as soon as it was filled. The crate covers were nailed on closely, as if for shipment, during the storage, three crates of the graded and five of the ungraded fruit being used.

Test 4. — Part of this fruit came from one of Dr. Rogers' bogs and part from the station bog. It was picked September 26 and October 3, and was all stored in the basement of the station screenhouse just as it was picked until it was divided on November 28. The grader took out about 23 per cent of the quantity of the first lot. Both lots were run into bushel picking crates placed close to the spouts of the separator. When the fruit was screened, November 30, it was run from the mouths of the screen into picking crates placed close to them, and was then stored in the same crates. Each lot was taken into the warm screening room a bushel at a time, and each crateful was taken out as soon as screened. The crates were left open during the storage, four crates of graded and six of ungraded fruit being used.

Test 5. — This fruit was picked on the station bog September 27, and was stored just as it came from the bog in the basement of the screen-house until it was divided on December 3. Both lots were run through the separator December 5, and were run into bushel picking crates placed close up to the spouts of the separator. The grader took out about 17 per cent of the fruit of the first lot. When the fruit was screened, December 5, it was run from the mouths of the screen into the barrels as usual, no easers being used. The berries were taken into the warm screening room a bushel at a time, and each barrel was taken out as soon as screened. The barrels were all shaken thoroughly and heaped as nearly alike as possible before they were headed up, the distance between the head, resting on the heaped berries, and the chimes being carefully measured in every case. Two barrels of graded and three of ungraded fruit were used.

The fruit of each of these tests except the first was carefully sampled and examined at the beginning of the storage period. Column 8 of the table gives the percentages of berries then found showing decay. These must be subtracted from those in the last column to get a fair idea of the relative keeping of the graded and ungraded fruit. The latter kept somewhat better in every case, this result nullifying that of experiments previously reported.[1] In most of these tests the berries were screened and sampled both at the beginning and at the end of the storage. The average cup-counts given in the table show how the sound berries shrink in size in ventilated containers.

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[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 208–211.

TABLE 9. — *Tests of the Relative Keeping of Graded and Ungraded Cranberries.*

Test No.	Variety.	Container.	Percentage of Berries taken out by Grader.	Period of Storage.	Average Cup-counts of Sound Berries. At Beginning of Test.	Average Cup-counts of Sound Berries. At End of Test.	Percentage of Berries showing Decay. At Beginning of Test.	Percentage of Berries showing Decay. At End of Test.
1	Early Black,	Bushel picking boxes,	30	Oct. 10 to Jan. 14	107	120	–[1]	49.97
			Not graded		126½	139	–[1]	51.69
2	Early Black,	Barrels,	30	Oct. 29 to Jan. 14	105	–[1]	7.13	62.46
			Not graded		117	–[1]	8.58	56.82
3	Howes,	Beaton half-barrel crates,	27	Nov. 27 to Feb. 1	112½	113	5.68	30.26
			Not graded		132	132	7.12	28.90
4	Howes,	Bushel picking boxes,	22.5	Dec. 1 to Feb. 1	112	116	7.44	30.45
			Not graded		125	131	6.29	26.47
5	Howes,	Barrels,	17	Dec. 5 to Jan. 16	106	–[1]	8.21	25 83
			Not graded		122	–[1]	11.47	26.16

[1] Not determined.

7. *The Relative Keeping of Wet and Dry Cranberries.*

Table 10 describes two experiments in this connection with fruit from the station bog. In each test the fruit was stored in bushel picking crates the day it was picked, four crates of each lot of the Early Black and six of each lot of the Howes berries being used. The results confirm those of tests heretofore reported.[1]

TABLE 10. — *Relative Keeping of Wet and Dry Cranberries.*

Test.	VARIETY.	Time of Day the Fruit was picked and stored.	Temperature at which the Fruit was picked and stored (°C.).	Condition in which Fruit was picked and stored.	Period of Storage.	Percentage of Berries showing Decay at End of Storage.
1	Early Black, .	7 to 8 A.M.	14 to 17	Wet	Sept. 19 to Nov. 13	47.88
		11 A.M. to 12 M.	31	Dry		33.60
2	Howes, . .	7 to 8 A.M.	13 to 16	Wet	Sept. 26 to Nov. 13	39.86
		4 to 4.15 P.M.	–	Dry		13.57

As it was thought that berries picked wet might keep less well than those picked dry because of being bruised more in the process of picking, an experiment in which one of the lots was wetted in the crates after picking was tried. The berries were of the Early Black variety, and were picked on September 14 and stored in bushel picking crates. There were three crates in each lot. On November 14 the berries were examined for rot, and 66.34 per cent were found showing decay in the wetted lot against 45.85 per cent in the dry one. The result clearly shows the harmful effect of wetness among stored cranberries.

8. *The Effect of an Admixture of Cranberry Leaves on the Keeping of the Berries.*

The fruit of two varieties, Early Black and Howes, was tried in this connection. The berries were picked and stored September 22, in bushel picking crates, twelve crates of each variety being used, six with leaves and six without. The berries and leaves were put into the crates in alternate layers, and each layer of leaves was mixed with the berries beneath it by careful shaking, this probably doing little or no harm to the fruit. Three quarts of leaves were used in each crate to which they were added. The berries were examined for rot on December 26 and 27. The examination showed the following percentages of decay: —

Early Black: with leaves, 62.74; without leaves, 47.77.
Howes: with leaves, 42.59; without leaves, 27.36.

[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 201–204.

These results strongly confirm those previously reported.[1] It was noticed that a large percentage of the rot spots shown by berries with which leaves were mixed were quite small.

9. *The Effect of an Admixture of Decayed Early Black Cranberries on the Keeping of Berries of that Variety.*

Two lots of berries in quart cans were used in this test. There were 18 cans in each lot. The berries were examined and put in storage during the days of October 18 to 23. The decayed berries put in lot 2 were entirely soft but unbroken. The can covers were tight but not sealed. Lot 1 contained 9,105 sound berries, and lot 2, 4,957 sound berries mixed with 5,541 rotten ones. On December 28 the berries were examined. Lot 1 contained 3,823, and lot 2, 1,159, sound berries. The percentages of berries found to have wholly or partly softened during the storage were as follows: lot 1, 58.01; lot 2, 76.62. The admixture of rotten fruit apparently promoted decay among the sound berries; but this result contradicts a like test with Howes fruit previously reported.[2]

10. *Berries separated with Hayden and with White Machines compared as to Keeping Quality.*

Boxes of fruit from a commercial lot of Howes berries were divided by dumping, and one part was cleaned with a Hayden and the other part with a White separator on November 12. The fruit from each machine was packed in a half-barrel and shipped to New York. It was examined there December 12, 20.9 per cent of that cleaned with the Hayden separator and 21.8 per cent of that cleaned with the White then showing decay. This result accords with that of like tests heretofore reported[3] in showing little difference in the injury caused by the two kinds of separators.

11. *Barrels* v. *Crates as Containers for shipping Cranberries.*

The two following shipping tests were conducted: —

(*a*) *New York Shipment.* — This fruit was gathered on one of Dr. Rogers' bogs on October 3 and kept in picking crates, just as it came from the bog, in the basement of the station screenhouse until November 16, when the contents of the crates were divided into two lots by alternate dipping with a quart measure. Both lots were put through a Hayden separator November 17, picking crates being placed close up to the separator spouts to receive the berries, instead of barrels. Only the fruit coming from the spouts of the separator was used on either side of the test. A grader with a thirteen-thirty-second-inch spacing was used with both lots. The berries were screened November 17, easers being used with those that were barreled, while Beaton crates were placed close to

[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 205, 206.
[2] Bul. No. 168, Mass. Agr. Expt. Sta., 1916, p. 19.
[3] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, pp. 206–208.

the mouth of the screen to receive the other lot. There were two barrels in one lot and four half-barrel crates in the other. Both lots were packed November 17. They were left in the basement of the screenhouse, the barrels on the bilge, until November 22, when they were shipped to New York. One crate was broken in transit. The rest of the shipment was examined December 12, as shown in Table 11, the result distinctly favoring the crates.

TABLE 11. — *Barrels v. Beaton Crates as Containers for shipping Cranberries.*

Beaton Crates.

	Location in the Container from which the Sample was taken.	Sound Berries in the Sample.	Berries showing Decay.	
			Number.	Per Cent.
Crate.				
1	¼ middle,	114	8	6.6
	¼ edge,	85	14	14.1
	½ middle,	141	12	7.8
	½ edge,	102	6	5.5
2	¼ middle,	114	19	14.3
	¼ edge,	122	17	12.2
	½ middle,	106	14	11.7
	½ edge,	103	6	5.5
3	¼ middle,	116	16	12.1
	¼ edge,	143	10	6.5
	½ middle,	96	12	11.1
	½ edge,	86	10	10.4
Totals,		1,328	144	9.8

Barrels.

Barrel.				
1	Top,	114	18	13.6
	¼ middle,	107	19	15.1
	¼ stave,	151	18	10.7
	½ middle,	100	15	13.0
	½ stave,	110	13	10.6
2	Top,	210	37	15.0
	¼ middle,	113	19	14.4
	¼ stave,	105	17	13.9
	½ middle,	109	16	12.8
	½ stave,	121	16	11.7
Totals,		1,240	188	13.1

(*b*) *Chicago Shipment.* — The two lots of Early Black berries used in this test were picked in the same place on the station bog some time between September 20 and 28, the contents of picking boxes being divided by alternate dipping with a quart measure on October 25 to make the two lots. The berries were stored in the basement of the screenhouse as they came from the bog until they were divided. Both lots were put through a Hayden separator October 26, and were run from the spouts of the machine into boxes placed close to them. Both lots were graded with a thirteen-thirty-second-inch grader. They were screened in the afternoon of October 26 and the morning of the 27th. Those packed in barrels were run from the mouths of the screen as usual, no easer being used, while the other lot was run from the mouths of the screen into crates placed up close to them. The berries were packed for shipment October 27 and left in the basement of the screenhouse until November 1, when they were taken to Wareham in an auto truck and shipped to Chicago on top of a carlot of berries. The two barrels and four crates included in the test were examined in Chicago November 15, the crates showing 18 per cent of spoiled fruit, and the barrels 22 per cent.

12. *Shipping Cranberries in Chaff* v. *shipping them in the Clean Condition.*

Table 12 shows the experience with fruit of the McFarlin and Middleborough varieties packed at Wareham October 26 and shipped to Chicago. The first lot of each variety was shipped in the chaff. Each second lot was carefully separated and sorted before shipment, and the shrinkage noted. All the lots were run through a separator at Chicago on November 15, and the shrinkage again noted. With both varieties the total loss of berries was greater with those cleaned before than with those cleaned after shipment. This was especially noticeable with the Middleborough variety, which contained no frosted berries and therefore gave a more reliable test.

Shipping in chaff involves the extra expense of freight charges and containers for the chaff and rotten berries which would be taken out in cleaning. On the other hand, fruit shipped in the chaff may be held in storage and run through a separator as sold. Hand-sorting not being necessary, the cost of preparing for sale is materially reduced.

TABLE 12. — *Shipping Cranberries in Chaff* v. *shipping them in the Cleaned Condition.*

Variety.	Lot.	Containers.		Condition in which Fruit was shipped.	Shrinkage in separating and sorting before Shipment (Per Cent).	Shrinkage in separating at Chicago (Per Cent).	Total Shrinkage (Per Cent).
		Kind.	Number.				
McFarlin,	1	½ barrel boxes,	5	In chaff,	-	28.7	28.7
	2	½ barrel boxes,	5	Separated and screened,	20	10.2	30.2
Middleborough,	1	½ barrel boxes,	5	In chaff,	-	27.0	27.0
	2	½ barrel boxes,	5	Separated and screened,	20	15.5	35.5

Insects.

The Span Worm (*Epelis truncataria* var. *faxonii* Minot).

In 1917 a bog under the writer's observation near East Wareham was reflowed June 20 while the moths of both sexes of this insect were numerous on a large share of it. The water was let off June 23. It either destroyed or drove ashore all the moths, very few being seen afterwards, but it apparently did little or no harm to the eggs which had been laid before the flooding, for the worms appeared on the bog in great numbers in July. When the worms were small, this infestation was treated once with 6 pounds of arsenate of lead paste to 50 gallons of water with great success, no noticeable injury from what started as a severe infestation appearing afterward. But few of the worms could be found by sweeping the bog with an insect net a few days after the spraying.

This insect did much harm on a bog in Carver in early August, 1918. It worked late because the winter flowage had been held until near the 1st of June, the pupæ enduring this prolonged submergence.

The Cranberry Root Grub (*Amphicoma vulpina* Hentz.).

The writer gives the above common name to a grub found occasionally in great numbers in the sand covering of cranberry bogs, where it works much like the root worm (*Rhabdopterus picipes*), feeding mainly on the small roots. The infestation usually is confined to limited areas, seldom extending in severity in one patch over more than 15 or 20 square rods at most. The areas affected are often very irregular, but sometimes quite circular. Occasionally the injury is so severe that the vines are entirely killed in patches, the roots being so eaten that they can be rolled back easily like a rug. More often the infested area looks yellowish and sickly, the vines failing both to grow well and to produce much fruit, this condition usually lasting several years. Vines thus affected often die suddenly in patches, or their growing tops and green berries wither, this happening only in periods of hot, dry weather. It probably takes vines that are not killed two or three years to recover after the insects finish their work and disappear, as they finally do.

The grubs look somewhat like those common in gardens, but are smaller and with a thin coat of fox-red hair which is well distributed over the body. They are from 28 to 30 millimetres long when mature, but all sizes from 8 millimetres long up are commonly found working together, the various sizes perhaps being of different broods.

The writer has never reared the adults of this species, but he found associated in the soil with the grubs of one infestation great numbers of both sexes of the beetles of *Amphicoma vulpina* Hentz.[1] Many pupæ and pupa skins of this species were also present. These beetles were first found July 5, 1917. They were in a dormant condition, most of them being about 3 inches below the surface of the sand. They were present in about the same numbers and condition on July 11. On July 17 these

[1] Identified by Mr. A. I. Bourne of the Massachusetts Agricultural Experiment Station.

conditions were mostly the same, but three of the beetles were found crawling around on the vines above ground. On July 21 the beetles were distinctly less abundant in the sand than before. These beetles are about five-eighths of an inch long. The males have quite a coat of fox-red hair. The females also have a hairy covering, but it is thinner and more olive-colored, and the hairs are much shorter. Both sexes are usually sluggish in their movements, but they sometimes were seen to fly well. When either the beetles, taken from the soil, or the grubs are placed on sand they bury themselves at once.

The work of this insect was noted as that of a species of Lachnosterna in the report of the cranberry investigations of 1911.[1]

The Spittle Insect (*Clastoptera vittata* Ball[2]).

This insect abounds on occasional cranberry bogs every year, it often being so prevalent that its spittle will wet one's shoes like a heavy dew. It commonly infests dry bogs, and apparently also those that are winter-flowed but not reflowed. It is said to winter in the egg stage. In this stage it seems to endure the long flooding. The writer has not yet found it abundant on a bog reflowed according to the usual practice.

The season was very late in 1917, and the young nymphs were found just starting their spittle on cranberry vines on June 13. The spittle masses were abundant and well-developed on several bogs on June 25. They were plentiful from then until after mid-July, but had nearly disappeared by the 20th of that month. The first grown insect obtained in confinement emerged July 12. The adults of both sexes came out rapidly from the 15th to the 19th. These insects are from about one-eighth to nearly three-sixteenths of an inch long. They are glossy, the males being black and the females black with yellow stripes. They jump lively when disturbed.

In 1918 the season was much earlier than in 1917, and the small masses of spittle were first found May 28. Judging by the size of some of the masses the insect must have begun hatching four or five days before this. It was noted July 10, 1918, that nearly all the adults had emerged.

Some cranberry growers have long considered this species very harmful when abundant. To determine this point the writer marked several hundred infested uprights with blue, and as many uninfested ones with red, yarn a little after mid-July, 1917. These uprights were examined December 7. The results, shown in Table 13, give striking proof that this is a very injurious insect, and ought to be controlled wherever it becomes abundant on a bog.

A heavily infested area was sprayed July 5, 1917, with Black-Leaf 40, 1 part to 400 parts of water, resin fish-oil soap being added at the rate of 2 pounds to 50 gallons. The insects were then nearly full-grown and well enveloped in spittle. The writer examined the treated area July 6, and found most of the insects had been killed and most of the spittle had dried up.

[1] Twenty-fourth Ann. Rept., Mass. Agr. Expt. Sta., Part I, p. 22, 1912.

[2] Called *C. proteus*, Fitch, in the Ann. Rept. of the Cape Cod Cranberry Growers' Assoc., 1917, p. 8.

TABLE 13. — *Condition in December of Cranberry Uprights that had been infested during the Summer with the Spittle Insect (Clastoptera vittata) as compared with that of Uprights that had not been infested.*

[The infested and uninfested uprights on the same bog and in the same location were marked with yarn of different colors, and were examined Dec. 7, 1917.]

Uprights Infested or not in July.	Total Number of Uprights marked in July and examined in December.	Leading Branch of Upright apparently Dead, without a Berry or Leaf or Bud at Tip.				Leading Branch of Upright with Few Leaves, no Berries and no Bud at Tip.				Leading Branch of Upright with at least a Fair Amount of Leaves, but no Berries. With or without a Bud at the Tip.				Leading Branch of Upright with at least a Fair Amount of Leaves and One or More Berries.			
		One or more side-shoots with at least a fair amount of leaves.		Either no living side-shoot or the side-shoot with few leaves and with no bud at tip.		One or more side-shoots with at least a fair amount of leaves.		Either no living side-shoot or the side-shoot with few leaves and with no bud at tip.		One or more side-shoots with at least a fair amount of leaves.		Either no living side-shoot or the side-shoot with few leaves and with no bud at tip.		One or more side-shoots with at least a fair amount of leaves.		Either no living side-shoot or the side-shoot with few leaves and with no bud at tip.	
		Bud in Tip of Side-shoot (Number of Uprights).	No Bud in Tip of Side-shoot (Number of Uprights).	Living Side-shoot Present (Number of Uprights).	No Living Side-shoot (Number of Uprights).	Bud in Tip of Side-shoot (Number of Uprights).	No Bud in Tip of Side-shoot (Number of Uprights).	Living Side-shoot Present (Number of Uprights).	No Living Side-shoot (Number of Uprights).	Bud in Tip of Side-shoot (Number of Uprights).	No Bud in Tip of Side-shoot (Number of Uprights).	Living Side-shoot Present (Number of Uprights).	No Living Side-shoot (Number of Uprights).	Bud in Tip of Side-shoot (Number of Uprights).	No Bud in Tip of Side-shoot (Number of Uprights).	Living Side-shoot Present (Number of Uprights).	No Living Side-shoot (Number of Uprights).
Infested, .	320	15	20	36	142	2	0	11	66	1	0	1	25	0	0	0	1
Not infested,	302	40	16	7	4	10	7	4	14	14	4	11	151	2	0	0	18
Total infested, .		213				79				27				1			
Total not infested,		67				35				180				20			

On June 2, 1918, an infested area was sprayed with Black-Leaf 40, 1 part to 800 parts of water, soap being added as in 1917. The nymphs were small and the treatment was very effective, practically all the spittle masses disappearing, while they remained abundant on the untreated surrounding parts of the bog.

In 1918 the writer reared adults of this species from the following: —

1. *Gaylussacia frondosa*, Torr. & Gray.
2. *Gaylussacia resinosa*, Torr. & Gray.
3. *Vaccinium vacillans*, Solander.
4. *Vaccinium corymbosum*, L.
5. *Vaccinium macrocarpon*, Ait.
6. *Andromeda ligustrina*, Muhl.
7. *Leucothoe racemosa*, Gray.
8. *Cassandra calyculata*, Don.

The insect infested all these species except *V. corymbosum* very abundantly. As some of these plants grow in great abundance around or near most Cape bogs, they furnish a large source of infestation for them. As the insect does not infest reflowed bogs, however, its progress from the uplands onto the bogs must be very slow.

Clastoptera proteus, Fitch, has been defined to include a variety of forms.[1] The writer thinks that the forms (subspecies *flava* and subspecies *nigra*, var. *a*, of Ball) which Professor Osborn bred from dogwood[2] really belong to species distinct from the one (subspecies *vittata* and subspecies *nigra*, var. *b*, of Ball) infesting the cranberry and other plants of the heath family. The writer has seen some of Professor Osborn's specimens. Of these, one female and one male belonged to Ball's subspecies *flava*, and two males to subspecies *nigra*, var. *a*. The writer has reared hundreds of specimens of both sexes from ericaceous plants. Nearly all his females belong to subspecies *vittata*. A few of his females and all his males belong to subspecies *nigra*, var. *b*. He has captured specimens of *vittata* and *nigra*, var. *b*, in coition. The pronotum of *vittata* and of *nigra*, var. *b*, always has a slight median longitudinal sulcus. None of Osborn's specimens were at all sulcate longitudinally on the middle of the pronotum, the two males of *nigra*, var. *a*, even being slightly carinate longitudinally there instead. Further structural differences should be looked for in the male genitalia.

The Cranberry Tip Worm (*Dasyneura vaccinii* Smith).

The Proctotrypid, heretofore reported[3] as the most important parasite of this species, has been identified[4] as *Ceraphron pallidiventris* Ashm. It was bred from the maggots in great numbers in 1917 as it had been in 1916.

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[1] Ball, E. D.: Proc. Iowa Acad. Sci., III., 1895, pp. 186, 187.
[2] Bul. No. 254, Maine Agr. Expt. Sta., 1916, p. 284.
[3] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 226.
[4] By Mr. A. B. Gahan of the Bureau of Entomology.

The Gypsy Moth (*Porthetria dispar* L.).

Early in January, 1917, several batches of the eggs of this insect, collected from trees shortly before, were submerged in two or three feet of water in a pond, two lots being left in the basement of the screenhouse as a check on the hatch of the others. The hatch of those kept in the basement was nearly perfect, while less than 1 per cent of those taken from the pond May 16, and none of those removed May 24, May 29 or June 2, hatched. All these eggs were put on sand in pails when taken from the water, and kept in the upper part of the screenhouse, as were also those from the basement. A lot taken from the pond June 7 was put at once on the station bog, the egg masses being spread under the vines, with care to place them as a moth might lay them. This lot was observed until July 4, and but one egg was known to hatch, a newly hatched worm being found on a vine above the eggs June 21. These results confirm those of former years in showing that the eggs do not endure very late holding of the winter water.

Mr. C. W. Minott of the Bureau of Entomology and the writer co-operated in an experiment at the Wankinco bog in 1917, to determine the amount of the wind drift of the first-stage caterpillars. A horizontal tanglefoot-covered screen was used. This was placed 583 feet on its south side, 837 feet on its northeast side, and 635 feet on its northwest side from the upland. It covered 53⅓ square feet, and during the wind-drift period caught two of the larvæ. If this shows fairly the wind drift onto the central part of the bog, 1,634 gypsy worms per acre blew onto it during the season. This result is significant, as the bog is so large and its environs were so little infested in the early spring that it seemed doubtful if the experiment would pay.

On June 15, 1917, a grower told the writer he had recently successfully treated gypsy caterpillars floating on the flowage of some bogs with kerosene. He used 5 gallons to 6 acres, and poured it on the water on the windward side. The worms must have been fully a third grown.

On June 9 the writer sprayed oak bushes much infested with gypsy caterpillars with Black-Leaf 40 used at the rate of 1 part to 400 parts of water, with resin fish-oil soap added at the rate of 2 pounds to 50 gallons. The worms were in their second, third and fourth stages, being from 6 to 15 millimetres long, and the spray killed all it hit. Other bushes covered with gypsy worms were sprayed with Black-Leaf 40 used at the rate of 1 part to 800 parts of water, with soap as before. This treatment was partially effective, but very many caterpillars survived it. On June 19 infested bushes were sprayed with Black-Leaf 40 used at the rate of 1 part to 400, soap being added as before. The caterpillars were in their third, fourth and fifth stages, being 10 to 22 millimetres long, and the treatment killed most of them, though many of the larger ones survived. Nearly full-grown caterpillars were sprayed July 5 with Black-Leaf 40 used at the rate of 1 part to 200, with soap as before. This was not effective.

All these tests were tried in sunny weather. Judging by their results, the 1 to 400 Black-Leaf 40 spray kills the worms in their early stages, but is of no use when they are nearly full-grown. One part to 800 parts of water is too weak at any time. Further experiments may show that a medium strength, such as 1 part to 600, will kill the very young caterpillars.

These conclusions are of special interest in relation to the recent developments in the control of the black-head fireworm.

The Black-Head Fireworm (*Rhopobota vacciniana* (Pack.)).

This pest was well controlled in several 1917 tests where Black-Leaf 40 was used at the rate of 1 part to 400 parts of water, with 2 pounds of resin fish-oil soap to 50 gallons added. After this treatment the infestation always was greatly reduced and the worms were found dead among the sewed-up vines in great numbers. The plots treated with the 1 to 800 Black-Leaf 40 spray were not well located to show results, the infestation in no case proving great enough to hurt the vines around them much.

This insecticide must be tried more thoroughly before we can tell what strength to use under all conditions, but it certainly has displaced arsenate of lead as a control for this insect. It is expensive, costing about $7 per acre per application when used at the rate of 1 part to 400 of water. The number of applications advisable depends on how severe the infestation is and how well it can be curbed by reflowing. While this spray checks either brood, it can as a rule be used more profitably against the first than against the second.

Control of the gypsy moth and the fireworm with the same application is feasible, as the time for the first treatment of the first brood of the fireworm is usually not too late for spraying the gypsy. When both insects are treated, the Black-Leaf 40 must be used as strong as 1 part to 600 of water, and 1 to 400 probably will pay better. Treatment of the spittle insect, the gypsy moth and the first brood of the fireworm with the same application of Black-Leaf 40 is practicable on bogs that are winter flowed but not reflowed.

The use of arsenate of lead with the Black-Leaf 40 in spraying for the fireworm and the gypsy moth is probably advisable, for the arsenate whitens the spray and so marks where it is applied, thus reducing the liability of leaving areas unsprayed. It also adds to the insecticidal value of the spray, and, as shown elsewhere in this report, gives it a fungicidal value when it is used on Early Black vines. Whale-oil soap is preferable to resin fish-oil soap for use with Black-Leaf 40, especially if arsenate of lead is added, for the arsenate and the resin soap make a burning combination.

Several fireworm-infested bogs on the Cape had their winter flowage held until the 10th of July, 1918. While this greatly reduced the infestation, there was a considerable hatch in every case after the water was let off. It is now doubtful if late holding can be relied on to eradicate the pest entirely unless it is continued to the 1st of August. The most successful treatment applied on large bogs in 1918 was that of letting the winter flowage off about June 1 and flooding again from three weeks to a month later. This has been reported as very effective heretofore.[1]

In 1917 the first brood was first found hatching on June 4, the spring having been very late and cold. At this time none of the worms observed seemed more than two days old. This is the latest date for the beginning of the hatch the writer has ever noted.

The Cranberry Fruit Worm (*Mineola vaccinii* Riley).

In 1917 the eggs of this insect showed a range in Chalcidid (*Trichogramma minuta*) parasitism of from 83 to 89 per cent on dry bogs, and from 29 to 88 per cent on those with winter flowage. In 1918 the range was from 36 to 89 per cent on dry bogs and from none to 15 per cent on flowed ones.

The fruit worm did much more injury in 1917 than in 1916.

On June 27, 1917, the writer covered large numbers of fruit-worm cocoons, in quart cans partly filled with moist sand, with measured and uniform one-third inch, one-half inch and 1 inch depths of sand. Checks of cocoons without any covering were kept for comparison. The cocoons had been kept in good condition on sand in cans during the preceding fall, winter and spring, and it is certain that when these tests were started the worms had all either pupated or been destroyed by the formation of the parasite pupæ. As in like tests previously reported,[2] both the moths and parasites emerged through the one-third and one-half inch coverings fairly freely, but the inch covering smothered them almost completely.

Large numbers of cocoons of fruit worms were buried under a measured inch of sand in the late fall of 1917. Most of the worms left their cocoons, worked their way up through the sand, and in some cases built very meager secondary cocoons after reaching the surface. The pupæ of the worms and parasites were formed on or near the surface.

These results show that the fruit worm may be smothered by heavy sanding, but that the sand must be applied after pupation to be effective. As shown heretofore,[3] pupation is not completed until the middle of June, and bogs cannot be sanded then without doing much injury.

The difference in the results obtained with this insect by covering cocoons heavily with sand before the worms pupate as compared with like covering after pupation may explain why the writer [4] had so much greater success than Scammell [5] in smothering the girdler (*Crambus hortuellus* Hübner). The writer applied the sand late in May, while Scammell applied it in November. The girdler usually pupates in the last half of

[1] Twenty-fifth Ann. Rept., Mass. Agr. Expt. Sta., Pt. I, 1913, p. 232.

[2] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 228.

[3] Bul. No. 168, Mass. Agr. Expt. Sta., 1916, p. 40.

[4] Twenty-fourth Ann. Rept., Mass. Agr. Expt. Sta., Pt. I, p. 19, 1912.

[5] Bul. No. 554, U. S. Dept. of Agr., 1917, p. 18.

May and very early June, if the winter water is let off early, as it was at the bog where the writer made his tests. The writer observed Scammell's experiments and saw nothing in them to criticize.

The fruit-worm injury in 1918 was the least of any season in the writer's experience. This, after so severe a winter, seemed surprising.[1] Its injury to the station crop was estimated to be 3 to 4 per cent.

The Greasy Cutworm (*Agrotis ypsilon* Rott.).

In a previous report[2] a destructive visitation of the fall army worm (*Laphygma frugiperda* S. & A.) on cranberry bogs, following closely and evidently somehow caused by the removal of the winter flowage in mid-July, was noted. This season a similar visitation by the greasy cutworm (*Agrotis ypsilon* Rott.) occurred in August on a large part of the Wankinco bog, the bog having been flowed from early June to July 10. The blackish worms in their feeding dropped a litter of uneaten leaf fragments onto the sand under the vines. They were first seen about August 10, many being then considerably grown, and they disappeared on the bog about August 24. They seemed to be cannibals when confined in tightly closed cans in numbers together, for they became rapidly fewer under such conditions without any other evident reason. They pupated in confinement in late August and early September, and the moths emerged from September 18 to October 2.

The writer thinks there may be several more species that on occasion will infest cranberry bogs, bared of their winter flowage in midsummer, in this way. Scammell's explanation that the moths of the fall army worm seem to be attracted to bogs recently bared of the flowage, and there lay their eggs in preference to bogs from which the flowage was removed at the normal time, is probably correct for that insect and other species as well. Observations made by the writer in 1917 on a bog in Plymouth support this opinion. The winter flowage was let off this bog August 10, and a few days later great numbers of moths were found among the vines on all parts of it. The moths were of the three following species, most of them being of the first two: —

1. *Nomophila noctuella* S. V.
2. *Drasteria erechtea* Cram.
3. *Autographa falcigera* var. *simplex* Gn.

These moths were not noticed on any bog that had the winter flowage off early. No worm infestation developed later where the moths appeared. The cranberry may not be a food plant of any of the three species, or the moths may have laid most of their eggs before they came onto the bog.

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[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 227.
[2] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 232.

Resanding.

The 1918 experience with two plots on the station bog that have not been sanded since the fall of 1909 is shown in Table 14. The check areas in each case were adjacent to and on different sides of the plot. The berries were of the Early Black variety, and were picked and placed in storage September 16. The fruit was stored in bushel crates, 8 bushels being used in each case, and was examined December 17 to 19 by the "seven-sample" method.

The fruit from the plots kept distinctly better than that from their checks in nearly every case, this result contradicting that of 1916 with fruit from these areas.[1] These plots yielded as heavily on the average as the surrounding bog until 1916.[2] Table 15 shows that since 1915 their average productiveness has fallen distinctly below that of their checks. For the past three years the vines on these plots have been much thinner than those of the surrounding bog.

Table 14. — *Sanding Plots in 1918. Effect of Resanding on Quantity and Quality of Cranberries.*

Plots and Checks.	Area (Square Rods).	Resanded.	Yields per Square Rod (Bushels).	Percentage of Berries showing decay at End of Storage.
V,	9	Not since November, 1909,	1.59	31.25
V (check 1),	6	Spring of 1912, fall of 1914 and spring of 1917,	2.33	31.89
V (check 2),	6	Spring of 1912, fall of 1914 and spring of 1917,	2.56	38.43
V (check 3),	6	Spring of 1912, fall of 1914 and spring of 1917,	2.22	44.54
O,	9	Not since November, 1909,	1.39	21.65
O (check 1),	6	Fall of 1911, fall of 1914 and spring of 1917,	2.11	25.87
O (check 2),	6	Fall of 1911, fall of 1914 and spring of 1917,	1.72	29.31
O (check 3),	6	Fall of 1911, fall of 1914 and spring of 1917,	2.03	24.05

Table 15. — *Productiveness of Sanding Plots V and O in 1916, 1917 and 1918.*

Plots and Checks.	Resanded.	Yields per Square Rod (Bushels).			
		1916.	1917.	1918.	Average for Three Years.
V,	Not since 1909,	.93	.60	1.59	1.04
V (checks),	Thrice since 1909,	1.39	.65	2.37	1.47
O,	Not since 1909,	.93	.63	1.39	.98
O (checks),	Thrice since 1909,	1.24	.63	1.95	1.27

[1] Bul. No. 180, Mass. Agr. Expt. Sta., 1917, p. 219, Table 18.

[2] Bull. No. 168, Mass. Agr. Expt. Sta., 1916, p. 27, Table 15.

FERTILIZERS.

Tables 16 and 17 show the results had with the station bog fertilizer plots in 1917 and 1918, respectively. The area of each plot is 8 square rods, and the variety treated, the Early Black. In 1917 the fertilizers were applied on June 29 and 30, and the berries picked on September 17 and 19. Seven bushels were used in each of the storage tests. In 1918 the fertilizers were applied on June 8. Eight bushels of berries from each plot were examined for rot.

Plots 1, 5, 9, 13, 17 and 21 are all untreated checks. The meanings of the symbols used in the tables are as follows: —

0 = Nothing.
N = 100 pounds nitrate of soda per acre.
P = 400 pounds acid phosphate per acre.
K = 200 pounds high-grade sulfate of potash per acre.
L = 1 ton of slaked lime per acre.
Kcl = 200 pounds muriate of potash per acre.
$N_{1\frac{1}{2}}$ = 150 pounds nitrate of soda per acre.
N_2 = 200 pounds nitrate of soda per acre.
$P_{1\frac{1}{2}}$ = 600 pounds acid phosphate per acre.
P_2 = 800 pounds acid phosphate per acre.

In combination they mean, for example, N_2PK=200 pounds of nitrate of soda+400 pounds of acid phosphate+200 pounds of high-grade sulfate of potash per acre.

TABLE 16. — *Fertilizer Plots in 1917. Condition and Relative Keeping Quality of the Berries.*

Plot.	Fertilizer.	Yields per Square Rod (Bushels).	Percentage of Berries showing Decay. October 4.	Percentage of Berries showing Decay. December 8 and 10.	Percentage of Sound Berries that became more or less Rotten during Storage.
1	O,	1.21	-	-	-
2	N,	1.21	-	-	-
3	P,	1 28	-	-	-
4	K,	1.33	-	-	-
5	O,	1.33	-	-	-
6	NP,	.94	-	-	-
7	NK,	.81	29.33	-	-
8	PK,	.92	22.18	-	-
9	O,	.69	8.95	-	-
10	NPK,	.63	16.47	-	-
23[1]	O,	.58	-	-	-

[1] This plot was dressed with leaf mold in 1916.

TABLE 16. — *Fertilizer Plots, etc.* — Concluded.

Plot.	FERTILIZER.	Yields per Square Rod (Bushels).	PERCENTAGE OF BERRIES SHOWING DECAY.		Percentage of Sound Berries that became more or less Rotten during Storage.
			October 4.	December 8 and 10.	
11	NPKL,[2]	.83	33.40	63.38	44.97
12	NPKcl,	1.05	20 74	–	–
13	O,	1.06	9.75	36.63	29.78
14	$N_{1\frac{1}{2}}PK$,	1.05	22.91	–	–
15	N_2PK,	1.11	26.48	59.42	44.79
16	$NKP_{1\frac{1}{2}}$,	1.22	15.37	–	–
17	O,	1.10	6.50	37.16	32.80
18	NKP_2,	1.35	14.17	–	–
19	$NPK_{1\frac{1}{2}}$,	1.22	11.78	–	–
20	NPK_2,	1.09	13.16	–	–
21	O,	1.19	5.39	33.31	29.60

[1] The lime was added separately the day after the fertilizer.

TABLE 17. — *Fertilizer Plots in 1918. Yield, Time consumed in Picking, and Relative Condition of the Berries.*

Plot.	FERTILIZER.	Date picked.	Time consumed in Picking (Picker-minutes).	Yields per Square Rod (Bushels).	Date examined.	Percentage of Berries showing Decay.
1	O,	Oct. 4	147	2.50	Oct. 14	11.67
2	N,	Oct. 5	240	2.65	Oct. 15	14.35
3	P,	Oct. 5	252	2.60	Oct. 16	12.94
4	O,	Oct. 5	168	2.56	Oct. 17	22.92
5	O,	Oct. 5	288	2.42	Oct. 18	17.55
6	NP,	Oct. 5	366	2.56	Oct. 17	18.41
7	N,	Oct. 5	306	2.38	Oct. 17	27.41
8	P,	Oct. 8	210	2.54	Oct. 14	16.81
9	O,	Oct. 8	150	2.38	Oct. 14	18.28
10	NP,	Oct. 8	238	2.60	Oct. 14	24.89
11	NPL,	Oct. 4	378	2.39	Oct. 15	28.36
12	NP,	Oct. 4	273	2.48	Oct. 15	26.04
13	O,	Oct. 4	162	2.40	Oct. 15	22.77
14	$N_{1\frac{1}{2}}P$,	Oct. 4	245	2.46	Oct. 16	21.41
15	N_2P,	Oct. 4	287	2.50	Oct. 15	27.35
16	$NP_{1\frac{1}{2}}$,	Oct. 4	252	2.75	Oct. 15	15.66
17	O,	Oct. 4	192	2.54	Oct. 15	16.75
18	NP_2,	Oct. 1	256	2.63	Oct. 18	15.46
19	NP,	Oct. 1	232	2.44	Oct. 18	16.32
20	NP,	Oct. 1	280	2.77	Oct. 17	17.74
21	O,	Oct. 1	200	2.43	Oct. 16	15.01

Column 4 of Table 16 gives the percentages of berries showing decay two weeks after the fruit was picked. Most of this rot was surely present when the berries came from the bog. The fertilizer evidently greatly increased the rotting on the vines. The last column of this table shows that the fertilizer also greatly harmed the keeping quality of the fruit. The berries from only a part of the plots were examined, as this was all that seemed necessary to bring out the facts.

The last column of Table 17 shows the condition of the fruit two weeks after it was picked in 1918. The percentages for some reason fail to tell so marked a story as those of 1917. The figures in the fourth column of this table were obtained by multiplying for each plot the minutes consumed in picking by the number of pickers. They therefore show the relative cost of harvesting the various plots. This expense was much greater with the treated areas than with the checks.

The treated and check areas yielded at about the same rate in 1917, but the checks produced less in 1918.

In both 1917 and 1918 the fertilized plots developed a considerable growth of weeds, especially of fireweed (*Erechtites hieracifolia* Raf.) and beggar-ticks (*Bidens frondosa* L.), not much found elsewhere on the bog.

The fruit of the plot treated with lime decayed more than that of any other plot in both 1917 and 1918, as it had in the three previous years. Table 18 shows the results with two new plots to which slaked lime at the rate of 1 ton per acre was applied on June 13. The berries were of the Early Black variety, and 8 bushels from each plot and each check were examined. On the whole, the fruit from these limed areas rotted more than that from the checks. This result, as far as it goes, accords with that of fertilizer plot 11.

Table 19 gives the yields of the station fertilizer plots by years and the total yields since they were started. Considering all the experience with these plots, it seems that the advantage of any slight increase in yield that may have been caused by the fertilizers has been much more than balanced by the cost of the treatment, the deterioration in the quality of the fruit, the greater cost of picking due to the increased vine growth, and the incursion of weeds.

TABLE 18. — *Effect of Liming the Bog on the Quality of the Fruit.*

Plots and Checks.	Area (Square Rods).	Location on Station Bog.	Date picked.	Yields per Square Rod (Bushels).	Date examined.	Percentage of Berries showing Decay.
Lime 1,	8.0	Section 1	Sept. 22	2.59	Oct. 21	21.51
Lime 1 (check 1),	8.0	Section 1	Sept. 22	2.59	Oct. 21	17.95
Lime 1 (check 2),	8.0	Section 1	Sept. 22	2.72	Oct. 21	15.02
Lime 2,	7.6	Section 21	Sept. 11	2.66	Oct. 22	12.30
Lime 2 (check),	7.5	Section 21	Sept. 11	2.58	Oct. 22	11.92

Table 19. — *Effect of Fertilizers on Cranberry Yield.*

Plot.	Fertilizer.[1]	Yields (Bushels).								
		1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	Total.
1	O,	10.0	1.9	15.8	9.0	5.8	10.7	9.7	20.0	82.9
2	N,	12.0	3.2	16.5	9.5	6.2	9.3	9.7	21.2	87.6
3	P,	11.0	2.0	15.7	8.8	5.5	9.0	10.2	20.8	83.0
4	K,	11.0	1.7	17.0	8.0	5.5	9.6	10.7	20.5	84.0
5	O,	13.0	1.8	19.3	6.5	7.6	9.2	10.6	19.3	87.3
6	NP,	16.0	3.1	19.2	6.7	7.8	6.3	7.7	20.5	87.3
7	NK,	14.5	3.9	18.8	7.7	8.0	6.6	6.5	19.0	84.9
8	PK,	14.5	2.7	17.8	8.7	8.2	8.0	7.3	20.3	87.5
9	O,	14.0	2.3	17.7	6.5	4.9	9.0	5.5	19.0	78.9
10	NPK,	14.0	4.0	20.0	8.7	7.3	6.9	5.0	20.8	86.7
11	NPKL,	16.0	3.5	17.7	8.2	6.3	2.9	6.7	19.1	80.4
12	NPKcl	15.0	3.4	20.3	7.8	7.2	6.0	8.4	19.8	87.9
13	O,	12.0	2.5	19.2	7.7	5.7	7.7	8.5	19.2	82.4
14	$N_{1\frac{1}{2}}PK$,	12.0	4.8	17.7	10.0	6.9	5.5	8.4	19.7	85.0
15	N_2PK,	10.0	6.1	9.8	10.4	5.8	4.5	8.9	20.0	75.6
16	$NKP_{1\frac{1}{2}}$,	10.0	5.7	18.0	9.0	7.0	7.2	9.7	22.0	88.6
17	O,	10.5	3.2	20.3	9.7	7.0	9.3	8.8	20.3	89.1
18	NKP_2,	10.0	5.5	18.0	10.0	6.2	8.3	10.8	21.0	89.9
19	$NPK_{1\frac{1}{2}}$,	10.0	4.0	19.1	9.0	6.8	7.8	9.8	19.5	86.0
20	NPK_2,	12.5	4.2	20.0	6.8	7.3	9.0	8.8	22.2	90.8
21	O,	11.5	3.0	22.1	10.3	6.1	10.3	9.5	19.4	92.2
22	O,	11.5	3.1	-	10.8	-	-	-	-	-
23	O,	14.5	2.0	20.0	6.3	-	8.0	4.6	-	-

[1] The potash salts were omitted in 1918.

Weather Observations.

Weather observations and records were made in both 1917 and 1918 as previously, daily reports being telegraphed to the Boston office of the Weather Bureau in the spring and fall, and special frost predictions being telephoned to growers when asked for.

Severe winterkilling occurred in 1916–17 on exposed bogs, the injury being more extensive than in any year since 1906. The damage came much earlier in the winter than usual. Many bogs winter flowed the first days in February and some flooded late in January were badly hurt. The winterkilling seemed a slow process. It probably took several days and perhaps a week or two to complete it, as the weather and bog conditions were so long the same. Unprotected bogs were frozen deeper than the cranberry roots extended for some time before the killing took place, and the vines were exposed to strong, dry, northerly winds most of the three weeks ending February 5. On some badly injured bogs, areas not picked the fall before showed little harm, and new plantings in which the vines were still in the hills were not hurt, while heavy vines near by that had been picked were badly killed.

From these and other observations the writer ventures to guess that cranberry winterkilling usually is due to a drying out of the vines resulting from a freezing in of the roots that prohibits their taking in moisture to replace that given off by the leaves exposed to strong, dry winds. As the dormant cranberry foliage is hard and tough, it probably parts with its moisture very slowly, even in the most drying weather, and the writer thinks it usually takes several days of such exposure to kill the vines. The escape from injury of new plantings and unpicked vines may have been due to their being less dry before they were exposed to winterkilling conditions than were the picked vines, their roots not having been disturbed.

The spring and early summer of 1917 were late, cold and wet, and as a result the cranberry crop was very tardy in ripening. There was little or no frost injury in the spring, but on the nights of September 10 and 11 hard freezes caught the berries still in a green or slightly colored condition. The minimum bog temperature recorded at the station on the 10th was $24\frac{1}{2}$° F., and on the 11th, 26° F. The first night the wind at the station was from the northeast, with a velocity of 10 miles an hour at 8 P.M., and an average of $3\frac{2}{3}$ miles from midnight to 6 A.M. This wind was very generally, though, as it proved, unwisely, relied on to prevent a hard frost. Temperatures as low as 18° F. were reported from some bogs, severe injury being common except in Barnstable County and on the Vineyard and Nantucket, all of which escaped with little or no hurt. The night of the 11th, however, bogs in Barnstable County suffered much loss.

From growers' reports the writer estimated the Cape cranberry loss for both nights to be 60 per cent. Mr. V. A. Sanders, field agent of the Bureau of Crop Estimates, set the loss in Plymouth County at about 67 per cent, and in Barnstable County at about 37 per cent. This reduction, added to that due to the winterkilling and the rather large fruitworm injury, left the smallest crop picked on the Cape since 1905, only 118,574 barrels of berries, exclusive of those marketed locally and those canned and evaporated, being shipped from this section.

From observations made on Sept. 2, 1916, and on the night of Sept. 10, 1917, it is certain that cranberries in the greenish white state that immediately precedes the ripening of the fruit will endure a temperature of 26° F. without hurt, and of 25° F. with little injury, but 24° F. seems to harm such fruit greatly if it continues long.

The winter of 1917–18 was the most severe in New England of any on record. The ponds and streams were low in the late fall and early winter, and so an unusually large percentage of the bogs was exposed to the winter. Winterkilling of the vines was as severe and widespread as in the previous winter, and the attending weather conditions were much the same.

A hard frost occurred the night of June 20, 1918, reducing the prospective crop, as estimated, over half. The lowest temperature recorded at the station was $26\frac{3}{4}$° F., and 23° F. was reported from some bogs. The vines had begun to bloom, and many growers used water more sparingly than they should have on that account. A widespread effect of this frost was noted later in the season. The vines had failed to recover and form buds for the next year on considerable areas. On such areas, therefore, the frost really destroyed two crops.

Frost Studies.

As the records made at the station during the past five years seemed a fair basis for a study of frost conditions on cranberry bogs on Cape Cod, and as the great loss from frost in September, 1917, made the need of closer predictions seem imperative, the writer gave most of the following winter to a careful investigation in this connection. The most important result was a new method for computing minimum temperatures on any night in which frost conditions prevail. The method is probably as reliable for computing on windy nights, if they are clear, as on still ones, but much cloudiness during the night renders it inaccurate.

Predictions by the new method are made from readings at 8 P.M., standard time. As a few minutes are needed to take the readings and make the calculation, the forecast is not ready until 8.15. As damaging frost may occur as early as 11 P.M., this warning will sometimes give only three hours in which to flood. Frost flooding can be done on many bogs in this time, but it takes several hours more on most of the larger areas with their present flumes and canals. Many growers would profit by greatly enlarging these equipments so as to flood more quickly and make full use of the warnings obtained by the new method.

The 8 P.M. temperature at a height of from 17 to 20 feet above the bog level is one of the factors used in the new method. Quite accurate predictions have been made for the Atwood bog at South Carver by substituting the shelter temperature at that bog for the station shelter temperature in the formula used in calculating. This suggests that growers may help both themselves and the work by placing Green thermometers in elevated locations near their bogs, and telephoning to the station their 8 P.M. reading.

Blueberry Work.

On May 14, 1917, thirty-nine swamp blueberry bushes, selected for the quantity and quality of fruit they bore in 1916, were transplanted from the wild to the station blueberry plantation at East Wareham. The writer spent a week in New Jersey in late July and early August, 1917, studying methods of cranberry and blueberry growing there. He brought back bud wood of two very select blueberry strains (Nos. 620A and 834A of the Bureau of Plant Industry), carrying it on ice in a thermos bottle during the trip home. It was cut from bushes in Miss Elizabeth C. White's plantation at Whitesbog, N. J., on the morning of August 4. Buds from it were inserted on sprouts in the station plantation on dates and in numbers as follows: —

August 8, No. 834A, 12 buds.
August 9, No. 620A, 40 buds.
August 10, No. 620A, 7 buds.

Prof. F. V. Coville's and Miss White's methods were followed in this budding. Only two of the fifty-nine select buds inserted developed into sprouts in 1918. The severe winter probably killed a large percentage of them.

The writer visited Miss White's plantation again in 1918, and brought back more select bud wood, buds from which were inserted in sprouts in the station plantation as follows: —

July 28, No. 834A, 23 buds; No. 1004A, 11 buds.
July 29, No. 1004A, 8 buds; No. 620A, 32 buds.
July 30, No. 620A, 3 buds; No. 823A, 20 buds.

The bud wood was cut from Miss White's bushes on the afternoon of July 25.

BULLETIN No. 193 OCTOBER, 1919

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

The Supply and Distribution of Connecticut Valley Cigar Leaf Tobacco

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BULLETIN No. 193.

DEPARTMENT OF AGRICULTURAL ECONOMICS.

THE SUPPLY AND DISTRIBUTION OF CONNECTICUT VALLEY CIGAR LEAF TOBACCO.

PART I.

HISTORY OF CONNECTICUT VALLEY TOBACCO PRODUCTION AND THE CIGAR INDUSTRY.

The culture of tobacco in the Connecticut valley is almost coeval with its first settlement. It was grown here during the years from 1640 to 1660. The stringent legislation of Connecticut restricted, under severe penalty, the use of tobacco to that grown in the colonies. In 1646 a law was passed prohibiting the use of tobacco by any one under twenty-one years of age, and requiring those who had not already acquired the tobacco habit to present a certificate from a physician before beginning it. A fine of a sixpence was imposed for the use of tobacco in the public streets. These restrictions did not stop the cultivation of tobacco, but tended to increase exportation and diminish home consumption. Nevertheless, until the latter part of the eighteenth century the production of tobacco in New England was of comparatively little importance. During the first quarter of the nineteenth century the manufacture of cigars began as a household industry in some of the towns of the valley. The industry grew very slowly, and correspondingly slow progress was made in the growing of cigar leaf, which likewise was undertaken first in the Connecticut valley, in the section lying between Hartford, Conn., and Springfield, Mass. In no period prior to 1801 did the annual production of tobacco exceed 20,000 pounds.

Over a century ago Connecticut tobacco was recognized as essentially different from the Virginia types, and peculiarly fitted to the manufacture of cigars. In 1801, 20,000 pounds of tobacco were produced in the Connecticut valley, and cigar manufacturing began in a small way. The first tobacco warehouse was established at Warehouse Point, Conn., in 1825. About 3,200 pounds of tobacco were packed here and shipped to New York. The first factories were established in 1810, one at East Windsor, and another at Suffield, Conn. The cultivation was gradually extended, and in 1840 it was a general crop, though small, grown as regularly as any other in the valley.

It is to Mrs. Prout, the wife of a farmer of South Windsor, Conn., that the men of this country are indebted for the first cigar in America. The Indians had made and smoked a roll of tobacco, but the cigar as we know it to-day had its birth in America in 1801. Wives of other farmers joined Mrs. Prout in her enterprise, and peddled their cigars from village to village in wagons. The "Long Nines" and "Windsor Particulars" soon came to be the principal brands.

Other areas suitable for the production of cigar leaf types of tobacco were exploited at about the same time as the Connecticut valley. The present areas in Lancaster and York counties, Pennsylvania; the Gadsden county area in Florida; the Miami valley area in Ohio; and the Onondaga and Big Flats area in New York are the chief sections. Nowhere, however, did the production of cigar tobacco attain much importance till the decade just preceding the civil war. This fact is very clearly indicated in the table below.

TABLE 1. — *Production of Tobacco in the United States by Localities, 1849 and 1859.*[1]

Localities.	Production (Pounds).			
	1849.		1859.	
Connecticut valley: —				
Connecticut,	1,267,624		6,000,133	
Massachusetts,	138,246		3,233,198	
Total for Connecticut valley,		1,405,870		9,233,331
Pennsylvania,		912,651		3,181,586
Ohio (Miami valley),		1,200,000		3,900,000
Florida,		998,614		828,815
New York,		83,189		5,764,582
Total cigar leaf,		4,600,324		22,908,314

[1] Compiled from census reports.

The present important Wisconsin area had no commercial importance until after the civil war.

This rapid increase in the production of cigar leaf tobacco from 1850 to 1860 was coincident with a great increase in the use of cigars in this country, which was reflected in our imports of cigars and cigar leaf for the same period. The number of cigars imported in 1850 was 124,303,000, valued at $1,469,097; this was increased to 460,404,000 cigars valued at $4,581,551 in 1860. Imports of unmanufactured tobacco (practically all cigar leaf) likewise increased from 2,480,446 pounds, valued at $272,438, in 1850, to 6,940,671 pounds, valued at $1,365,695, in 1860. Most of the leaf was imported from Cuba and Germany. The high-grade cigars came from Cuba, and the lower grades mostly from Germany.[1]

Since the Cuban tobacco made an acceptable blending with the domestic leaf, the popularity of the Cuban cigar increased. Connecticut, however, preferred her own leaf, being noted between 1850 and 1860 for her production of "Clear New England" cigars.

It was not until the middle of the century that cigars gained commercial importance. The following table shows the gradual increase in the number manufactured in the United States from 1864, the first entire fiscal year for which returns are reported by the Commissioner of Internal Revenue, to the present time: —

TABLE 2. — *Increase since 1864 in the Number of Cigars manufactured in the United States.*[2]

Fiscal Year.	Number of Large Cigars.	Fiscal Year.	Number of Large Cigars.
1864,	492,780,700	1910,	6,810,098,416
1870,	1,139,470,774	1911,	7,048,505,033
1880,	2,367,803,248	1912,	7,044,257,235
1890,	4,087,889,983	1913,	7,571,507,834
1900,	5,565,669,701	1914,	7,174,191,944
1907,	7,302,029,811	1915,	6,599,188,078
1908,	6,488,907,269	1916,	7,042,127,401
1909,	6,667,774,915	1917,	7,559,890,349

The first tax on cigars was imposed by act of Congress July 1, 1862, and took effect September 1 of the same year. Licenses for dealers and manufacturers were not required until 1868.

CONNECTICUT VALLEY.

Twelve counties in New England produce one acre or more of tobacco, but only ten — Windham, in Vermont; Cheshire, in New Hampshire; Franklin, Hampden and Hampshire, in Massachusetts; and Hartford, Middlesex, Tolland, Litchfield and Fairfield, in Connecticut — reported more than 10,000 pounds each in 1909. Approximately 94 per cent of the tobacco is raised in the Connecticut River valley proper; the tobacco of Litchfield and Fairfield counties (Connecticut), amounting to about 6 per cent of the total, is grown in the Housatonic valley. Moreover, the quality

[1] Mathewson, Bull. No. 244, Bureau of Plant Industry, p. 18.

[2] Compiled from reports of Commissioner of Internal Revenue.

of tobacco grown in both valleys is similar and known to the trade as Connecticut valley leaf. Hence it seems best to consider all the tobacco grown in the ten counties as Connecticut valley tobacco, and the entire district as the Connecticut valley.

Growth of the Industry.

Tobacco has been grown in the Connecticut valley since about 1640. With the exception of a few bad years the crop has steadily increased since that time. The last fifteen years have seen by far the greatest increase.

TABLE 3. — *Acreage, Production and Value of Cigar Leaf Tobacco since 1859.*

In the United States.

Year.	Acreage.	Production (Pounds).	Value.
1859,	(1,880)	18,643,832	-
1879,	68,975	90,749,997	-
1909,	166,240[1]	195,960,000	$19,190,000
1916,	178,800	223,444,000	36,361,000
1917,	189,800	218,627,000	56,079,000
1918,	208,800	260,592,000	55,823,000

In the Connecticut Valley.

Year.	Acreage.	Production (Pounds).	Value.
1859,	-	9,264,157	-
1879,	12,196	19,716,363	-
1909,	21,745	37,961,893	$5,670,000
1916,	31,300	51,285,000	13,522,000
1917,	33,000	46,200,000	17,740,000
1918,	35,000	52,500,000	22,500,000[2]

TABLE 4. — *Tobacco Production in the United States, 1839–1918 (United States Census).*

	Pounds
1839,	219,163,319
1849,	199,752,655
1859,	434,209,461
1869,	262,735,341
1879,	472,661,157
1889,	488,256,646
1899,	868,112,865
1909,	1,055,764,806
1918,[3]	1,340,019,000

[1] Estimated.
[2] Preliminary estimate.
[3] Estimate, United States Department of Agriculture.

TABLE 5. — *Production of Tobacco in the United States (Pounds).*[1]

STATES.	1918.	1917.	1916.	1914.	1899.[2]
Kentucky,	427,500,000	426,600,000	435,600,000	364,000,000	314,288,000
North Carolina,	282,000,000	204,750,000	176,000,000	172,250,000	127,503,000
Virginia,	146,300,000	129,500,000	129,200,000	113,750,000	122,885,000
Ohio,	113,288,000	99,072,000	95,000,000	78,120,000	65,957,000
Wisconsin,	65,170,000	45,885,000	55,753,000	53,808,000	45,500,000
Pennsylvania,	64,752,000	58,100,000	49,096,000	47,995,000	41,503,000
Tennessee,	62,240,000	81,810,000	81,760,000	63,468,000	49,158,000
South Carolina,	62,208,000	51,120,000	20,280,000	36,500,000	19,896,000
Connecticut,	37,500,000	29,540,000	36,186,000	35,754,000	16,931,000
Maryland,	23,738,000	22,594,000	19,635,000	17,600,000	24,589,000
Indiana,	15,159,000	14,060,000	13,764,000	12,150,000	6,882,000
Massachusetts,	15,000,000	11,833,000	12,118,000	11,550,000	6,407,000
West Virginia,	9,792,000	9,040,000	12,690,000	8,856,000	3,087,000
Florida,	4,416,000	3,410,000	3,025,000	4,300,000	1,126,000
New York,	3,750,000	3,125,000	4,551,000	5,980,000	13,958,000
Missouri,	2,970,000	2,820,000	3,040,000	4,920,000	3,042,000
Georgia,	2,668,000	1,600,000	1,534,000	1,900,000	1,106,000
Alabama,	700,000	146,000	60,000	140,000	312,000
Illinois,	532,000	560,000	525,000	468,000	1,447,000
Arkansas,	210,000	210,000	250,000	427,000	832,000
Louisiana,	126,000	210,000	90,000	280,000	102,000
New Hampshire,	–	167,000	165,000	177,000	182,000
Vermont,	–	165,000	160,000	170,000	291,000
Texas,	–	134,000	140,000	116,000	550,000
Totals,	1,340,019,000	1,196,451,000	1,150,622,000	1,034,679,000	867,534,000

[1] United States Department of Agriculture estimates.
[2] United States Census Report.

STATE.	ACRES.
N.H.	79
VT.	103
MASS.	5,521
CONN.	16,042
N.Y.	4,109
PA.	41,742
MD.	26,072
VA.	185,427
W.VA.	17,928
N.C.	221,890
S.C.	30,082
GA.	2,025
FLA.	3,987
OHIO.	106,477
IND.	23,694
ILL.	1,313
WIS.	40,458
MO.	5,433
KY.	469,795
TENN.	90,468
LA.	519
SCATTERINGS	1,747
TOTAL	1,294,911

Map 1.

TABLE 6. — *Production of Cigar Leaf Tobacco in the United States (Pounds).*[1]

	1918.	1917.	1916.	1915.	1914.	1913.	1912.
New England,	52,500,000	46,200,000	51,285,000	38,270,000	47,651,000	38,295,000	39,950,000
New York,	3,750,000	3,125,000	4,551,000	5,280,000	5,980,000	4,386,000	5,200,000
Pennsylvania,	64,752,000	58,100,000	49,096,000	42,390,000	47,995,000	46,680,000	64,090,000
Ohio, Miami valley,	67,326,000	61,692,000	58,200,000	54,270,000	54,144,000	37,449,000	53,460,000
Wisconsin,	65,170,000	45,885,000	55,753,000	36,900,000	53,808,000	50,740,000	54,438,000
Georgia and Florida,	7,084,000	5,010,000	4,559,000	5,045,000	6,200,000	5,800,000	3,766,000
Totals,	260,582,000	220,017,000	223,444,000	182,155,000	215,778,000	183,350,000	220,904,000

TABLE 7. — *Production of Tobacco in the Connecticut Valley (Pounds).*[1]

	1918.	1917.	1916.	1915.	1914.	1909.	1899.[2]	1879.	1869.	1859.	1849.	1839.
Massachusetts,	15,000,000	11,833,000	12,118,000	8,030,000	11,550,000	9,549,000	6,407,000	5,369,000	7,313,000	3,233,000	138,000	65,000
Connecticut,	37,500,000	29,540,000	36,186,000	29,970,000	35,754,000	28,110,000	16,931,000	14,045,000	8,329,000	6,000,000	1,268,000	472,000
New Hampshire,	–	167,000	165,000	140,000	177,000	137,000	182,000	171,000	155,000	19,000	–	–
Vermont,	–	165,000	160,000	130,000	170,000	165,000	291,000	131,000	73,000	12,000	–	1,000
Totals,	52,500,000	41,705,000	48,629,000	38,270,000	47,651,000	37,961,000	23,811,000	19,716,000	15,870,000	9,264,000	1,406,000	538,000

[1] Crop estimates, United States Department of Agriculture.

[2] United States Census.

TABLE 8. — *Production of Tobacco in Massachusetts (Pounds).*[1]

COUNTIES.	1865.	1875.	1885.	1895.	1905.	1909.[2]
Barnstable,	360	–	–	–	–	73
Berkshire,	198,800	99,609	229,462	34,531	104	–
Bristol,	2,420	530	–	–	–	110
Dukes,	800	–	–	–	–	–
Essex,	4,850	1,000	–	–	–	105
Franklin,	3,143,799	1,997,091	1,174,845	1,329,421	2,718,979	2,659,969
Hampden,	1,569,463	1,224,670	912,112	987,379	2,215,685	1,852,773
Hampshire,	4,394,925	2,655,561	1,893,006	2,665,765	4,626,675	5,035,454
Middlesex,	3,405	240	–	–	–	320
Norfolk,	775	–	–	–	–	–
Plymouth,	1,646	70	28	–	–	35
Worcester,	40,218	14,895	1,450	–	10	467
Totals,	9,361,461	5,993,666	4,210,903	5,017,096	9,561,453	9,549,306

[1] Massachusetts State Census Reports.

[2] United States Census Reports.

TABLE 9. — *Production of Tobacco in Connecticut.*[1]

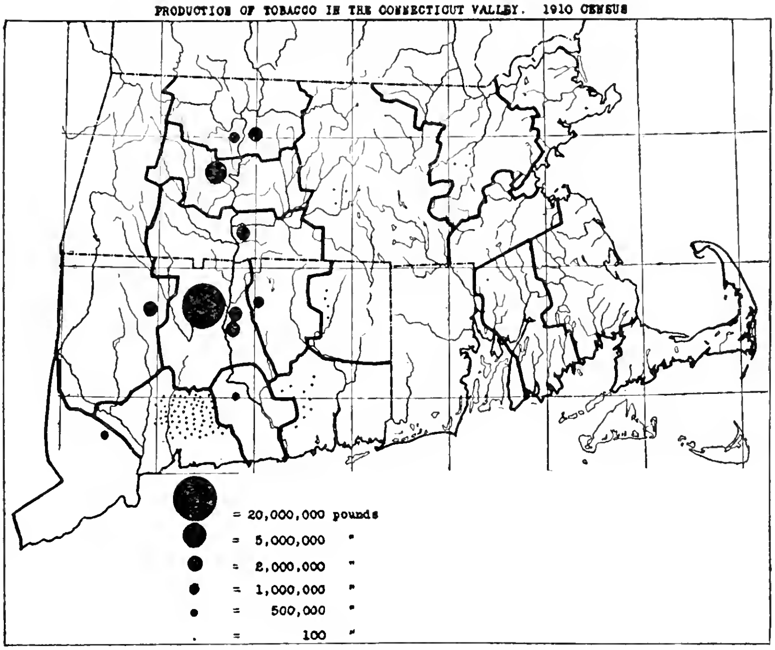
Counties.	1859.		1879.		1889.		1899.		1909.	
	Acres.	Production.	Acres.	Production.	Acres.	Production.	Acres.	Production.	Acres.	Production.
Fairfield,	–	61,975	808	973,933	375	426,093	399	584,640	253	412,095
Hartford,	–	4,221,474	5,112	9,039,514	4,606	6,598,517	8,007	13,577,860	13,774	24,365,134
Litchfield,	–	736,185	1,586	2,211,151	1,011	1,376,472	1,138	1,817,260	1,144	1,897,205
Middlesex,	–	433,245	573	906,753	144	198,587	228	333,050	308	504,330
New Haven,	–	153,453	167	215,195	40	41,350	18	18,410	4	7,356
New London,	–	325	19	29,622	–	–	3	4,000	2	1,030
Tolland,	–	393,476	405	666,634	155	233,905	326	595,510	557	922,873
Windham,	–	–	2	1,850	–	–	–	40	–	430
Totals,	–	6,000,133	8,672	14,044,652	6,331	8,874,924	10,119	16,930,770	16,042	28,110,453

[1] United States Census Reports.

The cigar type industry of New England is confined principally to the Connecticut and Housatonic valleys, extending through Connecticut and Massachusetts into the southern counties of New Hampshire and Vermont. Hartford County, Connecticut, produces 64.7 per cent of the New England total, and six counties, Hartford, Litchfield and Tolland in Connecticut, and Hampshire, Franklin and Hampden in Massachusetts, produce approximately 97.5 per cent.

TABLE 10. — *Tobacco Growers and Acreage in Massachusetts in 1916.*

	Number of Growers.	Number of Acres.				
		Havana Seed.	Broadleaf.	Primed.	Shade.	Total.
Hampshire County.						
Amherst,	43	246	-	-	-	246
Easthampton,	23	122	-	-	-	122
Hadley,	193	1,605	126	-	33	1,764
Hatfield,	174	1,753	-	35	70	1,858
Northampton,	37	162	-	-	40	202
Pelham,	1	6	-	-	-	6
Southampton,	25	103	-	-	-	103
Williamsburg,	8	13	-	-	-	13
Totals,	504	4,010	126	35	143	4,314
Hampden County.						
Agawam,	79	616	16	108	225	965
Chicopee,	2	35	-	-	101	136
East Longmeadow,	5	10	-	-	-	10
Granville,	10	33	-	-	-	33
Longmeadow,	2	15	-	-	1	16
Southwick,	93	671	3	41	210	925
Springfield,	2	2	-	-	-	2
Westfield,	36	264	57	110	-	431
Totals,	229	1,646	76	259	537	2,518
Franklin County.						
Ashfield,	2	-	7	-	-	7
Buckland,	1	-	1	-	-	1
Conway,	21	55	15	-	-	70
Deerfield,	91	606	-	-	62	668
Greenfield,	2	17	-	-	-	17
Leverett,	6	29	-	-	-	29
Montague,	20	81	-	-	-	81
Northfield,	17	42	-	-	-	42
Sunderland,	66	433	-	20	83	536
Whately,	102	707	-	-	130	837
Totals,	328	1,970	23	20	275	2,268
Grand totals,	1,610	7,626	225	314	955	9,120



Map 2.

The preceding tables show the rapid increase in production of tobacco in the Connecticut valley up to 1914. Because of the unfavorable season of 1915 the production that year was less than normal. Since 1915 the production has slightly increased.

The acreage in 1917 may be divided as follows: broadleaf, 7,200 acres; Havana seed, 16,446 acres; and shade-grown, 5,854 acres. The tobacco acreage in 1917 was probably affected by the large acreage of onions, the growing of this crop being stimulated by the high prices of the previous year. The labor shortage and the war-time demand for a larger production of food crops may also have influenced the tobacco acreage. The shade-grown industry, however, steadily increased, as evidenced by Table 13 on page 161. While the Connecticut State Council of Defense endeavored to check any material increase in tobacco acreage in that state, and to encourage the production of more food products, the Federal government did not discourage the production of tobacco during the period of the war. The United States production during 1918 amounted to 1,340,019,000 pounds: in New England the acreage was 35,000, and the approximate yield 52,500,000 pounds.

Distribution of Acreage.

Figure 1 shows the mode or most common acreage to be between 2 and 5 acres per farm. There were 77 farms in Hampden County, Massachusetts, in 1916; Hampshire County had 161 and Franklin County 143, having from 2 to 5 acres, making a total of 381 farms. The next most common acreage is from 5 to 8 acres. Hampden County had 41 farms, Hampshire County 132 farms, and Franklin County 65 farms reporting this acreage, with a total for the three counties of 238 farms. There were 163 farms in the three counties that reported from 8 to 11 acres, 80 that reported from 11 to 15 acres, 65 that reported from 15 to 20 acres, 80 that reported 20 or more acres, and 53 farms that reported under 2 acres. The mode, then, is between 2 and 5 acres, but the average per farm in the three counties is 8.4 acres, distributed as follows: Franklin County, 7 acres; Hampshire County, 8.6 acres; and Hampden County, 11 acres.

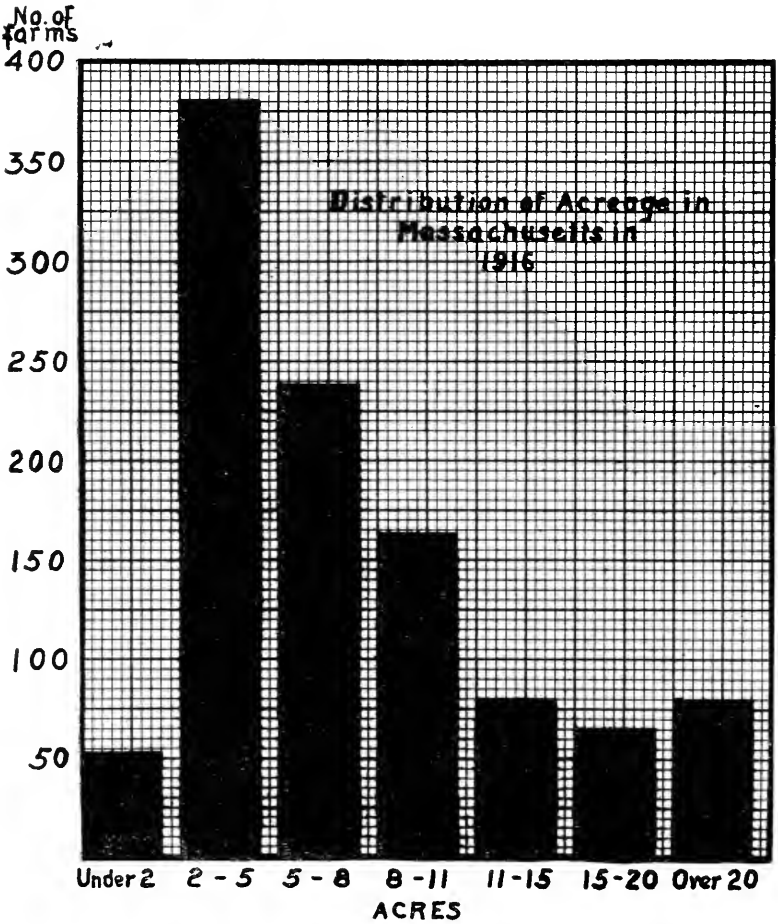


Fig. 1. — Number of farmers with specified acreages of tobacco. Note that of the 1,060 farms depicted, nearly 60 per cent have between 2 and 8 acres per farm, and approximately 40 per cent have each 5 acres or less.

The distribution of acreage according to counties and towns within the counties is given in the following table: —

TABLE 11. — *Distribution of Acreage of Tobacco according to Counties and Towns in Massachusetts.*

Franklin County.

Location.	Average Acres per Farm.	Location.	Average Acres per Farm.
Ashfield,	3.2	Montague,	4.0
Buckland,	1.0	Northfield,	2.5
Conway,	3.3	Sunderland,	8.1
Deerfield,	7.3	Whately,	8.2
Greenfield,	8.2	Average,	7.0
Leverett,	4.8		

Hampshire County.

Amherst,	5.7	Pelham,	5.5
Easthampton,	5.3	Southampton,	4.1
Hadley,	9.1	Williamsburg,	1.6
Hatfield,	10.7	Average,	8.6
Northampton,	5.5		

Hampden County.

Agawam,	12.2	Southwick,	9.9
Chicopee,	68.0	Springfield,	1.0
East Longmeadow,	1.9	Westfield,	12.0
Granville,	3.3	Average,	11.0
Longmeadow,	8.0		

The comparatively large acreage in Chicopee is due to the inclusion of large shade-grown plantations. To a lesser extent this is true of Southwick and Agawam, but the land in these sections is generally level and the soil favorable to the production of tobacco. Consequently the acreage per farm is larger.

TYPES OF CIGAR LEAF TOBACCO.

Tobacco-growing in the United States is a highly specialized industry. Certain well-defined areas produce tobacco of such quality and texture as to make it desirable for some special manufacturing or export trade.

The following is a rough classification of the varieties and types of tobacco listed by the cigar leaf districts of America in which they are produced: —

TABLE 12. — *Varieties, Location and Types of Tobacco in the Cigar Leaf Districts.*

VARIETIES.	Where grown.	Types or Uses.	Length in Inches.
Zimmer Spanish,	Ohio,	Fillers,	9-18
Little Dutch,	Ohio,	Fillers,	12-21
Ohio seed leaf,	Ohio,	Wrappers and binders,	16-26
Wisconsin binder,	Wisconsin,	Binders,	14-24
Pennsylvania broadleaf,	Pennsylvania,	Binders and fillers,	14-26
Connecticut broadleaf,	Connecticut valley,	Wrappers,	14-28
Connecticut Havana seed,	Connecticut valley,	Wrappers,	14-28
Connecticut shade-grown,	Connecticut valley,	Wrappers,	12-20
York State Havana,	New York,	Wrappers,	14-26
Florida shade-grown,	Florida,	Wrappers,	12-18
Georgia shade-grown,	Georgia,	Wrappers,	12-18

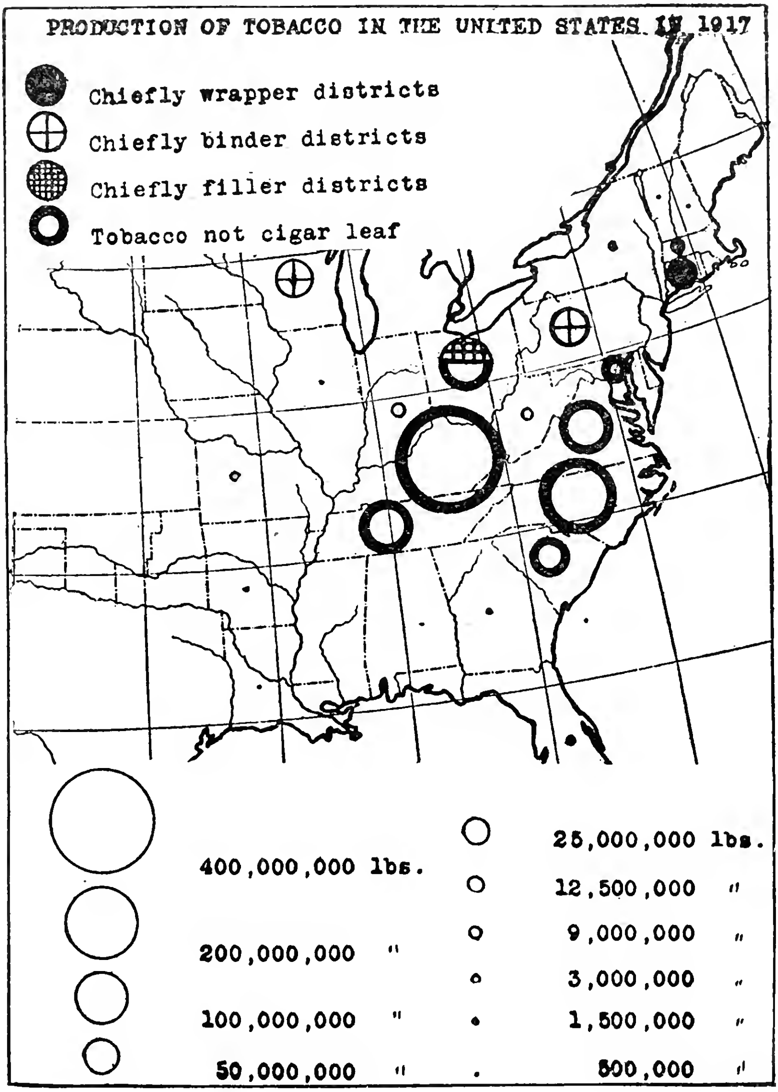
Such districts are peculiarly adapted to the growing of tobacco for commercial purposes because of distinctive climatic and soil conditions which have much to do with the quality of the leaf.

According to the United States Department of Agriculture, tobacco districts are classified as producers of either the cigar type or the chewing, smoking, snuff and export types. It is with the cigar type grown in the Connecticut valley that we are here concerned.

Tobacco of the cigar type may be still further classified into wrappers, binders and fillers, all three classes being necessary in making a cigar. The wrapper, as its name implies, is the outer covering of the cigar. Only comparatively large leaves of special color, texture, aroma and burning qualities can be used for cigar wrappers. A very few wrappers are produced in Pennsylvania and Wisconsin, but the principal competing areas are in Florida, Cuba and Sumatra. Approximately 55 per cent of the cigar wrappers used in America are grown in the Connecticut valley district, and only 29 per cent elsewhere in the United States; the remainder are imported.

Binders is the name given to the tobacco used in making the body of the cigar just under the wrapper. This also requires certain specific qualities found only in tobacco grown in a few limited areas. Wisconsin produces most of the binders, but Pennsylvania, New York, the Connecticut valley and a few other places provide some tobacco of this quality.

The filler is the center or core of the cigar. Small or broken leaves, seconds and otherwise unusable leaves may be used for fillers. Ohio produces much filler, but the wrapper and binder districts contribute their seconds, broken leaves and other inferior tobacco for fillers. In cheap cigars the filler is composed of a very poor grade of tobacco.



Map 3.

Generally speaking, wrappers command the highest price, binders the next and fillers the lowest of cigar making tobacco. The Connecticut valley produces all three varieties, but Connecticut valley tobacco is of the wrapper type so far as the trade is concerned, since 60 per cent of the crop is used for wrappers. For a similar reason Wisconsin is known as the binder-producing district. Nevertheless, there is considerable overlapping, and Wisconsin, New York and Pennsylvania all produce a certain amount of wrappers, varying somewhat from year to year.

Several factors determine whether the leaf will be used as wrapper, filler or binder, such as the length of leaf, aroma, toughness and the condition of leaf, *i.e.*, whether damaged by hail or wind. Under normal conditions a light sandy loam produces a light wrapper leaf. The coarser leaf is used for binders, and the broken, frost-bitten, short and worm-eaten leaves for fillers.

Tobacco Soils.

Tobacco may be grown on a great variety of soils, but the climatic conditions, texture and physical properties of the soil determine the distribution of the different classes and types. Climatic conditions control, of course, the general distribution, but the influence of the texture of the soil in modifying the effect of these climatic conditions determines the local distribution of types. Tobacco readily adapts itself to a wide range of climatic conditions, as is seen in the distribution of the plant in our country from Florida to Wisconsin. While it adapts itself very readily to the different conditions of temperature and rainfall which normally prevail during the growing season throughout this wide range of territory, seasons which are either too wet or too dry very often reduce the yield per acre and impair the quality of the product. The plant is, furthermore, peculiarly sensitive to the conditions of moisture and heat.

The best soils for the different types of tobacco in the United States range from the light, sandy lands for the fine bright wrappers of the Connecticut valley, to the heavy clay soils of the limestone areas of the South for the heavier grades of tobacco.

The influence of soil upon the quality of the leaf grown in the Connecticut valley is very marked. Where the soil is a heavy clay loam or is normally very moist, a thick leaf is produced which has considerable oil and gum in its tissues. It cures a dark color, and will bear sweating well, but it is not suitable for cigar wrappers. Upon light, sandy soils, the quality is very fine, the texture of the leaf is thin and the color is light. It is this type of tobacco which is at present in demand for cigar wrappers.

Varieties of Tobacco.

The Connecticut valley produces three varieties of wrapper leaf, — the broadleaf, the Havana seed leaf and shade-grown. This area is classed as a wrapper and binder section. The tobacco is produced mainly in the open, without shade, under intensive methods of cultivation, fertilization and handling. The highest quality leaf makes acceptable wrappers for cigars, and the remainder is principally used for binder purposes. Since 1901 a considerable acreage of shade-grown tobacco has been cultivated in the Connecticut valley each year.

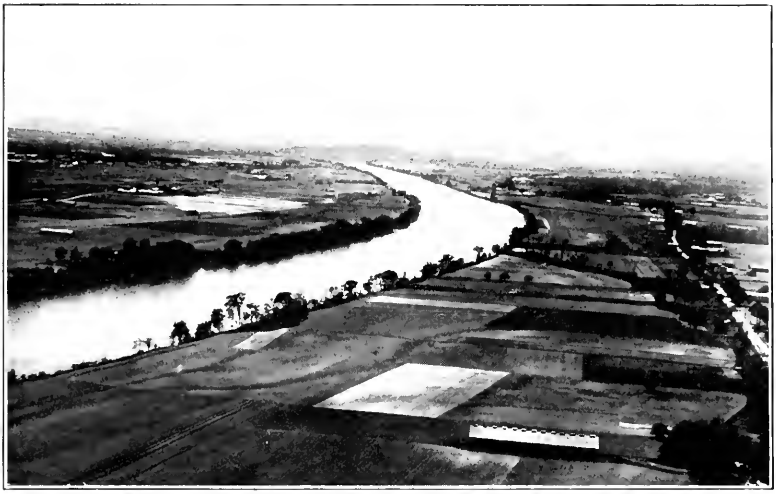


Fig. 2. — A part of the Connecticut valley as seen from Mount Sugarloaf, South Deerfield, Mass. The "meadows" are dotted with tobacco barns; the soil is very fertile and well adapted to the production of wrapper tobacco.

Sun-grown Tobacco.

Broadleaf. — The broadleaf variety has a broad, silky leaf, very elastic and possessing a rich grain and color two-thirds of its length from the top. Small veins are also characteristic of the leaf. There is only one principal area in the Connecticut valley adapted to the growth of this variety, — a small tract on the east side of the river between Hartford and Springfield.

Havana Seed. — The leaf of the Havana seed is smaller and narrower than the broadleaf. It is exceedingly thin and silky, but possesses less elasticity and covering quality; it does not have the rich grain of the broadleaf, and the middle and lower parts are glossy with large veins, rendering this portion of the leaf undesirable for wrapper purposes. However, the larger part of the leaf can be used for wrappers. The Havana seed yields more wrappers to the acre than does the broadleaf. The Havana seed variety of the New England area is grown almost entirely on the west side of the Connecticut River.

The heavier and slightly damaged or unevenly colored leaves of both the Havana seed and the broadleaf varieties are used for binders. Both varieties are principally air-cured, packed in cases weighing about 300 pounds, and either force-sweated for ninety days, or left to ferment by the natural process during the spring and summer months.

Growing Sun Tobacco.

The Seed Bed. — Both for shade-grown and sun-grown tobacco the young plants are developed from seed in a cold frame or hotbed until they have reached a size suitable for transplanting. The beds are sown from the middle of March to the middle of April. In cold frames from six to eight weeks are required to produce plants of sufficient size for transplanting, and in hotbeds four to six weeks are required. If cloth instead of glass is used to cover the seed beds, eight to ten weeks are required before the plants are large enough to transplant. The usual custom is to transplant them when they have reached a height of 5 to 6 inches.

Transplanting and Cultivating. — The plants are set in rows 3 feet 3 inches to 3 feet 6 inches apart, and from 14 to 20 inches apart in the rows. A machine for transplanting has largely taken the place of the old hand method. When the plants are transplanted with a machine, the distance between plants and the application of water is automatically regulated.

Cultivation begins about a week after setting, and is continued until the plants become too large to permit of cultivation. Ordinary surface cultivation to maintain a loose, fine mulch about the plant is essential, with frequent hoeing to keep down weeds.

Topping and Suckering. — When the seed buds of the plants appear the plant is "topped." In a week or ten days after topping suckers will appear, starting from the base of the three or four top leaves. These are picked off, or, as the tobacco farmer says, the plant is "top suckered." Later the leaves farther down the stalk begin to throw out suckers, and these in turn must be picked off. When the bottom suckers are removed the plant is usually ready to harvest. Ordinarily the plant is allowed to "ripen," a condition which is further indicated by the slightly wilted appearance of the bottom leaves. Light green blotches also appear on the top leaves. If cut too green the leaf becomes dark colored and will not command the best price.

Shade-grown Tobacco.

The year 1900 marks the real beginning of the "tobacco grown under cloth" industry in the Connecticut valley. It was begun as an experiment in the production of Sumatra wrappers. Imported Sumatra seed was sown, but it was soon found that real Sumatra could not be grown successfully in the Connecticut valley. Cuban Havana, having a little heavier leaf, was tried next; it grew well in its new surroundings. Through careful seed selection it approached more nearly the ideal leaf. An acclimated strain of Cuban seed is now used exclusively for "tent grown" tobacco.

SHADE-GROWN TOBACCO ACREAGE IN THE CONNECTICUT VALLEY

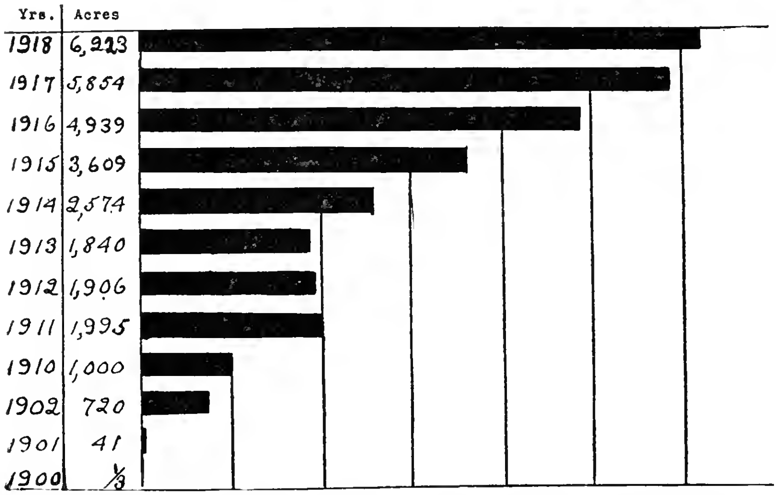


FIG. 3. — Production of shade-grown tobacco. Notice the rapid and remarkably uniform increase in acreage since 1913.

History. — The early history of the industry was marked by varied successes and failures. One grower, for example, a pioneer in the shade-grown venture, sold his first crop for $1.62 a pound, while his second crop yielded him 50 cents a pound. As a result he went back to sun-grown tobacco entirely. Another grower began in 1902, but raised no shade-grown in 1904 and 1905. He tried the industry again in 1906, and has

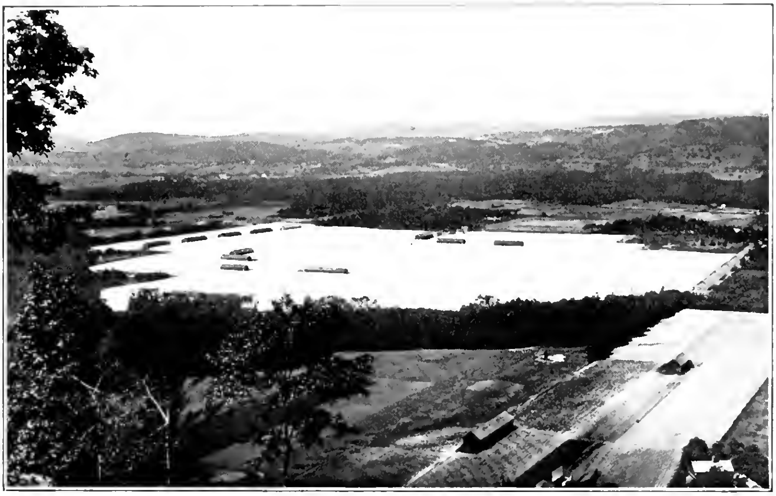


FIG. 4.—125 acres of tobacco under cloth, South Deerfield, Mass.

been very successful since that time. As in the marketing of all specialties the chief difficulty at first was the lack of dependable markets. Manufacturers were afraid to substitute shade-grown for the well-known Sumatra wrapper in their better grades of cigars. To-day this is entirely changed. Connecticut valley growers are not able to raise sufficient shade-grown wrappers to supply the market. We import yearly about 30,000 bales of Sumatra and Java tobacco for wrapper purposes.

From its small beginning the shade-grown tobacco industry has had a remarkable growth, as is shown in the following table. The future looks promising for an extended and increased growth of this particular kind of tobacco. Capital is available for future development and extension, and the owners of choice tobacco land have numerous opportunities to lease it to firms desirous of increasing the acreage under cloth.

TABLE 13. — *Production of Shade-grown Tobacco in the Connecticut Valley.*

YEAR.	Acres.	Bales.[1]
1900,	–	2
1901,	41	240
1902,	720	4,320
1910,	1,000	6,000
1911,	1,995	11,970
1912,	1,906	11,436
1913,	1,840	11,040
1914,	2,574	15,444
1915,	3,609	20,454
1916,	4,939	29,634
1917,	5,854	35,124
1918,	6,223	–

[1] A bale contains 150 to 175 pounds.

TABLE 14. — *Acreage of Shade-grown Tobacco in the Connecticut Valley, 1915–18.*

	Grower.	1915.	1916.	1917.	1918.
Connecticut.					
Tariffville District,	1	254	240	252	–
	2	30	40	40	40
	3	50	35	50	50
	4	8	20	29	21
	5	42	45	46	48
	6	27	30	30	60
	7	–	30	30	–
	8	26	45	50	50
	9	–	–	–	7
	10	–	–	–	252
	–	437	485	527	528

TABLE 14. — *Acreage of Shade-grown Tobacco in the Connecticut Valley, 1915–18* — Continued.

	Grower.	1915.	1916.	1917.	1918.
Connecticut — Con.					
Avon-Simsbury District,	11	40	35	40	27
	12	16	26	31	32
	13	150	195	196	196
	14	14	–	–	–
	15	–	84	94	57
	16	30	38	38	38
	–	250	378	399	350
Congamond Pond District,	17	–	–	–	13
	18	–	62	87	105
	19	125	165	185	185
	20	178	200	206	206
	21	30	36	40	40
	22	26	26	26	26
	–	359	489	544	575
Suffield District,	23	50	50	50	75
	24	–	17	17	18
	25	–	20	24	–
	26	–	–	–	24
	–	50	87	91	117
Windsor Locks District,	27	150	200	200	213
Poquonock District,	28	60	73	74	75
	29	60	80	90	72
	30	25	25	35	35
	31	25	40	45	40
	32	22	22	12	13
	33	15	15	50	60
	34	–	25	25	32
	35	5	8	20	21
	36	–	20	20	25
	37	62	68	68	68
	38	214	254	256	–
	39	–	–	–	237
	40	–	–	16	16.5
	41	–	11	16	20
	42	15	38	41	50
	43	–	–	–	10
	44	–	–	–	30
	45	–	–	–	10
	46	–	–	–	10
	47	–	–	–	10
	48	–	–	–	22
	–	503	679	768	856.5
Griffin District,	49	–	–	–	230
	50	210	285	350	–
	51	50	45	49	49
	52	125	108	75	–
	53	160	157	175	260
	–	545	595	649	539
East Hartford-Manchester-East Windsor District,	54	–	–	80	112
	55	115	115	118	–
	56	–	108	108	108
	56	–	–	–	118
	57	250	265	265	265
	58	55	75	80	75
	59	29	29	46	46
	60	–	25	40	42
	61	220	249	325	350
	62	–	39	39	39
	63	16	55	60	60

TABLE 14. — *Acreage of Shade-grown Tobacco in the Connecticut Valley, 1915–18* — Concluded.

	Grower.	1915.	1916.	1917.	1918.
Connecticut — Con.					
East Hartford-Manchester-East Windsor District — *Con.*	64	-	-	-	25
	65	-	-	50	60
	66	20	20	20	20
	67	-	-	30	-
	68	-	12	12	-
	69	-	-	52	62
	70	-	-	-	32
	71	-	-	-	100
	-	705	992	1,325	1,514
Hazardville District, . . .	72	-	-	20	20.5
	73	-	43	65	-
	74	-	35	42	59
	75	40	40	62.5	62.5
	76	60	70	105	110
	77	38	52	52	-
	78	-	-	13.5	32
	79	20	25	65	-
	80	-	-	-	185
	81	-	-	-	30
	82	-	-	-	47.5
	-	158	265	425	546.5
Massachusetts.					
Hampden District, . . .	83	-	-	14	12.5
	84	1	1	-	-
	85	223	200	230	130
	86	60	60	64	64
	87	-	101	120	120
	88	-	-	59	60
	89	-	-	-	28
	90	-	-	-	20
	-	284	362	487	434.5
Hatfield District, . . .	91	-	35	35	50
	92	-	10	10	12
	93	33	33	33	33
	94	34	68	68	60
	95	-	-	-	32
	96	-	-	-	47
	97	-	-	-	35
	98	-	-	-	16
	-	67	146	146	285
Sunderland District, . .	99	-	35	35	-
	100	11	9	11	-
	101	-	70	70	60
	102	90	112	112	112
	103	-	35	65	65
	104	-	-	-	28
	-	101	261	293	265
Totals, ...	-	3,609	4,939	5,854	6,223.5

The above table indicates that the shade-grown tobacco is confined to the following districts: Tariffville, Avon-Simsbury, Congamond Pond, Suffield, Windsor Locks, Poquonock, Griffin, East Hartford–Manchester–East Windsor, Hazardville, in Connecticut; and the Hampden, Hatfield and Sunderland districts in Massachusetts.

A peculiarity of the industry is the relatively large acreage per grower. Table 15 shows the number of farms, the number of growers and the number of growers operating two or more farms, with the average acreage in each case. It will be seen that the average acreage per grower increased during the first three of the years indicated, falling again in 1918. The decline in this year was due in part to the appearance of 20 new producers of shade-grown tobacco, whose average acreage was but 35.2 acres. Without these the average acreage would have shown an increase greater than that of the previous years.

TABLE 15. — *Average Acreage per Farm and per Grower.*

	1915.	1916.	1917.	1918.
Number of acres,	3,609	4,939	5,854	6,223
Number of farms,	49	69	76	88
Average acreage,	73.6	71.58	77	70.7
Number of growers,	46	60	67	77
Average acreage,	78.4	82.3	87.37	80.8
Growers operating two or more farms,	3	4	4	3
Average acreage,	388.67	430	481.75	562.33

There seems to be a tendency toward concentration of the shade-grown industry in the hands of one large company operator, the proportion of the total area controlled by this company ranging from 14.3 per cent in 1915 to 21.7 per cent in 1918.

TABLE 16. — *Farms classified by Acreage of Shade-grown Tobacco, 1915–18.*

ACRES.	1915.	1916.	1917.	1918.
10 acres or less,	3	4	1	5
11 to 20 acres,	8	7	13	10
21 to 50 acres,	19	29	29	36
51 to 100 acres,	7	12	19	19
101 to 150 acres,	5	5	5	8
151 to 200 acres,	2	6	4	3
201 to 250 acres,	5	2	2	4
251 and over acres,	1	3	5	4

Several things militate against the small grower, such as the high initial expense and the cost of production. The syndicates have the capital to tide them over the "off year," which frequently occurs in the tobacco business. However, some small growers are very successful. They begin by changing from ordinary sungrown to primed Havana, and gradually work up to shade-grown tobacco.

Preparation and Cultivation. — To prepare for producing shade tobacco the entire field is set with posts 9 feet high and about 33 feet apart each way. Heavy wire is stretched from one post to another. This framework is then covered with a specially woven fabric similar to cheesecloth.

The plants, transplanted from the seed beds to the fields from May 15 to June 15, are set in rows 3 feet apart, and from 15 to 20 inches apart in the row, then the sides of the tent frame are covered, the cloth reaching to the ground.

The growing plants are well cultivated in order to keep the soil loose and free from weeds. With good soil and thorough cultivation the plants reach a height of nine feet, and bear from 15 to 20 good sound leaves. The plants of shade-grown tobacco are neither topped nor suckered, enabling the plant to produce more and thinner leaves, the quality so much desired in wrappers.

Harvesting. — Harvesting usually begins about July 20, as soon as the leaves begin to ripen. All the leaves are picked by hand, four or five pickings being made at intervals of from seven to ten days. The harvest begins with the bottom leaves, from four to six leaves being removed each time. The best leaves are generally found in the second picking. As the leaves are gathered they are put in baskets which are placed on low trucks and hauled outside the tent. The baskets are transferred to flat wagon beds and taken to the curing sheds. Sometimes small boys do this work, while the older and more experienced laborers are used in priming the tobacco.

At the curing sheds the leaves are strung on strings attached to laths. This work is usually done by women and children. The leaves are put face to face in pairs, twenty pairs on a lath. Stringers are paid (1917) about 45 cents per bundle of 50 laths. Experienced women and girls can easily earn from $2 to $3.50 per day.

The laths thus strung are hung in the curing sheds where they remain from three to five weeks. The up-to-date curing sheds may be ventilated by side openings made by placing every third or fourth board on hinges, and by ventilators placed at intervals of 10 feet along the ridge of the roof. During damp or cold weather charcoal fires are built. The use of charcoal fires has been the means of saving thousands of dollars' worth of tobacco annually.

Yields per Acre.

Aside from the question of the cost of producing tobacco, which has been tremendous in recent years, there is the important question of the yield per acre, which largely determines the profit. It costs almost as much to produce a 1,300-pound crop of tobacco as it does to produce a crop of 1,700 pounds, but the money value and the profit per acre are much less.

Farmers in the Connecticut valley have been disturbed in recent years by the gradual decline in the yield of tobacco. The table below shows this decline, not steady from year to year, but an actual decline. The average yield for the five-year period from 1905 to 1909 was 1,675 pounds in Massachusetts and 1,660 in Connecticut; from 1910 to 1914 it was 1,676 in Massachusetts and 1,675 in Connecticut; while for the four years succeeding, the average was 1,382 pounds in Massachusetts and 1,445 in Connecticut. The average for the whole period, however, was 1,592 for Massachusetts and 1,604 for Connecticut, both still well above the average for the period from 1870 to 1910. Of course the decrease from 1913 to 1918 is largely due to the poor growing season of 1915, to the wind storms of 1916 and 1917, and to the excessive hail and the late frost of 1917.

TABLE 17. — *Yields per Acre (Pounds).*[1]

Year.	Massachusetts.	Connecticut.
1880,	1,599	1,621
1890,	1,389	1,402
1900,	1,674	1,673
1905,	1,850	1,725
1906,	1,750	1,735
1907,	1,525	1,510
1908,	1,650	1,680
1909,	1,600	1,650
1910,	1,730	1,730
1911,	1,650	1,625
1912,	1,700	1,700
1913,	1,550	1,550
1914,	1,750	1,770
1915,	1,100	1,350
1916,[2]	1,500	1,500
1917,[2]	1,430	1,430
1918,	1,500	1,500

[1] Figures from United States Department of Agriculture, Bureau of Crop Estimates.
[2] 1916 and 1917 are revised estimates made by the Massachusetts Agricultural College and tobacco packers.

This decrease has been attributed to many causes, such as a hurtful accumulation of saline matters soluble in water, nitrates, sulfates and chlorides of potash, soda, lime and magnesia, in the surface soil; or an alkaline condition of the soil, resulting from the use of tobacco ash elements, cotton hull ash or carbonate of potash. However, the experiment stations have questioned the truth of these two assumptions. Some attribute the short crop of the last few years to the unnoticed prevalence of root rot in the field; others attribute it to bad weather, hail, wind storms, frost, etc. Tobacco depends almost entirely upon a sufficient amount of rain and warm weather. The seasons of the last few years have not been favorable to a good growth of tobacco. Actually, the low yield of 1915 is the great cause of the low average.

Figure 5 presents in graphic form the history of the average yield in Massachusetts from 1900 to 1918. Of the Connecticut valley sun-grown crop in 1917 it is estimated that only 60 per cent was not injured by hail, wind or frost, while the loss in shade-grown tobacco by hail was perhaps not over 3 per cent.

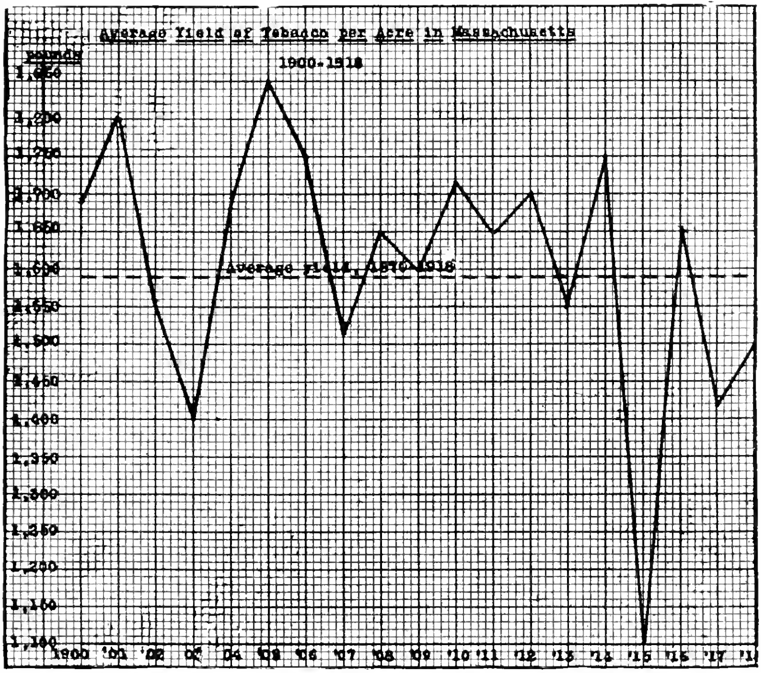


FIG. 5. — Average yield of tobacco per acre in Massachusetts, 1900–18.

The production per acre and the total farm value per acre for the chief tobacco-producing states are given in the following table. It is evident that the largest per acre yields in the United States are still reported from the Connecticut valley tobacco fields.

TABLE 18. — *Production and Farm Value per Acre in 1917 of the Principal Tobacco States.*

	Production (Pounds).	Value.
New Hampshire,	1,670	$450 90
Vermont,	1,650	445 50
Massachusetts,	1,409	541 06
Connecticut,	1,400	537 60
Pennsylvania,	1,400	294 00
New York,	1,250	275 00
Florida,	1,100	627 00
Georgia,	1,000	570 00
Ohio,	960	240 00
Wisconsin,	950	166 25
Kentucky,	900	204 30
Tennessee,	810	137 70
Maryland,	790	158 00
South Carolina,	710	164 01
Virginia,	700	185 50
North Carolina,	630	198 45
Average,	826.30	$205 20

COST OF PRODUCTION.

The tobacco grower has felt war conditions keenly. Prices of cloth, twine, glass, fertilizer, implements, labor, paper and other materials necessary in the production of tobacco have advanced very materially since the war began. It costs far more to produce an acre of tobacco to-day than it did prior to the war.

The average farmer does not know what it costs to raise his crop because he keeps no record of expenses. Of those who endeavor to keep accounts, very few enter all the items of expense in production.

Below is an accurate cost account kept by a tobacco grower in Massachusetts, on blanks prepared and sent out by the Massachusetts Agricultural College for that purpose. The expenses are for 1917 on a farm comprising 50 acres of tobacco, — 35 acres of shade-grown and 15 acres of primed Havana seed. He kept a separate account for each variety. It cost this grower $629.38 per acre, or 74 cents a pound, to grow his shade tobacco, which averaged 850 pounds to the acre. He sold on contract for 90 cents a pound, or an average of $765 per acre. The profit was $135.62 per acre.

This cost is less than the actual expense, since it does not include depreciation on wire, posts, etc., and does not cover laths and glass which were on hand from the previous year. The cost for a beginner ranges from $1,000 to $1,100 an acre. The tools and implements mentioned were used on the total 50 acres, so the amount used on the 35 acres was estimated from the total. The investment in machinery per acre is reasonable.

TABLE 19. — *Cost of Producing an Acre of Shade-grown Tobacco.*

Value of land,	$340 00	
Rent (interest calculated at 5 per cent),		$17 00
Tools, implements, etc.: —		
3 plows at $12,	$36 00	
3 Acme harrows at $27,	81 00	
1 fertilizer sower,	48 00	
1 wheel harrow,	48 00	
1 Meeker harrow,	27 00	
1 roller,	25 00	
2 tobacco setters at $95,	190 00	
4 Planet, Jr., cultivators at $17,	68 00	
1 stalk cutter,	25 00	
Total,	$548 00	
Total per acre,	10 96	
Interest on value of equipment,		55
Taxes,		3 40
Depreciation on equipment at 15 per cent,		1 65
Cloth (5,000 yards at 5¾ cents),		287 50
Man labor, 513.8 hours at 30 cents,		154 14
Horse labor, 100 hours at 25 cents,		25 00
Shed rent,		4 29
Fertilizer for beds,		64
Glass for beds,		31
Timothy for cover crop,		47
Soft coal,		23
Manure,		20 97
Paris green for poisoning cutworms,		83
Water piping,		21
Sewing twine,		97
Stringing tickets,		035
Wool twine,		1 06
Jute twine,		62
Tobacco baskets,		64
Molasses,		048
Bran for cutworms,		91
Hose,		52
Guy wire clamps,		16
Sewing needles,		032
Tobacco plants,		08
Shed repairs,		30
Insurance,		70
Fertilizer,		100 00
Fertilizer V. C.,		1 50
Cottonseed meal,		3 66
Freight on tobacco,		96
Total per acre,		$629 38
Total per pound,		74

TABLE 20. — *Cost to the Landowner of Producing an Acre of Sun Tobacco.*

Value of land,	$350 00	
Rent (interest calculated at 5 per cent),		$17 50
Tools, implements, etc.: —		
Walking plow,	$6 25	
Broadcast fertilizer sower,	12 00	
Tobacco setter,	23 75	
Wheel harrow,	12 00	
Acme harrow,	6 75	
Planet, Jr., cultivator,	4 25	
Tobacco press (simple, farm-made),	1 25	
4 hatchets,	50	
2 stringing horses,	1 25	
For an acre,	$68 00	
Depreciation on equipment per acre, $68 at 15 per cent,		10 20
Depreciation on sheds, $700 at 5 per cent,		35 00
Taxes,		6 00
Insurance,		2 00
Fertilizer, 2,000 pounds at $60 per ton,		60 00
Manure, 3 cords at $10,		30 00
Labor: —		
Making seed bed, 2 men, one day,		6 00
Weeding and attention to plant beds,		6 00
Applying manure,		3 00
Plowing land,		8 00
Harrowing and ridging,		5 00
Drawing and setting plants,		7 00
Cultivating and hoeing 4 times, 2 men, eight days; 1 horse, four days,		36 00
Topping, worming and suckering,		25 00
Harvesting, 6 men, 2 teams, one day,		28 00
Taking down and stripping, 6 men, one day,		18 00
Bulking,		3 50
Delivering 3 miles at 10 cents per 100 pounds,		1 40
Feed,		20 00
Seed, 1 ounce,		1 00
Twine,		50
Paper,		3 00
Charcoal,		1 30
Oil,		1 00
Horseshoeing,		1 00
Veterinary,		15
Total per acre,		$335 55
Total per pound,		24

TABLE 21. — *Cost to a Tenant of Producing an Acre of Sun Tobacco.*

Value of land,	$350 00
Rent of land, sheds and cold frames and laths (land, $60; sheds, $30; cold frames and laths, $5),	$95 00
Interest and depreciation on investment in tools (calculated),	4 00
Fertilizer, 2,000 pounds at $60 a ton,	60 00
Manure, 3 cords at $10,	30 00
Labor: —	
Making seed bed, 2 men, one day,	6 00
Weeding and attention to plant bed,	6 00
Applying manure,	3 00
Plowing land,	8 00
Harrowing and ridging,	5 00
Drawing and setting plants,	7 00
Cultivating and hoeing 4 times, 2 men, eight days; 1 horse, four days,	36 00
Topping, worming and suckering,	25 00
Harvesting, 6 men, 2 teams, one day,	28 00
Taking down and stripping, 6 men, one day,	18 00
Bulking,	3 50
Delivering 3 miles at 10 cents per 100 pounds,	1 40
Feed,	20 00
Seed, 1 ounce,	1 00
Twine,	50
Paper,	3 00
Charcoal,	1 30
Oil,	1 00
Horseshoeing,	1 00
Veterinary,	15
Total per acre,	$363 85
Total per pound,	26

The above tables (numbered 20 and 21), on the cost of producing sun tobacco, were taken from the records of growers, and presumably represent an average cost of producing the crop of 1917. The cost to the tenant is slightly more, which is justifiable considering the high rental value of land and sheds. Prior to the war the average cost of producing an acre of sun tobacco in the Connecticut valley was about one-third less than the cost in 1917, or from $225 to $250 per acre.

TOBACCO INSURANCE.

Because of the risks connected with growing tobacco, such as frequent hail and wind storms, farmers have made an effort to have their crops insured, and insurance companies have been quite willing to insure tobacco crops against damage by the forces of nature. The usual amount of insurance has been from $100 to $200 per acre, with $150 an average. The premium has been about $8 per $100 of insurance, or $8 to $16 per acre, and is commonly payable at the time the crop is insured.

The insurance company usually adjusts losses by wind or hail by sending an adjuster to inspect the damaged tobacco. The adjuster frequently decides upon the percentage in this manner: counting 16 leaves to a plant, if 8 are hail cut he allows 50 per cent. In 1916 one grower of Hatfield, Mass., received $700 for 12 acres insured at $150 per acre. In the same year a grower in Hadley, Mass., received $75 an acre on 12 acres insured for $100 an acre, and $6 an acre on 5 acres insured for $100 an acre. Another grower in Easthampton got $150 an acre on 11 acres insured at $150 per acre.

Insurance of the crop has been very helpful to tobacco farmers living in sections of excessive hail and wind storms, but it has not been successful in regions of little or no hail and wind. The insurance premium is high, and the maximum insurance is much less than the value of the crop. Moreover, farmers frequently pay out more money than they receive in damages. However, in 1917 and 1918 insurance companies were not eager to insure crops in regions of general hail and wind storms. Where they would insure the crops they put the premium so high that farmers felt they could not afford it. This lack of insurance puts the risk all on the farmer. In case of hail or wind storms he loses all. Crops are still insured in sections where hail and wind storms are rare.

Tenancy.

In 1910, 92 per cent of all Massachusetts farms were operated by owners,[1] 7 per cent by cash tenants, and 1 per cent by share tenants. In Connecticut, 90 per cent of all farms were operated by owners, 9 per cent by cash tenants, and 1 per cent by share tenants.

In Franklin, Hampden and Hampshire counties, Massachusetts, in 1910, 92.8 per cent of the farms were operated by owners, 4.5 per cent by cash tenants, and 2.7 per cent by share tenants. In Hartford, Litchfield and Tolland counties, Connecticut, 90.9 per cent of the farms were operated by owners, 5.5 per cent by cash tenants, and 3.6 per cent by share tenants. In the Connecticut valley 91.7 per cent of all farms were operated by owners, 5.3 per cent by cash tenants, and 3 per cent by share tenants. In fact, these two states exhibit an unusually large percentage of ownership. Very little change has occurred in this respect since 1880.

On the basis of tobacco alone, the percentage of tenancy is more than the above figures indicate. The proportion of tenants engaged in the growing of tobacco is comparatively high, since tobacco is a crop that lends itself readily to tenancy. It is a cash crop of large money value, requiring comparatively little machinery or horse labor, and adapted to hand labor, making the rise from tenancy to ownership comparatively easy. Most of the tenant farms are operated by immigrant families, the women and children doing much of the hand labor required for growing and preparing the crop for market.

Two types of tenancy are found in the valley, although but one is common. The one may be called share rental and the other cash rental. Share rental is usually for one-half the crop. Under this form the owner pays for the fertilizer in addition to supplying all the power machinery.

[1] "Owners" include farms operated by managers.

He also hauls his share of the tobacco to the warehouse. All the renter furnishes is his share of the seed, the labor and smaller implements required to grow and harvest the crop.

Cash rental is now the most usual form of tenancy in the valley, although share rent was more common in 1890. The cash rent paid for desirable tobacco land is from $50 to $60 per acre. The landowner furnishes nothing but the land. The cash tenant requires some capital; generally, however, he has no trouble in buying his fertilizer and implements on credit. By beginning as laborers, and taking advantage of this form of tenure, many Polish immigrants soon rise to farm ownership.

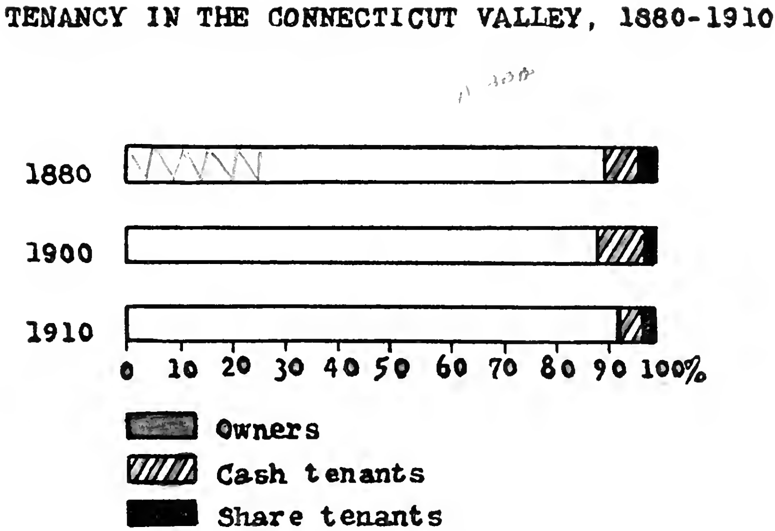


FIG. 6. — Tenancy in the Connecticut valley, 1880–1910.

PART II.

MARKETING CONNECTICUT VALLEY CIGAR LEAF TOBACCO.

NEW ENGLAND TOBACCO DISTRICTS.

The office of the United States Commissioner of Internal Revenue has divided New England into three districts, as follows: The States of New Hampshire, Vermont and Maine comprise the district of New Hampshire; in 1917 there were no dealers in leaf tobacco in the district of New Hampshire. The District of Massachusetts comprises the State of Massachusetts; in this district in 1917 there were 42 registered dealers in leaf tobacco. The Connecticut District includes the States of Connecticut and Rhode Island; in 1917 this district had 86 registered dealers in leaf tobacco.

SALE OF LEAF TOBACCO.

In this study an effort is made to trace the handling of unmanufactured tobacco from the producer to the manufacturer.

Tobacco passes through the hands of several middlemen from the time it leaves the farmer until it is ready to be manufactured. A brief discussion of these middlemen is in order. Fortunately the Commissioner of Internal Revenue has carefully defined the functions of most of these distributors, jobbers excepted.

Persons involved.[1]

Dealers in Leaf Tobacco. — A dealer in leaf tobacco is any person whose business it is, for himself or on commission, to sell, offer for sale or consign for sale on commission leaf tobacco. Dealers in leaf tobacco may sell to three classes only: (1) to other registered dealers in leaf tobacco; (2) to qualified manufacturers of tobacco, snuff or cigars; and (3) to persons who are known to be purchasers of leaf tobacco in packages for export.

Retail Dealers in Leaf Tobacco. — A retail dealer in leaf tobacco is any person whose business it is to sell leaf tobacco in quantities less than an original hogshead, case or bale, or who sells directly to consumers or to persons other than dealers in leaf tobacco; or to manufacturers of tobacco, snuff or cigars, or to persons who purchase in original packages for export.

Certain restrictions are imposed on retail dealers: first, they can handle only unstemmed leaf tobacco in the natural leaf, which is in the hand and not manufactured or altered in any manner, and which has been grown

[1] *Cf.* United States Internal Revenue Report for July 1, 1910.

in the United States; and second, they can purchase from two sources only, — (1) from a farmer or grower from whom they may purchase in any quantity and in any form of package; and (2) from another retail dealer in leaf tobacco, in which case the purchase must be less than an original hogshead, case or bale. Retail dealers cannot purchase or sell stems, scraps or any refuse arising from the handling of leaf tobacco by any other person, and must confine their business to dealing in tobacco in its natural state, — in the hand and unmanufactured.

The sales of retail dealers are likewise limited and must be made in quantities of less than an original hogshead, case or bale. A qualified retail dealer in leaf tobacco may sell leaf tobacco acquired by him to any person except manufacturers of tobacco, snuff, cigars and cigarettes, dealers in leaf tobacco, or persons who purchase leaf tobacco in original packages for export. Retail dealers in leaf tobacco are not permitted to manipulate the leaf tobacco sold by them by sifting, twisting, screening, plaiting, sweetening, flavoring, pressing or by any other process of manufacture.

Jobbers. — A jobber is a buyer and seller of packed tobacco. Often he is a speculator rather than a packer; his functions are purely commercial. He carries a stock throughout the year to meet the demands of the manufacturers. In doing this he runs the risk of shrinkage, which in itself amounts to a considerable percentage, and of a fall in prices. He also has the expense of insurance and interest. The services of the jobber relate less to local consumption and more to the demands of outside trade. His work is to distribute the supply to the centers of manufacture.

Sale by Manufacturers. — It is lawful for any licensed manufacturer of cigars to purchase leaf tobacco of any licensed dealer or other licensed manufacturer in quantities less than an original package for use in his own factory exclusively. A manufacturer of tobacco or cigars, therefore, has the right to sell leaf tobacco to a cigar manufacturer under the conditions named.

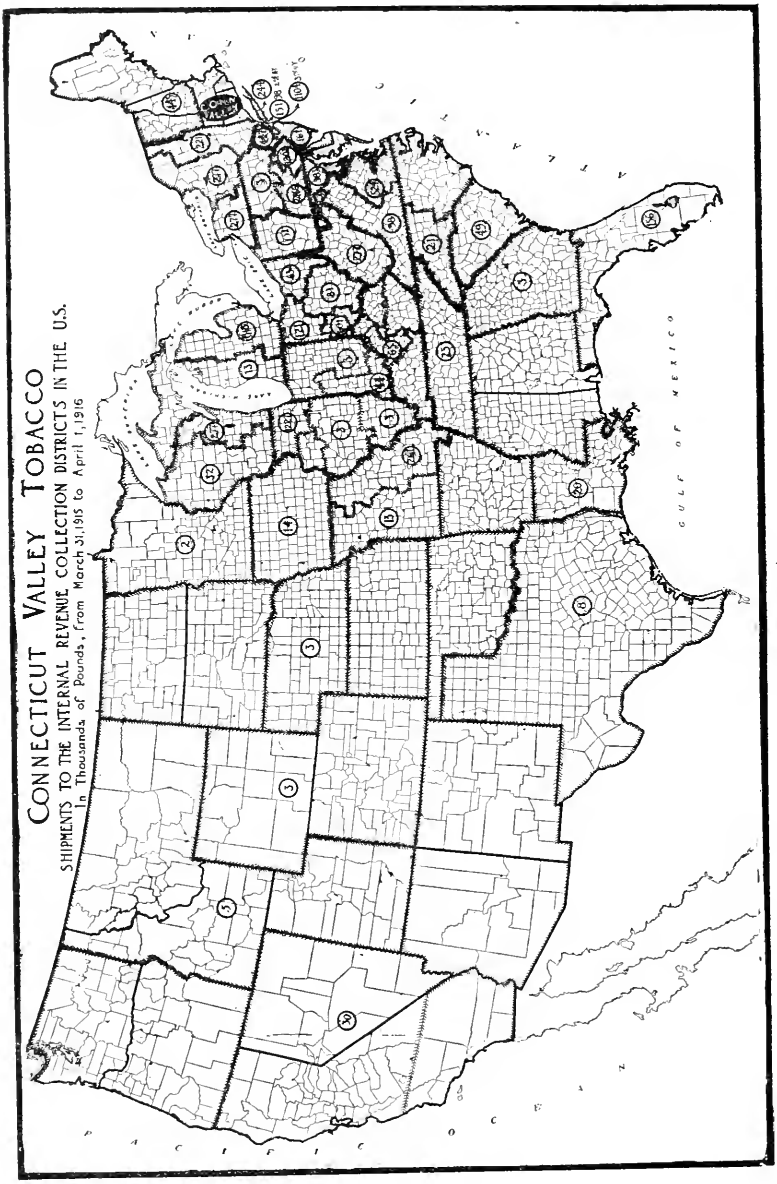
The sale and transfer of leaf tobacco by manufacturers is restricted to the return or sale of such tobacco as is found unsuitable for use in their own factories, for the purpose of closing the factory, or otherwise, but in emergency cases only.

Sale by Farmers or Growers. — A grower may sell his own leaf tobacco to any person and in any quantity, provided the condition of such leaf tobacco has not been changed in any manner from that in which it was cured on the farm. Unrestricted sales may be made in hogshead, case or bale, or loose in the hand. The farmer or grower may also sell in the same manner leaf tobacco received from his tenants as rent for land. These privileges are personal and cannot be delegated by the farmer to another person.

An agent may solicit orders for the sale of leaf tobacco for the farmer by sample, but the deliveries must be made by the farmer himself directly to the purchaser.

Sale of Unstemmed Leaf Tobacco.

Statistics furnished by the United States Commissioner of Internal Revenue, representing the sales of unstemmed leaf tobacco by dealers in leaf tobacco in the districts of Massachusetts and Connecticut to manufacturers and dealers in these and other districts from March 31, 1915, to April 1, 1916, are depicted in Map 4 and Table 22.



Map 4.

TABLE 22. — *Sales of Tobacco from Massachusetts and Connecticut to Manufacturers and Dealers (Pounds).*

	SALES TO MANUFACTURERS BY QUARTERS ENDING —				Yearly Total to Manufacturers.	SALES TO DEALERS BY QUARTERS ENDING —				Yearly Total to Dealers.	Total to Manufacturers and Dealers.
	June 30, 1915.	Sept. 30, 1915.	Dec. 31, 1915.	Mar. 31, 1916.		June 30, 1915.	Sept. 30, 1915.	Dec. 31, 1915.	Mar. 31, 1916.		
California,	-	-	-	4,282	4,282	6,412	1,881	12,188	5,385	25,866	30,148
Colorado,	1,249	-	926	942	3,117	-	-	-	-	-	3,117
Connecticut,	47,327	54,189	50,999	47,145	199,660	36,872	27,809	405,005	444,200	913,886	1,113,546
Florida,	14,812	68,132	23,456	40,021	146,421	3,944	316	-	5,368	9,628	156,049
Georgia,	885	500	1,147	530	3,062	-	-	-	-	-	3,062
Illinois,	4,238	27,471	39,191	36,263	107,163	196,388	298,369	288,398	339,228	1,122,383	1,229,546
Indiana,	8,493	13,796	11,607	12,183	46,079	-	539	-	-	539	46,618
Iowa,	257	1,400	10,885	1,343	13,885	-	-	-	-	-	13,885
Kentucky,	29,563	6,748	17,293	9,853	63,457	-	1,585	-	-	1,585	65,042
Louisiana,	795	473	3,825	5,393	10,486	1,487	1,461	1,517	4,846	9,311	19,797
Maryland,	23,813	26,602	43,518	32,769	126,702	212,750	209,736	288,123	145,777	856,386	983,088
Massachusetts,	24,408	25,545	25,139	22,891	97,983	939,213	49,814	201,669	290,144	1,480,840	1,578,823
Michigan,	85,287	192,205	292,007	118,117	687,616	54,575	19,282	51,123	18,393	143,373	830,989
Minnesota,	437	-	305	-	742	281	1,131	261	-	1,673	2,415
Missouri,	172	-	550	1,546	2,268	73,486	84,589	38,625	66,157	262,857	265,125
Montana,	260	265	-	-	525	-	-	-	-	-	525
Nebraska,	-	2,735	-	202	2,937	-	-	-	-	-	2,937
New Hampshire,	84,166	150,335	69,798	140,639	444,938	-	-	-	-	-	444,938
New Jersey,	99,711	120,402	219,748	150,071	589,932	371	1,450	-	16,859	18,680	608,612
New York,	189,800	214,242	247,372	289,796	941,210	7,643,957	2,626,881	2,837,894	5,763,129	18,871,861	19,813,071
North Carolina,	-	-	13,947	7,415	21,362	-	-	-	-	-	21,362
Ohio,	79,198	75,546	136,357	160,988	452,089	298,636	177,165	183,827	325,005	984,633	1,436,722
Pennsylvania,	112,204	83,248	70,718	105,448	371,618	807,322	838,103	1,357,295	1,348,677	4,351,397	4,723,015
South Carolina,	21,304	7,738	14,760	5,052	48,854	-	-	-	-	-	48,854
Tennessee,	4,978	8,091	2,478	7,110	22,657	-	-	-	-	-	22,657
Texas,	-	238	535	-	773	-	-	-	-	-	773
Virginia,	-	-	8,392	-	8,392	38,422	226,330	138,503	113,271	516,526	524,918
West Virginia,	1,001	1,221	3,316	712	6,250	45,472	-	21,878	24,317	91,667	97,917
Wisconsin,	-	1,920	-	145	2,065	35,885	92,939	78,446	99,878	307,148	309,213
Totals,	834,358	1,083,042	1,308,269	1,200,856	4,426,525	10,395,473	4,659,380	5,904,752	9,010,634	29,970,239	34,396,764

The sales to manufacturers amounted to 4,426,525 pounds, and to dealers, 29,970,239 pounds, a total for both manufacturers and dealers of 34,396,764 pounds for the period. Of this total, 19,813,071 pounds went to the State of New York alone, and 4,723,015 pounds went to Pennsylvania. The remainder, approximately one-third, was distributed rather generally over the other states east of the Mississippi River and in some states west of it.

For the four quarters ending March 31, 1917, the sales of unstemmed leaf tobacco from the Connecticut valley to dealers and manufacturers in the same and other districts amounted to 30,368,117 pounds, or about 12 per cent less than for the four quarters ending March 31, 1916.

One reason for the wide distribution of Connecticut valley cigar leaf tobacco is the great demand for wrapper leaf of a superior quality. The other cigar leaf producing states are mainly producers of either the binder or the filler type of leaf, inferior in wrapper quality. The imported Sumatra is the only cigar leaf wrapper competing with the Connecticut valley leaf in this country, and the imports of this have fallen off since 1914.

Table 22(*a*). — *Sales of Unstemmed Leaf Tobacco by Farmers in the Connecticut Valley, 1915–19, by Quarters.*

	1915.	1916.	1917.	1918.	1919.
January, February, March,	–	13,145,562	14,607,796	49,794,150	36,994,438
April, May, June,	8,288,532	6,011,579	7,818,773	14,089,663	–
July, August, September,	702,528	1,016,090	2,045,304	2,995,224	–
October, November, December,	5,383,787	6,081,221	30,230,690	18,953,141	–
Totals,	–	26,254,452	54,702,563	85,832,178	–

During the four quarters ending March 31, 1916, the total purchases of unstemmed leaf tobacco from farmers in the Connecticut valley amounted to 27,520,409 pounds, and for the four quarters ending March 31, 1917, to 27,716,686 pounds. The largest purchases were made from January to March, amounting to nearly one-half the total purchases. The next largest purchases were from April to June, and the smallest amounts were purchased during the quarter from July to September.

The above data show in a general way the breadth of the market for New England-grown tobacco. The demand in the different sections varies from year to year, and the extent to which New England tobacco fills the demand also fluctuates seasonally, depending, of course, upon the quantity of first-class tobacco produced. The market always demands wrapper leaf of the quality grown in the Connecticut and Housatonic valleys. When, however, there is an exceptionally large yield of light wrappers of fine quality, for example, the manufacturer who uses light wrappers will buy heavily and hold a portion of his purchases in his own or a local warehouse. This reserve may be sufficient to supply his wants without large additional purchases the following season, provided quality and prices are not satisfactory. Owing to the high prices and the poor quality of tobacco in New England in 1917, many dealers made little effort to purchase from the farmers, but used instead their reserve stores from the 1915 and 1916 crops. This fact is a partial explanation of seasonal and yearly variations in purchases.

Cigar Leaf Tobacco held by Manufacturers and Dealers.

The war in Europe brought about conditions in the tobacco world never before dreamed of. The United States has produced but one-third of the world's supply of tobacco; the other two-thirds have heretofore been grown in various parts of Europe. Europe is not yet in a condition to raise much tobacco, and it may be years before normal conditions can be brought about. Food crops naturally receive first attention. Hence for years to come we are likely to see a continuance of high prices for tobacco.

The table below gives the total consumption, production and imports of tobacco for specified countries before the war.

Table 23. — *Total Consumption, Production and Imports of Tobacco for Specified Countries before the War (Pounds).*

Country.	Average Annual Consumption.	Average Annual Production, 1909-13.	Average Annual Imports, 1909-13.
World,	-	2,712,204,000	-
Total for countries enumerated,	2,259,000,000	2,061,519,400	358,927,601
United States,	786,000,000	996,175,000	52,767,739
India,	481,000,000	450,000,000	6,537,759
Germany,	222,000,000	66,935,800	168,436,515
Austria Hungary,	209,000,000	178,994,400	49,983,593
Russia,	179,000,000	210,808,000	-
Great Britain,	98,000,000	-	112,334,018
France,	96,000,000	40,959,800	63,918,094
Japan,	91,000,000	93,611,600	-
Italy,	54,000,000	22,199,800	47,731,626
Netherlands,	43,000,000	1,829,000	57,218,267

The United States, Russia and Japan are the only countries enumerated that produced prior to the war more tobacco than they consumed. Russia is producing practically none now, and other European countries are producing far below normal. This means that the United States must supply this enormous tobacco deficit. But how well prepared are we at the present time to supply this deficit? Our position in regard to cigar leaf is indicated in the following table: —

TABLE 24. — *Cigar Leaf Tobacco held by Manufacturers and Dealers.*

	Oct. 1, 1915.	Oct. 1, 1916.	Jan. 1, 1917.	Jan. 1, 1918.
United States,	335,367,657	270,275,297	231,737,847	223,432,876
New England,	57,771,149	54,528,973	50,602,672	51,722,780
Broadleaf,	31,217,506	29,884,371	26,276,744	21,670,911
Havana seed,	24,359,058	22,731,599	21,849,157	26,262,206
Shade-grown,	2,194,585	1,913,003	2,476,771	3,789,663
New York,	-	3,989,282	3,065,209	2,558,481
Pennsylvania,	105,460,066	79,294,496	69,536,194	62,969,786
Ohio,	74,329,126	59,913,485	50,303,531	52,589,602
Wisconsin,	78,891,003	59,783,228	46,473,396	40,714,197
Georgia and Florida,	8,515,339	7,697,077	6,567,538	5,213,161
Porto Rico,	5,888,910	4,780,971	4,567,256	7,307,787
All other domestic,	261,576	287,785	622,051	357,082
Imported types,	63,658,729	58,290,911	54,768,526	59,397,226

The total stocks of cigar leaf tobacco in the hands of manufacturers and dealers have steadily decreased in the last few years. The quantity on hand on Jan. 1, 1917, amounted to 231,737,847 pounds, and on Jan. 1, 1918, to 223,432,876 pounds, a decrease of 8,354,971 pounds in one year. Since Oct. 1, 1915, the stocks of cigar leaf tobacco have decreased 111,934,781 pounds, or 33 per cent. The decrease in New England has not been so rapid as in New York, Pennsylvania, Wisconsin, Georgia and Florida. The states of New York and Pennsylvania are by far the largest manufacturers of cigars in the United States, New York alone having received over 18,000,000 pounds of Connecticut valley leaf in 1916 to say nothing of large receipts from other cigar producing states.

The above figures only partly tell the story. They represent the quantity of leaf tobacco reported as held by manufacturers and dealers who, according to the returns of the Commissioner of Internal Revenue, manufactured during the preceding calendar year more than 250,000 cigars, or had on hand more than 50,000 pounds of tobacco. What about the small manufacturers who, in the scramble for the 1916 and 1917 crops, were unable to get their quota? Since the war the large manufacturers have entered the field on a wholesale scale, and have outbid the smaller concerns for the leaf. Consequently, if we could take into account the smaller dealers and manufacturers, this reduction in cigar leaf would be even more striking.

FIG. 7. — One method of hauling tobacco from field to curing shed.

The production of cigar leaf tobacco in the United States has remained practically the same from 1912 to 1917. With the crop of 1917 smaller by 5,000,000 pounds than the 1916 crop, and the production in the European countries very materially decreased, it became necessary for European countries to secure the larger part of their tobacco from this country. Our exports of all kinds of tobacco leaf and trimmings to some countries have considerably increased, while to others the increase has not been large, owing to the lack of transportation facilities.

Preparation for Market by the Grower.

Harvesting.

Three methods of harvesting tobacco are in vogue in the valley to-day. The first two described below have been in practice for years; the third is a new method that is gaining in favor. The first is "hanging on lath." The plants are cut close to the ground with a thin-bladed hatchet made for the purpose. They are then laid lengthwise of the row and overlapping each other. When wilted they are handed to the "stringer" who strings them on a lath. One end of the lath is attached to a "stringing horse" and the other end is fitted with a steel needle. The plants are strung on the lath by forcing the needle through the butts of the stalks about 6 or 8 inches from the end, five or six plants being strung on a lath. The full lath is placed on a wagon fitted with a rack made to prevent the plants from being broken while being hauled to the curing sheds. The laths are arranged in the curing sheds so that each end of the lath rests on a pole. These poles are usually 15 feet long and allow room for 25 to 30 laths.

"Hanging on string" is the second method of harvesting tobacco, and many growers favor it above all others. The plants are cut as before, only they are laid crosswise of the row, and after being allowed to wilt are loaded directly on low wagons, the butts all laid one way. The plants are then drawn to the shed, where they are hung on poles with twine. The hanger carries a bag on his back, which holds a ball of twine. With this he hangs the plants about 8 inches apart on the poles by tying a half hitch around each plant. When the pole is full the end of the twine is tied around the last plant.

Priming.

This is a method of harvesting tobacco which came in with the shade-grown industry and has found favor among many growers of sun-grown tobacco. The barn is differently arranged, with the tiers only half as far apart as in the methods previously described. The plant is not cut, but the leaves are picked or "primed" as they ripen, four or five leaves at a time at intervals of from seven to ten days. The bottom leaves are picked first and the top leaves last. The pickers walk between two rows, priming both and placing the leaves in little piles. These piles are gathered up, placed in baskets and drawn to the end of the row on a hand truck. There they are loaded on a wagon and hauled to the shed where they are strung on poles. Generally the stringing is done by women and children, with large needles, placing about forty leaves on a string. The ends of the string are knotted and hung on a lath which has been notched at the ends. These laths are then hung up tier after tier. In a few days the second priming begins, and so on until the crop is harvested. Sometimes it is possible to cure and take down the first priming before the last is made, thus giving a chance to use the shed a second time in the same season. Consequently primed tobacco takes less shed space than that harvested by other methods. When the crop is to be primed it is not necessary to top the plant, thus saving considerable labor.

Curing.

The curing shed is really one of the limiting factors to increased production. To hang an acre of tobacco requires a shed 30 by 30 feet. A building of this size will cost from $450 up, depending upon whether it is of frame or of pole construction. In 1916 it cost from $700 to $800 to construct a frame shed of sufficient size to hold an acre of tobacco. The frame shed is constructed so that every third board is a trap door which can be opened for purposes of ventilation. The pole shed is built by setting the posts in the ground, and is not framed, the braces being nailed on. This type of shed is not so common now as it was a few years ago.

After the crop is placed in the shed the grower must watch it closely, opening the ventilating doors on certain days and closing them on others, depending upon the weather. Crops are ruined each year by neglect of this matter. With tons of water in the crop which must be evaporated within a few weeks, this is a critical time for the grower. Too much moisture in the atmosphere retards evaporation. Then, too, there is danger of "pole sweat." In a dry season, with the doors open all the time, the tobacco will dry, and not cure. In recent years the majority of growers have used the fire-cure method, building a charcoal fire under each bent in the shed, and thus to some extent becoming independent of the weather.

Taking down.

As soon as the crop is cured it is taken down. The tobacco has changed from a heavy green leaf to a thin light brown one, and has become so dry that it will easily crumble. Therefore, to get the crop down whole, it must be handled in damp weather when the leaf is said to be in "case." "As soft as a kid glove" is an expression often used in describing this condition. When this warm, rainy weather, or "tobacco damp," comes, no matter if in the middle of the night or on Sunday, the grower gets all the help he can command, and takes down as much tobacco as he thinks he can strip before it dries. With the lath method the laths are simply slipped off the poles, and, with a man on each tier, are handed very carefully and quickly to the man on the floor. There the tobacco is removed from the laths and piled with the butts laid both ways. If piled too high,

Fig. 8 — Cutting tobacco. Much of this work is done by boys.

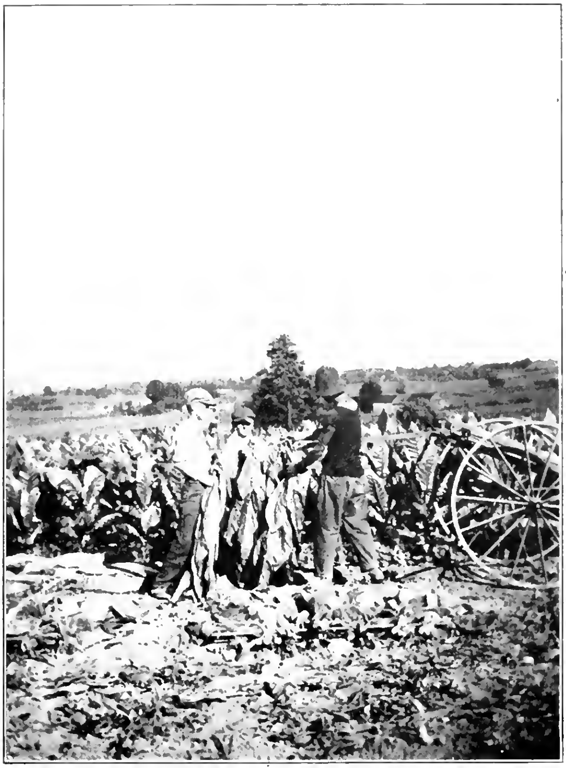


Fig. 9. — Stringing tobacco on a lath fastened to a stringing horse.

early in the fall when the stalks are green, there is more danger of the tobacco heating.

When hung on a string, a man at each end of the pole pushes the tobacco into a bunch in the middle of the pole. One man with a sharp knife then cuts the string, another hands the bundle to the man lower down, and it is piled as before.

Primed tobacco is simply stripped off the string and at once made into bundles.

A tobacco damp lasts only a short time, and the farmers must get down as much tobacco as possible. To keep the tobacco from drying as soon as it is taken down, it must be covered in order to shut out the wind and retain the moisture. The crop after it is taken down must be kept damp and the shed closed as tightly as possible to keep out the wind.

Stripping.

As soon as possible after the tobacco is taken down stripping begins. With the stripping crew on either or both sides of the pile a section is uncovered, each plant is taken up, and the leaves rapidly picked off one by one. The stripper holds the stalk in one hand and strips the leaves with the other, beginning at the butt. The leaves are placed in the stripping boxes which are of different sizes, 36 by 12 by 12 inches being about the average. The box is made with one side hinged. First, string is placed in the box at four different places, then the box is lined with paper. After the box is full the paper is brought over the top, the strings tied, and the bundle taken out of the box by opening the hinged side. The bundles vary in weight, but average from 35 to 40 pounds each. The bundles are then ready for delivery to the place agreed upon at the time of sale, either to a local sorting or packing shop or shipping point.

Hauling to Market.

Through personal investigation it has been found that the most common initial haul from the field to the sorting shop or shipping point in Massachusetts is about 3 miles, but some farmers haul their tobacco less than 1 mile, while others haul 10 miles or more. Transportation charges vary according to the distance from the farm to the shipping point, and from the shipping point to the manufacturer.

An average two-horse load contains about 150 bundles of tobacco of 30 pounds each, or 4,500 pounds. Two loads per day would make 9,000 pounds. The team and driver cost about $9.50 per day. This would make the cost per pound of tobacco $0.00106, or a little over one-tenth of a cent per pound, or 10 cents per 100 pounds.

As a matter of fact, the cost of hauling tobacco from the farm to the warehouse or shipping point is very insignificant, since such a large value can be hauled at a load. The tobacco is mostly hauled on sleds during the winter months while snow is on the ground, which makes it possible to haul a load of very large bulk, weight and value.

Large growers, notably growers of shade tobacco, ship some tobacco to dealers and manufacturers, but very little tobacco is shipped by farmers. Most of the tobacco is sold by the farmer to local packers who pack, sweat and sell it in the case, or in the bundle to other packers, dealers or manufacturers. The steps in marketing performed by the farmer are now ended. Before the packers are ready to market the crop it must go through several stages of preparation, which will be discussed in the next few pages.

Description of Packers' Preparations for Market.

Functions of the Packer.

The first function of the packer is to purchase from farmers the quantity of tobacco of the grade desired by the trade which he supplies. He does this himself or through his local agent. The local agent is usually a prominent grower who owns a building equipped for receiving, sorting, packing, sweating and storing tobacco. Frequently these buildings, fully equipped, are built by dealers for their local agents. In other cases they are leased for a period of years, but usually they are owned by the local agent, who receives a fixed price per pound or case for packing the tobacco.

The second function of the packer is to receive the tobacco at the sorting shop. Very frequently it is purchased in the field long before it is ready to harvest, and naturally there is no assurance as to the condition of the crop when it comes from the curing shed. When tobacco is delivered at the warehouse it is inspected, and if too much damaged is refused or accepted at a reduced price. Much damage may result from taking down tobacco too dry or too damp. Farmers are usually paid in full as soon as the tobacco has been accepted and weighed at the packer's warehouse.

The third function of the packer is to open the bundles and deliver the tobacco to the sizers, who separate the leaves one by one according to length. Then the different sizes are taken to the sorters who grade them according to quality and color.

The fourth function is sorting. As a rule, no attempt at sorting is made by the farmer. He simply delivers his bundles of stripped tobacco. The sorting is usually done by some one hired by the packer. This agent gets his help ready to begin about November 10, and continues until about the first week in April.

For the fifth function the tobacco thus sorted is tied with short tops into hands. These hands are placed in stalls properly labeled, and covered with blankets to keep the tobacco "in case."

The sixth function is packing and sweating. From these stalls it is put into cases lined with paper, and the tobacco is so placed, with the tips toward the center, as to lap from 4 to 6 inches. The lap is necessary in order to start sweating. The cases are then moved into the sweat room.

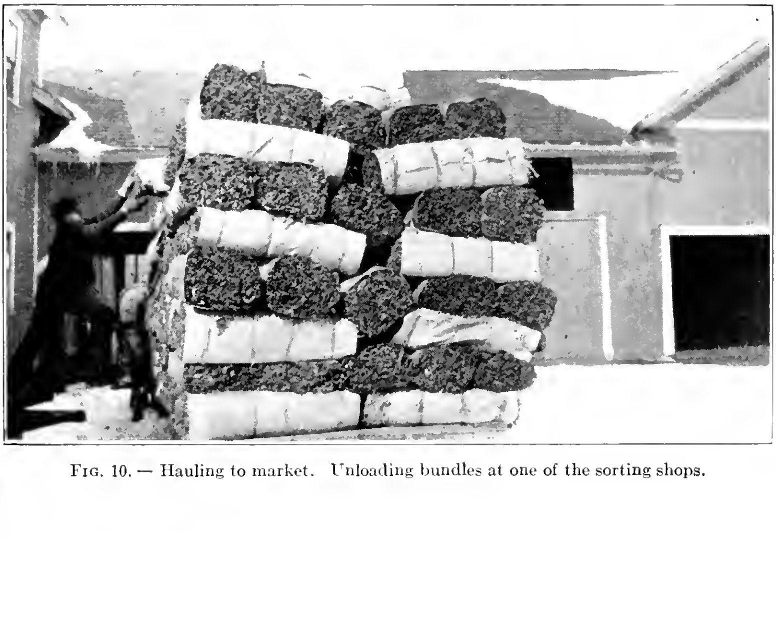


Fig. 10. — Hauling to market. Unloading bundles at one of the sorting shops.

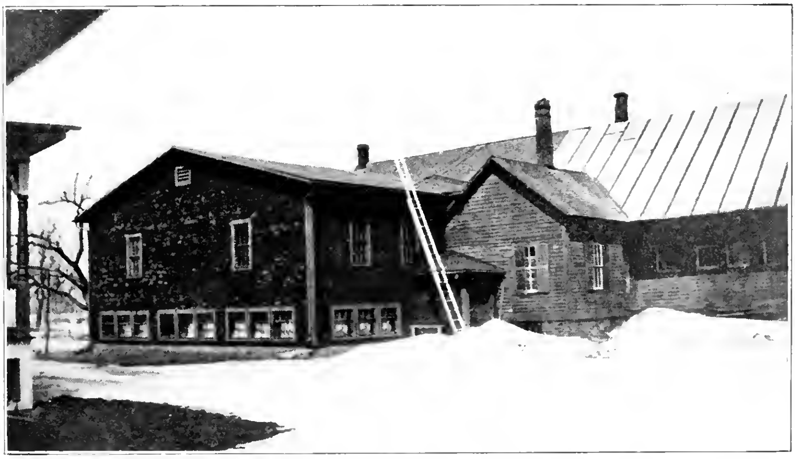


FIG. 11. — A typical shop for sorting sun-grown tobacco. Note the windows at the bottom, which furnish light for the sorting tables.

The seventh function is sampling. After a case comes out of the sweat and is cooled to normal, it is opened and four hands are taken from various parts of the case and tied together as a sample, which is guaranteed in any part of the United States.

Sorting and Tying. — When the tobacco comes into the sorting shops from the farm it is loose in the bundle and is not graded. This tobacco needs to be assorted according to grade, length, texture and color, and tied in small bundles of from fifteen to twenty leaves, called hands. This means a lot of labor, for each leaf must be handled. This kind of work is mainly done by women and children.

Each sorter has a sorting table consisting of boxed-off compartments from 10 to 12 inches deep and 8 to 10 inches wide, and of varying lengths, perhaps 16 to 22 inches, to fit leaves of different sizes. Each leaf is placed in the compartment corresponding most closely to its length, and with skilled labor no time is wasted in placing the leaves in their proper places. The leaves of different grades are kept separate, — light wrappers, dark wrappers, medium wrappers, brokens, seconds, fillers and binders. The various grades are packed in hands of from fifteen to twenty leaves each, tied with a leaf of tobacco; then the tobacco is ready to be packed in cases and placed in the sweating room.

Sweating. — There are three methods of fermentation, or sweating, now in use in the Connecticut valley. By the first and most common method from 300 to 350 pounds of sorted leaf tied in hands are tightly and smoothly packed into a wooden box which is fairly tight on the sides, but with one-half inch spaces between the end boards. The leaf is packed with the tips toward the center and the butts toward the ends of the case. The cases are piled in an unheated storehouse as they are packed, turned once or twice, and after lying over one summer are sampled and ready for sale to manufacturers or jobbers.

This is the natural method, but in recent years a method known as "forced sweating" has been largely used in order to get tobacco into market quickly, or to finish tobacco which has not fermented enough. The tobacco, packed in cases, is kept for about six weeks in a room with a moist atmosphere maintained at 90° to 120° F. This method enables the packer to clean out his sweat room and put in a fresh supply of tobacco every five or six weeks, and consequently he is not crowded for space.

The "bulk method" of sweating is used to some extent for Havana seed and exclusively with shade-grown, though it has not been successful with broadleaf. With the bulk method, the sweat room is kept at a temperature of from 80° to 90° F., with humidity high enough to keep the leaf soft. Under these conditions the bulk immediately heats and fermentation proceeds rapidly. As soon as the thermometer inside the bulk shows a temperature of 110° to 130° F., the bulk is pulled down, the leaf lightly shaken out and immediately bulked again, putting that leaf which was on the outside of the former bulk on the inside of the new one.

In the new bulk the rise of temperature is slower. This operation of rebulking is continued until the leaf is finished.

The following record from an experiment at the Connecticut Agricultural Experiment Station shows the temperature which may prevail within a bulk from the day it is laid down: —

Table 25. — *Temperature of Bulked Tobacco.*

	Degrees F.
When built,	73
December 19,	85
20,	99
21,	113
22,	121
Shaken out and bulked again.	
December 23,	86
24,	92
25,	97
26,	104
28,	112
31,	115
January 1,	114
Shaken out and bulked again.	
January 3,	94
5,	99
7,	104
9,	108
11,	107
23,	100

The above represents one of the first experiments with bulk sweating, which was conducted by the Connecticut Experiment Station in co-operation with the United States Department of Agriculture in 1898. The results were satisfactory and this method is now widely used.

Fermenting tobacco containing from 18 to 25 per cent of moisture is germicidal in its action, and few if any bacteria are found on freshly fermented leaves. Fermentation is due to the soluble ferments or enzymes found in the growing plant, and perhaps also while wilting after harvest. The enzymes are not living organisms like microbes, but chemical bodies which under proper conditions cause extensive chemical changes. The main changes are caused by two oxidizing enzymes, by the action of which the oxygen of the air is made to unite with various compounds in the leaf. To this action chiefly is due the color and aroma of fermented leaf, the presence or absence of which either makes a cigar of high burning qualities, rich and flavored, or a cigar of no body and very poor burning qualities. The burning quality of tobacco cannot be determined until after it is taken from the sweat shop.

Tobacco loses in sweating and shrinkage about 15 per cent, which is an item to be considered by the packers. A case weighing 300 pounds when put into the sweat room will weigh only about 255 pounds when it comes out. The packer guarantees the case not to shrink more than a certain maximum, usually from 15 to 20 per cent.

Fig. 12. — A shade-grown sorting shop. The sorting is done in the basement, and the top stories are used for storage.

Sampling. — Sampling is generally done by a special sampler appointed by his firm, though sometimes it is done by a local packer appointed by the company for which he packs. The sampler charges 35 cents a case, one-half of which goes to the sampler and the other half to his firm. This fee of 35 cents does not include handling. It is estimated that it costs 15 cents to handle the cases and to deliver the samples to the manufacturer, making the total charge 50 cents per case.

Tobacco is sampled as soon as it comes from the sweat room by taking six hands from different places in a case. Beginning at the bottom a sample is taken from about every fourth layer of tobacco. From these six samples four are selected to represent the quality of the bale, and are tagged and numbered to correspond to the number on the bale from which the sample was taken. This sample is guaranteed anywhere in the United States to represent the quality of tobacco in the case.

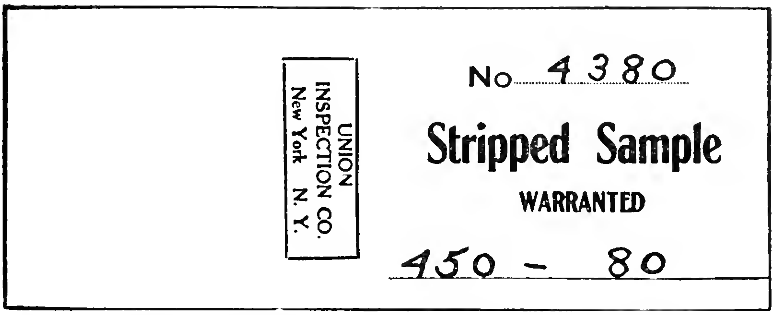


FIG. 13. — Tobacco sample tag, tied to the hands, and guarantees the tobacco anywhere in the United States. The number of the case here is 4380, the gross weight 450 pounds and the tare 80 pounds.

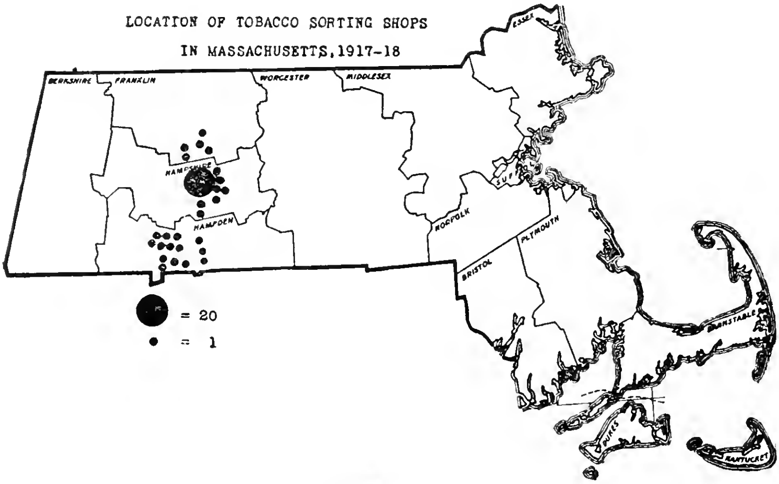
Amount of Tobacco assorted.

There were 7,280 cases of shade-grown tobacco assorted, sweated and stored in the warehouses of Massachusetts in 1917–18, and 35,971 cases of sun-grown tobacco, representing a combined total of 11,883,200 pounds. In 1917–18 there were 44 sorting shops open in Massachusetts which handled about 270,070 pounds per shop on an average. Some of these shops do a much larger business than others, depending upon the size of the shops and the number of laborers employed.

Nearly one-half of the Massachusetts tobacco is grown by Poles, and from one-half to three-fourths of the laborers employed in the sorting and packing shops are of Polish descent. In Connecticut Polish labor is not so important as in Massachusetts. Three-fourths or more of the tobacco in Connecticut is grown by natives, and over one-half of the labor employed in the sorting shops is native. The Polish farmers utilize the help of the whole family during the growing season and in the sorting shops during the winter months.

Sorting Shops.

Map 5 shows the location of these sorting shops in Massachusetts. During the sorting season of 1917–18 there were 46 tobacco sorting and packing shops employing 2,832 laborers, an average of 62 laborers per shop. Twenty of these local sorting shops, nearly one-half, are located in Hatfield, including North Hatfield and Bradstreet.



Map 5.

Table 26. — *Tobacco Sorting Shops in Massachusetts, 1917–18.*

Location.	Number of Shops.	Laborers employed.
Hatfield,	20	1,319
Hadley,	5	230
South Deerfield,	1	75
Sunderland,	1	25
Chicopee,	1	215
Westfield,	8[1]	212
Southwick,	1	60
Feeding Hills,	1	–[2]
Springfield,	2	510
Agawam,	1	6
Easthampton,	1	40
Northampton,	1	60
Whately,	3[1]	80
	46	2,832

[1] One closed 1916–17. [2] Labor transferred to Springfield.

FIG. 14. — Showing the roof of a sorting shop for shade-grown tobacco. Note the glass roof to provide light for the sorting tables.

Cost of Sorting, Tying, Storing, Packing, Sweating and Sampling.

Nearly all the sizing, sorting and tying is done by the piece, the laborers getting so much per hundred pounds of tobacco sorted and tied. In 1917–18 sorters got about $1.30 per 100 pounds of tobacco sorted, and tiers about $1.25. An average laborer can sort or tie about 225 pounds of tobacco in a day. Some can sort considerably more than this, but, to insure accuracy and careful handling, a limit is generally placed on the amount of tobacco a laborer can sort or size in a day. This amounts to about the same as paying a daily wage. The packers are paid by the day.

The average daily wage paid in 1915–16 was as follows: sorters, $1.75 per day; sizers and tiers, $1.50 per day; and packers, from $2 to $2.50 per day. In 1916–17 sorters were paid $2.50; sizers and tiers, $2.25; and packers, from $2.75 to $3. During the season of 1917–18 sorters were paid $3; sizers and tiers, $2.75; and packers, from $3.25 to $3.50.

The wages for 1917–18 were about 50 cents more for each class of labor than they were in 1916–17. The packers in certain localities agreed upon the wage they would pay.

Table 27. — *Sizes and Costs of Cases for Shade-grown Tobacco.*

32-inch case,	$1 50
34-inch case,	1 55
36-inch case,	1 60
38-inch case,	1 65
40-inch case,	1 70
42-inch case,	1 75
44-inch case,	1 80
46-inch case,	1 85
48-inch case,	1 90

Cases for shade-grown in 1917 and 1918 cost about $2.50. The matting to wrap the tobacco costs 17½ cents per mat, and three mats are necessary to a case. One handicap of the packers of shade tobacco is the fact that they can no longer get manila twine, which has been used for tying the hands of tobacco. Instead they use cotton twine, which is less satisfactory.

TABLE 28. — *Size of Cases and Pounds per Case.*

Lights and Seconds.

Length of Leaves (Inches).	Size of Case (Inches).	Pounds per Case.
16,	42	320
18,	32	250
20,	36	270
22,	38	290
24,	42	310
26,	44	325

Darks and Mediums.

Length of Leaves (Inches).	Size of Case (Inches).	Pounds per Case.
16,	42	350
18,	32	310
20,	36	320
22,	38	330
24,	42	350
26,	44	360
28,	44	370
Fillers,	42	350
Brokens,	38	350

Summary.

In 1915 the packers estimated that it cost them $3\frac{1}{2}$ cents a pound to sort, tie, store, pack, sweat and sample their tobacco. This includes all labor, lumber for cases, nails, twine, paper, sampler's fee and other expenses connected with packing. In 1916 the packers estimated their cost at 5 cents a pound. The depreciation on buildings and equipment, cost of heating, lighting, taxes, etc., are not included in the above. Including these last-named items, the 1916 cost was about 7 cents per pound. In 1917 the packers estimated that processing and marketing cost them, from the time the tobacco reached their hands until delivered to the manufacturer, wholesaler or jobber, 11 cents a pound for sun-grown tobacco, and 28 cents a pound for shade-grown.

TABLE 29. — *Cost of Packing a 350-Pound Case in 1917–18.*

Shrinkage, 10 per cent at 30 cents, price paid farmer,	$10 50	
Sweating, 5 per cent at 30 cents, price paid farmer,	5 25	
		$15 75
Paper, 1 pound at 11 cents,	$0 11	
Price of white pine case,	2 50	
Nails for case,	03	
Twine, 1 pound at 20 cents,	20	
Labor: —		
Tying 350 pounds at $1.25 per 100,	4 37	
Sorting 350 pounds at $1.30 per 100,	4 55	
Packing,	1 50	
Sampling,	35	
Cartage and inspection,	15	
		13 76
Price paid producer for 350 pounds at 30 cents, $105; interest on $118.76 ($105+$13.76) at 6 per cent,	$7 13	
Storage, 1 year (including taxes and insurance),	50	
Light,	10	
Heat,	1 00	
Transportation to New York at 20 cents per 100 pounds, less shrinkage and sweating,	60	
Office help,	20	
Collecting,	10	
Depreciation on buildings, $5,000 at 5 per cent on basis of cases packed,	54	
		10 17
Total cost per case,		$39 68
Cost per pound,		113

Labor and all materials connected with packing have advanced since 1914. For the season of 1917–18 paper cost the packers about 11½ cents per pound. Three sheets weigh 1 pound and will line a case. Wire nails cost about $6 per keg. Cases have also advanced considerably. Table 27 gives the relative sizes and costs of cases for sun-grown tobacco in 1916. Add 90 cents per case to obtain the cost in 1917.

STORAGE.

Tobacco is a product which, in contrast to the great bulk of products, requires a period of storage before it is desirable for consumption. At least six months are required for the natural sweating and packing process, and from five to eight weeks for forced sweating. The longer tobacco is in storage the better the quality. It can be held two, three, five or even more years without any deterioration in quality. Some large firms advertise their product by some such catchy phrase as "mellowed by age." This is one reason why it is so easy to regulate prices; crops are safely held over from years of overproduction to years of underproduction, although since 1914 we have been drawing heavily on our reserve supply. Consequently the length of time in storage depends to a large extent upon market conditions. In general, we may say that tobacco is in storage six to eight months, although the periods range from two months to two years.

Little tobacco is stored by the producer for any length of time. Instances occur, however, where it is necessary for the grower to hold some of his crop after it is taken from the poles. In such cases it is packed into bundles and stored in a tightly closed shed or sorting room to prevent drying. When prices are low some farmers store and sweat their tobacco, hoping to sell at an increased price. Though there is a good opportunity for co-operative warehouses, nothing has yet been done along this line. The essential features of this plan will be discussed later.

Tobacco warehouses in the Connecticut valley are all privately owned. The big storage plants are under the control of the packers. Each dealer who has a sufficiently large business has at least one warehouse and sometimes several. These warehouses are usually constructed with the sorting rooms partly under ground, but so arranged that good light is available for sorting tables. The storage room is above the sorting room, so arranged that it is convenient to move the tobacco from the sweating room into the storage after it has been packed.

Besides the storage by packers or dealers, the manufacturers store large quantities of tobacco, sometimes buying when tobacco is plentiful and holding until an off year. Table 24, on page 180, gives the amount of tobacco stored by manufacturers and dealers for a number of years.

Cost of Storage.

Cost of storage varies with the time the crop is stored and the time the sweating occupies. Figures for the leaf-producing sections of Pennsylvania give the cost of storing the case for one year as 50 cents. The costs of inspection, sampling, etc., amount to 50 cents. There is also a shrinkage during storage which amounts to about 15 per cent. The total cost of storage for a year and the attendant labor amounts to about $2 per case.

The packers in the Connecticut valley estimated that it cost 11 cents a pound to handle the 1917–18 tobacco crop from the time it reached their hands until it was delivered to the purchaser. This figure is sufficiently large to cover all expenses of packing and selling. At this figure the packers could sell for 45 cents tobacco purchased from the farmers for 30 cents a pound, making a clear profit of 4 cents per pound sold. Wholesale prices, however, lead to the conclusion that far bigger profits are made.

Transportation.

Table 30. — *Freight Rates to Principal Manufacturing Centers.*

	From North Hatfield Station (Cents).	From South Deerfield Station (Cents).
New York City,	20.5	21.0
Elmira, N. Y.,	21.5	21.5
Washburn, N. Y.,	21.0	-
Harlem River, N. Y.,	16.8	16.8
Syracuse, N. Y.,	20.0	20.0
Erie, N. Y.,	18.0	-
Troy, N. Y.,	15.0	-
Philadelphia, Pa.,	24.0	24.0
Lancaster, Pa.,	24.0	24.0
York, Pa.,	24.0	24.0
Lititz, Pa.,	21.0	21.0
Norristown, Pa.,	21.0	21.0
Newark, N. J.,	21.0	21.0
New Brunswick, N. J.,	16.8	-
Cleveland, Ohio,	26.1	-
Chillicothe, Ohio,	29.8	29.8
Miamisburg, Ohio,	32.0	32.0
Chicago, Ill.,	36.8	36.8
Detroit, Mich.,	28.7	28.7
Duluth, Minn.,	39.0	-
Wheeling, W. Va.,	28.0	25.1
Kansas City, Mo.,	42.0	-
Los Angeles, Ca .,	39.0	-
Springfield, Mass.,	15.0	15.0
Lowell, Mass.,	17.5	17.5
Hartford, Conn.,	12.0	12.0
Hamilton, Ont., Can.,	25.7	28.0
Montreal, Can.,	27.5	23.9

These are not the only cities that receive tobacco shipped from North Hatfield and South Deerfield, Mass., over the Boston & Maine Railroad. The foregoing table simply shows the wide distribution of sales and the comparatively low freight rates to the principal shipping points. For example, 100 pounds of tobacco can be shipped from North Hatfield, Mass., to Los Angeles, Cal., for 39 cents, or a little over one-third of a cent per pound.

Shipments and Receipts of Tobacco, Massachusetts Local Shipping Points, 1915–17.

Shipments (Tons).

	1917.	1916.	1915.
January,	714.2	845.00	424
February,	576.5	831.00	415
March,	543.2	558.50	440
April,	855.5	504.00	450
May,	319.7	307.00	438
June,	452.0	501.00	314
July,	316.4	223.90	731
August,	386.5	297.29	693
September,	242.9	269.00	181
October,	268.1	271.65	695
November,	248.5	197.00	413
December,	301.2	276.00	555
Total (tons),	5,224.7	5,081.34	5,749
Total (pounds),	10,449,400	10,162,680	11,498,000

Receipts (Tons).

	1917.	1916.	1915.
January,	307	275	187
February,	154	136	238
March,	57	76	30
April,	36	59	32
May,	10	21	9
June,	20	6	91
July,	53	47	20
August,	30	30	26
September,	23	26	32
October,	57	45	14
November,	95	120	60
December,	109	96	77
Total (tons),	951	937	816
Total (pounds),	1,902,000	1,874,000	1,632,000

Note the heavy shipments for January, February, March and April of 1916 and 1917. The great demand for all classes of cigar leaf tobacco and the high prices offered by the manufacturers resulted in early shipments by the packers. The heavy shipments from July to December 1915, are the result of holding the 1914 crop for higher prices. Tobacco was not high in price at this time, but, on account of the war, dealers predicted a rapid rise in prices and held a large part of the crop.

The shipments for May and June are small for the three years; and July for 1916 and 1917. The sorting season is then over and the packers store tobacco for fermentation by the natural process during the summer months.

Most of the tobacco received from outside sources comes in during the months of November to February, when tobacco is being sorted. The buyers frequently import tobacco from other localities to be sorted in their shops.

Records of shipments and receipts were obtained from South Deerfield, Hadley, North Hatfield, Hatfield and Whately, Mass. Subtracting the receipts from the shipments, for the tobacco received is included in that shipped out, 9,866,000 pounds were shipped from these local stations in 1915; 8,288,680 pounds in 1916; 8,547,400 pounds in 1917. These shipments amount to about 3,000,000 pounds less than the annual production in Massachusetts. These 3,000,000 pounds not included in the shipments are probably shipped from stations in Hampden County, notably Westfield, Springfield and Chicopee.

Grades, Standards and Principal Varieties.

Tobaccos are divided into "classes," a "class" signifying the purpose for which the product is finally intended. Thus we have pipe, cigar, chewing, export and cigarette classes, and these are subdivided into various "types," depending upon certain qualities of the leaf, such as color, flavor, elasticity and strength.

Further divisions into "grades" are almost endless in variety, based on the differences in size, aroma, texture, quality, etc.

While sizes and grades vary somewhat among different packers, the following grades and sizes are common for sun-grown tobacco: —

Grades.	Inches.
1. Light wrappers,	14, 16, 18, 20, 22, 24, 26, 28.
2. Medium wrappers,	20, 22, 24, 26.
3. Dark wrappers,	16, 18, 20, 22, 24, 26, 28.
4. Seconds,	16, 18, 20, 22, 24, 26.
5. Brokens,	Broken leaves and all under 14 inches.

Connecticut valley shade-grown tobacco is assorted into grades according to color, texture and lengths.[1] The chief colors are: —

L No. 1,	Light color.
CL No. 2,	Light color.
LV No. 1,	Light green.
V,	Full green.
VV,	Dark green.

The texture is graded into light wrappers, medium wrappers and heavy or dark wrappers. Sizes run from 9 to 22 inches, and are measured by the inch. On an average there are about 60 grades and sizes to a crop, but sometimes there are as many as 250 grades and sizes.

In an average year about 25 per cent of the Connecticut valley tobacco crop goes for wrappers, Massachusetts and Connecticut producing a large quantity of wrappers of high quality. About 50 per cent of the crop is used for binders and 25 per cent for fillers.

The grades of tobacco are determined by the quality and length of the leaf. Those which are of fine texture, glossy, thin and silky make the best wrappers. Leaves of poorer and heavier quality are used for binders, and the short broken leaves are used for fillers.

In the shade-grown industry the grades are not so carefully distinguished there being many grades of slight variation. Therefore it is more difficult to grade shade-grown tobacco. The determining qualities are about the same as in the sun-grown. A very thin, silky leaf with open grain makes a high-priced wrapper.

Prices.

Supply and Demand.

The price of tobacco is determined by the quality of the leaf and the comparative demand for it. Overproduction of any special kind of tobacco lowers prices, although this is not so marked as with some other products, because the keeping qualities of tobacco are good, and buyers frequently purchase when the supply is plentiful and hold the product for manufacture until there is a short crop. Tobacco two or three years old is better than tobacco freshly packed and fermented.

On the other hand, during a year of low production the demand will exceed the supply, and prices are bound to rise. During 1916 and 1917 there was a great demand for all grades of tobacco, and consequently prices were unusually high. Production did not increase sufficiently to satisfy the larger population demand; moreover, the per capita consumption of tobacco has likewise increased. The annual per capita consumption of all forms of tobacco in the United States from 1863 to the present time is presented below.

[1] Some of the grades occurring in the crops assorted at the shop of Mr. Leslie Swift, North Hatfield, Mass., during the sorting season of 1917-18, are as follows: —

L 18.	L 11.	LL No. 2 15.	LV 15.	V No. 1 16.	V No. 2 16.
L 15.	LL 20.	LV 20.	LV 14.	V No. 2 20.	V No. 2 15.
L 12.	LL No. 2 18.	LV 16.	MW 16.	V No. 2 18.	Broken 15.

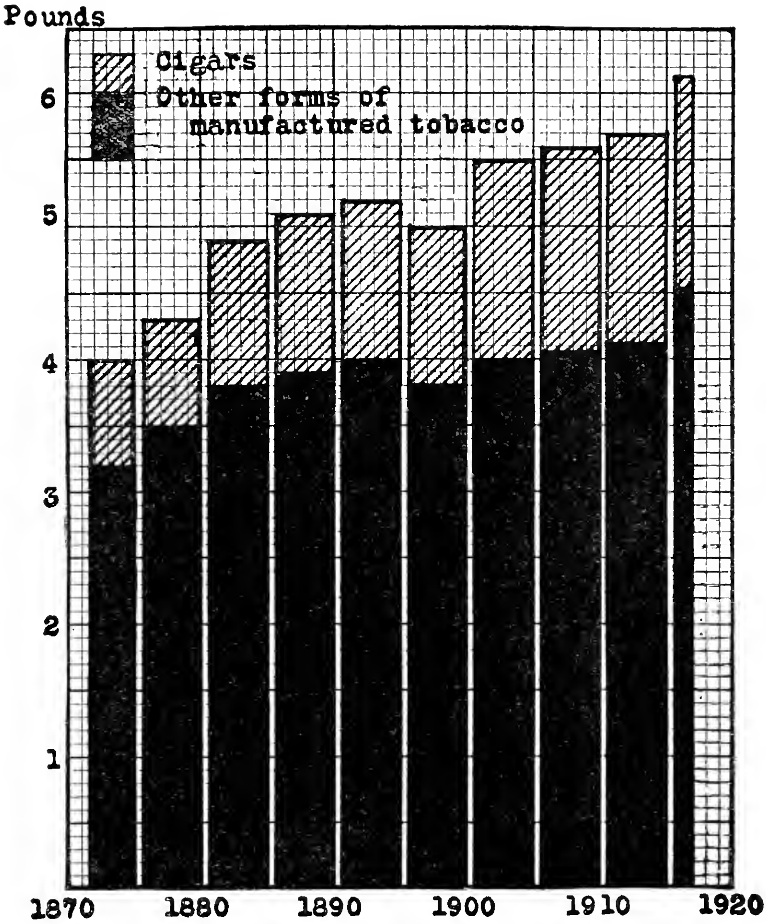


FIG. 15. — Per capita consumption of cigars and other forms of manufactured tobacco in the United States, 1870–1917.

TABLE 31. — *Annual Quantity per Capita of Leaf Tobacco manufactured in the United States (Pounds).*[1]

YEARS.	All Tobacco.	Cigars.	YEARS.	All Tobacco.	Cigars.
1872–75, ...	4.0	.79	1896–1900, . .	5.00	1.20
1876–80, ...	4.3	.80	1901–05, ...	5.50	1.54
1881–85, ...	4.9	1.11	1906–10, ...	5.60	1.57
1886–90, ...	5.1	1.19	1911–15, ...	5.70	1.58
1891–95, ...	5.2	1.18	1916–17, ...	6.12	1.60

[1] Internal Revenue Reports, 1872–90, estimated.

Per Capita Consumption for Different Countries (Pounds).[1]

	1871-75.	1876-80.	1881-85.	1886-90.	1891-95.	1896-1900.	1901-05.	1913.
United States, .	4.0	4 3	4.9	5.1	5 2	5.0	5.5	5.70
Germany, . .	3.9	3.7	3.0	3 3	3 3	3.5	3.5	3.77
France, . . .	1.7	1.9	2.0	2 0	2.1	2.1	2.1	2.43
England, . .	1.3	1 4	1.3	1.4	1.6	1.8	1.9	2.05

[1] Adapted from Jacobstein, The Tobacco Industry, p. 44.

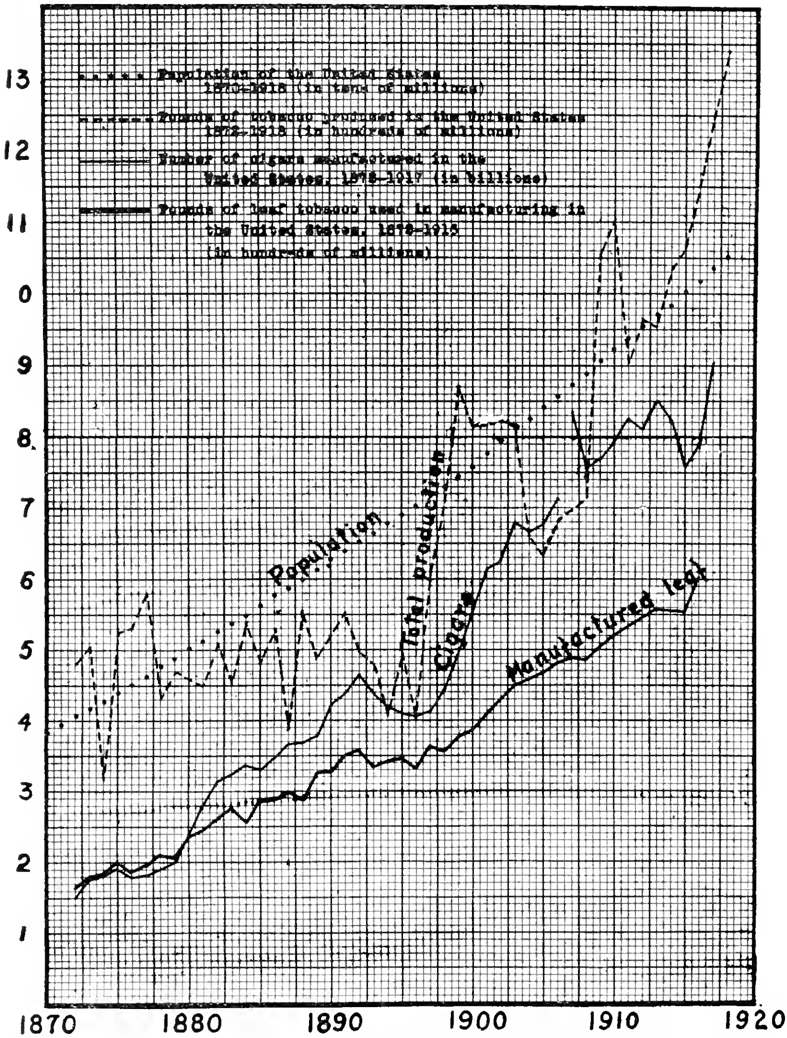


FIG. 16. — Notice the tendency of tobacco production, the number of cigars and the amount of manufactured leaf to follow the upward trend of population.

The United States is by far the greatest consumer of tobacco, using one and one-half times as much as Germany, the next largest consumer, in 1913. From 1872 to 1913 the per capita consumption of tobacco in the United States increased 42.5 per cent, in England 58 per cent, in France 43 per cent, and in Germany decreased 33 per cent.

In 1875 the per capita consumption of cigars in the United States was about .8 of a pound; in 1916 to 1917 it was 1.60 pounds, an increase of about 100 per cent. During this period the per capita consumption of plug, smoking and chewing tobacco increased 28 per cent; from 1900 to 1918 the total cigarette production increased over 900 per cent, and the per capita output of cigarettes increased approximately 740 per cent. This indicates the increasing demand for cigars and cigarettes in comparison with other tobaccos.

Connecticut Valley Tobacco in the Market.

Map 4 shows the shipments of Connecticut valley cigar leaf tobacco to districts within and without Connecticut and Massachusetts. This map also shows the chief manufacturing and consuming centers; for example, in 1916 the state of New York received 18,871,861 pounds of Connecticut and Massachusetts wrapper; Pennsylvania received 4,351,397 pounds.

The Connecticut valley produces a high grade of wrapper tobacco which is famous the world over. A cigar wrapped with a Connecticut wrapper bears its own trade-mark. No other section of this country, barring a small area in Florida, is so well suited to producing high-grade wrapper tobacco.

Methods of Sale.

There is no organized market for leaf tobacco grown in the Connecticut valley. Most of it is sold to "packers," manufacturers or dealers in leaf tobacco, who act as packers as well as jobbers. Many of these packers and dealers have a local representative or agent who may or may not purchase from the farmer.

As a rule, the grower sells to so-called "tobacco buyers," who may be local dealers in leaf tobacco, local agents for so-called "packers," representatives of manufacturers, or traveling buyers for wholesale dealers in leaf tobacco. These buyers purchase the growers' crops by the pound, to be delivered stripped and tied in bundles at one of the local sorting shops. Practically all the tobacco is sold in this way. Of course there are still some farmers, especially large growers, who keep their help throughout the year and pack and grade their own tobacco and sell it in cases directly to manufacturers or jobbers.

Tobacco in the Connecticut valley may be sold either before or after harvesting. Sales consummated before the tobacco is harvested, or by the "contract method" of sale, are made in two ways: —

1. The grower contracts to grow a certain number of acres of a certain kind of tobacco to be delivered at a specified price and place in good merchantable condition.

2. While the crop is growing it may be sold at a fixed price per pound, to be delivered on or before a certain date at a warehouse or shipping point agreed upon at the time of sale and in specified condition. In all cases of sale by contract the buyer makes a payment on the crop when he contracts for it in order to make the contract binding, to which both buyer and seller agree. This method is very common when the crop looks promising and the tobacco outlook is satisfactory, especially after a poor year from the standpoint of both yield and quality. A large proportion of the 1916 crop was sold in the field because of the anxiety of the buyers to procure a supply after the disappointing season of 1915.

Harvested tobacco may be sold as follows: —

1. After the tobacco is cured and stripped it may be sold to be delivered as agreed upon at the time of sale at a certain price per pound, or to be assorted into certain grades with a price for each grade, or a flat price for all grades.

2. After the grower has assorted his crop he may sell it by grades or for a flat price for all grades.

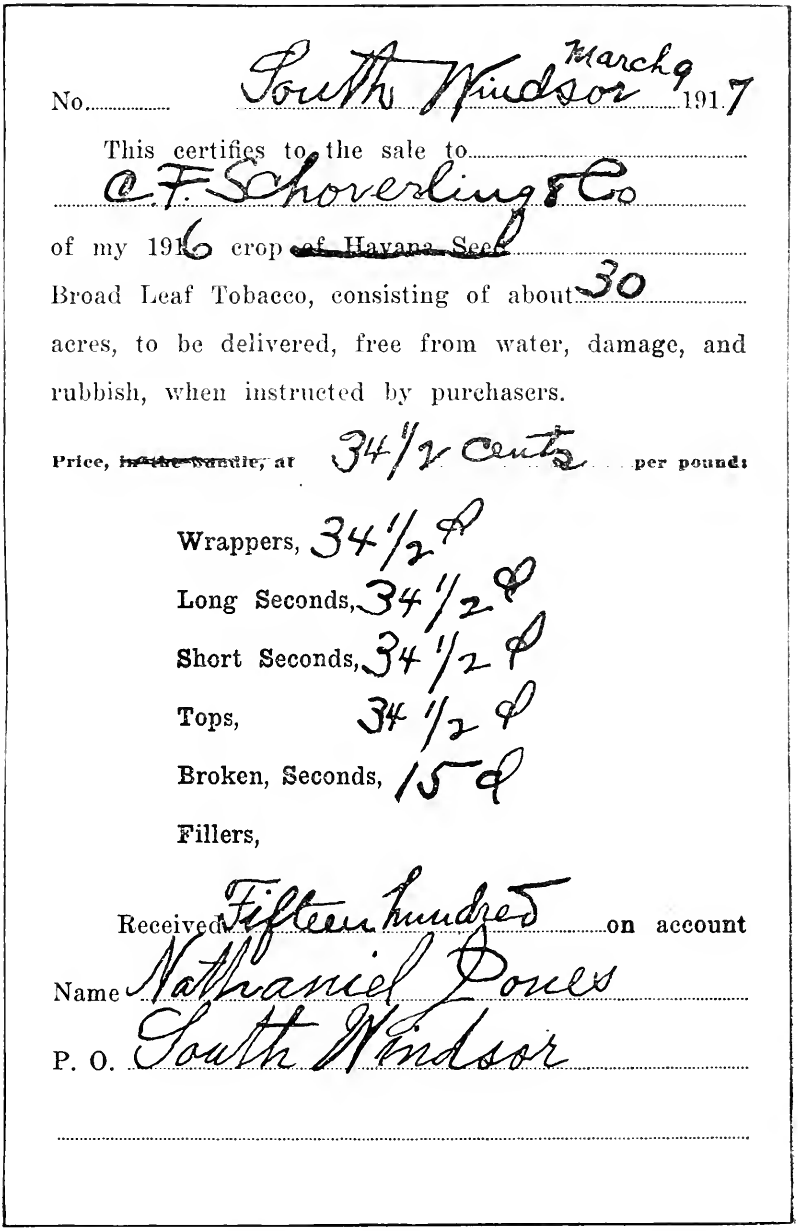
3. The grower may assort and case his crop, sweat it and put himself in the position of a tobacco dealer. This last method is adopted only by large growers who have sufficient capital to carry a crop.

In the marketing of tobacco the buyer has every advantage. He knows the condition of the market. The farmer, on the other hand, is primarily a grower, and as a usual thing wants to sell when the crop is harvested. Lack of operating capital often forces the farmer to sell early. The small grower is obliged to sell immediately because he needs the cash to pay bills, purchase farm supplies and plant a new crop.

Under the contract method of sale the farmer has all to lose, with no corresponding gain, the buyer, little or nothing. With one the matter is intensely personal, with the other entirely impersonal. The buyer represents big organization familiar with trade conditions, prospective consumption and competing agencies. If the buyers do not work together they are not as shrewd business men as the writer gives them credit for being. It would be good business. The farmers have done little collectively to obtain trade information or to control the mechanism of processing or distributing the product. Having no knowledge of the market, and not belonging to a farmers' shipping organization, he is at the mercy of the buyer. Perhaps the only way for the average farmer to improve his prospects is through some co-operative organization for collective bargaining, the purposes, organization and scope of which are discussed later in this bulletin.

Defects of the Contract Method of Sale.

1. Farmers naturally do not have as great interest in their crop after it is sold as before. They are likely to become careless in handling the tobacco.



No.......... South Windsor March 9 1917

This certifies to the sale to C. F. Schoverling & Co

of my 1916 crop ~~of Havana Seed~~

Broad Leaf Tobacco, consisting of about 30

acres, to be delivered, free from water, damage, and rubbish, when instructed by purchasers.

Price, ~~in the bundle,~~ at 34 1/2 cents **per pound:**

Wrappers, 34 1/2 $

Long Seconds, 34 1/2 $

Short Seconds, 34 1/2 $

Tops, 34 1/2 $

Broken, Seconds, 15 $

Fillers,

Received Fifteen hundred on account

Name Nathaniel Jones

P. O. South Windsor

Fig. 17. — A tobacco grower's contract. Fifteen hundred dollars is paid down to bind the contract.

2. It is impossible to sell a crop on its merits. The tobacco is sold while it is growing or even before it is planted, and no one can tell what the quality of the crop will be after it is cured. It is simply a gamble; the buyer gambles for the grower's crop, and he endeavors to set the price sufficiently low to guarantee himself against loss.

3. It means frequent adjustments. Fifty per cent of the 1916 crop bought on contract was delivered at a discount. This statement comes from dealers and packers as well as farmers. The contract says that the tobacco must be delivered in good merchantable condition, free from water, damage and rubbish, when instructed by the buyer. This gives the buyer a large leverage, and it is comparatively easy for him to take the ground that a farmer's crop contains water or rubbish, and to dock him from 3 to 5 cents per pound.

4. The farmer is tempted to take his tobacco down too soon, which causes fatty stem; or he may sprinkle it to make it workable. The crop has been sold and he wants the cash as soon as possible.

5. The contract is drawn up by the buyer and does not bind him to the extent it does the farmer. The buyer is bound only to the extent that he must purchase the tobacco from the farmer, but not necessarily at the price agreed upon in the contract. On the other hand, the farmer must sell to the buyer even though he is docked 10 cents a pound; he can sell to no one else. A case occurred in 1917 where a farmer resold his tobacco to another buyer because of an advance in price. The first buyer brought suit and won, and it cost the farmer a large sum of money to get out of the difficulty.

6. Fifteen or twenty buyers in one locality or district at the same time necessarily mean a waste of time. Instead of buyers traveling over the valley for five or six months in the year, a much better plan would be for them to wait until the crop is harvested, cured and sweated, and the samples sent to some central selling office in New York or Hartford, where the buyers could collect and inspect the samples and leave orders for the grades they desire. Such a method of sale could be accomplished through a co-operative organization which would include the tobacco growers of the entire Connecticut valley.

Collusion among Buyers.

There is a very strong feeling among tobacco growers that the buyers have a working agreement or understanding among themselves as to the general average of prices to be paid. This is naturally a difficult matter to prove, but, considering their associations, dinners and frequent meetings, there is ground for the belief of the growers. It is reported that buyers first go over the tobacco territory apparently with no intention of purchasing. Occasionally a man will ask if they are buying tobacco, and they answer, "No; why? Have you some to sell?" If the grower says, "Yes," they ask his price; if it is high, they drive on, but if low, they purchase his tobacco. A few crops are thus purchased in each locality, and these low prices are made the basis for future purchases. Sometimes a buyer will offer a farmer a fair price for his tobacco and the offer will be refused. A few days later a second buyer will come along and offer a price just a little lower, and a third buyer a price a little lower still. By this time the grower is growing fearful that he cannot sell his crop, so lets it go for a low price.

Apparently this is a scheme agreed upon by the buyers. In 1915 one man in the valley was offered 12 cents a pound for his tobacco, a little later 9 cents, and finally it sold for 6 cents. The quality of the crop was as good when it was finally sold for 6 cents as it was when the first man offered 12 cents. Other growers report similar experiences. This has been the practice in the Connecticut valley ever since the industry was established. The farmer who has held for a good price has frequently been boycotted by the buyers. Hence, reliable growers have had to sell crops of good quality at a low figure just because their neighbors sold early and at a low price.

This practice did not work well during the war because of the growing scarcity of tobacco. The growers who sold late in the season got the best prices. However, the old practice bids fair to be resumed just as soon as the supply of tobacco has been sufficiently increased. In fact, the decline in price, beginning about Oct. 1, 1918, was held by many to be due to the determined effort on the part of buyers to depress the price. From September, 1918, through January, 1919, few farmers received any offer whatever for their crops. A few were offered 25 to 30 cents a pound for tobacco for which formerly they had been offered 45 cents a pound.

Prices to Farmers.

As has been noted, tobacco is sold in the Connecticut valley by contract, the buyer frequently contracting for the grower's crop while it is growing or even before it is planted. This factor has probably been the main reason why prices to the farmer have been comparatively low. The crop has not been sold on its merits, and consequently the farmer has had to take whatever the buyer offered him. Fig. 17 shows that the supply and price of tobacco in New England bear very little relation to each other. For example, during the years 1910–12 the supply gradually increased, likewise the price. In 1912–13 the supply and the price quite uniformly decreased. In 1914–15 the supply decreased and the price also decreased, but not with any uniformity. The quality of the 1915 crop was, however, very poor. The only years that show any normal relation between the supply and price were 1904–05, 1913-14 and 1916–17. The great demand for tobacco from 1916–17 is the chief reason for the rapidly advancing price.

Ordinarily when the supply increases the price decreases, and *vice versa*, but no such relationship is exhibited in this figure. This is due partly to the fact that tobacco can be held for a number of years, permitting only slight fluctuations in prices. Partly, however, it is due to the fact that the tobacco crop in competing areas may be large, while the Connecticut valley crop is small. Partly, too, it may be due to imports, but no doubt it is also in part attributable to the faulty method of sale.

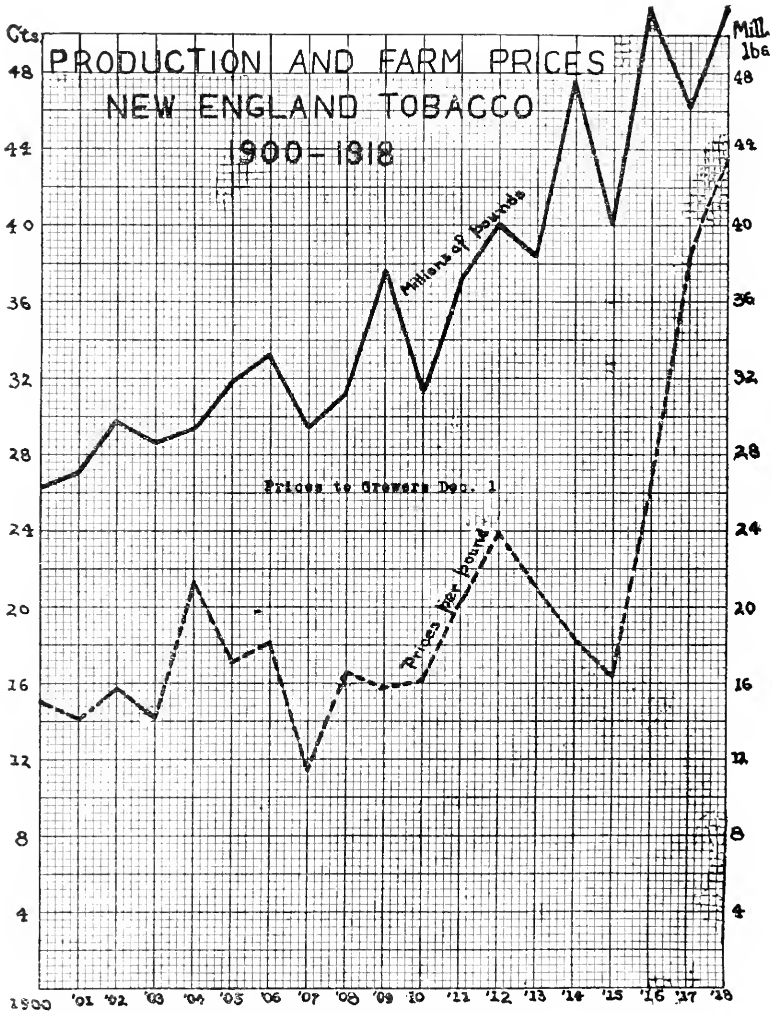


FIG. 18. — Production and farm prices of New England tobacco, 1900–18.

Prices of Connecticut valley tobacco have increased, however, since 1916, reaching the maximum in July, 1918, with an increase of 80 per cent over 1916. This increase was due to the great demand for low grades of leaf tobacco, and the decrease of the better grades through injury by storm and frost. The demand for low grades steadily raised the minimum price until the price for average or binder goods naturally followed. The continued ravages of the elements during the growing season, culminating in the frost of September, 1917, naturally resulted in higher prices for the top grades. It is estimated that 40 per cent of the Connecticut valley sun-grown was injured by hail, wind or frost, while the loss in shade-grown was perhaps 3 per cent, nearly all caused by wind.

It would be difficult to indicate the average price for the 1917 crop because of damage by storm after contracts had been made in the field, and because of the almost unheard-of prices paid for damaged tobacco. But it is safe to say that prices ranged from 23 to 30 cents for the average run of stalk-cut Havana seed on early contracts, with the average at 26 cents and 30 cents for the leaf sold late. Primed Havana crops sold for about 34 cents, with the range from 28 to 45 cents. Broadleaf sold around 30 cents, with the range from 24 to 36 cents in the bundle, the latter price in South Windsor, Conn., for crops contracted late. Shade tobacco on contract ranged from 70 cents to $1.10 in bundles, 85 cents being the prevailing price.

Prices prior to the war varied more or less from year to year. The crop of 1915 was very poor in quality and of light weight, and prices were consequently low, averaging only 14.5 cents in Massachusetts and 16.43 cents in all New England.

The crop outlook varied in the other cigar leaf sections. The growing conditions indicated in midsummer a 95 per cent normal crop in Pennsylvania, an 80 per cent crop in Wisconsin, a 90 per cent crop in Ohio, and a 90 per cent crop in New York. Frost seriously damaged the Ohio crop, striking also 30 per cent of Pennsylvania acreage and 35 per cent of Wisconsin acreage.

Binder shortage presented the greatest problem of the cigar industry. Instead of 100,000 cases of binders which Wisconsin produces in normal years, the 1917 crop did not produce more than 15,000 cases. About 48,000 acres were planted in 1917, and this compared favorably with the average for the last five years. The crop was planted under favorable conditions, chiefly in the last part of June and the early part of July. A period of extremely dry weather, the late planting and an early frost caused Wisconsin to face a discouraging outlook for a fair yield of good binders. About 5,000 acres were cut by hail; about 7,000 acres were shredded before the frost; about 26,000 acres were frozen, a small portion only yielding some binders; and about 10,000 acres were badly frozen in the fields. A late harvest and very poor curing weather added to the loss.

This absolute scarcity of binders brought about unheard-of prices. The manufacturers paid as much or more for binders in 1917 and early 1918 as they did for wrappers two or three years ago. Not only is there a strong demand for binders, but filler tobacco has increased in proportion more than either binder or wrapper tobacco.

TABLE 32. — *Prices received by Farmers in the United States, 1899, 1909.*[1]

States.	Average Value per Pound (Cents).		Average Value per Acre.	
	1909.	1899.	1909.	1899.
New Hampshire,	13	15	$232 96	$256 15
Vermont,	11	15	169 09	272 61
Connecticut,	16	18	275 27	303 79
Massachusetts,	13	15	220 62	249 97
Florida,	29	23	257 20	123 64
Georgia,	20	14	146 75	69 30
New York,	08	08	97 96	103 67
Pennsylvania,	09	07	94 06	106 60
Ohio,	10	07	84 51	68 10
Wisconsin,	08	06	95 28	85 67
Kentucky,	10	06	84 86	48 19
South Carolina,	08	07	70 59	49 91
Virginia,	09	06	65 63	39 11
North Carolina,	10	06	62 41	39 59
Tennessee,	08	06	62 58	38 25
Maryland,	08	06	55 89	33 52
United States, average,	10	07	$80 55	$51 74

[1] United States Census, 1910.

TABLE 33. — *Average Farm Price of Cigar Leaf per Pound, December 1 (Cents).*[1]

	1900.	1905.	1910.	1915.	1917.	1918.
Connecticut,	15	17.0	16.5	17.0	38.4	44.0
Massachusetts,	15	16.9	15.0	14.5	38.4	40.0
New York,	8	10.5	8.5	9.5	22.0	30.0
Pennsylvania,	6	10.8	9.3	9.2	21.0	25.0
Ohio,	7	8.4	8.5	9.0	25.0	27.0
Wisconsin,	7	10.0	7.5	6.0	17.5	30.0

[1] United States Department of Agriculture Yearbook.

TABLE 34. — *Average Farm Price of Cigar Leaf per Pound in the Connecticut Valley (Cents).*

	Massachusetts.	New England.
1910,	15.0	12.91
1911,	18.0	18.10
1912,	20.9	21.06
1913,[1]	19.2	18.62
1914,[1]	17.7	18.32
1915,[1]	14.5	16.43
1916,[1]	18.0	19.20
1917,[1]	28.0	29.00

[1] Average prices for the season obtained from growers.

TABLE 35. — *Average Farm Prices per Pound in Massachusetts in 1916.*

Franklin County.

	Average on 12 Best Farms.	Average on 58 Farms.
Number of acres,	9.10	6.71
Yield per acre (pounds),	1,610	1,541
Price per pound,	$0.15	$0.13
Total receipts,	$2,235.00	$1,299.00

Hampshire County.

	Average on 19 Best Farms.	Average on 83 Farms.
Number of acres,	22.0	11.6
Yield per acre (pounds),	1,679	1,678
Price per pound,	$0.205	$0.187
Total receipts,	$7,527.000	$3,645.000

Hampden County.

	Average on 10 Best Farms.	Average on 44 Farms.
Number of acres,	18.20	9.05
Yield per acre (pounds),	1,751	1,724
Price per pound,	$0.27	$0.224
Total receipts,	$8,613.00	$3,506.000

Average price on 41 best farms, $0.208.
Average price on 185 farms, $0.18.

TABLE 36. — *Farmers' Prices in Leading Producing Areas in the Connecticut Valley in 1917.*

	Per Pound (Cents).
North Amherst, Mass.,	26
Sunderland, Mass.,	27
Hatfield, Mass.,	29
Hadley, Mass.,	29
South Deerfield, Mass.,	27
Westfield, Mass.,	29
Average,	27.8
Windsor, Conn.,	31
South Windsor, Conn.,	32
Broadbrook, Conn.,	28
Suffield, Conn.,	30
Granby, Conn.,	28
Average,	29.8

Wholesale Prices of Connecticut Valley Wrappers and Binders.

The following is a list of prices quoted to manufacturers printed by one of the largest leaf tobacco houses in the United States: —

TABLE 37. — *Wholesale Prices of Connecticut Valley Wrappers and Binders, February and March, 1918.*

Connecticut Havana Seed Wrappers.

Lot No.	QUALITY.	Price per Pound, Actual Weight.
197	Extra fancy, very light colors,	$1 75
198	Fancy, packed Sumatra style,	1 25
199	Old-fashioned, sun-grown wrappers, medium colors, perfect burn,	1 50
200	The finest East Hartford, light colors,	1 00
201	Extra fine, light colors, thin and silky,	90
202	Very fine, light colors, thin and silky,	85
203	Very fine, light to medium colors,	75
206	Our leader in splendid value, medium colors,	60
207	Medium to dark, leafy, fine quality and burn,	50
	Average,	$1 01

TABLE 37. — *Wholesale Prices of Connecticut Valley Wrappers and Binders, February and March, 1918* — Concluded.

Connecticut Broadleaf Wrappers.

Lot No.	Quality.	Price per Pound, Actual Weight.
218	Finest ever grown; fancy light,	$1 50
219	The limit of good quality,	1 25
220	Perfect Havana colors, finest quality grown,	1 15
221	Very fine, Havana colors, perfect quality,	1 00
222	Extra fine, brown Havana colors,	90
223	Fine light to medium Havana colors,	75
224	Very fine, dark brown colors, strictly quality,	90
225	Rich Havana colors,	75
	Average,	$1 02

Connecticut Primed Wrappers.

Lot No.	Quality.	Price per Pound, Actual Weight.
230	The very finest, light, primed wrappers,	$3 00
231	Extra fine, light, primed wrappers,	2 50
232	Very fine, light, primed wrappers,	2 00
233	Our leader in fine, light, primed wrappers,	1 50
234	Light to medium primed wrappers,	1 00
235	Extra fine, medium to light, "workers,"	75
	Average,	$1 79

Connecticut Havana Seed Binders.

Lot No.	Quality.	Price per Pound, Actual Weight.
239	The very finest Connecticut binders grown,	$0 68
240	Extra fine, seconds, light colors, Suffield-grown, 22 to 24 inches, contains many wrappers.	65
241	Fancy East Hartford seconds, full and thin,	60
242	Fine East Hartford seconds, thin and silky,	50
246	Good East Hartford binders, slightly broken,	35
248	Medium to dark wrappers,	50
249	Same, thin, leafy binders,	40
	Average,	$0 52

Connecticut Broadleaf Binders.

Lot No.	Quality.	Price per Pound, Actual Weight.
258	The very finest binders, a fine grade of seconds,	$0 70
259	Fine South Windsor, full of light, medium wrappers,	60
260	Fancy seconds,	55
261	Fine seconds, quality the best,	50
262	Fine quality, very leafy binders,	40
264	Connecticut broadleaf top leaves, fine quality fillers,	45
	Average,	$0 53

Another large cigar leaf tobacco house quoted practically the same prices to the manufacturers. These houses deal in good quality leaf, so that these prices are probably slightly higher than the average price paid by the manufacturer. Below is a list of wholesale prices obtained by interviewing the tobacco manufacturers in the valley, and from prices quoted by the Tobacco Merchants' Association of New York. These prices are certainly none too high, and presumably represent the average price paid by the manufacturer to the dealer for cigar leaf tobacco.

TABLE 38. — *Wholesale Prices of Havana Seed and Broadleaf.*

	Price Per Pound.	
Year 1915-16: —		
Light wrappers,	$0 60-$0 70	Average .46.
Medium wrappers,	35- 45	
Dark wrappers,	30- 35	
Spring of 1917: —		
Light wrappers,	70- 80	Average .55.
Medium wrappers,	45- 55	
Dark wrappers,	35- 45	
Fall and Winter, 1917: —		
Light wrappers,	1 00- 1 25	Average .75 for light, medium and dark; average .585 for light, medium, dark, seconds and brokens.
Medium wrappers,	60- 70	
Dark wrappers,	40- 55	
Seconds,	35- 45	
Brokens,	25- 30	
Spring of 1918: —		
Light wrappers,	1 25- 1 35	Average .90 for light, medium and dark; average .705 for light, medium, dark, seconds and brokens.
Medium wrappers,	70- 80	
Dark wrappers,	60- 70	
Seconds,	45- 55	
Brokens,	30- 35	

The above table shows clearly the rise in the wholesale prices of Havana seed and broadleaf tobacco from 1915 to 1918. The 1918 prices were just double those of 1915-16, yet the price to the farmer increased only 51 per cent, being about 40 per cent more than the price in 1916. The farmer sold his tobacco at from 25 to 30 cents a pound, and this same tobacco, deducting the loss in sweating and shrinkage, and 11 cents per pound for packing, making the cost to the dealer 43 to 48 cents a pound, was sold to the manufacturer for an average of 71 cents for all grades.

Sun-grown Tobacco: Analysis of "Spread," Grower to Manufacturer.

The table below gives the cost of marketing a pound of tobacco from the farmer to the manufacturer. Most of the tobacco is sold by the packer, or, theoretically, by the dealer whom the packer represents, directly to the manufacturer. This table shows the profits when sold by the dealer directly to the manufacturer. The farmer whose cost of production was ascertained received in 1917-18, for tobacco in the bundle, 29 cents a pound. It cost the landowner 23.7 cents and the tenant 26 cents per pound to produce the tobacco. The profit to the landowner was 5.3 cents and to the tenant 3 cents per pound. The dealer's cost of packing and selling, including the packer's salary and commission for buying, was 12 cents per pound. Adding to this the 29 cents paid the farmer we have a total cost to the dealer of 41 cents per pound. The average price received by the dealer per pound of tobacco was 71 cents. Hence the dealer's "profit" was 30 cents a pound. Naturally this situation cannot be continued indefinitely. These were war years. Moreover, there were many variations.

TABLE 39. — *Sun-grown Tobacco, 1917. Estimated Average Cost and Spread per Pound, Grower to Manufacturer.*

	Land-owner.	Tenant.	Percentage of Farm Price.		Percentage of Manufacturer's Cost.	
Farmer: —			Land-owner.	Tenant.	Land-owner.	Tenant.
Cost of production,	$0.237	$0.26	81.7	89.7	33.2	36.4
Farmer's margin,	.053	.03	18.3	10.3	7.4	4.2
Farmer's selling price,	$0.290	$0.29	100.0		40.6	
Dealer: —						
Salary of packer and buying commission,	.0067	.0067	2.4		1.0	
Cost of packing and selling,	.1130	.1130	39.0		15.8	
Dealer's margin over costs,	.3000	.3000	103.5		42.0	
Dealer's selling price: —						
60 per cent of crop at 90 cents per pound. 25 per cent of crop at 50 cents per pound. 15 per cent of crop at 33 cents per pound. Average,	.71	.71	244.9		99.4	
Broker's commission $1.50 per case,	.004	.004	1.4		.6	
Manufacturer pays,	.714	.714	246.3		100.0	

In the last analysis each tobacco handler pays his expenses and takes his profits out of the tobacco he handles. If we think of these items being paid in tobacco rather than in money the above facts may be presented from a different point of view. The farmer delivers to the local packer a case of tobacco of 350 pounds. The local packer or dealer takes the equivalent of 203 pounds, which represents the cost of packing, sweating, shrinkage, storage, transportation and other expenses from the time the tobacco reaches his hands until he receives his final check. The amount delivered to the wholesale distributor is 147 pounds. The wholesale distributor takes 30 pounds of the 147, so that the manufacturer receives only 117 pounds. The difference between 350 and 117 pounds, or 233 pounds, represents the cost of marketing tobacco in its natural or unmanufactured state. In other wor ds, the manufacturer pays as much for 117 pounds as the grower receives for 350 pounds. The wholesale distributor is included in the chain of middlemen because he handles a considerable amount of tobacco.

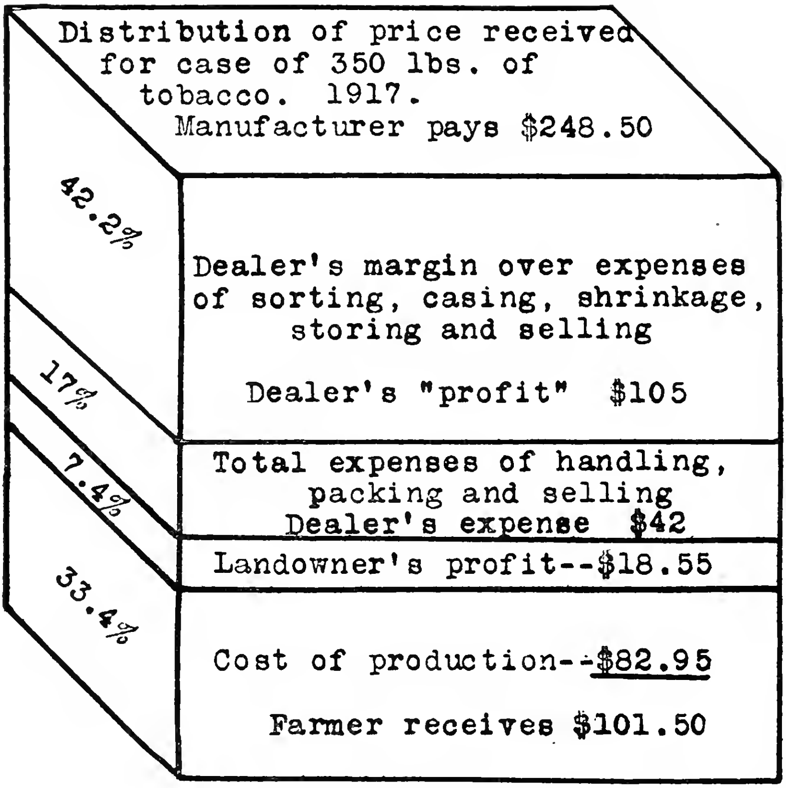


FIG. 19.— Sun-grown tobacco. Analysis of spread between grower and manufacturer on case of 350 pounds, 1917. Needless to say the figures are assumptions based on averages.

Farmers' Prices for Shade-grown Tobacco.

The shade-grown industry is peculiar in that the crop is largely produced by large syndicates and manufacturers. The American Sumatra Company has 1,500 acres in shade tobacco in Connecticut and Massachusetts. This company raises its own tobacco, sorts, packs and sells directly to manufacturers. The same is true of practically all the large syndicates. As previously stated, tobacco grown on contract by the farmer in 1917 ranged from 75 cents to $1.10 in the bundle, with the bulk at 85 cents. The range for the previous years was from 60 to 80 cents a pound, with the average at about 70 cents.

Wholesale Prices for Shade-grown Tobacco.

The wholesale prices of shade-grown tobacco from 1915 to 1917 reported by the Tobacco Merchants' Association, and secured through a personal interview with the tobacco manufacturers, are given in the following list: —

	Per Pound.
Finest grade, 1915 crop,	$2 00 to $2 75
Finest grade, 1916 crop,	2 00 to 3 00
Light to medium, 1916 crop,	75
Medium bright, 1916 crop,	1 00
Fancy medium brown, 1916 crop,	1 15
Finest grade, 1917 crop,	3 75
Fancy medium brown, 1917 crop,	3 50
Medium bright, 1917 crop,	3 00
Light to medium, 1917 crop,	2 00
Extra fine, light color, 1917 crop,	1 75
Fine, medium to light, 1917 crop,	1 50

It is difficult for the farmer who raises shade tobacco on contract at the present time to make any profit. The cost of production for 1916 has been estimated at 75 cents a pound for the man with an established business, and $1 a pound for the beginner. The large syndicates who raise, sort and pack their own tobacco and sell it directly to the manufacturer secure for themselves all profits between the producer and manufacturer, with an especially big profit on the shade-grown. But the large claims of clearing from $1 to $1.50 per pound on shade tobacco must be taken with some qualifications. The high cost of cloth, labor and supplies cuts deeply into the profits by greatly increasing the cost. On tobacco contracted by the farmer for from 65 cents to $1 a pound the dealer now clears about $1,000 per acre.

During 1917 Sumatra cost the manufacturer from $6 to $7 a pound, after adding the duty of $1.85 a pound. The large manufacturers claim that the Connecticut shade-grown is equally good, if not better, for wrapper purposes than the imported Sumatra.

Co-operation in Marketing Tobacco.

The Connecticut valley produces a wrapper leaf of superior quality, but so long as the method of sale by contract prevails, wastes and abuses are sure to occur. The only way whereby farmers will be able to realize a fair profit from their crop is through some form of co-operation, and few industries are so well adapted to co-operative organization as the tobacco industry. The acreage is large and fairly unified, making organization rather easy. Yet up to 1917 nothing had been done along this line in the Connecticut valley, and very little has been accomplished in other states. In the South tobacco is sold by auction, and uniform warehouse receipts are issued to the farmers. This method of sale has been very satisfactory, each farmer's crop being sold on its merits. The warehouse receipts enable the farmers to borrow money from any national bank to tide them over during the growing season.

There are 53 tobacco associations in the United States, 21 of which are in the State of Kentucky, 8 in Connecticut, 7 in Ohio, 5 in North Carolina, 5 in Virginia and 2 in Massachusetts. Of the 49 tobacco associations from which information was obtained as to the type of organization, only 17 are co-operative, the other 32 being joint stock companies.

Of the strictly co-operative associations 8 are in Connecticut, and 2 each in Massachusetts, Virginia and Kentucky. One of the Connecticut organizations has been in existence for some time, but the other 7 were organized very recently, the crop of 1918 being the first handled co-operatively.

The tobacco growers of the Massachusetts districts discussed the question of organization for some time, but no organizations were effected till the early part of 1919. Two associations are now in operation, one in the Hampden district and one in the Hatfield district. The matter is still under consideration in the Sunderland district, no association having as yet been formed.

These organizations control about 20 per cent of the total tobacco acreage of the Connecticut valley, and it is predicted that this proportion will soon be considerably increased.

The by-laws of one of these organizations are given in Appendix I.

The various co-operative associations of the tobacco growers of the Connecticut valley are federated into what is known as The Connecticut Valley Tobacco Growers, Incorporated, with headquarters in Hartford, Conn. The purposes of this federation are to supply an efficient selling agency for the member associations, to widen and improve the market for Connecticut valley tobacco, to establish uniform grades, to assist its members in standardization of the product, and to act as agent for the members in the purchase of supplies.

The by-laws of The Connecticut Valley Tobacco Growers, Incorporated, appear as Appendix II.

The warehouses of the 7 co-operative associations in Ohio are capitalized at $10,000 each, with twenty-five to seventy-five stockholders. Each handles the tobacco of from 150 to 200 growers, representing from 250,000 to 300,000 pounds per year. The best system in operation is probably that at Covington, Ky. In this company thirty-five stockholders own the building. These men pay no dues for having their tobacco worked, and dividends amounting merely to the interest are paid. In addition there are 150 members of the company who pay dues of $2 per year and a commission of 1½ cents per pound for having their tobacco worked. All patrons must be members of the Cigar Leaf Growers' Union. The company claims to have raised the price to the growers 2 cents per pound in normal years without any appreciable increase in the market price. The manager is bonded at $3,000. The growers are paid when the tobacco is sold. At the Troy warehouse one-half of the amount due is advanced at a discount of 7 per cent.

TABLE 40. — *Number of Tobacco-selling Associations in the United States, classified by States and Type.*[1]

State.	Number of Tobacco Associations.			Total.
	Co-operative.	Joint-stock.	Unknown.	
Massachusetts,	2	–	–	2
Connecticut,	8	–	–	8
Virginia,	2	3	–	5
North Carolina,	1	3	1	5
Ohio,	–	7	–	7
Kentucky,	2	17	2	21
Other States,	2	2	1	5
Totals,	17	32	4	53

[1] Data for states outside of the Connecticut valley from United States Department of Agriculture Bulletin No. 547.

RECOMMENDATIONS.

After a careful study of the tobacco industry in the valley, the following recommendations are offered: —

1. There should be in the hands of the farmers more general and definite information concerning the production (acreage, condition and yields) of tobacco. Farmers need to know the condition of the cigar leaf crop in all the cigar leaf producing states.

2. The grower should have more exact information on market conditions and prices to guide him in selling his crop.

3. A government reporter should be stationed in the valley to report weekly on the condition of the market and the prices. A weekly news letter should be sent to each tobacco farmer and dealer in the valley. This information should also be published in the newspapers.

4. Some improvements in sales methods are needed whereby the crop can be sold on its merits. The contract method of sale is fair neither to the buyer nor to the grower. The tobacco is sold while it is growing, or before it is planted, and no one can predict with certainty the quality of the crop. It is simply a gamble; the buyer gambles for the growers' crop, and he sets the price low enough to safeguard himself from loss.

Tobacco should be handled co-operatively by farmers, as described on page 213. This would permit each crop to be sold on its merits, and would eliminate some useless middlemen.

5. Farmers should be encouraged to keep cost accounts of production. Not one farmer in a hundred knows what it costs him to grow a crop of tobacco.

6. Every tobacco grower in the valley should take at least one good tobacco journal. The following journals are satisfactory: "The Tobacco

Leaf," published in New York, "The United States Tobacco Journal," published in New York, and "The Western Tobacco Journal," published in Cincinnati.

7. The tobacco growers should make more use of the various agencies which are in a position to assist them in producing and marketing their product, such as: —

(1) The United States Department of Agriculture, Washington, D. C. This office has tobacco specialists who will gladly assist in testing soils and furnishing information on the production of tobacco, and control of diseases and pests. This department publishes from time to time bulletins which the farmer should have, and which will be furnished free of charge.

(2) The Massachusetts Department of Agriculture, State House, Boston, Mass. This Department is interested in the production of farm crops in the state, and will gladly assist any farmer to obtain information concerning legislation and regulations dealing with diseases, pests, soils, fertilizers, etc. This information will be furnished from headquarters through reports, bulletins or correspondence.

(3) The Massachusetts Agricultural College, Amherst, Mass. The Agricultural Experiment Station and the Extension Service will assist growers in the production, handling and marketing of their crops. The Experiment Station has a tobacco specialist who is aiding the farmers in many ways along lines of production, soil and plant diseases, fertilizers, cover crops and the like. From the Extension Service a specialist on marketing and farmers' co-operative organizations will furnish information on marketing or assist in organizing farmers' co-operative purchasing and selling associations.

(4) The county farm bureaus. Each county has a farm bureau, working in co-operation with the United States Department of Agriculture and the Massachusetts Agricultural College, which is interested in the production and marketing of farm crops within the county. These bureaus will gladly aid individual tobacco growers in methods of production and handling their crops. Such information will be furnished by correspondence, personal interviews, demonstrations or reports.

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Appendix I.

BY-LAWS OF THE HAMPSHIRE COUNTY TOBACCO GROWERS, INCORPORATED.

Article I.

Name and Membership.

Section 1. The name of this corporation shall be the Hampshire County Tobacco Growers', Incorporated. Its principal office shall be located at Hadley, Mass.

Section 2. The voting membership of this corporation shall be confined to persons actually engaged in tobacco production at points tributary to the shipping stations of the corporation, who sell their products through the corporation, who have been approved as eligible candidates for membership by a majority vote of the directors, and who have paid their membership fees in full and agreed to conform to the provisions of the by-laws. No one who in the opinion of the directors is a professional buyer of tobacco shall be eligible to membership.

Section 3. Any member who in the opinion of the board of directors ceases to be a producer shall be dropped by a majority vote of the directors, but such action shall not invalidate any legitimate charges or accounts which the corporation has against the member so dropped. Such charges shall be a lien on any funds due the member from the corporation and on any loan notes required of the member by the by-laws of the corporation. A member dropped in this manner shall forthwith lose voting privilege in the corporation.

Section 4. Any member who violates his contract with the corporation may be expelled from membership in the corporation by a two-thirds majority vote of those present at any regular called meeting of the corporation, provided that notice of such proposed action was mailed to the person so dropped at least five days before date of such meeting, and provided that opportunity was given to the accused member to defend himself personally or by counsel and witnesses before such vote is taken. The financial conditions set forth in the preceding paragraph shall also apply in the case of a member expelled from the corporation.

Article II.

Purposes.

Section 1. The purposes of this corporation shall be to produce, sort, grade, pack, manufacture, sell, transport, store, market and otherwise handle for sale tobacco and other farm products; to secure and employ laborers and supervise labor contracts and conditions in the growing territory covered by this corporation; to own, lease, buy, build and otherwise acquire title to buildings, machinery and other property; to hold, use and operate the same for any lawful purpose; to buy, sell, transport, store, manufacture or otherwise deal or trade in food products, agricultural products or requirements, or any other products, animals, goods, articles or materials; to acquire any other rights, engage in any business, perform any other lawful acts or take any measures that the corporation may deem advisable for the purposes of protecting the property of the corporation or carrying into effect the foregoing purposes or furthering the interests of agriculture or country life.

Article III.

Board of Directors and Other Officers.

Section 1. The board of directors of this corporation shall consist of seven members divided into three classes. They shall be chosen by ballot by majority vote of those present and voting at the regular annual meeting of the corporation. At their first meeting the members shall elect three directors of the first class for a term of one year, or until next annual meeting; two directors of the second class for a term of two years, or until the second annual meeting; and two directors of the third class for a term of three years, or until the third annual meeting. At the expiration of the terms of the directors so elected their successors shall be chosen in like manner for terms of three years. Directors shall hold office until their successors have been elected and qualified.

Section 2. Within ten days following their election, and each annual election, the board of directors shall meet and elect by ballot from their own number a president and vice-president, whose terms shall be for one year. The board of directors may also appoint a manager, who may be the clerk or treasurer of the corporation.

Section 3. Four members of the board of directors shall constitute a quorum to do business at any meeting of the board.

Section 4. The other officers shall be a clerk, a treasurer, and a committee of audit of three members. They shall be elected by ballot at the annual election by the qualified voters from their own number. They shall hold office for one year and until their successors have been elected and qualified.

Section 5. Any director or officer of the corporation may, for cause, at any annual meeting or at any special meeting called for the purpose, at which a majority of the members shall be present, be removed from office by vote of not less than two-thirds of the members present. Such director or officer shall be informed in writing of the charges at least five (5) days before such meeting, and at such meeting shall have an opportunity to be heard in person, by counsel, and by witnesses, in regard thereto.

ARTICLE IV.

Vacancies.

SECTION 1. If a vacancy occur in the board of directors, it shall be the duty of the president to call a special meeting of the corporation to fill such vacancy, and such director shall hold office until his successor is elected and qualified.

SECTION 2. Other vacancies shall be filled by the directors at their first meeting after such vacancy occurs.

ARTICLE V.

Meetings.

SECTION 1. The annual meeting of the members of this corporation shall be held in Hadley, Mass., at a place designated by the board of directors, on the second Wednesday in April, at 11 o'clock A.M.

SECTION 2. One-fifth of the voting members shall constitute a quorum to do business at the annual or any special meeting.

SECTION 3. At the annual meeting reports shall be presented in writing by the board of directors, the regular officers, manager, the committee of audit, and other committees; directors, a clerk, a treasurer and a committee of audit shall be elected for the ensuing year. Such other business as may properly come before the meeting shall be transacted.

SECTION 4. Special meetings of the corporation may be called by the president or board of directors, and shall be called within seven days from receipt of written petition of seven members. The president shall give the members written notice of all annual or special meetings at least seven days previous to the date of such meeting, stating the purpose for which the meeting is called.

SECTION 5. The directors shall hold regular meetings to consider the business of the corporation on the first Saturday of each month at Hadley, Mass. Special meetings of the board of directors shall be held on call of the president, or within seven days from receipt of written petition of three members of the board. The president shall give the members of the board four days' notice of such meetings. The directors shall receive no remuneration for their services except that the clerk and treasurer may receive such compensation as may be determined by the corporation.

SECTION 6. The fiscal year of this corporation shall begin April 1, and end the following March 31.

ARTICLE VI.

Duties of Officers.

SECTION 1. The president shall preside at all meetings of the directors or members of the corporation, call all meetings of the board of directors and special meetings of the corporation except as otherwise provided, preserve order, sign all orders regularly passed bv the board of directors and attested by the clerk or manager, and perform all other duties appertaining to his office, or any other assigned him by the corporation. The president shall have no vote at any meeting except in case of tie.

SECTION 2. It shall be the duty of the vice-president to perform the duties of the president in his absence, or when for any reason the office of president may become vacant.

SECTION 3. The clerk shall keep a record of the proceedings of all meetings of the members and of the directors. He shall keep the corporate seal of the corporation and shall be custodian of all books, papers and other valuable instruments belonging to the organization. He shall keep all books of the issuance and withdrawal of certificates of membership and affix the seal of the corporation; he shall serve all notices and make all reports required by law or by the by-laws, and perform such other duties as may be required of him by the corporation or the board of directors.

SECTION 4. The treasurer shall receive all money due or paid to the corporation and deposit it as the directors may instruct; and pay out said funds upon his own order, countersigned by the president. He shall make full and detailed report of the financial condition of the corporation at the annual meeting of each year, and at such other times as called upon by vote of the members. He shall give bond in a sum and form to be approved by the board of directors, for the faithful performance of his duties and as surety for the funds, books, papers and other instruments of the corporation which may be placed in his custody. The cost of such bond may be borne by the corporation.

SECTION 5. The directors shall have general control and direction of the business and affairs of the corporation; they shall make all necessary rules and regulations for the management of the corporation and the guidance of the officers and employees; they shall perform all duties assigned them by the by-laws of the corporation. The directors may, by a majority vote, appoint or discharge any employee of the corporation, determine the duties of officers and employees, and fix their compensation, except as limited by the members. The directors may delegate the employment or discharge of laborers, agents or other employees to the manager.

SECTION 6. The manager shall have entire charge of the marketing and handling of the products of the corporation, of purchases made by the corporation for the members, and of the daily business transactions of the corporation subject to the oversight and supervision of the board of directors and the provisions of the by-laws and the growers' contracts. He shall have charge of the grading, packing, inspection, marketing, labeling and advertising of the products handled by the corporation. He shall supervise the making and execution of labor and crop contracts, and shall enforce their provisions. He shall assist in securing and furnishing to the members such market and crop information as they may desire concerning the products marketed by the corporation, and shall perform such other duties as the corporation or its directors may require. He shall attend the meetings of the board of directors and shall have the same right to originate and propose motions and amendments and to participate in deliberations as a director, but he shall have no vote in that body.

All payments over $5 made by the manager for purchases and general expenses shall be made by check signed by him and countersigned by the treasurer. He shall keep permanent record of all his business transactions.

The manager shall be required to give bond in a sum and form to be approved by the board of directors for the faithful performance of his duties, and as surety for the funds and property of the corporation which may be placed in his custody. The cost of such bond may be borne by the corporation.

Article VII.

Committee of Audit and Accounts.

Section 1. A committee of audit, consisting of three members, shall be elected by ballot at the annual meeting of the corporation. Officers and directors of the corporation shall be ineligible to membership on said committee.

Section 2. It shall be the duty of the committee of audit to examine and audit the books of the corporation at least twice a year, to report their findings to the board of directors, and to examine and audit the books, and report at such other times as may be ordered by the directors or by vote of the corporation. An audit by a competent accountant shall be made prior to each annual meeting and presented in detail at that meeting.

Section 3. The corporation shall install an adequate system of accounts and provide such accounting equipment as may be necessary to conduct the business in a safe and satisfactory manner.

Article VIII.

Membership Certificates and Fees.

Section 1. Upon entering the corporation and paying its membership fee the corporation shall issue to each member a certificate of membership signed by the secretary and countersigned by the president. Certificates of membership shall not be transferable.

Section 2. Each member shall pay in advance to the corporation a membership fee, and annual dues determined by the board of directors.

Section 3. Any member may withdraw from the corporation at any time between the first day of February and the first day of April following, provided that his indebtedness to the corporation is fully paid. Such withdrawal shall not affect any right or any lien which the corporation has against such member or his property.

Section 4. Any member, having a grievance or complaint against the corporation, may appeal to the board of directors or to the members at any regular or special meeting. No member shall be suspended or expelled or deprived of the benefits of the corporation without first having charges preferred against him, reasonable notice thereof having been given, and a hearing before the board of directors having been duly held.

Article IX.

Funds and Indebtedness.

Section 1. All funds belonging to this corporation shall be deposited in a bank or banks designated for the purpose by the board of directors.

Section 2. The amount of indebtedness which may be incurred by or on behalf of this corporation shall at no time exceed $50,000.

Section 3. The expenses of operating the corporation shall be met by a uniform percentage charge laid upon returns for produce sold or by a uniform fixed commission per package, and by a percentage charge upon supplies purchased, the amount of such charge to be fixed by the board of directors.

Article X.

Supplies.

Section 1. Merchandise or supplies may be ordered through the corporation by the members, and all business so transacted shall be conducted on a cash basis or on credit arranged for through some bank approved by the board of directors at the date of ordering.

Section 2. Supplies shall be sold to members of the corporation at prices determined by the board of directors.

Article XI.

Voting and Earnings.

Section 1. The voting membership of the corporation shall consist of those members who have paid in full their dues and fees and have satisfied any other obligations due the corporation and who have signed growers' contracts for the current year. Other persons who have paid their membership fees and dues, but who have not signed contracts for the current season, may retain their membership in the organization, but shall have no vote.

Section 2. Each member of the corporation shall have one vote and one only. Proxy voting shall not be permitted.

Section 3. The net receipts accruing from the business of the corporation shall be distributed on the pro rata basis of business of the members transacted through the corporation.

Article XII.

Capital.

Section 1. In order to provide capital for current needs and for the transaction of the necessary business of the corporation each member shall deliver to the corporation a negotiable promissory note payable on demand to the order of the corporation. Such note shall be for the sum of $50 and an additional $10 for each acre of tobacco to be grown by the maker to be marketed through the corporation. In no case shall this note be for a sum less than $60. Such note may be given at the time of joining the corporation, or at any time thereafter when called upon by the board of directors.

SECTION 2. The board of directors may pledge these notes as collateral security for any loan that may be necessary for conducting the business of the corporation. The note of any member may be available in settlement of any liquidated damage that may result from the failure of a member to live up to his contract with the corporation.

SECTION 3. For the purpose of buying, leasing or constructing land, warehouses or other necessary buildings, or in providing machinery or equipment, the board of directors may require each member to loan to the corporation an amount, to be determined by the board but based on acreage of tobacco, not less than $5 nor more than $15 in cash per acre during one year. Such loans may be required at the time of uniting with the corporation or at any time thereafter. They shall draw interest at the rate of 5 per cent per annum.

Such loans shall be repaid from a special loan fund collected by levying a percentage assessment on the produce sold and the supplies bought through the exchange, the amount of such percentage to be fixed by the board of directors; but not more than one-fifth of the entire loan and interest thereon shall be paid in any one year.

ARTICLE XIII.

Contracts.

SECTION 1. Every member of the corporation shall enter into a contract with the corporation in the form required by the board of directors. Such contract shall provide that the member appoints the corporation his sales agent, to handle all products grown by him for sale or purchased for his use, or such part thereof as shall be satisfactory to the board of directors, and obligates himself to deliver such products for sale at the time and place which the corporation directs. Said contracts shall run continuously unless cancelled by the member on April 1 of any year by giving written notice to the corporation at least sixty days prior to said date that he desires to cancel his contract, subject to any indebtedness due from him to the corporation, and by delivering his copy of the contract to the corporation on or before April 1. Said canceling of contract shall not apply to the previous year's crop.

SECTION 2. On or before April 1 of each year each member shall report to the corporation the number of acres of products to be grown by him and to be marketed through the corporation. During the year each member shall furnish such information concerning the products pledged to the corporation as may be requested by the manager.

The directors may authorize increases or decreases in the acreage reported by any member, as required by this section.

SECTION 3. In case any member is offered a price in excess of the price then obtainable by the corporation, said member shall turn over such bid to the corporation for filling from said grower's goods.

SECTION 4. Any member who fails to fulfill his contract or fails or refuses to market his tobacco through the corporation shall pay to the corporation, as liquidated damages, the sum of 5 cents for each pound of tobacco grown by him; and such damages may be deducted from any money in the possession of the corporation due the member. Any such claim shall be a lien upon the member's loan note.

ARTICLE XIV.

Amendments.

These by-laws may be altered or amended by a two-thirds vote of the members present at any regular annual meeting or at any special meeting called for the purpose, provided that the subject-matter of such an amendment shall have been presented in writing at a previous regular or special meeting, or is included in the notice calling such a meeting.

Appendix II.

BY-LAWS OF THE CONNECTICUT VALLEY TOBACCO GROWERS, INCORPORATED.

(1) This association shall be known as The Connecticut Valley Tobacco Growers, Incorporated, duly organized under chapter 190, revision of 1918 of the general statutes relating to co-operative associations. Its principal office and place of business shall be located in the city of Hartford, State of Connecticut, and it shall do business in the States of Connecticut and Massachusetts and elsewhere.

(2) The nature of the business to be transacted and the purposes to be promoted or carried out by said corporation are as follows: —

To provide and maintain for its members a selling agency through which they may sell their tobacco and do all things or acts necessary or convenient to make such selling agency efficient in assisting its members in marketing said tobacco; to enlarge and improve the market for Connecticut valley tobacco, and to aid in supplying manufacturers and others with good tobacco at a reasonable price; to assist its members in standardizing, sorting, packing and warehousing their tobacco, and to encourage the improvement of the products which it handles, either by trade-marks, by trade names or otherwise; to act as agent for its members in the purchase of any supplies which they may require; and to do any other lawful things which may be for the benefit of the members.

(3) Any local co-operative tobacco growers' association located in this State or in the State of Massachusetts may acquire and hold stock in this association.

(4) Each local association holding stock in this association shall elect two of its members to represent it in this association. At the annual meeting of this association these representatives shall elect from their own number a president, vice-president, secretary and treasurer, who shall hold office for one year, or until their successors are duly elected and qualified. These representatives shall constitute the board of managers of this association.

(5) In order that this association may have necessary working capital at the beginning of any season, each local association owning the stock of this association shall advance to the treasurer of this association, not later than August 15 of any year, the sum of $1 for each acre of tobacco represented by said local association.

(6) The capital stock which this association is authorized to issue is $50,000, divided into 500 shares of the par value of $100 each.

(7) SECTION 1. The annual meeting of this association shall be held at its office in Hartford on the third Saturday of July of each year. At this meeting officers shall be elected for the ensuing year; reports in writing presented by the president, treasurer and auditors; and such other business shall be transacted as may properly come before the meeting.

SECTION 2. Special meetings shall be held upon the call of the president, or within ten days of a written request of five members. Five days' notice of such meetings shall be given, and notices shall state the purpose for which said meeting is called.

SECTION 3. At all meetings a majority of the members shall constitute a quorum.

(8) The board of managers shall choose three auditors from among the members of the local associations owning stock in this association who are not directors, officers, agents or employees of this association. Such auditors shall hold office for one year, or until their successors are duly elected and qualified.

(9) Any vacancy in the offices of board of managers shall be filled for the unexpired term at any regular meeting or at any special meeting called for the purpose, in the manner provided for the original election of directors and officers.

(10) A majority of the members of the board of managers shall constitute a quorum at any meeting of the board.

(11) The board of managers shall manage the business affairs of the association, and make all necessary rules and regulations, not inconsistent with law or with these by-laws, for the management of the business and the guidance of the officers, employees and agents of the association.

(12) The board of managers may employ and dismiss for cause a general manager, and fix his compensation, who shall have charge of the business of the association under the direction of the board of managers. They may also employ and dismiss other employees and fix their compensation.

(13) The board of managers shall require the treasurer and all other officers, agents and employees, charged by the association with the responsibility for the custody of any of its funds or property, or to carry out any functions assigned them, to give bond with sufficient surety for the faithful performance of their official duties, the cost of said bonds to be paid by the association.

(14) The board of managers shall meet regularly once each month at the office of the association at a date and hour to be determined by them. Special meetings of the board shall be held upon the call of the president or upon written request of at least three members of the board. A majority of the members of the board shall constitute a quorum.

(15) It shall be the duty of the president to preside at all meetings of the association and of the board of managers; to sign, as president, with the treasurer, or in his absence, with the secretary, all checks, notes, deeds and other instruments in behalf of the association; to call special meetings of the association and of the board of managers, and perform all other acts and duties usually required of such officer.

(16) In the absence or disability of the president, the vice-president shall preside and perform the duties of the president.

(17) The secretary shall keep a complete record of all meetings of the association and of its board of directors; serve all notices required by law and by these by-laws; and keep a complete record of all business of the association, and make a full report of all matters and business pertaining to his office to the members at their annual meeting, and make all records required by law.

(18) The treasurer shall, with the president, sign all checks, notes, deeds and other instruments on behalf of the association; receive and disburse all funds and be the custodian of all property of the association; and perform such other duties as may be required of him by the association and the board of managers.

(19) Under the direction of the board of managers, the general manager shall employ and discharge all employees, agents and laborers. He shall secure information as to crop and market conditions, and shall furnish same to stockholders on request. He shall encourage the production of the best varieties of tobacco demanded by the trade. He shall, as may be required by the board of managers, provide a uniform system of assorting, grading and packing, and disseminate information regarding same among the local associations. He shall also provide and assist in installing uniform systems of accounting for the local associations. He shall inspect all products handled by the association, and shall prescribe the brands and labels of the association and their use of such products, in accordance with the rules of the association. Subject to the terms of the contracts made by the members with this association for the marketing of their products, and to the order of the board of managers and the by-laws and rules of this association, the general manager shall have charge of the sale and marketing of such products.

(20) All brands, labels, trade-marks and the like, established by this association for the protection of the products sold by it, shall be registered and become its property, and shall be attached only to such tobacco as shall be specified by the board of managers.

(21) Every local association owning the stock of this association shall enter into a contract with this association in the form to be agreed upon, subject, however, to the following provisions: —

(*a*) That said stockholder, by said contract, appoints The Connecticut Valley Tobacco Growers, Incorporated, its sales agent to sell its tobacco in such amount and condition and in such manner as the contract shall prescribe, and binds itself to deliver such products for sale at such time and place as this association directs.

(*b*) That said contract shall run continuously unless cancelled by either party on July 15 of any year, written notice having previously been given by one party to the other at least thirty days prior to that date, stating that it desires to cancel its contract; and subject to any indebtedness due from either party to the other.

(22) Each stockholder shall have a number or mark which shall be permanently stamped on every case or other package packed by him, or under his direction, for sale through this association. Any loss occasioned by improper packing or grading shall be chargeable to the stockholder whose mark is found on said package.

(23) Tobacco packed by, or for, any stockholder shall be inspected by an inspector of this association to establish uniformity of grades.

(24) Any stockholder may withdraw from this association on the fifteenth day of July by giving written notice to the board of managers thirty days before said date, and by transferring his holdings to the association at their book value as shown by the last official report of the association, but at not less than the par value of the shares. Such withdrawal shall not affect any right of lien which the association has against the withdrawing member or his property until his indebtedness to the association is fully paid. Said transfer of shares shall be made only upon the books of this association.

(25) Any stockholder having a grievance or complaint against the association may appeal to the board of managers or to the members at any regular or at any special meeting. No member shall be suspended or expelled or deprived of the benefits of the association without first having charges preferred against him, reasonable notice thereof having been given and a hearing before the board of managers having been duly held.

(26) After a season's expenses are paid, a sum equal to 10 per cent of the net savings of the association for the past year shall be set aside for a contingent fund until there shall have been accumulated thereby a sum equal to 20 per cent of the capital stock of the association. The balance of the season's savings on products shall be divided among local associations holding the stock of this association in proportion to the amount or value of their products sold, and the balance of the season's savings purchased shall be divided in like manner.

(27) Any stockholder who fails to perform his agreement, or fails or refuses to market his tobacco through this association, as provided in his contract with this association, shall pay to this association, as liquidated damages, the sum of 2 cents for each pound of tobacco which he fails to deliver, and such damages may be deducted from any money in the possession of the association due the stockholder.

(28) The books and business of this association shall be audited quarterly by auditors selected, as aforesaid. A complete annual audit shall be made previous to the date of each annual meeting, at which meeting the auditor's report shall be presented in full. Special audits shall be made upon order of the board of managers, or upon a majority vote of the members at any regular or at any special meeting.

(29) These by-laws may be amended or repealed at any meeting by a two-thirds vote of the members present, provided that notice of such proposed amendment or repeal is included in the call for said meeting, and provided that such changes shall be approved by the local associations.

BULLETIN No. 194 DECEMBER, 1919

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

A Fertilizer Experiment with Asparagus

By W. P. BROOKS and F. W. MORSE

This bulletin contains a description of a fertilizer experiment with asparagus on typical asparagus land in the town of Concord. The experiment was planned and supervised by Dr. Wm. P. Brooks while Director of the Experiment Station, and his comments and conclusions follow the description.

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
Amherst, Mass.

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BULLETIN No. 194.

DEPARTMENT OF AGRICULTURE.

A Fertilizer Experiment with Asparagus.

DESCRIPTION OF THE EXPERIMENT.

F. W. MORSE.

The fertilizer experiment with asparagus reported in the following pages was planned and supervised by Dr. Wm. P. Brooks, then director of the Experiment Station. The experiment was conducted in the town of Concord, on land owned by C. W. Prescott, and arrangements were made with him to act as superintendent of the substation. The plans prepared by Dr. Brooks for the experiment were executed by Mr. Prescott throughout the entire period from 1906 to 1915. His interest in the work and his careful attention to all its details permitted the successful conduct of the substation and the satisfactory completion of the fertilizer comparisons. Valuable assistance was given each year by Prof. J. B. Norton of the United States Department of Agriculture, who was stationed at the field for the purpose of developing a rust-resistant type of asparagus, and who took an active interest in the fertilizer experiment. This description of the experiment has been prepared by the writer, who was engaged on chemical studies of the asparagus plant which gave opportunity for familiarity with the fertilizer comparisons, although he had no part in the planning and supervision of the experiment which were solely the work of Dr. Brooks.

The land selected for the experiment lies on Bedford Street in the town of Concord.[1] For a number of years prior to its selection the field had lain fallow, and was overgrown with weeds, blackberry vines and small birches. It was considered to be typical of the fields used for asparagus culture in the vicinity, where the crop is largely grown, and the soil was deemed to contain only the natural store of fertility.

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[1] Mass. Agr. Expt. Sta., 20th Ann. Rept., p. 16.

The field is part of a sandy plain in the area drained by the Concord River, a tributary of the Merrimac, and its soils would probably be classed with the Merrimac Series described by the United States Bureau of Soils.[1] It consists of a coarse, sandy loam about 2 feet in depth, underlaid by several feet of sand and gravel, as shown by a railroad cut about 200 yards distant from the plots.

The land was cleared of bushes, and in May, 1906, it was plowed, the soil being turned over to a depth of 8 to 9 inches. The field was repeatedly harrowed with a disc harrow to pulverize the turf and kill the weeds. Late in June an application of fertilizers was made to each acre, consisting of —

	Pounds.
Fine ground bone,	1,000
Acid phosphate,	600
Muriate of potash,	350
Nitrate of soda,	150

The fertilizers were thoroughly mixed with the soil by the harrow. About two weeks later 2,000 pounds of agricultural lime per acre were applied and harrowed in.

Just after the middle of July buckwheat was sown. The crop made a vigorous growth and reached a height of 36 to 42 inches when in full bloom, about the third week in September, at which time it was plowed under. After harrowing the field it was sown with winter rye and rolled, which completed the work on the field for the year.

In April, 1907, the rye was plowed under, the field was harrowed and rolled, and then laid out in plots for the experiment.

Forty plots of one-twentieth acre each were arranged in two parallel groups of 20 plots. Each one measured 129 feet in length by 16 feet, 10.5 inches in width, and was separated from the adjacent plots by division strips which measured 5 feet, 1.5 inches in width. Each plot contained five rows of plants which were set 30 inches apart in the row, thus permitting 250 plants per plot, or 5,000 per acre. Each division strip also had a row of plants through the center, by which arrangement all rows on the plots were under closely similar conditions of space and light for their development.

The plants were grown by Mr. Frank Wheeler of Concord from a strain of Giant Argenteuil which had been selected by him for its vigorous growth and resistance to rust. They were one year old and exceptionally large and strong. The crowns were placed in the furrows at a depth of 6 inches below the level surface of the field. After the plants were set the first lot of fertilizers prescribed by the experiment for each plot was applied. The description of these fertilizers will be given later when the results of the experiment are considered.

Practically all the plants lived and made a vigorous start. Their growth throughout the season was strong, and numerous stalks attained

[1] U. S. Dept. Agr., Bur. of Soils, 8th Rept. (1906), pp. 57–63; Bul. No. 55 (1909), p. 158.

a height of 6 feet before growth ceased for the season. Beetles were numerous, but were held in check by spraying with arsenical insecticides, lead arsenate proving most satisfactory.

In September oats were sown as a cover crop, which made a good growth before winter set in. Before the buds started in the spring of 1908, as soon as the soil could be worked, the dead tops and cover of oats were worked into the soil with the disc harrow, and the prescribed fertilizers were applied to the different plots. The young shoots were of such size and appearance that Mr. Prescott made three cuttings in early May, and though the roots were but two years old from the seed, some stalks were an inch in diameter.

It was noted that the violent spring winds seriously affected some of the plots by blowing the sharp sand against the young shoots. To prevent this a windbreak of cotton cloth tacked to posts was maintained during the early part of the season while the stalks were tender. The field was kept free from weeds by summer tillage, and the beetles were held in check by a lead arsenate spray. The growth of the plants was excellent, and the tops at the end of the season nearly filled the spaces between rows.

In the succeeding years of the experiment the culture and fertilization were conducted in general as in 1908.

The cutting season in 1909 lasted about four weeks, but in subsequent years the stalks were harvested each season for about two months. The limits of the cutting season for each year were as follows: —

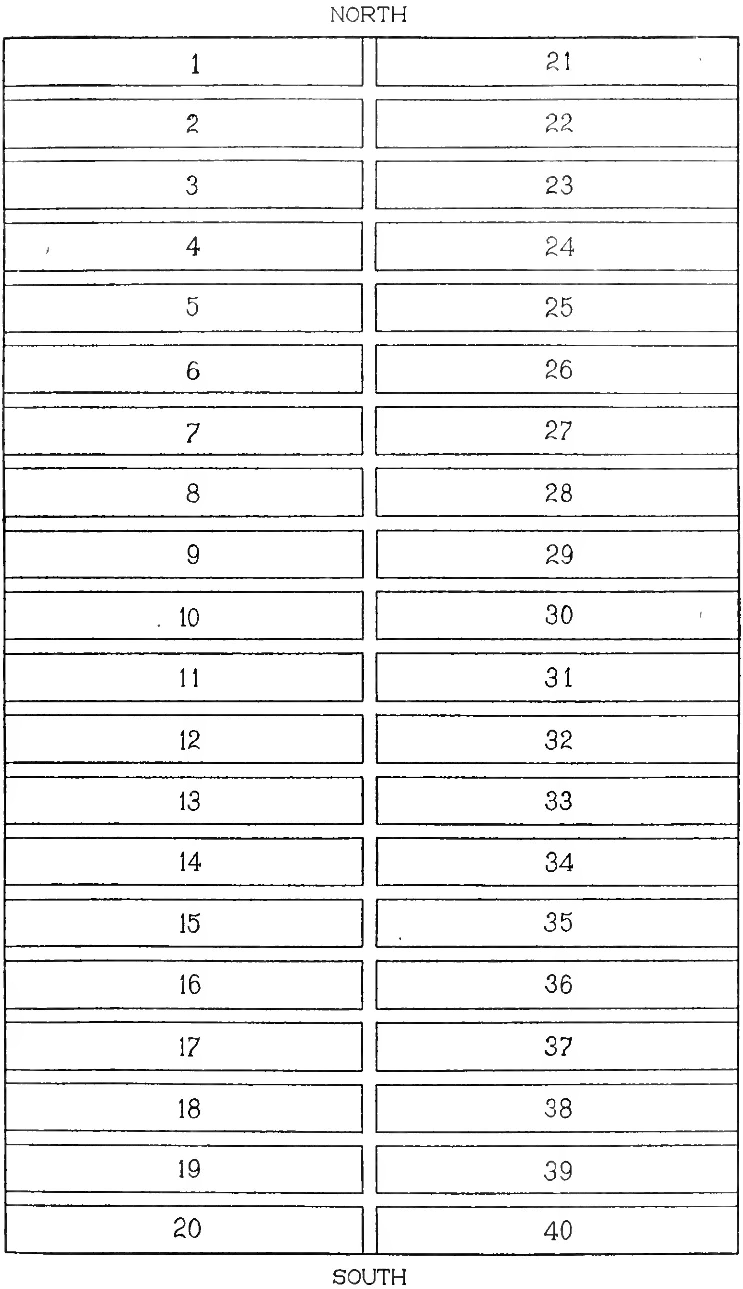
1909, May 7 to June 6.
1910, April 23 to June 29.
1911, May 8 to June 24.
1912, May 5 to June 25.
1913, April 27 to June 27.
1914, May 8 to June 27.
1915, April 26 to June 26.

In the summer of 1910 portions of the field were attacked by rust. The rust spores came from an adjoining field on the north, and the disease was severest at the outer edge, diminishing in intensity toward the middle of the lot. Plots 1 and 21 were most affected, and plots 11 and 31 were apparently uninjured. A slight attack occurred from the southeast on plots 33 to 40, but it did not seem to affect the yields noticeably. The attacks were not serious in succeeding years, and the plots appeared to recover fully before the close of the experiment.

In April, 1907, before the field was divided into plots, samples of the soil were taken by Mr. Prescott, in accordance with Dr. Brooks' instructions, from each quarter of the field. These samples were analyzed by E. B. Holland and R. D. McLaurin of the department of chemistry. The determinations of the soil constituents were made in solutions obtained with hydrochloric acid, after the methods of the Association of Official Agricultural Chemists.

TABLE I. — *Composition of Soil (Per Cent).*

	Southeast.			Southwest.			Northeast.			Northwest.		
	Surface.	First Foot.	Second Foot.	Surface.	First Foot.	Second Foot.	Surface.	First Foot.	Second Foot.	Surface.	First Foot.	Second. Foot.
Coarse material above 0.5 millimeter,	18.97	-	-	13.96	-	-	14.55	-	-	12.95	-	-
Fine earth,	81.03	-	-	86.04	-	-	85.45	-	-	87.05	-	-
Analysis of Fine Earth.												
Insoluble matter,	89.43	91.012	92.290	89.86	93.321	94.035	90.49	93.307	95.621	90.27	92.842	96.036
Potash (K_2O),	.09	.096	.105	.09	.093	.123	.10	.102	.096	.07	.087	.089
Lime (CaO),	.20	.080	.070	.22	.135	.097	.23	.060	.061	.22	.036	.059
Magnesia (MgO),	.07	.010	.019	.02	.029	.001	.02	.022	.041	.01	.003	.021
Phosphoric acid (P_2O_5),	.25	.030	.033	.21	.039	.060	.27	.052	.048	.20	.080	.039
Sulfuric acid (SO_3),	.04	-	-	.04	-	-	.04	-	-	.05	-	-
Volatile matter,	4.26	2.613	1.881	4.55	2.117	1.175	4.14	2.173	.791	4.25	2.709	.800
Humus,	1.97	-	-	1.94	-	-	1.85	-	-	1.78	-	-
Total nitrogen (N),	.13	.052	.024	.14	.054	.014	.13	.044	.014	.13	.055	.008



PLAN OF FIELD

The different samples show a marked uniformity in the percentage of constituents, which are low with the exception of phosphoric acid in the surface soil. This marked proportion of phosphoric acid in the surface soil is not due to the liberal application of phosphatic fertilizers, however. Assuming the surface soil of an acre to weigh 2,000,000 pounds, there are 5,000 pounds of phosphoric acid contained in it. The fertilizers applied to an acre contained approximately 350 pounds. The vegetable matter in the surface soil is probably the means by which the phosphoric acid, lime and nitrogen are accumulated in the surface layer when compared with the lower depths.

There is observable a small difference in the proportion of fine soil in the sample from the southeast quarter, which may in part account for a poorer yield of asparagus from the plots on that area.

The arrangement of the plots is shown in the plan on page 235, and the kinds of fertilizers and the yearly yields of asparagus are given in Table II.

TABLE II. — *Yields per Plot (Pounds).*

Plot.	Fertilizers applied.	Pounds.	1909.	1910.	1911.	1912.	1913.	1914.	1915.
1	Nitrate of soda, Acid phosphate, Muriate of potash,	– 6.67 13.00	109.3	229.9	182.2	197.5	310.7	346.4	305.4
2	Nitrate of soda, Acid phosphate, Muriate of potash,	15.56 6.67 13.00	110.8	236.6	212.3	230.6	350.2	406.8	367.2
3	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 13.00	110.6	256.8	236.8	263.8	386.9	423.5	394.8
4	Nitrate of soda, Acid phosphate, Muriate of potash,	31.12 6.67 13.00	112.3	236.1	226.2	265.5	379.9	413.4	387.5
5	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 – 13.00	115.4	232.3	221.1	270.9	388.0	404.3	382.3
6	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 4.44 13.00	121.4	241.4	221.1	273.4	385.8	420.4	391.3
7	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 13.00	110.0	241.6	240.8	281.1	387.8	436.9	415.4
8	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 8.89 13.00	123.6	252.8	252.6	298.4	403.3	436.4	412.1
9	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 –	103.2	208.6	210.6	258.6	324.0	366.7	334.6
10	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 8.67	117.9	237.2	237.3	284.8	373.6	408.4	387.6
11	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 13.00	136.1	277.8	290.1	342.1	446.8	478.9	433.9
12	Nitrate of soda, Acid phosphate, Muriate of potash,	23.33 6.67 17.33	126.1	262.7	269.6	302.8	409.8	458.5	417.9

TABLE II. — *Yields per Plot (Pounds)* — Continued.

Plot.	FERTILIZERS APPLIED.	Pounds.	1909.	1910.	1911.	1912.	1913.	1914.	1915.
13	Manure, ... Nitrate of soda, . . Acid phosphate, . . Muriate of potash, . .	1000. - - -	112.1	241.8	274.9	315.6	409.4	440.6	386.1
14	Manure, ... Nitrate of soda, . . Acid phosphate, . . Muriate of potash, . .	1000. 15.56 4.44 8.67	105.8	242.9	287.4	329.0	411.4	431.1	382.6
15	Manure, ... Nitrate of soda, . . Acid phosphate, . . Muriate of potash, . .	1000. 23.33 6.67 13.00	120.4	260.1	291.4	337.4	435.3	453.5	408.2
16	Manure, ... Nitrate of soda, . . Acid phosphate, . . Muriate of potash, . .	1000. 31.12 8.89 17.33	112.9	244.8	273.8	336.4	422.0	438.4	412.1
17	Nitrate of soda, . . Acid phosphate, . . Wood ashes, . . .	23.33 6.67 130.00	97.8	204.4	257.9	287.3	372.8	373.5	342.4
18	Nitrate of soda, . . Acid phosphate, . . High-grade sulfate of potash, ...	23.33 6.67 13.00	77.3	181.6	224.1	266.0	327.0	327.1	306.2
19	Nitrate of soda, . . Acid phosphate, . . Low-grade sulfate of potash, ...	23.33 6.67 25.00	84.8	190.5	240.6	276.6	327.3	345.9	305.8
20	Nitrate of soda, . . Acid phosphate, . . Kainit, ...	23.33 6.67 50.00	108.9	223.9	248.2	308.2	375.7	396.7	371.6
21	Manure, ...	1000.	103.3	237.4	191.4	202.9	347.8	373.8	343.1
22	Manure, ... Nitrate of soda (spring),	1000. 15.56	100.0	226.2	199.4	216.5	346.2	361.7	339.6
23	Manure, ... Nitrate of soda (summer),	1000. 15.56	103.3	247.1	218.0	252.2	378.6	385.5	352.8
24	Manure, ... Nitrate of soda (spring and summer), . .	1000. 15.56	101.4	230.2	223.5	250.2	380.4	387.6	365.6
25	Manure, ... Nitrate of soda (spring), .	1000. 23.33	103.1	222.2	220.8	273.5	382.1	388.3	365.2
26	Manure, ... Nitrate of soda (summer),	1000. 23.33	106.0	213.4	227.4	277.3	393.6	390.4	381.8
27	Manure, ... Nitrate of soda (spring and summer), . .	1000. 23.33	107.1	225.4	225.7	283.8	386.7	413.2	378.9
28	Manure, ... Nitrate of soda (spring), .	1000. 31.12	102.0	214.1	218.4	273.0	370.4	400.0	376.6
29	Manure, ... Nitrate of soda (summer),	1000. 31.12	94.2	187.6	205.3	256.8	353.1	373.3	351.9
30	Manure, ... Nitrate of soda (spring and summer), . .	1000. 31.12	104.3	216.4	238.3	296.3	390.4	423.2	390.1
31	Nitrate of soda (spring), . Acid phosphate, . . Muriate of potash, . .	15.56 6.67 13.00	117.3	220.9	223.8	272.4	375.1	395.8	370.0

TABLE II. — *Yields per Plot (Pounds)* — Concluded.

Plot.	FERTILIZERS APPLIED.	Pounds.	1909.	1910.	1911.	1912.	1913.	1914.	1915.
32	Nitrate of soda (summer), Acid phosphate, . . Muriate of potash, .	15.56 6.67 13.00	115.9	221.3	242.4	284.4	401.6	406.3	374.8
33	Nitrate of soda (spring and summer), . . Acid phosphate, . . Muriate of potash, .	15.56 6.67 13.00	101.8	222.6	239.8	291.2	378.4	389.8	372.9
34	Nitrate of soda (spring), . Acid phosphate, . . Muriate of potash, .	23.33 6.67 13.00	96.4	214.3	240.5	288.0	381.9	378.6	350.8
35	Nitrate of soda (summer), Acid phosphate, . . Muriate of potash, . .	23.33 6.67 13.00	97.6	217.1	247.8	288.9	368.3	368.4	353.7
36	Nitrate of soda (spring and summer), . . Acid phosphate, . . Muriate of potash, . .	23.33 6.67 13.00	99.6	210.2	224.2	268.5	357.4	362.3	337.0
37	Nitrate of soda (spring), . Acid phosphate, . . Muriate of potash, . .	31.12 6.67 13.00	96.1	193.9	223.3	283.8	345.2	340.9	327.7
38	Nitrate of soda (summer), Acid phosphate, . . Muriate of potash, .	31.12 6.67 13.00	93.6	196.2	234.9	303.0	367.1	347.4	335.4
39	Nitrate of soda (spring and summer), . . Acid phosphate, . . Muriate of potash, . .	31.12 6.67 13.00	94.4	214.2	230.7	288.4	358.6	351.7	328.7
40	Nitrate of soda, . . Acid phosphate, . . Muriate of potash, . .	– 6.67 13.00	84.0	181.3	202.2	263.4	307.5	314.3	275.1

One change was made in the fertilizers in the spring of 1912, when the quantity of acid phosphate was increased so that the low, medium and high amounts were, respectively, 10, 15 and 20 pounds, instead of 4.44, 6.67 and 8.89, as tabulated.

The chemicals were standard high-grade materials, and were analyzed each year to check their guarantees.

Acid phosphate contained 14 per cent soluble and available phosphoric acid. Wood ashes carried slightly more than 5 per cent of potash. The stable manure varied but little from 70 per cent moisture, 0.7 per cent nitrogen, 0.5 per cent phosphoric acid, and 0.7 per cent potash.

The asparagus was cut regularly and prepared for market. The weights were made before the stalks were bunched and trimmed, and the yields therefore include the butts and waste stalks with the marketable crop. No data were secured from which to estimate the probable marketable bunches per plot, but the estimate of practical growers is that the waste involved in preparation for market constitutes about one-fifth of the total weight cut.

The attack of summer rust in 1910 caused the affected plots to produce less weight in 1911 than in 1910, which is shown clearly by the table. The plots thus affected were Nos. 1 to 10 and 21 to 27. Plots 37 to 40 were somewhat affected without showing it in a depressed yield. The yields for 1914 and 1915 showed a nearly complete recovery from the rust. The percentages of increase of the crops for 1914 over those of 1910 were determined and the recovery was well shown, except in plots 1, 21, 22 and 23, which were most severely affected. The percentages of increase on these plots were, respectively, 51 per cent on plot 1, 57 per cent on plot 21, 59 per cent on plot 22, and 56 per cent on plot 23. On the rest of the plots the majority of percentages of increase ranged between 70 and 80 per cent, with a few above 80 per cent, and the recovery from the rust attack on plots 2 to 10 and plots 24 to 29 was evidently thorough.

The effect of the rust has been considered in comparing the relative effects of different methods of fertilizing the crop, and the yields for the years 1911, 1912 and 1913 have been omitted from the comparisons. The results of the first two years and the last two years are sufficient, however, to give a good view of the effects, since the former serve to show the immediate and the latter the cumulative effects of the fertilizers.

When the crop yields of the different plots are surveyed as a field it will be noted that plots 11, 12, 13, 31, 32 and 33 yielded out of proportion to the rest of the field, and from the plan it will be seen that these plots formed a section across the middle of the field. This persistently high yield could not have been caused by the fertilizers, but was probably due to a slightly greater depth of soil above the underlying gravel, by which the plants had a slightly greater supply of moisture throughout the season.

Plots 3, 7, 11 and 34 were fertilized exactly alike with the medium quantities of nitrogen, phosphoric acid and potash. Plots 21 and 13 received equal amounts of manure with no chemicals. Plots 1 and 40 received medium weights of acid phosphate and muriate of potash without nitrogen. From these plots it can be seen that the western half of the field, including plots 1 to 20, was more productive than the eastern sections, containing plots 21 to 40. The southeastern corner, plots 34 to 40, was the poorest part of the field, all things considered, which may have been due to the slightly coarser character of the soil, as mentioned with the analyses.

Plot 11 has produced the biggest weight of stalks every year, although by no means the most heavily fertilized.

Asparagus is considered to be a hearty feeder, and to require an abundance of plant food to produce profitable results. Three groups of plots were planned to compare graduated amounts of chemical fertilizers. These plots were Nos. 1 to 12. Table II shows the yields. This section was attacked by rust, as already described, but plot 1 alone failed to recover completely from its effects by the year of maximum production, 1914. It is clearly demonstrated that the maximum amounts of fertilizer were of no appreciable effect, and that the medium quantities were ample for a full yield. The actual need of the medium amount of nitrate of soda indicated by plots 2 and 3 is contradicted by the results from plots 31 and 34 when they are compared in like manner. The soil conditions on the latter plots have been already mentioned and should be taken into account. Its poorer quality may have offset the increased amount of nitrate.

The relative effects of manure and chemicals were compared on plots 13 to 16, and the comparison may also be extended to plots 11 and 12 adjacent to 13. The best interpretation of the results is to say that manure alone and chemicals alone were equally effective, and that the respective quantities of each were sufficient for the soil conditions in producing a crop. There is also no appearance of any cumulative effect of the manure in increasing the crop. The gains of 1914 over 1910 were as follows: plot 11, 72 per cent; plot 12, 74 per cent; plot 13, 82 per cent; plot 15, 74 per cent; plot 16, 79 per cent. This is of interest when one considers the sandy soil and low humus content.

TABLE III. — *Chemicals supplying Nitrogen, Phosphoric Acid and Potash in Connection with Manure (Pounds).*

Plot.	Fertilizer Treatment.	1909.	1910.	1914.	1915.
13	Manure alone,	112 1	241.8	440.6	386.1
14	Manure with low chemicals,	105.8	242.9	431.1	382.6
15	Manure with medium chemicals,	120.4	260 1	453.5	408.2
16	Manure with high chemicals,	112.9	244.8	438.4	412.1
21	Manure alone,	103 3	237.4	373.8	343.1
3	Medium chemicals alone,	110.6	256.8	423.5	394.8
7	Medium chemicals alone,	110.0	241.6	436.9	415.4
11	Medium chemicals alone,	136.1	277.8	478.9	433.9
34	Medium chemicals alone,	96.4	214.3	378.6	350.8
12	Chemicals high in potash,	126.1	262.7	458.5	417.9

Plots 21 to 30, inclusive, were fertilized to determine the value of nitrate of soda as a top-dressing in addition to an application of 10 tons of manure. The value of the added nitrate was rendered questionable by the rust which has been shown to have severely reduced the yields of plot 21 even in 1914, when most plots had apparently recovered. The yield on plot 13, receiving manure alone, was increased 82 per cent in 1914 over the yield in 1910. If the 1910 yield of plot 21 is increased by 75 per cent and compared with the actual yield in 1914 it is seen to be 415 pounds instead of 373.8, which would bring it up to a full equality with the yields of the plots which received nitrate of soda. The economy of the added nitrate is made doubtful.

There were three methods of applying the nitrate of soda, and the results are decidedly in favor of the application in two portions, half in spring and half in summer.

TABLE IV. — *Nitrate of Soda applied at Different Seasons in Addition to Manure (Pounds).*

Plot.	Season of applying Nitrate.	1909.	1910.	1914.	1915.
	Manure with Low Application of Nitrate of Soda.				
22	Spring, ...	100.0	226.2	361.7	339.6
23	Summer, ...	103.3	247.1	385.5	352.8
24	Half in spring, half in summer, . .	101.4	230.2	387.6	365 6
	Manure with Medium Application of Nitrate of Soda.				
25	Spring, ...	103.1	222.2	388.3	365.2
26	Summer, ...	106.0	213.4	390 4	381.8
27	Half in spring, half in summer, . .	107.1	225 4	413 2	378.9
	Manure with High Application of Nitrate of Soda.				
28	Spring, ...	102.0	214 1	400 0	376.6
29	Summer, ...	94.2	187.6	373 3	351.9
30	Half in spring, half in summer, . .	104 3	216.4	423.2	390.1

A similar comparison of different quantities and methods of application of nitrate of soda with chemicals instead of manure was made on plots 31 to 39. The yields on the minimum amount of nitrate were unquestionably superior to those on the higher amounts. It has, however, been pointed out that there seemed to be a lower state of fertility in this corner of the field where the larger quantities of nitrate were used, and that plots 31 and 32 were in a strip of superior fertility. In this series there is a slight advantage in favor of applying the nitrate in the summer at the end of the cutting season, since in four years out of seven each of the summer plots out-yielded slightly the others. The difference is not enough to make it a rule to apply nitrate only in the summer.

TABLE V. — *Effect of applying Nitrate of Soda at Different Seasons in Connection with Fertilizers supplying Phosphoric Acid and Potash (Pounds).*

Plot.	Season of applying Nitrate.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	Average.
	Low Application of Nitrate of Soda.								
31	Spring, . . .	117.3	220.9	223.8	272.4	375.1	395.8	370.0	282.2
32	Summer, . .	115.9	221.3	242.4	284 4	401.6	406.3	374.8	292 4
33	Half in spring, half in summer.	101.8	222.6	239.8	291.2	378.4	389.8	372.9	285.2
	Medium Application of Nitrate of Soda.								
34	Spring, . . .	96.4	214.3	240.5	288.0	381.9	378.6	350.8	278.6
35	Summer, . .	97.6	217.1	247.8	288.9	368 3	368.4	353.7	277.4
36	Half in spring, half in summer.	99.6	210.2	224.2	268 5	357.4	362.3	337.0	265.6
	High Application of Nitrate of Soda.								
37	Spring, . . .	96.1	193.9	223.3	283.8	345.2	340.9	327.7	258.7
38	Summer, . .	93.6	196.2	234.9	303.0	367.1	347.4	335.4	268.2
39	Half in spring, half in summer.	94 4	214.2	230.7	288.4	358.6	351.7	328.7	266.7

The inferiority of this corner of the field is clearly indicated by comparing the annual yields of plot 40 with those of plot 1, which was fertilized exactly like it. In the years of no rust plot 1 produced much larger yields than plot 40.

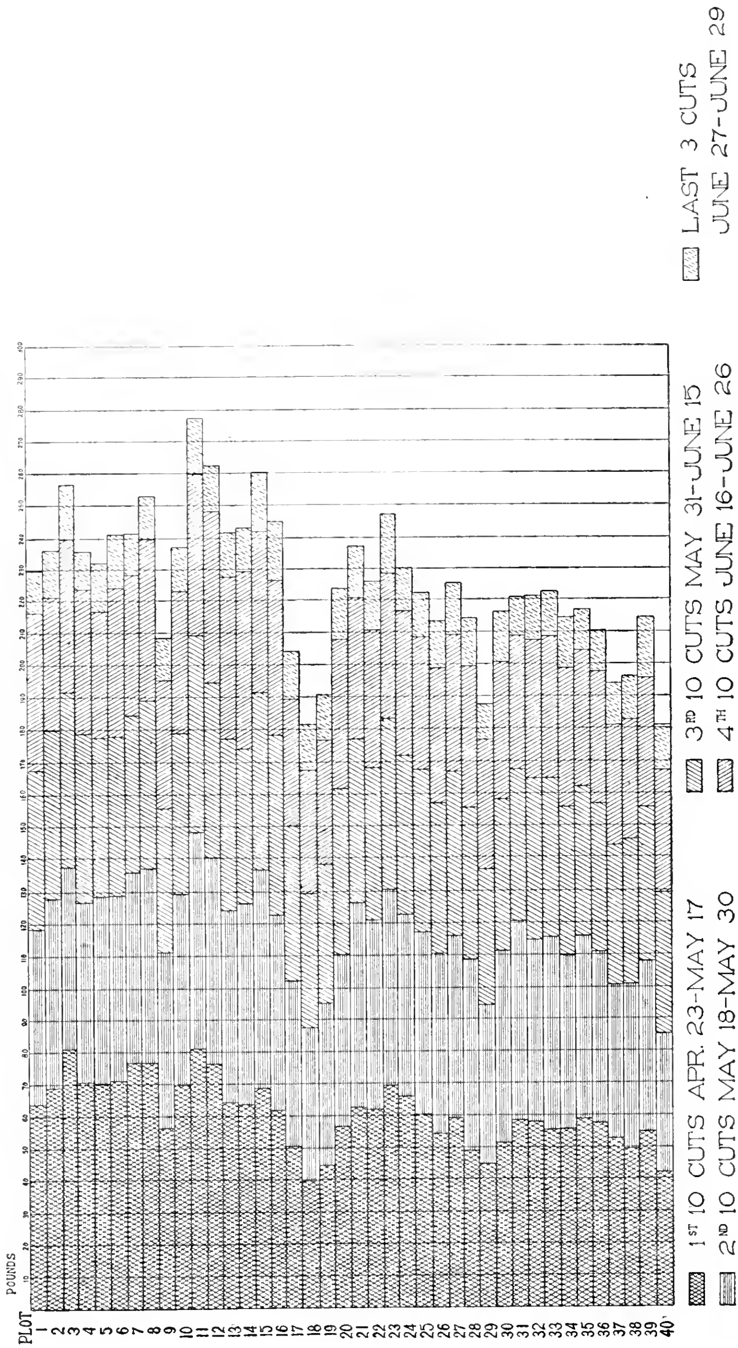
In the comparison of the different forms of potash materials used in fertilizing the asparagus plots 17. to 20, Table II, the first impression would be that muriate was much superior to other forms, and that sulfate was no better than none. A more careful comparison will reveal a close agreement in yields between wood ashes on plot 17, kainit on plot 20, and muriate on plots 34, 35 and 36, all of which received equal amounts of nitrate of soda and acid phosphate. The low yields on plots 18 and 19 were possibly due in part to the proximity of a large oak. The tree was nearer plots 18 and 19 than to any others, but was far enough not to shade the plots until nearly sunset. The extent of its roots in the gravelly subsoil may have been greater than was supposed.

It has been stated that the effects of rust were limited to one-half of the field or less, and that there was a nearly full recovery from the attack as the years passed. This is clearly shown by percentages of losses and gains in yields in Table VI. The first and fourth columns show the losses and gains in yields in 1911 compared with the yields in 1910. It will be noted that the outside plots 1 and 21 suffered much larger shrinkage than the succeeding plots, and that no injury was apparent after passing the middle of the field. In the second and fifth columns the maximum crop of 1914 was compared with the first full crop cut in 1910, and the percentages of gain are shown to be very much alike after passing the first two or three plots, which were worst affected by rust. The third and last columns show the percentages of shrinkage when the 1915 crop was compared with that of 1914. In general, the percentages are small, and the shrinkages are fairly uniform.

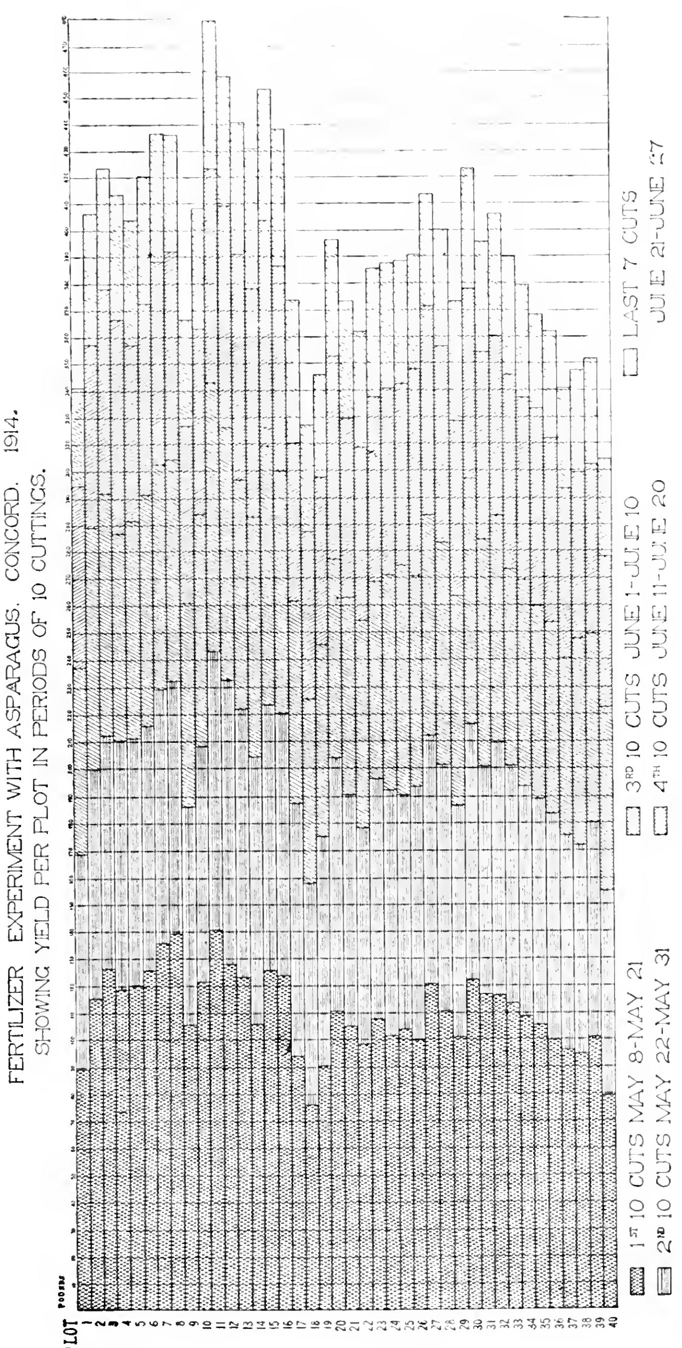
TABLE VI. — *Percentages of Gains and Losses in Different Years.*

Plot.	1910 to 1911.	1910 to 1914.	1914 to 1915.	Plot.	1910 to 1911.	1910 to 1914.	1914 to 1915.
1, ...	—20	51	—11	21, ...	—19	57	—8
2, ...	—11	71	—10	22, ...	—12	59	—6
3, ...	—8	65	—7	23, ...	—12	56	—9
4, ...	—5	75	—7	24, ...	—4	68	—6
5, ...	—5	74	—5	25, ...	—1	74	—6
6, ...	—9	74	—7	26, ...	6	83	—3
7, ...	—1	80	—5	27, ...	0	83	—9
8, ...	0	72	—6	28, ...	2	86	—6
9, ...	1	76	—9	29, ...	9	100	—6
10, ...	0	72	—6	30, ...	10	91	—8
11, ...	5	72	—10	31, ...	1	79	—7
12, ...	2	74	—9	32, ...	9	83	—8
13, ...	13	82	—12	33, ...	8	75	—5
14, ...	18	78	—12	34, ...	12	76	—8
15, ...	12	74	—10	35, ...	14	69	—4
16, ...	11	79	—6	36, ...	7	72	—10
17, ...	26	82	—9	37, ...	15	76	—4
18, ...	23	80	—7	38, ...	19	77	—4
19, ...	26	81	—13	39, ...	8	64	—7
20, ...	11	77	—7	40, ...	11	73	—12

The question arose in the course of the experiments whether any of the plots produced more early asparagus in proportion to the total crop which might be due to the fertilizers applied. Each year's crop was carefully charted in ten-day periods by Norton for such a comparison. The charts for 1910 and 1914, drawn by R. L. Coffin, are published here, and it will be seen that there were no plots where the first ten days produced proportionally greater weights of stalks compared with other plots than the total crops show. In other words, large yields in the first ten days were followed by continued large yields throughout the season.



FERTILIZER EXPERIMENT WITH ASPARAGUS. CONCORD. 1910.
SHOWING YIELD PER PLOT IN PERIODS OF 10 CUTTINGS.


FERTILIZER EXPERIMENT WITH ASPARAGUS. CONCORD. 1914.
SHOWING YIELD PER PLOT IN PERIODS OF 10 CUTTINGS.
PLOT
POUNDS
1ST 10 CUTS MAY 8-MAY 21
2ND 10 CUTS MAY 22-MAY 31
3RD 10 CUTS JUNE 1-JUNE 10
4TH 10 CUTS JUNE 11-JUNE 20
LAST 7 CUTS
JUNE 21-JUNE 27

Summary.

A fertilizer experiment with asparagus was conducted for a period of nine years in the town of Concord on coarse, sandy loam, which was typical of the soils used for asparagus culture. Seven crops of young stalks were produced during the experiment, and the yield steadily increased each year until the sixth, which was the crop of maximum size on nearly every plot.

Of the chemical fertilizers used, a mixture of 466 pounds nitrate of soda, 300 pounds acid phosphate, and 260 pounds muriate of potash per acre produced the best yields.

Manure at the rate of 10 tons per acre produced nearly as good results as the chemicals, while combinations of manure with chemicals and with nitrate of soda were no better than manure or chemicals used separately.

There was no apparent cumulative effect produced by the annual use of manure, and the asparagus tops harrowed into the soil each year seemed to supply sufficient organic matter for the efficient use of chemicals.

When nitrate of soda was added to manure it was most efficient when applied in two portions, one in the spring and one in the summer. Nitrate of soda applied with acid phosphate and muriate of potash was slightly more effective when applied in summer in four years out of seven.

Muriate of potash was, on the whole, the most satisfactory potash compound used.

Following the second crop an attack of rust from an adjacent field swept over about half of the plots. The plots nearest the source of the attack were reduced in yield the next season nearly 20 per cent, and were permanently injured. The remainder of the plots apparently recovered before the maximum yield of the sixth crop.

The sixth or maximum crop averaged about 80 per cent greater than the second crop, which was the first full cutting. The seventh crop was less than 10 per cent smaller than the maximum sixth crop.

COMMENTS AND CONCLUSIONS.

WM. P. BROOKS.

Asparagus is an important garden crop in this State, its culture being centered, however, largely in two or three sections: one, and the most important, in Middlesex County, with Concord the most important town; another in Barnstable County, in a number of Cape Cod towns with soils for the most part light; and in several smaller centers, one being on the plain land in Hampden and Hampshire Counties, with the product marketed for the most part in the cities of the Connecticut valley.

My appreciation of the desirability of careful investigations as to the fertilizer needs of the crop, although of earlier date, was stimulated greatly by the outbreak of rust, particularly in the Middlesex and Barnstable sections. The disease was carefully investigated by Dr. George E. Stone, at that time a member of the station staff, and discussed in a number of our publications.[1]

The culture of asparagus in the localities mentioned had, previous to the destructive outbreak of rust in 1897 and 1899, as a rule, been highly profitable, and success, while requiring careful and appropriate attention to details, had not been difficult. The outbreak of rust in this State — a disease which appeared nearly simultaneously in some other parts of the country, and which had been known in Europe for a good many years — seemed for a time to threaten the industry. Fortunately the adoption of improved methods — perhaps most important the introduction of more rust-resistant varieties — has greatly reduced the amount of damage from rust, but the increasing difficulties experienced by even the most skillful growers after the serious rust outbreaks of 1897 and 1899 made apparent the need of investigation in the effort to discover methods of prevention or lessening the severity of attacks. Accordingly, by means of visits and correspondence, I sought to learn in considerable detail what were the most usually accepted and followed methods of the best growers.

This effort had been preceded, however, by observations and chemical work based upon results obtained in my home garden. The total weight of shoots of the old variety, Moore's, cut in a good bed 85 feet in length and 6 feet in width, two rows having been set, was at the rate of 15,061 pounds per acre, while the weight of the tops grown after the cutting season, which ended June 18, was at the rate of 14,875 pounds per acre. Both classes of material were carefully sampled and analyzed under the direction of the late Dr. C. A. Goessmann. The shoots were cut from May 2 to June 18, 1901; the tops, just after the first severe frosts, Nov.

[1] For a list of these publications, see the bibliography at the end of this bulletin.

1, 1901. Table I shows the plant-food contents of the spring shoots as cut, of the marketable portion of these shoots, and of the tops grown subsequently to the growing season.[1]

Table I. — *Amount of Plant-food Elements in Asparagus Shoots and Tops (Pounds per Acre).*

	Shoots cut.	Marketable Shoots.[2]	Tops.
Nitrogen,	49.5	40.0	54.29
Phosphoric acid,	16.2	13.0	11.01
Potash,	49.4	40.0	148.80
Lime,	-	-	61.00

Plant Food taken from the Land annually.

The amounts of the leading elements of plant food shown in the above table to have been contained in the shoots (in a commercial crop) represent the total of these elements which in the practice of good growers in Massachusetts need be taken into account in determining a system of manuring or fertilizing which will make good to the land the amounts of these elements annually carried off in a large crop, for it is the practice of all our good growers to allow the tops grown after the end of the cutting season to stand during the winter, and to break them down and harrow them into the ground the following spring. The total commercial crop obtained in my garden is probably at least three times the average total obtained by commercial growers. The late Mr. Frank Wheeler of Concord was looked upon by those acquainted with his methods as one of the best informed and most successful asparagus growers in the State. In replying to a communication from me in which I had reported the results obtained in my own garden, Mr. Wheeler writes under date of Sept. 30, 1901: —

> In regard to the amount of crop per acre, it seems to me that you have got a very large yield. . . . I shall have to get at my conclusions in regard to the number of pounds of crop removed in the cutting season by partial guesswork. I think that 300 dozen bunches is a liberal estimate of the average of the crops hereabouts. It is too high for the last two years. One dozen should weigh 15 pounds, making 4,500 pounds per acre, plus butts cut off and thrown away, which I think would not exceed 1,000 or 1,500 pounds, equaling 5,500 or 6,000 pounds at the most.

The very large yield which I obtained is doubtless in part accounted for by the fact that the two rows set, though placed only about 3½ feet apart, to some extent fed outside of the 6-foot width, the figure used in computing the area occupied by the bed.

[1] Actual analyses by H. D. Haskins.

[2] These figures are based upon the estimate of the best growers, to the effect that the butts cut off in preparation of the shoots for market constitute on the average one-fifth of the total weight cut.

The Amounts of Fertilizer used by Good Growers.

In connection with the correspondence with Mr. Frank Wheeler, to which reference has just been made, the question as to whether in the practice of good growers plant food was not applied in quantity much in excess of the amounts which the crop could use was taken up. Upon this point Mr. Wheeler writes as follows: —

> It has also struck me very forcibly that we were applying two or three times as much fertilizer material as the crop was taking out, but I never doubted but what it was . . . profitable to do so. I can hardly think that any asparagus bed (commercial) was ever hurt by overmanuring. I have known of a number of old beds destroyed and used for other purposes, and they prove to be most productive for other crops (crops too, that we suppose do not need as much manuring as asparagus) under continued applications of fertility. As to the unsatisfactory results from the asparagus crop for two or three years back, I think very strongly that it was the fault of the rust, and cold seasons of 1900 and 1901.
>
> Although I agree with you most decidedly that the growth of the previous summer is a good indication of what the crop is to be, I do feel most strongly that a liberal application (not excessive) of nitrate of soda in the early spring is profitable. Of course you know that the first growth that any plant makes in the spring is feeding root fibers. Now do you think that they are for only taking up moisture? I feel they are for both moisture and food. I think that an asparagus plant (one year old) when set out will start off much stronger if set out in good rich soil than if set in sand or a poor one, or any other plant or seed will do the same. I have no doubt but what some of the early application of nitrate of soda is lost, but think it is still profitable. I know of no experiments to prove either for or against this conclusion.

Mr. Wheeler wrote that as the result of earlier experiments and observations it was his practice in asparagus growing to supply from 200 to 250 pounds of actual potash per acre annually. Table II shows the total amounts of plant food applied annually in Mr. Wheeler's practice, and in the second column (taken from Table I) the amounts annually carried off in the asparagus as bunched. These elements were derived in part from manure and wood ashes, but mainly from tankage, nitrate of soda and muriate of potash.

Table II. — *Amount of Plant-food Elements supplied and removed (Pounds per Acre).*

	Supplied.	Removed in Marketable Asparagus.[1]
Nitrogen,	125	40
Phosphoric acid,	100	13
Potash,	200–250	40

[1] It seems to me proper, in considering plant food removed, to take into account only the asparagus as bunched, because the butts cut off in the preparation of the shoots for market might be returned to the bed at the close of the cutting season at a negligible cost, practically speaking.

The figures in Table II will suggest to every thoughtful reader the question as to whether the practice of good growers as exemplified by that of Mr. Wheeler does not furnish a very much greater amount of the different leading plant-food elements than can be necessary, and therefore whether the net profits of asparagus growing would not probably be increased by some reduction in the amount of fertilizer applied. In the case of the element nitrogen no large accumulation in the soil as a result of excess application is likely, but if the generally accepted conclusions relative to the relations of phosphoric acid and potash to the soil are correct, the practice under discussion must in a series of years mean a large accumulation of these elements in the soil.

Plan of the Home Fertilizer Experiment.

The fertilizer investigations with asparagus upon the home grounds were laid out in 1903; those in Concord were, with the exception of a few minor details, a duplicate of the home experiment.[1] It seems desirable, therefore, to make a clear and full statement of the principal questions upon which it was hoped light would be thrown by these experiments. The preceding paragraphs, taken together with the quotations from the correspondence with the late Frank Wheeler, will, it is thought, sufficiently indicate my reasons for the particular inquiries taken up, namely: —

1. To test the question as to the amounts of the different elements of plant food, all in the form of chemicals, which can be employed with advantage.
2. To test the question as to how much, if any, fertilizer can be used with advantage in connection with manure.
3. To determine what difference, if any, there is in value between the different materials which may be used as a source of potash.
4. To determine whether nitrate of soda used in connection with manure is beneficial, what quantity, if any, it pays to use, and whether it should be put on in the summer (that is, at the close of the cutting season), in the spring, or equally divided between the two seasons.
5. To determine the same points with reference to the use of nitrate of soda in connection with chemical fertilizers supplying phosphoric acid and potash.

The Concord Investigations.

In 1907, in submitting to Dr. True, then of the Office of Experiment Stations, an outline of the investigations with asparagus in view in Concord as an investigation under the Adams act, the following brief statement (in substance) was made. Two general objects are in view: —

1. An effort will be made to breed more rust-resistant types of asparagus. This investigation was undertaken in co-operation with the Bureau of Plant Industry at the head of which at that time was Dr. B. W. Galloway.

[1] The plan of the Concord experiment, and, further, a statement of the fertilizing materials applied to the several plots, is found in Table II under the "Description of the Experiment."

2. To determine the principles which should underlie practice in the use of fertilizers for asparagus. This investigation is to include not only the most varied applications of plant-food elements as to kind, quantity, forms of combination and season of application, but studies as well of effects of the varied treatments upon: (1) the characteristics of the soil, — physical, chemical and biological; and (2) the plant as influencing the character of its development, its physiology and its health.

Breeding Investigations. — The co-operative breeding experiments were from the first under the direct charge of Dr. J. B. Norton of the Bureau of Plant Industry.[1] It is generally held by the majority of those who have examined the breeding grounds in Concord, and tried the better of the new varieties produced, that his work has been attended with a large measure of success. The better varieties are all designated by the class name "Washington," which was the name given to the male plant which, having given the best results in comparative crosses made, was chosen for most of the breeding work. Several of the varieties of this class produced seem to combine a large measure of capacity to resist rust with desirable commercial characteristics.

A number of plants of some of these varieties have been distributed by this Experiment Station to asparagus growers in different parts of the State for trial as compared with older varieties. A considerable number of reports have been received, but since the earliest distributions were made in 1915 it is yet too early for decision as to the rank which these varieties will finally take among those cultivated by Massachusetts growers. It may be said, however, at this point that the majority of those reporting have expressed favorable opinions. There have been some who have thought the new varieties which they had under trial were hardly equal to the best older varieties, while others have reported that they could see no particular difference in ability to resist rust.

Fertilizer Investigations. — In a statement of the plan of research proposed, submitted to Dr. True for approval under the Adams act, it was stated to be the plan to study the results of the variant fertilizer treatments from two points of view in addition to the apparent direct effect upon the yield; namely, as above stated, first, the characteristics of the soil; and second, those of the plant. Various conditions affecting the possibilities for investigational work in the Station have prevented giving much attention to the study of the effects upon the soil, most important among them being changes in the personnel of the chemical and microbiological staffs. The second line of investigation, however, — namely, the effects upon the plant, — has engaged considerable attention. The investigations along this line have been under the direct charge of Professor Morse, and for the most part conducted by him. The leading results of these investigations have been reported in a number of different papers.[2]

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[1] Dr. Norton has reported the results of his work in publications which are listed in the bibliography.

[2] For a list of these papers, see the bibliography.

My conclusions as to the significance of the results obtained from year to year, as well as many details of the experiment, including the general description of the soil and its preparation, have been presented in the annual reports referred to in the bibliography and in addresses at annual conventions of the Massachusetts Asparagus Growers' Association. It seems advisable to present these conclusions here, and for the sake of completeness I include also conclusions based upon observations on points not considered in the description of the experiment: —

1. In the year 1910 a late frost considerably reduced the yield of shoots as cut. The cutting season of 1910, moreover, was characterized by low average temperature. For these reasons, the total cut of 1910 was undoubtedly less than normal; nevertheless, even greater emphasis might well be placed on the effect of rust on a portion of the plots than has been done in the discussion.

2. The medium amounts of the different fertilizers furnishing the leading plant-food elements applied have furnished the maximum amounts of these elements which prove useful to the crop as indicated by yields produced.

3. The oak tree which stood near the northeast corner of the experiment field exercised an adverse influence upon the yields of some two or three plots, including those to which sulfates of potash had been applied for comparison with muriate used on plots in other parts of the field. While the plots referred to were not actually shaded by the tree, there can be no doubt that some of its roots extended a short distance into these plots, for it is generally recognized that as a rule the roots of trees which stand in the open extend outward from the trunk in every direction a considerable distance beyond the tips of the branches. The adverse influence of these roots was clearly shown in the inferior growth of the tops after the close of the cutting season.

However, muriate of potash appears to be the best form in which to supply that element, this conclusion being based not alone upon the results obtained in the series of experiments under discussion, but in large measure upon results obtained in much longer-continued comparisons of muriate of potash with sulfates under conditions, so far as can be judged, absolutely fair to the comparison of these two forms of potash.[1]

The Humus Content of the Soil in Asparagus Growing.

In the discussion of the experiment particular attention is called to the fact that the continuous application of manure in this series of experiments with asparagus did not appear to exercise a cumulative effect on the humus content of the soil favorable to satisfactory production, and mention is made of the practice of our commercial asparagus growers of allowing the tops grown subsequently to the end of the cutting season to

[1] These results have been referred to repeatedly in annual reports, especially those discussing results obtained with asparagus on Field B on the home grounds. For references to details, consult indexes of annual reports for 1906–17 (nineteenth to thirtieth).

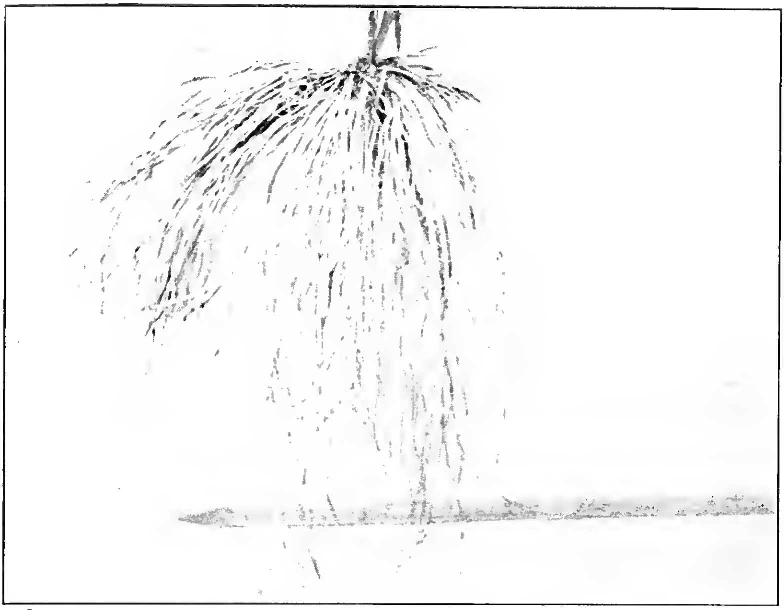

FIG. 1.—Root system of three-year-old asparagus plant taken November 7. Average length about 4 feet, a few of the roots 5 feet 6 inches in length.

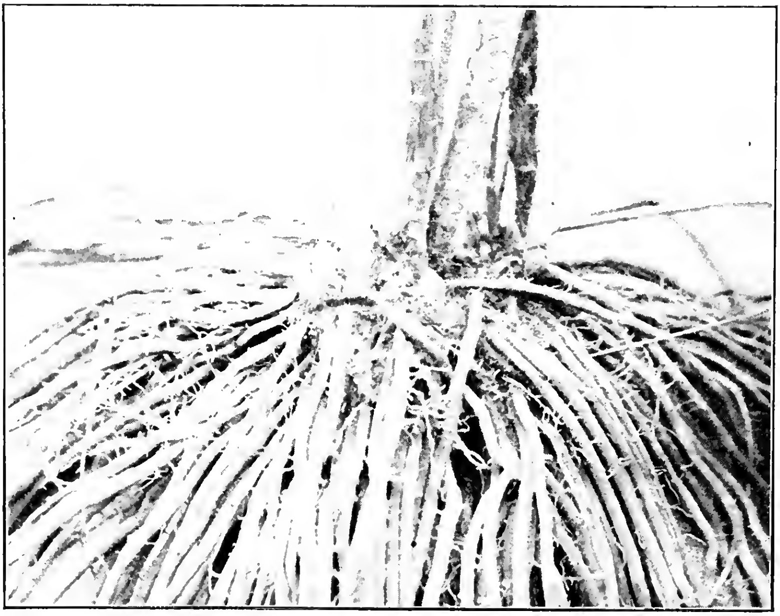

FIG. 2.—Shows crown and a part of the root system of three-year-old asparagus plant dug and photographed November 7. Weight of roots and crown as dug about 6 pounds, and estimated that the portion separated from the soil and weighed constituted only about three-fourths of the entire root system.

remain in the field to be harrowed under the following spring as perhaps accounting for the fact that there was no apparent favorable effect of manure as compared with chemicals which could be attributed to a greater supply of humus. There can be no doubt that the practice of harrowing in the tops is fully justified by results, both because of its relation to humus content and the lesser removal from the bed of plant-food constituents.

I would, moreover, call attention to a peculiarity in the growth of asparagus which I believe to be also an important factor in accounting for the apparent non-beneficial effect of continued use of manure as a source of humus. As is well known, the thick roots and the crowns of asparagus plants serve an important function in the economy of the plant as storage reservoirs for reserve materials which are drawn upon heavily in the production of the spring shoots which constitute the commercial crop. The root system is a very large one. Some of its peculiarities are clearly shown in Figs. 1 and 2. It will be noticed that there is a very large number of crowded, rather thick roots, and that these roots in the plants which have made only three years' growth — one in the seed bed and two after setting — have already attained a great length, and in the aggregate make up a heavy weight. The photographs from which the illustrations were made were taken by the late Mr. C. W. Prescott from one of the roots dug up for purposes of chemical examination, the results of which are reported in Bulletin No. 171. The roots just referred to were taken up in 1908. Another lot of roots was taken up for chemical examination in 1910, and no photographs were taken of any of the roots taken up at the later date. The different roots show considerable variation in total weight and other characters, but on the average were but little, if any, longer, more numerous or heavier than those shown in the illustration. Among the second lot of roots were found some evidently older roots which were hollow and inactive, having undergone partial decay. The conclusion to be drawn from this observation, strongly supported by analogies afforded by well-known facts concerning the life histories of a large number of other plants, both cultivated and wild, is that the root as a rule serves for storage perhaps only a single year, then becomes inactive, dies and decays in the ground. This is true, for example, of Solomon's seal, false Solomon's seal, sarsaparilla and numerous other plants. An analogy is afforded also by the familiar habit of numerous bulbous plants as, for example, the crocus, tulip, hyacinth, gladiolus, etc. There can be no doubt that this constant replacement of older roots by new, the older then decaying, contributed largely to the humus content of the soil, and would seem, therefore, to be a highly important consideration in accounting for the lack of favorable influence of manure on the humus content of asparagus beds.

The Relation of Variations in Fertilizer Application to Rust.

In the brief statement of the objects in view in the fertilizer experiment, already given, occurred the phrase: " . . . to include . . . studies . . . of effects of the varied treatments upon: . . . (2) the plant as influencing the character of its development, its physiology and its health."

In this brief reference I had in mind particularly any influence upon the extent of injury from rust, which at the time the experiments were planned was the only disease of asparagus which was proving at all serious. This line of investigation was suggested by the fact that numerous investigators had become convinced, as a result of their studies, that variations in the kinds, amounts, and perhaps also in the seasons of application, of chemical fertilizers had an important relation to the capacity of different cultivated plants to resist disease. One of the earliest in this country to believe this, both from his study of results obtained through the experience of others and from experiments conducted by himself, was the late Dr. C. A. Goessmann, who became convinced that peach yellows could be prevented by suitable applications of potash.[1]

It is not possible to demonstrate by means of figures showing the yields of commercial asparagus in the experiments in Concord that such variations in fertilizer treatment as were made in those experiments either did or did not affect the amount of rust. The principal reason why this is true is because the attacks of rust were determined chiefly by the location of plots both as to direction and distance from sources of infection, — in other words, from fields of the old and highly susceptible varieties of asparagus found in various parts of the district in Concord in which our experiments were located. It was impossible, therefore, to measure in figures any difference which might have been caused by variations in fertilizer treatment.

My conclusion, however, based upon frequent examinations of the growth, especially subsequent to the end of the cutting season when the tops and foliage were developing or fully developed, was that there was no influence on the amount of rust that could be attributed to a difference in the kind of chemicals used in the experiments. On the other hand, my examination of the plots — most important, the one made in late September in 1911, the year of the heaviest infestation of rust — led to the conclusion that variation in the time of application of the nitrate of soda did have considerable effect. At my request Mr. J. B. Norton, who saw the bed much more frequently than I, made a particular point of attempting to trace any effect of rust due to variation in fertilizer treatment. Mr. Norton, working entirely independently and without knowing what differences if any I had noticed, agreed with me almost absolutely as to relative amounts of rust on different plots. Our conclusion was

[1] Agriculture of Massachusetts, 1881, p. 84; 1882, p. 440; 1883, p. 360.

that the application of at least a portion of the nitrate of soda at the close of the cutting season reduced the amount of rust. It seemed to both of us, also, to be true that there was less rust where all the nitrate was reserved and applied at the end of the cutting season than when only one-half was so reserved and applied. In conclusion on this point, this then is the only effect of the wide variations in fertilizer treatment upon the health of the plants which can be confidently stated.

Conclusions.

The more important conclusions having either direct practical or scientific importance which the investigations reported in this bulletin appear to warrant may be stated as follows: —

1. The variety of asparagus and the location of the bed with reference to badly infected beds which may be sources of infection influence susceptibility to rust and probability of bad attacks to a greater extent than variations in manurial or fertilizer treatment.

2. A number of the varieties produced in the co-operative breeding experiments conducted in Concord appear to have to an exceptional degree the character of relative immunity from rust. The best of these are from crosses with a superior male plant found in a bed of Giant Argenteuil.

3. In commercial asparagus growing as usually carried on in this State it is a common practice to apply what appear to be excessive quantities of fertilizers.

4. The medium amounts of the several plant-food constituents applied in these experiments appear to have furnished the different leading elements of plant food in as large quantities as could be utilized by the crop.

5. These medium amounts are at the following rates per acre: —

	Pounds.
Nitrate of soda,	460
Acid phosphate,	300
Muriate of potash,	260

6. Nitrate of soda at the rate of about 400 pounds per acre in connection with manure at the rate of 10 tons per acre increased the crop, and appears to be the maximum amount which proved beneficial.

7. Among the different materials employed for the purpose of furnishing potash, the muriate, everything considered, proved most satisfactory.

8. The application of either acid phosphate or muriate of potash with manure at the rate of 10 tons per acre appears not to have increased the crop.

9. The immediate or even the cumulative effect of yearly applications of manure in increasing the humus content of the soil does not appear to have been beneficial; in other words, chemical fertilizers upon this sandy soil give as good results as manure.

10. The lack of benefit which can be attributed to humus furnished by the manure may be explained in part by the practice of our commercial asparagus growers in allowing the tops grown subsequent to the cutting season to remain on the ground to be worked into the soil the following spring.

11. The conclusion appears to be justified, through observations upon the root habit of the asparagus, that yearly replacement of roots used when relatively young for the storage of reserve material by younger roots is also an important factor in accounting for the lack of beneficial effects resulting from humus furnished by manure. The roots thus replaced decay, thus adding to the organic matter of the soil.

12. The season of application of nitrate of soda does not appear to affect the relative yield of commercial asparagus in successive ten-day periods throughout the season; in other words, the cut of commercial asparagus during the early part of the season is not increased by either small or large applications of nitrate made as early as the soil can be worked.

13. The season of application of nitrate of soda does appear to influence the susceptibility of asparagus to rust, which I am convinced is reduced by the application of at least a portion of the nitrate of soda at the close of the cutting season.

14. The character of the season, especially the amount and distribution of rainfall, appears to affect the probability of a serious attack of rust to a considerable degree, such attacks being more common in dry seasons than in those characterized by normal or abundant and well-distributed rainfall.

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—— Discussion of Asparagus Rust. In Hatch Expt. Sta. Ann. Repts. 9, p. 72; 10, p. 58; 12, p. 61; 14, p. 69; Mass. Agr. Expt. Sta. Ann. Rept. 20, p. 126.

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TOBACCO INVESTIGATIONS

PROGRESS REPORT

By G. H. CHAPMAN

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BULLETIN No. 195.

DEPARTMENT OF BOTANY.

TOBACCO INVESTIGATIONS.

PROGRESS REPORT, INCLUDING MISCELLANEOUS OBSERVATIONS ON TOBACCO.

BY G. H. CHAPMAN.

Introduction.

The production of cigar leaf tobacco has been for many years a very important agricultural industry in the Connecticut Valley, and in 1916 there were approximately 9,000 acres under cultivation in the Massachusetts section alone. By far the greater part of this was of the variety known as Havana, but some Broadleaf, shaded Cuban, and Sumatra were also grown. The value of the crop was estimated at, roughly, $3,600,000.

It can be seen from the above that the gross income derived from the growing of tobacco in Massachusetts is very large, and must of necessity be a very important factor in the regional community prosperity.

The successful raising, curing, and packing of tobacco is, as is well known, an art in itself, and very difficult of uniform attainment. The tobacco plant is very susceptible to comparatively slight changes of environment, and to grow tobacco successfully for a long period of years on the same soil requires, of necessity, extremely close observation and skill in agricultural practices. That success does not always attend the growers is more or less evidenced by the report alleging that the average yield in Massachusetts is falling off, and also that the percentage of wrapper leaves in crops is decreasing.

The season of 1915 was particularly unfavorable for the development of tobacco, and, as a consequence, the growers requested that experimental work be carried on by the station relative to ascertaining the fundamental underlying cause or causes of the apparent deterioration of the crop. No funds were available to carry on this work until the late summer of 1916, when an appropriation was made for this purpose. The collection of data relative to crop conditions and other phases of agricultural practice was commenced at this time with a view to outlining experimental field and laboratory work for the ensuing years.

It has seemed unwise to make a yearly report until the data of at least two years were available, and therefore the present report includes the preliminary observations made during the latter part of 1916, and a discussion of the results obtained from the different lines of experiment suggested by these findings. These will be treated under their proper headings in the body of the report, with a general summary of conclusions and recommendations following.

Preliminary work was undertaken so late in the season that it was impossible to collect first-hand data on seed-bed conditions. The work was therefore confined to making a survey of the crop and soils in general, with a view to obtaining accurate information regarding the situation. After compiling and correlating these data it was planned to establish in 1917 experimental plots in different sections, and by various treatments endeavor to produce a favorable tobacco condition in the so-called "sick" soils. The problem is not primarily one of soil fertility, as it is generally true that crops other than tobacco — such as onions, corn, etc. — make a very luxuriant growth on the "sick" tobacco soils, and this often without additional fertilization.

Investigations necessary.

From the results of our study of 1916 conditions, it was apparent that the questions involved required the undertaking of several lines of investigation in order to reach a satisfactory solution. Undoubtedly it may be found necessary to change or modify the various experiments as time passes, but there are certain questions which should be answered as soon as possible. Among the more important are the following: —

1. Is the average yield of tobacco gradually falling off from year to year, generally, throughout the valley?

2. Is the quality of the tobacco produced inferior to what has been the average quality?

3. Has the weather factor been a primary controlling factor in production, — especially in later years, — and what limits are permissible for profitable production? (This hardly seems necessary of demonstration.)

4. Is there a correlation between weather factors and diseases, such as root-rots caused by *Thielavia basicola* and other organisms?

5. Aside from the general decrease in crops in 1915–16, and to a lesser extent in 1917, what is the cause of the soil "sickness" on some fields, or parts of fields? Is it due to a parasite, or is it due to improper fertilization and cultural methods?

6. Is there any correlation between the fertilization methods and soil treatment, and the activity of the root-destroying organisms? In other words, have we got some of our fields into a condition which favors the

development of the disease-producing organisms, and which, at the same time, is unfavorable for the optimum growth of the tobacco?

7. What corrective fertilization and cultural methods may best be employed in the latter instance?

Briefly, the investigation may be divided into three main parts, as follows: —

1. *A study of the meteorological factors as related to the growth of tobacco.*
2. *A biochemical study of the soils of normal and "sick" fields, including fertilization experiments.*
3. *A study of the micro-flora and micro-fauna of normal and "sick" soils, including those forms found to be parasitic on tobacco.*

Is the Tobacco Crop actually failing?

It has been repeatedly stated that the average yield per acre of tobacco in Massachusetts is decreasing gradually, and has been so doing for the past ten or fifteen years. This, if true, would be very alarming, and would indicate a widely distributed, serious situation due to parasites or to improper cultural methods. The following data will show the situation as it really is. Some years ago the United States Department of Agriculture, through its Bureau of Statistics, began reporting various data regarding the principal crops of the United States. Tobacco was included, and the following data have been secured from the annual figures as published in the various Year Books of the Department.

The average yield of tobacco in Massachusetts from 1870 to 1910 is calculated as 1,580 pounds per acre. At present this would seem a rather high figure, as the acreage devoted to shade-grown Cuban has increased in the past ten years, until in 1918 approximately 1,100 acres were devoted to this crop out of a total acreage of some 9,000. The yield of shade tobacco is much less than field-grown, not averaging over 1,000 pounds per acre, and this low yield of the Massachusetts acreage would of necessity, reduce the average yield, if yield is calculated on total acreage. However, as no other figures are available, the above-mentioned average is taken for the period 1870 to 1910.

The yield per acre is plotted in Fig. 1, and is self-explanatory. The straight broken line indicates the average yield. The heavy black line represents the seasonal variation.

It is at once apparent that until the disastrous seasons of 1915 and 1916 the yield over a period of fourteen years was, with four exceptions, well above the average, and two of these years, 1902 and 1913, were only slightly below the average. If we average the yields as plotted for the eighteen years we find that, even with the exceedingly low yield of 1915 included, the average yield for the period has been 20 pounds above the average yield calculated for the forty-year period of 1870–1910, — namely, 1,580 pounds.

It is only too true that the figures available are based on estimates which are, perhaps, somewhat at variance with the actual facts; but in any case the factor of error would be identical from year to year, and the general comparative results may be considered trustworthy.

The yield has fallen off seriously only in 1915, and to a lesser extent in 1917; but in spite of these low yields the average yield of tobacco in the period 1900–18 has been above the average of the forty-year period 1870–1910.

There is no justification for the statement that the yield of tobacco on Massachusetts fields has been decreasing *gradually* for the past ten years; but, on the contrary, in spite of the exceedingly low yield of 1915

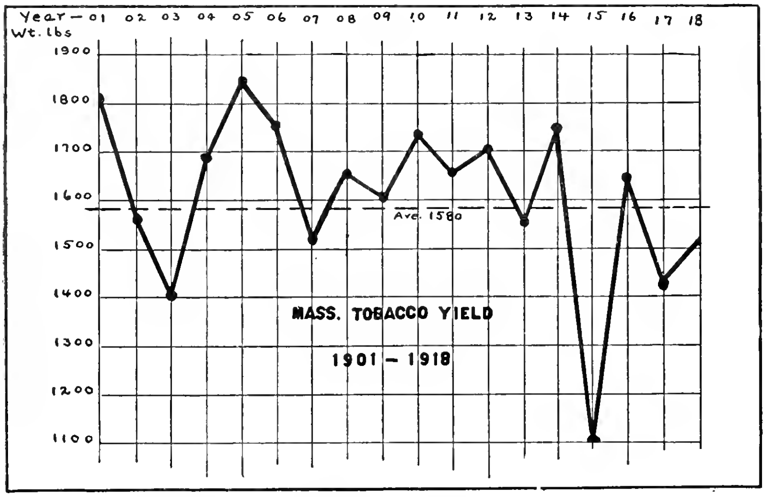


Fig. 1.—Average yield per acre of Massachusetts tobacco from 1901 to 1918, inclusive. The horizontal dash line indicates the average yield from 1870 to 1910.

the calculated average is being maintained. If, however, we consider only the yields of 1915, 1916, 1917, and 1918, it is true that a yield below the average will be found; but some of these seasons have been admittedly unfavorable for tobacco, from the meteorological standpoint, and high yields could not be expected. Also it is incorrect, or at least misleading, to base a statement of *general* yield on so few years' data. The same conditions meteorologically have in the past produced almost identical results, as will later be pointed out.

Weather Factor in Tobacco Growing.

In general, it may be stated that the first half or more of the growing season of 1916 was decidedly unfavorable to the growth of tobacco. Conditions improved from shortly after mid-season until the crop was harvested, and a rapid and apparently satisfactory growth was made. The leaf was of good size and color, but although seemingly in good condition, was inclined — as later developments proved — to run rather light in weight. There was a tendency on the part of many growers, resulting perhaps from their experiences in 1915, to harvest the crop before it was mature; whereas, as a matter of fact, the leaf matured in general rather late in 1916. This factor undoubtedly influenced somewhat the character and weight of the leaf.

It is a self-evident fact that rainfall, temperature, sunlight, humidity, etc., are very important factors in the normal growth of any crop, and perhaps exert a greater influence than usual in the case of tobacco, which is particularly sensitive to slight environmental changes. The season of

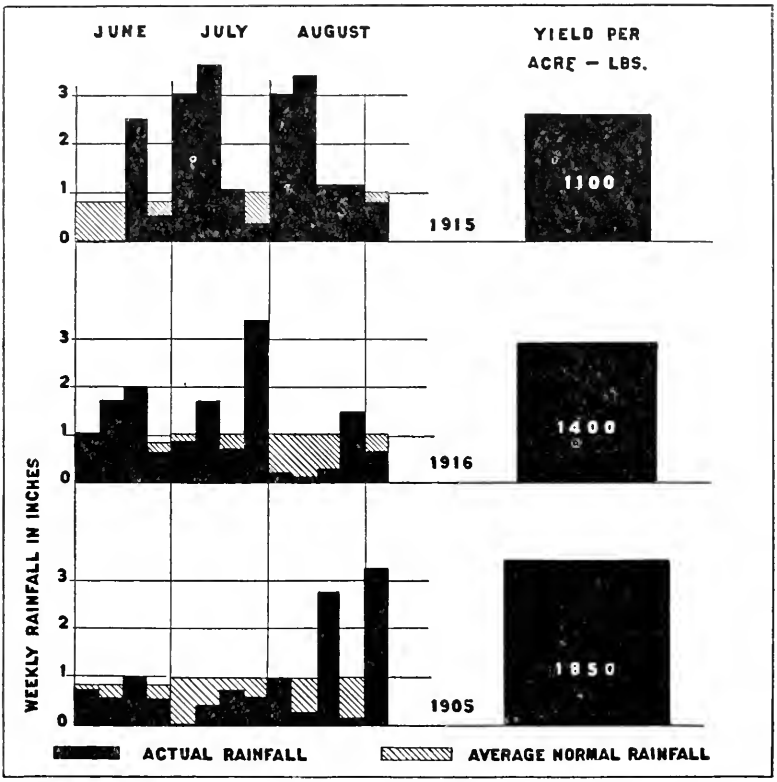


FIG. 2.—Comparison of actual rainfall and yield with normal rainfall for 1915, 1916, and 1905, a so-called "dry" year.

1915 was one of very heavy rainfall, as was that of 1916; therefore, as a means of comparison of conditions, the rainfall of 1916 has been plotted with that of 1915, and with a so-called "dry" year in which the crop was of good weight and quality. Fig. 2 shows the rainfall in inches week by week from June 1 to September 1, the variation from the normal, and the yield for each of the years. The correlation of excessive moisture and low yield is certainly very marked; also the converse: subnormal rainfall, well distributed, with a high yield.

It will be noted that the season of 1916, as a whole, was very wet, with excessive rainfall occurring during the first two-thirds of the growing period. The season of 1915, which was so disastrous, was even more wet; but a reversal of the 1916 conditions is found, most of the rainfall occurring during the last two-thirds or half of the season, when the crop was going through its period of greatest growth, and maturing. The season of 1905, while rather dry, produced many fine crops of tobacco (although they were later damaged by pole sweat), and it will be noted that the rainfall was low; in fact, the precipitation was below normal in many of the weeks and, as a whole, the season would be considered a droughty one. The fact that the last week or two were very wet, and consequently interfered somewhat with harvesting, does not in any way lessen the importance of the statement that the crop was very large. The quality, however, was slightly lowered.

There is no question but that the excessive precipitation of the two seasons first mentioned reduced the weight and quality of the crop; but its general effect was much less in 1916, when most of the excessive rains occurred in the first half of the growing season. These checked early growth in the field, but a subsequent return to normal, or thereabouts, in August allowed of a rapid development in the last few weeks, although, in spite of the favorable conditions, the crop was late in maturing. The excessive rainfalls of 1915 and 1916 have, in all probability, been an important factor also in intensifying the effects produced on the crop by the various forms of soil "sickness."

To illustrate: It was observed that on fields known to be badly infested with the root-rot fungus (*Thielavia basicola* Zopf.) the percentage of plants infected sufficiently to check growth was much greater than usual in 1915 and 1916. The apparent leaching out of certain plant foods, especially the more soluble forms of nitrogen, was also observable, as indicated by the character of growth on some fields. Mention will be made of a few interesting observations on this point later in the report.

The theoretical benefit which might be derived from the leaching out of the accumulation of soluble salines — which Haskins[1] found to be excessive (as compared with soils producing normal crops) in certain spots and fields producing unthrifty plants — was apparently observable in some cases and not in others. It is unfortunate that determinations of the change in amounts of these salines present in soils which had been previously examined were not made, but lack of time prevented this.

It is a well-recognized fact that rainfall, soil-moisture, and temperature all play an important rôle in the making of quality of tobacco, and it is also true that, as a rule, the finest quality of cigar leaf is raised on light soils which carry relatively only a small percentage of moisture, say from 7 to 15 per cent. Aside from quality alone, in seasons with excessive rains there is always a falling off in the crop, particularly as regards weight.

A study of the rainfall, relative humidity, hours of sunshine, and

[1] Haskins, H. D. Twenty-fourth annual report, Mass. Agr. Exp. Sta. (January, 1912), p. 35.

temperatures during the main growing season as compared with the weight of the crop has therefore been made. The data as to average yield and yearly production in Massachusetts were obtained from the various Year Books of the Department of Agriculture. These figures are the only ones available, and it is believed by the writer that in most instances, at least, they are reliable. The meteorological data are taken from the records of the Massachusetts Agricultural College observatory, and are fairly representative of conditions in this section of the valley. The observatory is located within two or three miles of the center of the Massachusetts tobacco area around Hatfield. Of course, observations taken only a few miles distant would differ somewhat, but only in minor details, and it is believed that we are fully justified in using these observatory records. No data are available as to seasonal differences in water content of the different soil types in the tobacco region in Massachusetts. The quality of the crop in the different years was also difficult to ascertain, as here it was necessary to depend largely on the grower's or packer's memory for data, and they often were unable to recollect a crop for a given year with sufficient accuracy to make a comparison reliable. Therefore quality has not been plotted.

The average yearly yield per acre in Massachusetts is given in Table I for the period from 1901 to 1918, inclusive, together with the average yield from 1870 to 1910.

TABLE I. — *Average Yield of Tobacco per Acre in Massachusetts, 1901–18.*

Year.	Yield (Pounds).	Year.	Yield (Pounds).
1901,	1,810	1911,	1,650
1902,	1,560	1912,	1,700
1903,	1,400	1913,	1,550
1904,	1,690	1914,	1,750
1905,	1,850	1915,	1,100
1906,	1,750	1916,	1,600[1]
1907,	1,525		1,400[2]
1908,	1,650	1917,	1,430
1909,	1,600	1918,	1,520
1910,	1,730	Average yield, 1870 to 1910,	1,580

[1] United States. [2] Massachusetts Agricultural College.

It will be seen that there is a marked variation in yield from year to year. The yield for 1916 as given by the United States Department of Agriculture (1,660 pounds) is much greater than the one estimated by the writer (1,400 pounds). This is probably due to the fact that the latter figures were obtained in part from the packing houses.

Fig. 1 is a graphic representation of the variation indicated by the above figures.

There was, unquestionably, a great reduction in yield in 1915, 1916, and 1917. *Can we look to a specific soil trouble, pathogen, or method of culture to account for this sudden and marked* GENERAL *decrease in yield?* It is hardly conceivable. A careful study of the yield in comparison with the meteorological conditions, however, does furnish us with important data, at least partially explanatory of the same. A study of Plates I and II (A and B), it is believed, will convince the most skeptical that the weather conditions during any given growing season determine to a great extent the yield, and that the *general* reduction in 1915 and 1916, as well as in other bad years, must be primarily attributed to these factors.

In these plates the normal for this locality is represented as the straight horizontal line or mean, and designated as (0). The variations of any given period — in this case, monthly — above or below normal are represented in black by the difference between the normal and that of any given month. Variations above normal are represented above the line, and below normal, below the line. Sunshine variation is given in hours, temperature variation in degrees Fahrenheit (F°), relative humidity in percentage, rainfall in inches, and yield in pounds per acre. Each season is divided into three parts, corresponding to the three principal months during which maximum growth occurs, — June, July, and August.

Studying these tables it is found that there is a rather close correlation between the various factors and the yield. Rainfall is, in Massachusetts, probably the most important factor bearing on the yield, followed closely by temperature and sunshine. The relative humidity apparently is not of such importance, so far as the actual yield is concerned. Calling attention to only a few of the more important differences will suffice.

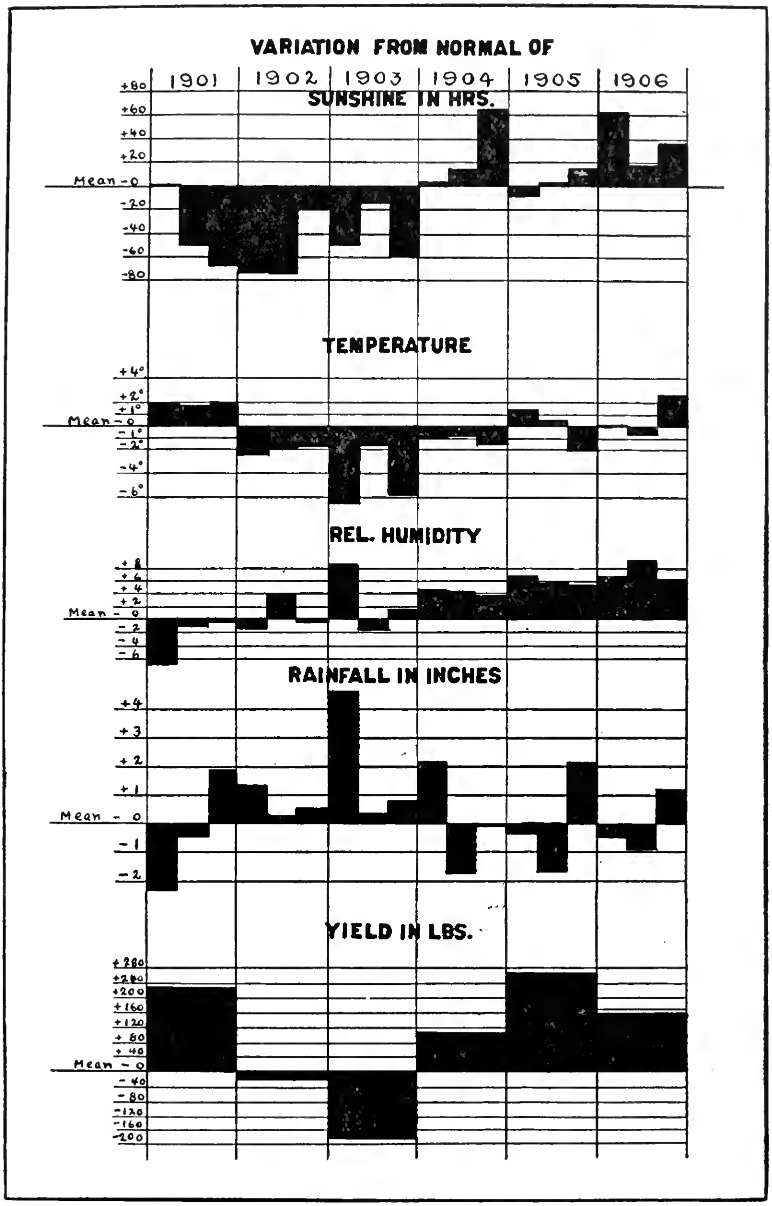
1915. — Sunshine slightly above normal in June, much below normal in July and August; temperature, 1.5–2.0° below normal for the entire growing season; relative humidity above normal except in June; rainfall practically normal in June, but from 4 to 5 inches in excess of normal during July and August; yield, 480 pounds below normal!

1916. — Here we have the reversal of conditions before mentioned: sunshine much below normal in June and July, above normal in August; temperature below normal for June, but above in July and August; rainfall excessive except in August, when it was 2 inches less than normal; yield better than in 1915, but still 180 pounds below normal.

1917. — Here we have a partial return to more normal conditions, but still somewhat abnormal; yield, 50+ pounds below normal for stalk tobacco.

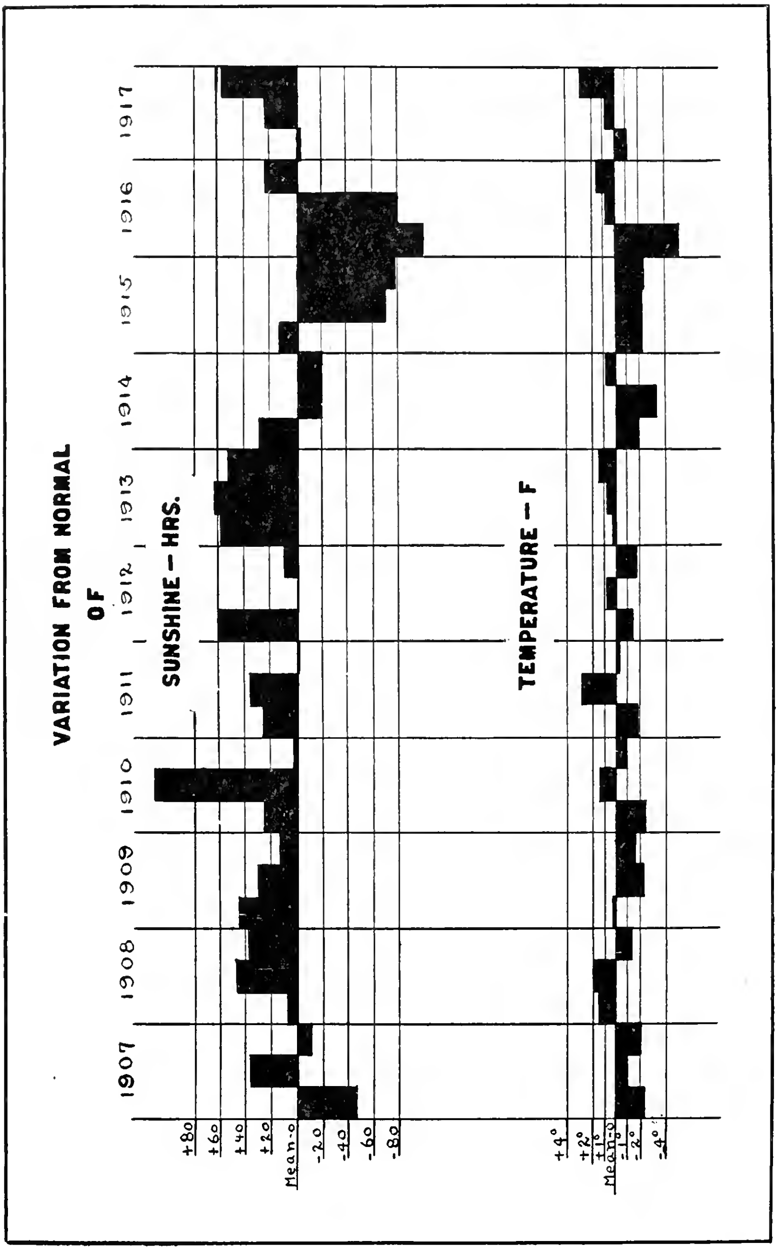
Going back still further it is possible to find analogous conditions in other years. It is safe to conclude that if there is excessive rainfall during the growing season, combined with low average temperature during the first half of the growing season particularly, the yield per acre will be small.

PLATE I.



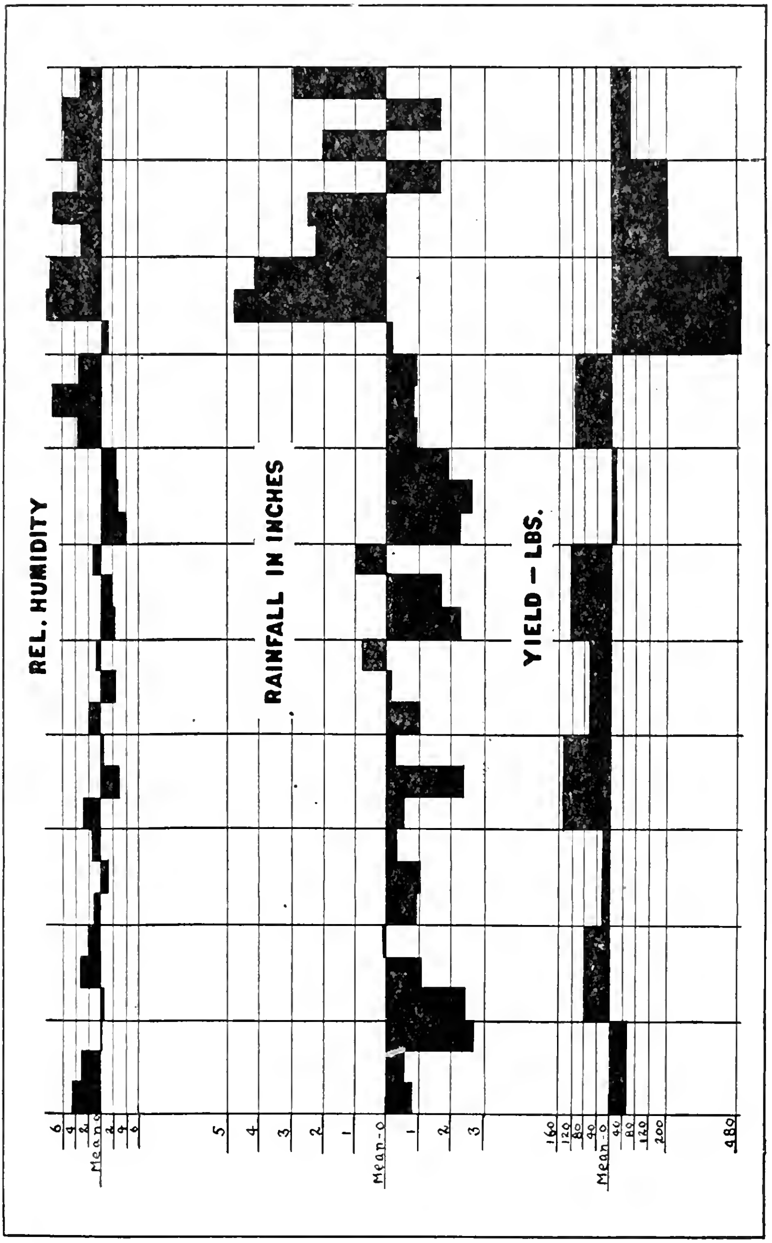
Variation from normal of sunshine, temperature, relative humidity, rainfall and yield, 1901-06, inclusive.

PLATE II A.



Variation from normal of sunshine and temperature, 1907–17, inclusive.

PLATE II B.



Variation from normal of relative humidity, rainfall and yield, 1907–17.

Excessive drought, combined with low or high temperatures, will also reduce the yield, but not usually to so great an extent as in the case of excessive rainfall. Good examples of the effects of drought on yield are to be found in 1907, and to a lesser extent in 1913.

Subnormal rainfall with subnormal temperatures does not reduce the yield to any great extent, providing they are not excessive (see 1909, 1910, 1912). The quality of the leaf is apt to suffer somewhat, however, in such cases.

A careful examination of the data leads us to the conclusion that for the development of our best crops we must have a season with normal or slightly subnormal rainfall, fairly well distributed, together with practically normal or supernormal temperatures.

Another factor of great importance is the distribution of the rainfall. For the best results the rainfall should be more or less evenly distributed over the growing period, not all in any one month or on a very few days of the month. The season of 1917 shows very well the effects of an unequal distribution of rainfall which, while averaging little above normal, reduced the yield. Here a very wet June, followed by a very dry July, brought the crop along to the danger point, and then the excessive rainfall of August, while helping growth, did not permit of a normal maturity, and as a result we get a subnormal yield.

As a result of the examination of these plates we may state that, in general, *rainfall is the major limiting factor of growth (and this necessarily includes soil moisture), together with temperature.*

Excessive seasonal rainfall is invariably followed by a reduction in yield independent of temperature.

Subnormal rainfall, when accompanied by temperatures excessively above normal, reduces the yield.

Subnormal rainfall, when accompanied by subnormal temperatures, does not apparently reduce the yield to any extent unless the rainfall is very much below normal.

In other words, there are apparently certain well-defined limits between which we may expect to get a normal yield, or better. A total rainfall for the season of from 6½ to 12 inches, if fairly well distributed, will give a good crop. Less than this or greater will give a yield below normal.

These conclusions are *general* and *seasonal*, and do not take into consideration other factors, such as *effect of precipitation* on soil temperature, fertilizer applied, parasitism of disease-producing organisms, type of soil, and method of culture. All these factors do play a more or less important rôle concurrently, but fundamentally rainfall and temperature are to be considered the limiting factors in production. The other factors mentioned are decidedly more local in their action, and are often possible of correction. They are what might be termed "individualistic," while the others are "communistic."

The effects, in any one season, of the rainfall and temperature as related to growth also make a very interesting study, and any one interested would do well to read Bulletin No. 39 of the Bureau of Soils, United States Department of Agriculture, in which is reported a season's study of these factors at Tarriffville, Conn. It would be out of place to detail them here.

In conclusion, it might be well to emphasize again that the *general* reduction of crop yield per acre is invariably associated with the seasonal rainfall and temperature, and not to any "running out" of the land (which was amply shown by the fact that the 1918 crop, according to returns, was much improved over those of 1915 and 1916, and was practically normal in spite of the July drought), due, primarily, to a specific wide-spread soil trouble.

This conclusion does not in the least minimize the fact that in many localities there is undoubtedly trouble due to improper fertilization, methods of culture, and disease-producing organisms; but these are *specific* problems, and not susceptible to *general* analytical consideration except in the group to which they belong.

They *may* assume major importance in seasons presenting abnormal meteorological conditions, and in such seasons are often held responsible for all reductions in yield. This should not be done, however.

Soil Relations.

During the season of 1916 many fields were observed where the unfavorable condition of the crop could not be accounted for by the presence of disease. On these fields the leaf was apparently normal in size or, in some areas, small and undeveloped; but it was thin and papery, and did not show the weight and quality of normal leaf grown on the same type of soil. In these cases not attributable to parasitic organisms we must look to an unbalanced physiological relationship between the plant and the soil, and this, naturally, first involves a study of the soil composition, reaction, and methods of fertilization.

Many theories have been advanced to explain this particular type of non-productiveness of tobacco soils, such as overfertilization, under fertilization, excess of soluble salines, toxic substances formed in the soil by the interaction of certain fertilizing constituents, injurious fertilizer constituents, the accumulation in the soil of toxic excretions from the roots of the tobacco plant, lack of potash, and a variety of other causes any one or more of which may possibly, under certain conditions, furnish the correct explanation. In general, however, it has been found difficult to ascribe the condition of the crop on such fields to any one factor with any degree of certainty, and it would appear that careful investigation is necessary to clear up some of these questions. In all probability no single factor is responsible.

It has generally been supposed that tobacco thrives best on a soil approaching neutrality, but our observations lead us to believe that this may not be entirely true, and that, possibly, some of our soils are too nearly neutral for the best development of tobacco. This seems to be particularly true where large quantities of lime have been applied to soils. The "good" tobacco soils examined showed a comparatively high "lime requirement," as determined by the Jones' method, using Haskins' factor for Massachusetts soils (4.46 instead of 1.8).

By the term "lime requirement," as used in this connection, is meant the amount of lime in the form of calcium oxide, CaO, it would be necessary to add to the soil to exactly neutralize it, *i.e.*, make it neither acid nor alkaline. It is not implied that the amounts of lime indicated in any given instance would benefit the tobacco crop.

The writer believes that, as a measure of the actual "lime requirement" or acidity of soils, none of the present methods of determination are satisfactory, and do not, in many cases, even approximate the true value sought; but when used as a comparative indicator for laboratory purposes in the examination of a series of soils they may be applied with advantage. In Table II will be found the "lime requirement" of some typical fields examined, together with comments on the crop, type of soil, etc.

TABLE II. — *Classification of Certain Soils according to "Lime Requirement," together with Data on Crop Condition, etc.*[1]

Group I.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
07	1,200	Very poor,	No,[2]	-	Yes.
03	2,700	Very poor,	No,	-	Heavily.
8	3,000	Poor,	Light,	-	Yes.

Group II.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
12	4,500	Poor,	Light,	-	Yes.
16	4,500	Poor; fair,	Light,	-	Heavily.
18	6,000	Fair,	Light; medium,	-	Heavily.
2	6,500	Very poor,	Very heavy,	6	Yes.
6	6,500	Thin; large growth,	Heavy,	40	Occasionally.
4	7,000	Poor; patchy,	Very heavy,	30-40	Occasionally.
14	8,000	Fair,	Light,	-	Little.
22	8,000	Very good,	Trace,	-	No.

[1] The data given in this table represent only a part of the total collected, but are typical of conditions in general.

[2] "No" indicates that no root-rot was found on roots of plants examined. It is entirely probable that a very extended examination might in all cases reveal a slight amount.

Table II. — *Classification of Certain Soils according to "Lime Requirements," together with Data on Crop Condition, etc.* — Concluded.

Group III.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
20	8,800	Good,	No,	-	No.
011	8,900	Excellent,	Trace,	-	- -
A21	9,400	Very good,	No,	4	No.
24	9,900	Good,	No,	-	- -
30	10,500	Good,	Trace,	-	No.
26	13,500	Very good,	No,	2	No.
V17	15,500	A virgin soil ready for tobacco.			

The results are significant, and indicate that tobacco is making a better growth on soils which, with our method of acidity measurement, would be classed as rather acid. Until further investigation is made it would be unwise to emphasize this point unduly. Apropos of this, the general observations of Beals[1] on limed and unlimed areas substantiate, in a measure, these experimental findings. He found that out of 58 growers who made reports 43 had used lime more or less continuously, and most of these reported soil "sickness," while among those not using lime, only one case of soil "sickness" was reported.

A Study of the Reaction of Normal and "Sick" Soils as indicated by the "Lime Requirement."

In the past three years over 300 determinations of the so-called "lime requirement" of soils of all types used for tobacco have been made, as well as some of virgin soil broken for the first time for tobacco. The samples collected in different years were taken at approximately the same week or month, as the case might be, and as nearly as possible under similar conditions. In Table III there are arranged in groups the values obtained, together with brief notes on the condition of the crop during the season in which the samples were taken. It has not been attempted to include in this table, individually, all the soils examined, as this would be too cumbersome. The theoretical "lime requirement" is given in terms of CaO, and not as limestone or other commercial forms of lime.

[1] Beals, C. In report of thirty-third annual meeting of New England Tobacco Growers' Association. Feb. 16, 1916, p. 25.

TABLE III. — *Tobacco Soils arranged in Groups according to "Lime Requirement," with General Notes on Crop Condition.*

	Number of Soils examined falling in Group.	Condition of Crop.	Root Diseases Present.
Group I: — 0-3,000 pounds CaO requirement.	21	Poor; fair,	None-slight.
Group II: — 3,000-8,000 pounds CaO requirement.	137	Poor; excellent (better as the higher limit is approached).	None-very heavy (usually present).
Group III: — 8,000-15,000 pounds CaO requirement.	29	Good: excellent,	None-slight (unusual).

The results given in this table apparently indicate that tobacco is making a better growth on soils which are rather more "acid" than we have been in the habit of believing to be best for tobacco. As a matter of fact, the soils which show the least acidity are those which have had in the past large and more or less consistent applications of lime, or those which have been planted to tobacco for a long period of time. Whether or not these soils which seem to be so "acid" actually are, is an open question. In all the methods of acidity determination used, we measure the amount of acidity and not the intensity, and it is being found that a determination of the concentration of the hydrogen ion gives us, often, different results.[1] These results are important, and bring before us the question of lime (for we reduce the acidity of our soils by liming or by certain systems of fertilization) and its use on tobacco soils. Do they indicate that we have been liming too much, and that if we keep off lime entirely for a time we will eradicate much of the trouble? This cannot be stated absolutely as a general proposition in the light of work carried on so far, but it can be positively stated that we have found many instances where lime, especially in active form, has been applied to soils with the result that in from two to three years the crop has been reduced considerably. This is particularly noticeable where lime has been dumped and then later spread. The areas on which the lime was dumped became very unproductive, and we are therefore justified in stating that it would be advisable to withhold lime from fields which have been in tobacco for some time, especially from lighter soils where the supply of organic matter is small. Apropos of the advisability of adding lime to tobacco soils, especially light soils, it should be noted that

[1] A study of the hydrogen ion concentration in our tobacco soils is in progress and nearing completion. This study is to include a comparison of results obtained by this method with those of the present report, and a discussion of the practical interpretation of the same. This paper, which will of necessity be more or less technical in character, will be published separately.

some of the fertilizers used are alkaline, and that most of the brands contain in the neighborhood of 200 pounds of some form of lime added for various purposes.

The question as to whether the addition of large quantities of lime is necessary on our soils for the best development of tobacco — and its effect on the burn, ash, etc. — is still open to investigation. It depends to a certain extent on the type of soil. Recent investigations by the Dutch East Indies station have shown that the addition of lime had little effect on these factors. On the contrary, in some cases where the burn was injured there was a beneficial effect on the quality and color. Other experiments showed opposite results, and in general no particularly good effects were observed.

There is no question but what some lime is necessary for the best development of the tobacco plant, but a small application every few years seems to be preferable to a heavy application two or three years in succession. The mechanical composition of the particular soil to which the lime is to be applied should also be carefully considered.

There is another factor, connected with the liming of our fields, aside from that of the direct injurious effect of lime on the growth of tobacco as a result of the changing of soil reaction toward neutrality. Certain of our experiments have shown that the fungus *Thielavia basicola*, which causes root-rot, is very susceptible to acids, and we have found that it is very difficult for the fungus to thrive on very acid media. On the other hand, on media approaching neutrality the fungus develops rather better and makes a far more rapid growth. We are at present testing out in the laboratory different concentrations of acids and different acids, together with soil extracts, to determine if there is any difference in their reaction on the fungus.

These data regarding Thielavia root-rot substantiate the findings of Briggs,[1] who in 1908 reported results on the intensity of root-rot infection on tobacco in alkaline and acid soils, and who also recommended the stopping of lime applications on infected fields.

Referring again to the preceding table it might be stated that the roots of plants on the various soils which were analyzed were examined for Thielavia root-rot infection, and some interesting data were secured. It was found that in the soils of Group I, as it has been called for the sake of convenience, — that is, those soils which showed a "lime requirement" of from 0 to 3,000 pounds CaO requirement, — the crop was very poor; but there was little or no Thielavia root-rot evident. On the soils which I have designated as Group II, the crop was poor and patchy, or good, and on many plants the Thielavia root-rot was present in sufficient amount to cause a marked loss of root-feeding area. These soils all fell within a range of CaO requirement of from 3,000 pounds to 8,000 pounds. In Group III were placed all the soils showing a "lime require-

[1] Briggs, W. The Field Treatment of Tobacco Root-rot. U. S. D. A., B. P. I., Circ. No. 7, 1908.

ment" above 8,000 pounds CaO, the crops of which were normal as far as growth was concerned, and many of them were very fine. In this group we find the acidity as measured in terms of the CaO requirement running as high as 13,500 pounds per acre. The highest value closely approaches the acidity of our virgin soils, such as are used when new tobacco plantations are established. Two of these virgin soils gave a "lime requirement" of over 15,000 pounds per acre.

From the preceding we can see that the situation with respect to liming is still further complicated. We have, on the one hand, the lime question and its effects on the growth of tobacco, pure and simple, and on the other, the effect of the soil reaction on the fungus which causes the Thielavia root-rot. If we lime continually and excessively land on which this root-rot is established, we are constantly getting it into a more nearly neutral condition, and hence into a more favorable condition for the development of the root-rot. In the end we will have a soil in which every year, irrespective of other factors favorable or unfavorable to the growth of the fungus, it will be able to develop vigorously and do great damage. In such cases soil reaction (changed by liming) should be looked upon as the primary cause of the trouble, and the presence of root-rot as secondary to this.

We find that this root-rot is not present to any great extent on soils showing a very low "lime requirement," which indicates that the soil is too alkaline for the development of the fungus, and also too alkaline for tobacco to make a satisfactory growth. At any rate, in this group (soils showing 0–3,000 pounds CaO requirement) the fungus is rarely found, though usually the crop of tobacco is very light and of poor quality. In the second group we find a large number of soils showing from 3,000–8,000 pounds CaO requirement, and it is to be observed that the Thielavia root-rot is present in a large number of fields. On these soils the crop varies from year to year, and in many cases is not of a satisfactory nature. On soils of this character in some years, however, good crops are produced, so we cannot here lay the damage to the lime alone, but must look to other additional factors.

In the third group we have soils which are acid and which show a high "lime requirement," — 8,000 pounds CaO and up, — but which are practically free from root-rot, and these soils are in practically all cases producing a good crop of tobacco. Does this not seem to indicate that the relationship between liming and Thielavia root-rot just discussed is a potent factor in many cases in the development of our troubles? There are, however, other factors to be taken into consideration, and in some cases these are of great importance also.

There is this fact patent, that on new land the tobacco always makes a good growth, although the quality of the leaf may not be all we desire. In these times, when the first consideration of the grower is apparently to get weight and let the quality come later, this is important, at least to the grower who has new land at his disposal. Most of the growers, however, have not new land that is suitable for tobacco, and cannot extend their activities in this manner, so of necessity they must confine their attention to keeping their tobacco fields in good tobacco condition by careful methods of fertilization.

Mere weight should not be the aim of the grower, as eventually this will lower the standard of Massachusetts tobacco. It is a well-recognized fact that heavy, rank tobacco is not, year in and year out, in demand by the manufacturers, and the aim should be to produce a fair weight of tobacco which has quality. A satisfactory price must be obtained for such a product, and it is due to the low price paid, more than to any other single factor, that the growers are striving to increase the weight of the crop. The cost of production is so great in Massachusetts that to secure adequate returns we must continue to grow a wrapper crop of good quality.

To return to the question of soil reaction and the practice of liming, it might be well to emphasize again the data collected by Mr. Beals of this station in 1914 (*loc. cit.*).

It is true that some growers have been using lime more or less continuously for some time, and are still producing excellent crops of tobacco, but this is the exception, and other factors — such as soil composition, organic matter supplied, etc. — are more or less responsible for the success of these men.

Humus or Organic Matter Content of Massachusetts Tobacco Soils.

The soils reported in Table II were analyzed for humus content by the method of the Association of Official Agricultural Chemists [1] as modified by Rather,[2] and a somewhat wide divergence in humus content was found, as might be expected. There were found some indications of a relationship between humus content and crop condition, as well as "lime requirement." Low humus content was more often associated with low acidity and poor crop condition. It may be safely stated that many of the soils producing poor crops are deficient in humus. Usually the presence of an optimum amount of humus or organic matter in a soil is considered an essential to crop production, but whether the quality of the leaf is injured or not by large amounts of humus in the case of tobacco is of importance. Growth and weight, without quality, are not to be desired. The question of the addition of humus to soils, found markedly deficient in this substance, is one which will bear investigation. Where it is found necessary to supply humus, we have the choice of crop rotation or cover-cropping and manuring, and, as most growers feel that they cannot practice extensive rotation with profit, cover-cropping and manuring would appear to be the only satisfactory solution of the matter so far as the question of humus is concerned. Whether, as some firmly

[1] Official and Provisional Methods of Analysis. U. S. D. A., Bureau of Chemistry, Bulletin No. 107.

[2] Rather, J. B. Texas Bulletin No. 139. May, 1911, pp. 10–15.

believe, to restore the "sick" soils it will be necessary to rotate on a three or four year basis, is an open question, but one which should be seriously considered by those whose land is in very poor condition. It is to be hoped, however, that some treatment will be discovered which will render this unnecessary.

Continued examination of normal and "sick" soils during 1917 and 1918 has served to substantiate the findings of the first year. Almost invariably there has been found to be a relationship between the organic matter content of a given soil and the development of the crop. This was especially true in the case of old fields which had been heavily limed, and fertilized for years with "chemical" fertilizers. These same fields, as a rule, had had no addition of organic matter, except such as came from the cottonseed applied, or from the stalks plowed under.

Our light and heavy soils, of course, vary widely in the content of organic matter when in a virgin condition, and, as a rule, the light types are the first to be depleted of their organic matter. These also are the soils which contain normally the smallest amounts of organic matter. Continued liming depletes the organic matter very quickly, and in this practice we have undoubtedly exceeded the limits to which we may go and maintain a favorable amount of humus in the soil.

Some of the soils show a very low humus content, — even less than half of 1 per cent, — and in some cases, even on the heavier types of soils, we found less than 2 per cent. The natural organic matter or humus content of our tobacco soils varies from about 1½ to 5 per cent or more, depending on the type of soil. It can be plainly seen that there is certainly a deficiency in many cases, and this should be remedied as soon as possible. Very few of the soils examined contained what would be considered the normal amount of humus for their type.

Organic matter is a very important factor in any soil, and particularly tobacco soils which are, in this section, cropped for years without any rest or rotation. Sufficient attention has not been paid to keeping up the supply of organic matter in the soils.

Organic matter affects the soil in many ways, both physically and chemically, and might almost be called a "soil regulator." Physically, it lightens heavier soils and binds lighter soils together and tends to make them loamy. It also increases the moisture-holding capacity enormously, and thus acts in a beneficial manner. Chemically, it adds to the plant food of the soil, as it contains the elements required by plants for food. Haskins' experiments at this station, in which he applied varying amounts of peat to some "sick" fields, showed very plainly that the peat exercised a beneficial effect on the growth of tobacco. These effects were due, probably, not only to the increase of organic matter in the soil, and the consequent action on the mechanical condition and water-holding capacity, etc., but also to the increase in soil acidity resulting from its application.

In our own experiments on "sick" soils — light and heavy — in the past two years we have shown conclusively that an application of even moderate amounts of organic matter increases the weight of the crop to a marked extent. In these experiments the organic matter was applied in the form of peat in varying amounts, from 2 to 4 tons, on a 12 per cent moisture basis. The following tabulation will show the increase in yield resulting from the addition of organic matter, all other factors in the fertilization being the same.

TABLE IV. — *Increase in Yield resulting from Application of Peat to Certain Soils.*[1]

PLOT NO.	Peat Application (Tons per Acre).	Average Yield of Peat Plots (Pounds per Acre).	Average Yield of No-peat Plots (Pounds per Acre).	Per Cent. Increase.
A, F, K,	-	-	1,330	10
B, G, X,	2	1,470	-	
26, 23,	1	1,400	-	-2
1, 4, 6,	-	-	1,420	-
R, O,	2	1,570	-	10

[1] The plots received uniform fertilization aside from peat. Manure plots, and peat and acid phosphate plots, gave still higher yields.

While these data have been obtained for only two years as yet, it is believed that they are sufficiently striking to warrant tentative conclusions being made, particularly as the check plots which contained no additional organic matter were subjected to the same conditions as regards planting, cultivating, etc.

Except in certain rare cases the application of organic matter in the form of peat would be out of the question on account of the excessive cost of the material and the labor involved in carting and spreading. *How can we add organic matter to our soils at a cost sufficiently low to be practicable?*

There are several ways in which this may be done. There is added to soil a considerable amount of organic matter from stalks, cottonseed meal, manure, etc., but naturally this is not sufficient to replace the losses. Heavy manuring will apparently be sufficient sometimes, but this is an expensive form in which to apply organic matter. We cannot afford to practice any extended system of rotation, but we can supply an enormous amount of organic matter by "cover-cropping" or planting a crop in the fall after the tobacco is taken off, and plowing it under in the spring before planting.

COVER CROPS.

Cover-cropping should be practiced wherever possible, not only as a means of adding organic matter to the soil but also to prevent washing and blowing, in the case of light soils.

The choice of a cover crop depends on several factors, such as character of soil, presence of Thielavia root-rot in the field, etc. Some leguminous crop has often been advocated as a cover crop, but it is questionable if this is advisable for tobacco, as so many of the legumes (clovers, etc.) are also hosts of the Thielavia root-rot fungus, and would thus perpetuate it. *Any crop which will serve as a host for the root-rot fungus (Thielavia) should not be employed as a cover crop for tobacco.*

Rye, barley and timothy have been used in many instances with varying success, rye perhaps being most generally used up to the present time. There is one objection to rye, particularly on light lands; *i.e.*, if favorable growing weather prevails in the spring and any considerable amount of land is to be plowed, such a rapid growth of the rye top occurs that it is difficult to turn under thoroughly, and consequently it does not decay properly.

Barley is not generally used, and its use is not advocated.

Timothy has been used by some growers with good success, and from observation and trial on some soils the writer can recommend its use strongly, as it usually makes a good root growth, and does not grow so high as to be difficult of plowing under.

Although no positive data are at hand, it is believed that rye as usually planted will not furnish as much organic matter as timothy. Rye makes more top growth, but not nearly as much root growth as timothy.

According to our data, an ordinary cover crop of timothy will add to the soil over 2 tons of dry organic matter to the acre. Some figures of German investigators indicate even higher values, as much as 3 tons per acre.[1]

In addition to the direct benefit to the soil in organic matter, such a cover crop will aid in other ways. It will conserve nitrogen by preventing leaching, and will bind light soils, consequently preventing the blowing and washing which is so common in many fields.

The cost, per acre, for seed is very little, as the amount sown should usually be not over one-third bushel of good seed to the acre. The saving in nitrogen alone would more than repay the cost involved. The seed should be sown broadcast on stalk-cut fields, as soon as the tobacco is off, and on primed and shade-grown Cuban fields should be sown after the third picking at the latest.

Every tobacco field in Massachusetts should have a cover crop each year, and, so far as we can at present state, the choice should be timothy first, with rye second.

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[1] Subsequent to the preparation of this report the Connecticut station and Hartford County Farm Bureau published analyses showing that the average amount of dry organic matter returned to the soil by a timothy cover crop amounts to 3½ tons per acre. This would be, so far as organic matter content is concerned, the equivalent of 15 tons of manure.

Tobacco Diseases.

In the Seed Bed.

It may be stated on the authority of growers that while the weather conditions in 1916 were unfavorable to a rapid and uniform development of the seedlings, the beds were relatively free from parasitic diseases. Comparatively little damping-off of seedlings was reported, but the chief trouble seems to have been the checking of plants due to cool, moist weather conditions early in the season. After setting in the field, recovery was fairly rapid in most instances, and vigorous plants were produced. Judging from field examinations later in the season there probably was less "mosaic" in the seed beds than in some years past, as the number of mosaicked plants on a large number of fields observed was less than what is considered the normal infection.

The practice of sterilizing the seed beds by means of steam or formaldehyde — preferably the former for the sake of convenience — is on the increase, and with more attention being paid to such details as high pressure, complete sterilization of all soil in the beds, etc., more uniformly favorable results should be obtained.

It is believed, however, that the practice of sterilization of the same soil in seed beds year after year may not eventually produce the results desired, as we really know very little as yet about the action of steam on the soil, and its effects may prove detrimental if long continued. Thorough sterilization, when necessary, is recommended rather than indiscriminate, careless, or partial sterilization, which only adds to the expense of the crop.

As to the presence of the root-rot fungus (*Thielavia basicola* Zopf.) in the seed beds in 1916 no positive data are at hand, as our field work was started too late to allow of any examination of the plants in the seed beds. It is fallacious, in the case of root-rot, to draw conclusions from field observations as to its probable prevalence in the seed bed, owing to the fact that the causal fungus is apparently well established in many of our fields, and has been for some time. *It becomes generally of great importance, from an economic viewpoint, only in certain years when favorable environmental conditions for its development exist.* Thorough sterilization of the seed bed will also control this fungus when it occurs there. From data at hand it is believed that many seed beds, heretofore unsuspected, are infected to a certain degree with the root-rot fungus.

In the Field.

In order of importance and frequency of occurrence the diseases affecting tobacco in Massachusetts may be classified as follows: *Thielavia root-rot*, "*mosaic*" and allied diseases, *leaf spots* of various kinds, including "*rusts*," *damping-off* in the seed bed, *stem-canker*, root-rots apparently induced by *Fusarium* or closely related forms, root-rots apparently induced by *Rhizoctonia* forms, *albinism* and similar chlorotic conditions, *sun-scald* of leaves, *bud-scald*, and *hollow-stalk* caused by injury and secondary invasions of organisms causing decay, and killing of plants by fertilizer applications.

Some few of these occur rarely and are of little importance, as, for instance, *hollow-stalk*, which has been observed only occasionally. *Bud-scald* was prevalent in the spring of 1919 in some fields which were planted during the extremely hot dry period in the latter part of June. The injury was not noticeable until the plants had been in the field ten days or more. The midribs of the bud-clasping leaflets were the parts most seriously affected, and, as a result of the killing of some of the cells on the underside of the midribs of the leaves which were closed over the bud, these failed to develop naturally, and the normal development of the leaf web and the upper side of the midrib caused the pair of leaves affected to bend sharply downward and grow very irregularly. Never more than one pair of leaves was found affected on any one plant. This injury, while sometimes resembling the type of injury caused by bud-worm, is quite distinct from it. *Sun-scald* of the leaves is, of course, something which cannot as a rule be prevented, and is usually noted on the leaves which have been turned over by the wind, exposing the under side to the hot sun. If water droplets collect on the leaves when in this position, and they are then exposed to the hot sun, there develops on the exposed areas a peculiar type of leaf spot due to burning, the water drops acting as lenses. *Fertilizer-burning* was noted in a few cases, but was usually found only in seed beds which had been treated with a large amount of quick-acting nitrogen to hasten their growth. Elsewhere in this report are noted observations on the overapplication of ground fish to tobacco beds. *Albinism*, a condition in which parts of the leaf are almost pure white while the rest of the leaf is normal green in color, has been noted rarely, and its occurrence is of little import. This condition may arise from a variety of causes, and has even been observed as a result of early frosts, but usually the plants outgrow the trouble and develop green coloring matter in the white areas.

There has been found a root-rot which is more or less similar in its effects to that caused by Thielavia, with the exception that there are no pronounced black lesions on the roots, but a more uniform browning and dirty discoloration, most of the injury being found on the fine, feeding rootlets, and not on the larger ones, as is often the case in a Thielavia infection. A form of Rhizoctonia has been isolated from diseased roots, but as yet it has not been possible to make satisfactory reinoculations with the cultures obtained. It would appear, so far as our observations go, that the fungus may be weakly parasitic in nature. There is a "damping-off" trouble, due to Rhizoctonia, which is found in the seed bed, but in this case infection is usually found near the surface of the ground, and often when such diseased plants are set in the field there results, under favorable conditions, the disease of the stem known as "stem-canker." The root-rot apparently due to Rhizoctonia is usually found in restricted localities in a field, and as yet is probably not of wide distribution. It remains to be proven whether the fungus is actually actively parasitic, or is capable of attacking only those plants which have become weakened by some other cause. As opportunity offers, work on this disease will be continued.

Root-rots, apparently induced by Fusaria or closely related forms of fungi, are seemingly on the increase, if we may take the isolation of these forms from diseased roots in almost pure culture as an indication of the causal agent. The roots of a large number of plants from patchy fields have been examined in the laboratory in the past two years, and in many cases forms of Fusarium, or closely related forms, have been isolated from the surface of the diseased roots. So far the few experiments in which it was attempted to infect the roots of healthy plants with pure culture material in the laboratory under control conditions have failed. It is a fact, however, that on many of the poorly developed plants in some fields we are consistently finding this fungus. A critical study of the question of Fusaria as the cause of a tobacco root-rot is being made by James Johnson of the Wisconsin station and the United States Department of Agriculture. In the writer's opinion, however, it may prove a difficult matter to establish the parasitism of this fungus, but it is to be hoped that something definite will result in the way of control measures. It should be noted that in fields where we have found the Fusarium associated with a root-rot of tobacco, there is a noticeable lack of infection due to Thielavia, the ordinary root-rot fungus of tobacco. This would indicate that the conditions necessary for the optimum parasitism of Fusarium are distinctly unfavorable to the development of the Thielavia. If this proves true, as these are both soil fungi, the question of control becomes rather perplexing. If it is shown that the Fusarium under certain conditions of soil reaction is actively parasitic, and these conditions are the ones that we have found to be practical for the control of Thielavia root-rot, the question of the finer adjustment of the soil reaction becomes an important factor, and more difficult of successful application.

Canker, noticeable in the field in 1916 as a decay and blackening of the stem at the ground, sometimes extending up the stem for some distance and occasionally girdling it, occurred only in isolated cases, and was of no importance economically. The direct causal organism, or organisms, is not well known, but the primary cause is probably due to a slight attack of damping-off in the seed bed, or even mechanical injury at the soil level, secondary organisms then gaining admission through the weakened tissue. So far the only field found to contain any considerable amount of canker is one to which very large amounts of manure were applied annually, the seed bed also being treated similarly. This excessive amount of organic matter furnishes a very favorable medium for the growth of bacteria and fungi, especially in the seed bed.

The leaf spots observed may be roughly divided into two classes, — those caused by organisms, and those with which no organism is associated. The second class is by far the more prevalent, and only in rare cases during 1916 were organisms found associated with a leaf spot. The amount of damage caused by leaf spots of this character is apparently slight, judging from the data at hand, but it is possible that more extended examination of fields may show different results.

The leaf spots not due to organisms were rather numerous in 1916, especially those classed as "rusts" by growers. One type of these "rusts" is usually found associated with the mosaic disease, and here the rusted spots which are made up of dead tissue are rather large and often coalescent, so that a comparatively large leaf area may be affected. Another type of "rust," believed by the writer to be associated also with the later stages of mosaic, was observed. In this case the spots were small, more regular in outline, not coalescent, and more thickly distributed over the leaf. There is some question, however, whether this type is always associated with the mosaic disease, as the same condition has been observed occasionally on plants not affected with this disease. In some shade-grown areas another type of spot or "rust" was observed, and it was not associated with mosaic. Here the spots were small, regular in outline, and widely scattered, some of the leaves showing only one or two such spots. It is not certainly known what the cause of this type of spot is, but it resembles a spot found in other tobacco sections where a lack of potash is said to exist. It may be due to other causes, however, and it is useless to even hazard an opinion on the question at this time. The whole matter of leaf spots requires investigation, particularly those spots which are not caused by organisms. It is expected that a study of these troubles will be taken up at a later date.

Mosaic disease was present in 1916 on many fields, but from an estimate of the amount on fifty-one areas it was apparently not present to so large an extent as in some years, approximately less than 3 per cent of the plants having the disease on commercial leaves. No account was taken of plants contracting the disease on the sucker growth appearing after topping, as it is believed that the presence of the disease on such growths does not affect the commercial leaves. The percentage of infection, in general, that season (1916) was below what may be considered the normal infection. (This count, however, included three very badly infected fields where a large percentage of the crop was affected, and this raised the percentage of infection considerably.) The prevalence of mosaic disease seems to be less than it was some years ago, and there has been only relatively small damage from this trouble in the tobacco section, as a whole, in the past two or three years. If more attention is paid to careful handling of plants in removal from the seed bed and during transplanting, the damage resulting from this disease can be reduced to an almost negligible amount. More attention should also be paid to fitting the land and keeping it in the best condition during the transplanting time and until the plant has obtained a good start. There is no question but that proper attention to such details and to the rejection of diseased plants in the seed bed will go far towards controlling the trouble, but it is improbable, owing to its nature, that it will ever be entirely eradicated. A good indication as to whether an infection is from the seed bed may be obtained by making a note of the time, after planting, of the first appearance of the disease in the field. If the disease is noticed at any time within a period of two weeks after setting, one may be sure that the infection came either from the seed bed or during the transplanting. If it appears after this length of time it is usually the resultant of a field infection. If all the leaves show the trouble it may also be stated that the infection came from the seed bed or from the conditions under which the plants were set. If it appears on some of the upper leaves at a later period the infection occurred in the field, and soil conditions should be looked into. A full discussion of the mosaic disease will be found in Bulletin No. 175 [1] of this station, a copy of which will be mailed on request to the director's office.

Thielavia root-rot, or the ordinary root-rot of tobacco, is probably the most widespread trouble of fungous origin we have in our tobacco fields, and as a primary and secondary cause of many of our "sick" fields it is of great importance.

This disease appeared to be more destructive in 1916 than usual, although the amount could not be compared with that of 1915, as no extended examinations were made during that season. Many fields presenting an unthrifty appearance were studied with the idea of obtaining data as to the presence of root-rot, but in some cases only slight infections were found, the root systems of the plants not being parasitized sufficiently to account, in our opinion, for the general unthrifty appearance of the field. However, some cases were observed where the plants on entire fields were, to a large extent, badly infested with the root-rot fungus, and unquestionably these fields are in need of immediate treatment looking toward the eradication of this trouble. In nearly every case these heavy infections were on fields long used for growing tobacco, and the soil reaction and other factors were rather abnormal. It would appear from the observations made during the season of 1916 that in our fields the causal organism of Thielavia root-rot is widely distributed, but produces noticeable ill effects only when the soil and its environment are unfavorable to the best development of the tobacco plant and favorable to the rapid development of the root-rot fungus.

The control of this disease in the seed bed has already been discussed. There is no question but that it can be completely controlled by thorough sterilization either by steam or formaldehyde. The control of the disease in the field is an entirely different matter, however, and it is practically out of the question to attempt to eradicate it in the field by methods used for its eradication in the seed bed, because of their prohibitive cost. Even if the cost of material were considerably less than it is at present the labor and time factor would render such methods prohibitive. It is believed by some that a method of control by steam or formaldehyde can be devised, and that it will not be impossible of application from the

[1] Chapman, G. H. Mosaic Disease of Tobacco. Mass. Agr. Exp. Sta. Bull. No. 175 (1917)

economic point of view; but so far this has not been done. It may be possible to apply some compound in a dry state to the field, and to do it economically, but any application of a salt in solution would demand so much water to obtain the requisite penetration that it would be out of the question. So far a dry compound possessing the requisite fungicidal action has not been discovered. Certain solutions and salts have been used experimentally, but unfortunately none can be recommended for use on a commercial scale. A brief statement of the results obtained in our experiments with various compounds will be given below. It is believed that control can be better obtained by changing the soil reaction to a more acid condition by means of fertilization and cover-cropping, as has been indicated. The whole question of the prevalence of root-rot and its infection in our fields is closely bound up with the question of soil reaction, and it can hardly be profitably discussed apart from that problem. We have been able, by the use of cover crops and acid fertilizer materials, to "bring back" some heavily infested fields in a remarkably short time, and have no hesitation in recommending the use of a timothy cover crop and the non-application of lime to fields infected with the Thielavia root-rot. Of course there may be danger of getting our soils into a condition too acid for the best growth of tobacco, and judgment should be used in the application of any raw acid materials. The grower should not forget that "while a little may be a good thing, too much may be highly injurious." An increase in the amount of phosphoric acid, applied in the form of acid phosphate, has been found to have a beneficial effect, and apparently does not adversely effect the quality of the tobacco. In our experiments application of both "aged" and "raw" acid phosphate, in amounts of 400 and 600 pounds additional to the acre, has given uniformly good results, particularly on the lighter soils.

Thielavia Root-rot Investigations.

A statement of the results of some of our experiments having to do directly or indirectly with the Thielavia root-rot has been made in connection with other lines of work. Some of the experimental work, while interesting and fundamental from the scientific standpoint, can hardly be made use of at present as a basis for the treatment of infested fields. As a matter of record, however, a brief discussion of experiments is included in this report. The first work undertaken was the attempt to control the disease in the field by the application of chemicals to the soil. The data presented represent the work of two years. The plots were located on fields known to be heavily infested with Thielavia root-rot. The substances used were formaldehyde, copper sulfate, iron sulfate, mercuric chloride, potassium permanganate, sulfuric acid, sulfur, and "By-product A," a commercial preparation. With the exception of the sulfur and "By-product A" the substances were all applied in solution. All plots were in duplicate. The following table will indicate the amounts applied, calculated to an acre basis. A check plot (no treatment) was left between every two plots.

TABLE V. — *Chemicals applied, and Rates of Application.*

	Pounds per Acre.		
Formaldehyde,	4,800	2,400	1,200
Copper sulfate,	400	200	100
Iron sulfate,	1,000	500	50
Mercuric chloride,	100	75	25
Potassium permanganate,	300	100	50
Sulfuric acid,	1,200	600	300
Sulfur,	2,000	1,500	1,000
"By-product A,"	4,000	2,000	1,000

The sulfur and "By-product A" were applied dry and thoroughly mixed with the 3 inches of top soil. The formaldehyde was so diluted that it was applied at the rate of one-half gallon of solution to the square foot of surface. On the first year's plots observations of a miscellaneous character were taken in addition to the root-rot data. The observations relating to growth are noted in the following table. They were made two weeks before harvesting. The growth data are calculated on the basis of the checks equalling 100, the plots being greater or less than this.

TABLE VI. — *Table showing Development of Tobacco in 1917 on Chemically Treated Plots.*

Chemical.	Amount applied (Pounds per Acre).	Color.	Growth (Check=100; no Treatment).
Formaldehyde,	4,800	Normal,	100
	2,400	Normal,	125
	1,200	Normal,	125
Sufuric acid,	1,200	Normal,	125
	600	Normal,	100
	300	Normal,	100
Sulfur,	2,000	Light,	40
	1,500	Normal,	60
	1,000	Normal,	100
Mercuric chloride,	100	Normal,	45
	80	Very dark,	90
	25	Very dark,	100
Copper sulfate,	400	Normal,	100+
	200	Normal,	110
	100	Normal,	110
Ferrous sulfate,	1,000	Light,	94
	500	Normal,	87
	250	Normal,	100
Potassium permanganate,	300	Normal,	87
	100	Normal,	85
	50	Normal,	85
"By-product A,"	4,000	Normal,	94
	2,000	Normal,	94
	1,000	Normal,	100

It will be noted that the only substances which did not have an inhibiting action on the growth were formaldehyde, sulfuric acid, and copper sulfate. The rest of the chemicals applied did inhibit the growth of the tobacco, at least in the amounts applied.

A careful examination of the root systems of the plants in the different plots was made by Mr. Krout of this department, who was in direct charge of the root-rot work, and he reported as follows: —

TABLE VII. — *Comparison of Treatment with Thielavia Infection and Root Development.*

CHEMICAL.	Application (Pounds per Acre).	Thielavia Infection (Check Infection=100).	Root Development (Check=100).
Formaldehyde,	4,800	0+	100
	2,400	15	150
	1,200	15	125
Sulfuric acid,	1,200	88	75
	600	95	103
	300	88	125
Sulfur,	2,000	80	38
	1,500	70	65
	1,000	80	90
Mercuric chloride,	100	83	78
	80	83	88
	25	88	90
Copper sulfate,	400	75	123
	200	85	108
	100	90	108
Ferrous sulfate,	1,000	90	70
	500	90	95
	250	100	115
Potassium permanganate,	300	90	100
	100	60	100
	50	95	100
"By-product A,"	4,000	100	93
	2,000	88	105
	1,000	90	95

From the above it may be seen that the only substance used which checked the development of the root-rot, or controlled it to any great extent, was the formaldehyde. The root growth also was apparently stimulated by the lower concentrations. Sulfur, mercuric chloride, and ferrous sulfate, while reducing the root-rot to some extent, had an injurious effect on root development. The copper sulfate and sulfuric acid reduced the amount of root-rot infection somewhat, and did not apparently, except in the case of the greatest strength of sulfuric acid, reduce the root development to any extent.

These experiments were continued in the following year with comparable results. It would seem that none of the substances used, with the exception of formaldehyde, were sufficiently beneficial in their action to warrant further experimental work at this time. The cost of this material and the labor involved, together with the large amount of water which is necessary, render it inadvisable to recommend this treatment on large areas. Small areas in a field might be so treated.

The sulfuric acid treatment did not give the results anticipated, but possibly a variation in amount applied might give more beneficial results. In this case, however, we should have to take into consideration the possible residual effect of the SO_4 radical (sulfate). Further data on this point will be available later. It would seem that, in view of the fact that Thielavia is so susceptible to acids, this might be a method of at least partial control.

The benefits to be derived from increasing the organic matter and general condition of the soil, in relation to the Thielavia root-rot, have already been briefly discussed, and further mention of them will be omitted.

Much laboratory work is in progress with the Thielavia fungus to determine the specific action of the different acids and bases on the growth and development of the fungus in culture, as well as to determine the limits between which the fungus is actively parasitic. The results, however, will not be discussed in this report, as additional work is necessary on this phase of the problem.

Fertilizer Experiments in Progress.

Beginning in 1917 there were established three experimental field plots on different soil types in the tobacco section. The yields on these fields were very low, so low on one of them that the crop had not been harvested. On one of the fields there was abundant evidence of a very serious Thielavia root-rot infection; on the other two, however, although the root-rot was present it did not appear to be of primary importance.

The experiments were designed to be general in character, and dealt with three principal questions, namely: (1) Are our soils in need of organic matter, and if so what is the response of the crop to the direct addition of the same in the form of peat, or in the form of stable manure? (2) Are our soils lacking in potash, owing to the inability of the growers to procure the usual amounts of the same since 1914, and if there is a lack how is it evidenced? (3) What benefits, if any, are to be derived from the addition of increased amounts of phosphoric acid in the form of acid phosphate to the normal fertilization? This question was suggested by the fact that very good results have been obtained in many cases by rotating tobacco and onions, and the latter crop is usually treated with a fertilizer containing a large amount of acid phosphate.

The results of 1919 are not at present ready for publication, but some rather definite results were obtained in 1917 and 1918. These will be briefly discussed here. The details of the experiments will not be taken up in this report, as the work is of sufficient volume to require a separate report, which is to be issued as soon as possible after the 1919 crop has been gone over and the results tabulated. Two of the plots were Havana and the third Cuban shade-grown. There has been a general similarity shown by the results on all of the plots.

In addition to the special treatments indicated below, it should be remembered that all the plots received an application of a 5–4–5 mixture, equivalent to an application of 3,000 pounds of commercial mixed goods of the same analysis per acre, except, of course, the no-potash plots. These received no potash in any form, except such as was in the manure or the cottonseed.

There was a marked increase in yield both in 1917 and 1918 on the plots which had received an application of organic matter in the form of peat at the rate of 2 tons to the acre (on a 12 per cent moisture basis), and also a slightly heavier yield with better quality on the manure plots than on the peat, the manure being applied at the rate of 10 tons to the acre. There was a still more marked increase in yield on the plots which had received organic matter, either as peat or manure, and acid phosphate at the rate of 300 to 600 pounds per acre. Where acid phosphate alone was used in conjunction with the regular fertilization without the addition of organic matter in some form the results even on the same plot were sometimes rather conflicting. It can only be stated that no uniformity of results was obtained. In some cases a marked benefit was noted as a result of the treatment; in others, on the same field, the results were apparently negative.

With respect to the lack of potash it was noticeable that there was no lack of this material indicated on any of the plots in 1917 and 1918. No differences were observed, so far as this material was concerned, between the plots which received applications of 350 pounds of high-grade sulfate of potash and those which received none at all. It should be stated, however, that the experimental plots were all located on land which had in the years prior to 1914 received liberal applications of potash, and it is quite probable that the supply of available potash in the soil was in no case exhausted. During the growing season of 1919 there were indications that on one of the fields there might be developing a lack of potash. The symptoms were not characteristic enough to warrant a positive statement on this point.

There is no evidence that our soils in general are suffering from a lack of potash, although a few local areas where this was the case have been brought to our attention during the past year. These cases were all on light soils and on soils which had not in the past received any heavy applications of potash in the fertilizer used. It would appear that new soils which have been used for a comparatively short period only before the shortage of potash are more liable to be suffering from a lack of potash than are some of the old fields which have for years received a very liberal application of this material. On these fields it is probable that there is an accumulation of potash in the soil sufficient to have carried the crop over the period of the shortage.

Organic matter, of course, can be economically applied to the soil in the form of a cover crop, as has already been mentioned, or as manure. This latter method is the more costly if all manure has to be bought, but some manure should be applied from time to time to get the best development of tobacco, apparently, although it is true that many growers are at present using commercial fertilizers and cover crops alone with good success.

The increased growth on acid phosphate in conjunction with applications of organic matter is conspicuous and rather difficult of explanation, aside from the points brought out in the discussion of the question of soil reaction. The tobacco plant uses very little of the available phosphoric acid of the soil, and certainly for direct fertilization effect, or as a food material, the plant needs only a small amount of the phosphoric acid available. It might be well to caution against the use of very large amounts of acid phosphate on our heavier soils year after year, as there is a tendency for this material to darken the leaf, and also, on account of the sulfate or sulfuric acid contained in it, to injure the burn. In our experiments, however, this has not occurred as yet.

Miscellaneous Observations.

Other Root-rots.

While making an examination of the roots of plants from a field which had presented an unthrifty appearance all season (1916), but on which very little root-rot (Thielavia) could be found, it was observed that certain of the plants showed a peculiar discoloration of the root stock just below the surface of the ground. The only organism isolated was a species of Actinomyces, which was characterized by Dr. P. J. Anderson of this department as differing, apparently, from the ordinary forms found in our soils. No connection has been established as yet between the presence of this fungus in soils and its relation to the tobacco plant. No infection experiments have been made, but a study of this organism, if found again, is projected. Forms of Fusarium were also isolated from this and other material, but their rôle is problematic.

"Mammoth" Types of Cuban and Connecticut Havana Tobacco.

From time to time there have appeared in the fields of Connecticut so-called "mammoth" plants of Cuban and Connecticut Havana tobacco. Beinhart and Hayes first experimented with the mammoth Cuban type found in Connecticut on the plantation of the Windsor Tobacco Corporation by its manager, Mr. J. B. Stewart, from whom the type takes its name, "Stewart Cuban." This mammoth type was first grown commercially in 1914, and was found to cure in a very satisfactory manner.

At present the Stewart Cuban, or a very similar mutant, is being grown not only in Connecticut, but in Massachusetts as well to a limited extent.

It apparently is also satisfactory to the trade, which is essentially the final test of all tobacco.

In 1912 and subsequently, mammoth mutants have been quite frequently found in fields of Connecticut Havana. In 1916 our attention was called to two plants in a field in Sunderland by Mr. Frank Hubbard. These plants were darker green in color and had a larger leaf than did the average plant, and showed no indication of budding when the plants in the rest of the field were ready for topping. The number of leaves per plant was also greater, and they were set much closer together on the stalk. These two plants were removed to the greenhouse early in September and allowed to mature. It was not until mid-April of the following spring that the plants blossomed, and seed could not be obtained until May.

Before transplanting to the greenhouse there were primed from these two plants thirty-eight and forty-six leaves, respectively. It was reported that these leaves cured satisfactorily. At the time of blossoming there had been produced on the main stalk of each plant one hundred and thirty and one hundred and ten leaves of sufficient size to be called marketable.

In 1918 some few hundred plants were set in two fields, one in Southwick, on the farm of Mr. C. H. Granger, and one in Sunderland, on the land of Mr. Frank Hubbard.

The comments of the growers are as follows: Mr. Granger said, "I primed forty to fifty leaves from a plant, but they never cured right, and about the only recommendation I can give this tobacco is a fine-shaped leaf and increased weight. I topped some of it but got no better results."

Mr. Hubbard reported that he was much pleased with the type and habit of growth, but that as the plants were not set on what he would consider prime tobacco land he would prefer to try it again. Some of the tobacco he had bulk-sweated, and it came through rather better than was expected. The leaf had a good body, vein, etc., but contained little or no light wrapper, consisting principally of medium and dark wrapper and binder. The taste and burn were fairly satisfactory. The yield, in comparison with the ordinary type of Havana, was approximately doubled.

Further work with this type of tobacco, looking toward improvement of quality by varying the fertilization and also a method for maturing seed earlier, is in progress. It is believed that this mammoth type of Connecticut Havana may possess commercial possibilities.

High-pressure versus Low-pressure Seed Bed Sterilization.

It has been universally recommended that in sterilizing the seed beds with steam, as high a steam pressure as possible be maintained at the boiler, usually from 75 to 125 pounds, and that the steam be allowed to act under the pan for from twenty to thirty minutes in order to insure thorough sterilization.

Low-pressure outfits developing around 20 pounds pressure have been used, and in many instances with entirely negative results so far as killing disease-producing organisms was concerned.

It has been stated by some growers that they were absolutely sterilizing their beds with low-pressure steam in the same time as with the high-pressure outfits. There is no question but that certain types of soils will permit the use of low-pressure, providing the soil is in exactly the right mechanical condition and has a minimum water content. This has been done experimentally and practically on light porous soils, but unless the grower is assured by thermometer readings, or the complete cooking of potatoes at the desired depth, that the soil is sterile, it is apt to be a costly and futile undertaking.

It is much safer to use high-pressure outfits, particularly when the work is done by outside parties. In any event, the grower should assure himself that he is sterilizing the soil and not merely killing a few weed seeds. For general application the high-pressure method should be used; the low-pressure method will sterilize, but economically it has only a very limited range of application on certain soils. Usually there is too much guesswork in sterilization.

Vitality of Tobacco Seed.

It has been generally believed that the seed of tobacco retains its vitality for a number of years, even up to twenty. This may be true in exceptional cases in which the seed has been preserved under ideal conditions, but usually after the tenth year the vitality of our seed is so much reduced as to render it unfit for use, even when preserved under the best conditions.

A grower, however, often wishes to use a particular lot of seed a number of years, and it is of interest to know approximately, at least, what the germination of seed of the different varieties is at different ages. The maintenance of vitality, of course, depends to a great extent on the conditions under which the seed is kept, and this factor should be taken into consideration in drawing conclusions as to the germinability of the seed. In the following table are given some of the results obtained with seed of different ages kept under excellent conditions in a cool, dry place, either in muslin bags or wide-mouthed glass containers plugged with cotton: —

TABLE VIII. — *The Vitality of Tobacco Seed of Three Varieties preserved properly for Various Lengths of Time.*

Variety.	Age of Seed (Years).	Test No.	Per Cent of Germination at Two-day Intervals.						Average.
			2	4	6	8	10	12	
Broadleaf,	10	1	0	0	0	0	16	45	50
		1*a*	0	0	0	0	12	55	
	9	2	0	0	0	12	21	67	66
		2*a*	0	0	0	0	16	65	
	5	3	0	0	58	89	95	95	95.5
		3*a*	0	0	62	92	96	96	
	2	4	0	0	60	85	88	90	91.5
		4*a*	0	0	54	80	91	93	
Havana,	37	5	0	0	0	0	0	0	0
		5*a*	0	0	0	0	0	0	
	25	6	0	0	0	0	0	0	0
		6*a*	0	0	0	0	0	0	
	9	7	0	0	0	0	0	2	1.5
		7*a*	0	0	0	0	0	1	
	6	8	0	0	61	68	–	–	68
		8*a*	0	0	58	68	–	–	
	4	9	0	–	–	95	–	96	95.5
		9*a*	0	–	–	92	–	95	
	2	10	0	0	–	–	98	98	99
		10*a*	0	0	–	–	100	100	
Cuban,	6	11	0	0	8	22	41	54	49.5
		11*a*	0	0	18	35	41	45	
	4	12	0	0	23	74	88	–	82
		12*a*	0	0	31	66	84	–	
	2	13	0	0	27	86	91	–	93
		13*a*	0	0	28	90	95	–	

Considerable variation will be noted in the above table, and perhaps a larger series would have changed the results somewhat, but it was impossible to find seed saved under these conditions. The results at least serve as an indicator of the probable vitality of these varieties. The Broadleaf variety apparently retains its vitality longer than either the Havana or Cuban.

A few samples from tin cans and corked bottles were germinated at the same time with the following results: —

Five-year-old Broadleaf germinated only 31 per cent.
Three-year-old Broadleaf germinated only 72 per cent.
Two-year-old Havana germinated only 87 per cent.

Seed should be thoroughly dry when placed in containers, and some means of ventilation, or better, aëration, should be provided; otherwise the accumulation of moisture in the containers will be very conducive to mold growth. Seed preserved in cloth bags in a cool, dry place will retain its vitality longer, and give higher percentage of germination, than seed stored in air-tight containers.

Top-dressing Tobacco Seed Beds with Dry Ground Fish.

It is the custom of many growers to top-dress the tobacco seed beds occasionally with some quick nitrogen fertilizer, such as ammonium sulfate, nitrate of soda, commercial "starter," or fish. The danger of using an excess of the three former is pretty well recognized by the growers, but in the use of dry ground fish not so much attention has been paid to the amount used, as it has been claimed that it is impossible to apply an excess of this material.

This view is erroneous, as at least three cases have been noted where an excess has been applied, the "burning" of the plants taking place four to six days after application. In all cases the plants were thoroughly sprayed and the fish well washed off the leaves. Experimentally, the same applications proved injurious in all three cases. The mechanical condition of the fish seems to play a very important part in the injury, as in all three cases the fish was very finely ground, and in all probability the nitrogen was more quickly available than with other coarser or less nitrogenous fish.

No set rule as to the amount to be applied can be given, but as much discretion should be used with fish as with the ammonium sulfate or sodium nitrate, as the loss of the beds from top-dressing is a very serious matter.

As a matter of fact, beds properly fertilized should not need any application of nitrogen except, perhaps, after they have been pulled over several times. While a large, apparently vigorous growth is obtained when the bed is repeatedly top-dressed with nitrogenous fertilizers, the plants are apt to be tender and succulent, and will not stand transplanting so well.

SUMMARY.

1. *The yield of tobacco in Massachusetts has not been gradually decreasing during the past ten years. Since 1914 the yield has been low, but this is due to adverse climatic conditions primarily.*

2. *In general, rainfall is the major limiting factor of growth (and this necessarily includes soil moisture along with it), together with temperature.*

3. *Excessive seasonal rainfall is invariably followed by a reduction in yield, independent of temperature.*

4. *Subnormal rainfall, when accompanied by temperatures excessively above normal, reduces the yield.*

5. *Subnormal rainfall, when accompanied by subnormal temperatures, does not apparently reduce the yield to any extent unless the rainfall is very much below normal.*

6. *There are, undoubtedly, in many localities specific problems to be worked on, such as the effects of improper fertilization, methods of culture, and control*

of disease-producing organisms; but these are "specific" and not "general" troubles as yet.

7. *The tobacco soils of Massachusetts fall into three groups, as regards acidity or "lime requirement." Soils with a "lime requirement" up to 3,000 pounds CaO per acre are not producing good crops, as a rule, and are comparatively free from root-rots. Those with a "lime requirement" of from 3,000 to 8,000 pounds CaO per acre are in good tobacco condition; but in this group pathogenic fungi are abundant in the soil, and the plants, during certain seasons, are very liable to suffer from root-rots caused by some of these fungi. Soils with a "lime requirement" of 8,000 pounds CaO up are usually comparatively free from such fungi, and even in unfavorable seasons little disease is found, but the tobacco is perhaps of slightly inferior quality.*

8. *Most of the tobacco soils in Massachusetts are deficient in humus or organic matter.*

9. *To supply this lack of organic matter cover crops, preferably timothy, should be planted and plowed under.*

10. *No satisfactory field soil treatment for the Thielavia root-rot has been worked out.*

11. *Many of the so-called "sick" soils are responding favorably to additional applications of organic matter and phosphoric acid in the form of acid phosphate. Care should be exercised in the application of these materials to guard against excess.*

12. *Our fields, generally, are not yet suffering from a lack of potash, as determined by plant growth and development.*

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 196 SEPTEMBER, 1920

METHODS OF APPLYING MANURE

By WM. P. BROOKS

This bulletin describes an experiment comparing late fall and winter spreading of manures with spring application and prompt incorporation with the soil, which continued twenty years, during the first twelve manure being applied (with one exception) annually, while the determination of the relative lasting effects has been the object of the last eight years. Results are briefly presented and discussed, and seem to show conclusively that holding the manure in a large heap until spring is the better plan, because it involves less waste, and during later years, especially, produces larger crops, more clover, more rapid early spring growth and earlier maturity.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

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BULLETIN No. 196.

DEPARTMENT OF AGRICULTURE.

METHODS OF APPLYING MANURE.

BY WM. P. BROOKS.

Introduction.

The question as to the best system of handling and applying manures is one which has always excited a great deal of interest, and is of very special importance at this time. The reasons which have given the question exceptional importance in recent years are several. Among the more prominent are these: —

1. The increasing insistence, on the part of those using the product of our dairy stock, not only that manure shall not be stored, as was formerly the custom, in a cellar beneath the stable, but that it shall be promptly taken away from the vicinity of the stable.

2. The increasing cost of the labor of taking manure from the stable to the fields where it is to be used.

There are, of course, great possibilities of variation in methods adopted, but one of the most prominent in the minds of those making use of manure has been the question as to whether, when removed from stable or other place where it has accumulated, it is advisable to spread it at once upon the land, irrespective of the season of the year when it must be so removed, or whether provision should be made to store it in some manner and hold it until it can be incorporated with the soil. This has always been a question upon which there has been a great difference of opinion, both plans having earnest advocates, especially the plan of spreading manure as fast as it must be moved, on account of reduced cost of labor connected with its application under that system, and reduction of the pressure of farm work in the spring. The experiment described in the following pages was planned with a view to throwing light upon this question.

The experiment began in 1900. The land available for use in the experiment lay on a moderate slope from the east toward the west, which was fairly uniform, though not quite ideal in respect to uniformity, and which lay at an angle with horizontal of about 4½ degrees. The location is near the foot of the west side of a drumlin of moderate elevation. According to a soil survey made by the United States Department of Agriculture the soil is of that type for which the name Holyoke Stony Loam was suggested. It is a type of soil which with minor variations is very common throughout Massachusetts, and is known in the ordinary language of the farm as a moderately strong gravelly loam, with good capacity for retaining and conducting moisture, and somewhat affected, more or less unevenly as is pointed out in another connection, by seepage water which tends toward the surface from the higher portions of the drumlin as it finds its way downwards.

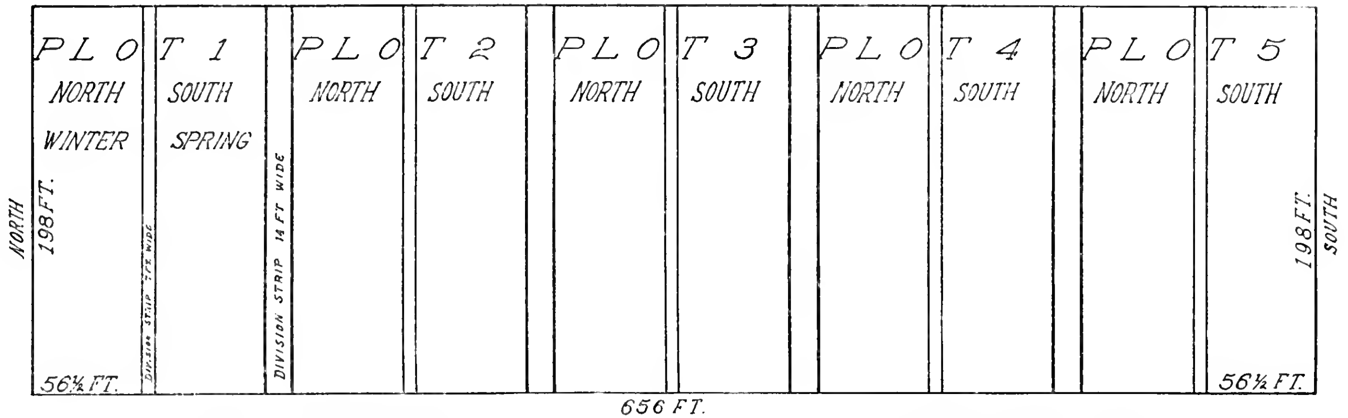
The land referred to had been used in an orchard experiment designed to test the relative results of different systems of manuring continuously followed from the year previous to the setting of the nursery stock. The kinds of fruit which had been used in the orchard experiment were peaches and pears. The land used was divided into five equal plots, each of which was uniformly manured annually from 1889 (the year previous to the setting of the trees) until 1897, both inclusive. As already indicated, the trees were set in 1890. The land proved unsuited to the peach and pear, a number of the trees died quite early in the experiment, and, since the number lost in different plots differed widely, it was decided to be inexpedient to continue the experiment with these kinds of fruit. Both manure and fertilizers used while the land was in fruit were applied broadcast in the early spring.

Plan of the Experiment.

The statements concerning the history of the area used in the experiment to be described have made it apparent that we had available five plots lying side by side upon a fairly even slope which had been respectively subjected to a widely varying fertilizer treatment. It is at once apparent that results on these plots could not be compared one with the other in such a way as to throw any light upon the question of the relative effects of different methods of applying manure. Accordingly each of the original orchard plots was divided in the middle by a line running directly up and down the slope. The different original plots were separated by unmanured or fertilized strips of land 14 feet wide, while the two halves of each of the original plots as laid out for the experiment under discussion were separated by a strip 7 feet in width. For purposes of record it was decided to retain the original orchard plot numbers, and to make the application of manure to the north half of each plot in winter, that to the south half in spring. The system followed to insure as closely as possible absolute equality in amount and kind of manure applied to north and south plots was as follows: —

All the manure used on plots 1 to 4, both north and south halves, was the product of the experiment station herd of milch cows. These cows were liberally bedded with baled planer shavings. The floor upon which the cows were kept was watertight, and the manure was removed at

PLAN OF PLOTS. MANURING EXPERIMENT.



FERTILIZER TREATMENT, 1889–97.

Plot 1, manure, 10 tons per acre.
Plot 2, wood ashes, 1 ton per acre.
Plot 3, nothing.
Plot 4, ground bone, 600 pounds per acre; muriate of potash, 200 pounds per acre.
Plot 5, ground bone, 600 pounds per acre; low-grade sulfate of potash, 400 pounds per acre.

MANURING EXPERIMENT, 1900–19.

Manure applied annually, 1900–11 (with the exception of 1907), at the rate of 10 tons per acre.
North half, winter application.
South half, spring application.
Plots 1 to 4, cow manure; plot 5, horse manure.
Plot 1, early winter; plot 4, late winter.
No manure applied since 1911.

least twice daily to concrete pits, watertight and roofed. There were two pits. Manure was allowed to accumulate in the pits until the amount was sufficient to supply the needed quantity for an entire plot. The manure was then conveyed to the field, being weighed load by load as it was moved. (In referring to the different plots, the north half will be designated as "N," and the south half as "S." The arrangement and previous history will be understood by reference to the plan, page 41.)

The first load of manure was spread on plot N; the second load taken out was dumped into the foundation of a heap to be built out of the manure which was to be spread in the spring (this being located on some part of plot S, differing from year to year). Alternating loads were taken, respectively, to N and S, and either spread on N or added to the heap on S. The total weight when removed from the pits to the field as described was the same for both N and S. The annual application was at the rate of 20 tons per acre.[1] In building the heap on S, it was the practice to drive over what had previously been dumped as long as possible; and when all the manure had been taken out, the heap was squared up and was usually about 4 or 5 feet in height, with sides nearly perpendicular. In other words, the manure was so piled as to expose it as little as possible to danger of loss through washing and leaching. As has been indicated, care was taken in successive years to place the heap of manure on the different plots S on different parts of the plot, in order to equalize as far as possible any effect due to leaching of material directly from the heap into the soil beneath and in its immediate vicinity. Manure held in heaps from the time it was hauled out until spring was in all cases allowed to stand in the heap, when a hoed crop was to follow, until the soil could be worked. It was then spread on the plot on which the heap stood as evenly as possible, and then the entire area, including that to which manure had been applied during the winter, was disked, thus at once mixing the newly spread manure with the soil. When the land was in grass the time of handling the manure from the heap was practically the same as when the land was to be put into a hoed crop, and after spreading the manure from the heap upon the mowing it was the usual practice to go over the entire area, winter as well as spring applications, with a brush, for the purpose of fining and promoting a more even distribution of the manure. The manure held in heaps on all plots was almost invariably all spread in each year on the same day, or, if conditions rendered this impossible, the work once begun was completed at the earliest possible moment.

When the land was to be put into a hoed crop the following year, it was either sown to a cover crop of rye the previous fall or plowed late in the fall across the slope of the field. No attempt was made to vary the date of application according to variations in the field conditions as regards covering with ice or snow or freedom therefrom, and any one

[1] A cord of undecomposed, well-saved cow manure from animals moderately bedded with planer shavings weighs about 3 tons.

familiar with the New England climate will understand that there was very wide variation in conditions at the time of application. Plots N and S on plot 1 were the first plots supplied with manure except in 1911, when the order was reversed. With the exception of the year just named, plots 2, 3 and 4 were supplied in the order named. The application to plot 4 was therefore, with one exception, either very late in the winter or in the early spring.

TABLE I. — *Variations in Date of Application of Manure and of Spreading from Heaps.*

Plot.	North Half.		South Half.			
	Spread.		Piled.		Spread.	
	Earliest.	Latest.	Earliest.	Latest.	Earliest.	Latest.
1,	Nov. 19	Mar. 13	Nov. 19	Mar. 13	Apr. 4	May 23
2,	Nov. 24	Feb. 26	Nov. 24	Feb. 26	Apr. 4	May 23
3,	Dec. 16	Mar. 31	Dec. 16	Mar. 31	Apr. 4	May 23
4,	Dec. 16	Mar. 28	Dec. 16	Mar. 28	Apr. 20	May 23
5,	Dec. 9	Mar. 8	Dec. 9	Mar. 8	Apr. 4	May 25

The manure applied to plot 5 was of different character. It was obtained from a local livery stable, and was horse manure usually comparatively fresh and containing a moderate amount of straw which had been used for litter. In supplying manure to N and S of plot 5, the plan described in outline for the other plots was followed; that is, alternate loads respectively spread on N and added to a heap on S, the total to N and S being the same for each.

In 1906 the whole field received an application of hydrated lime at the rate of 1 ton per acre. This was applied on the rough furrow and was worked in by the use of the disk harrow.

The experimental system of manuring described was continued annually from 1900 to 1911, both inclusive, with the exception of one year, 1907, when no manure was applied to any plot, and with a few minor variations which seem unimportant in their relation to the results obtained. In preparation for the experiment, the yield of all plots in the field under precisely similar manurial treatment for all was determined in 1899. In this year manure from the station herd of dairy cows was applied by means of the manure spreader driven transversely across all the plots in moderate and in precisely equal amounts to each, as nearly as careful regulation of the machine permitted. The field was planted with corn. There was considerable difference in the total yield of dry matter obtained on N and on S of plot 3, which reference to the plan (page 41) shows was the plot which during the continuance of the orchard experiment had been neither manured nor fertilized. These yields are shown in Table II, as also are the yields of dry matter in 1899 on all the other plots.

TABLE II. — *Dry Matter per Plot after Uniform Manuring in 1899. Ensilage Corn (Pounds per Plot).*

PLOT.	North Half.	South Half.
1,	1,559	1,660
2,	1,758	1,696
3,	756	1,271
4,	1,659	1,551
5,	1,616	1,703

It will be noted that there is but little variation in yield between N and S on the other different original plots, the extreme range being from 1,550 to 1,750 pounds. The results obtained, therefore, indicate that the conditions for the comparison of the two systems of applying manure were fairly satisfactory.

I would, however, call attention to the fact that probably more important than variations in fertility dependent upon differences in plant-food content were differences in moisture conditions on the different plots. The slope used in the experiment lay upon the west side of a drumlin, a geological formation extremely common and highly important in the agriculture of Massachusetts. As is likely to be the case with slopes on drumlins there is a tendency for seepage water, which sinks into the soil farther up on the slope or on the summit, to work outward toward the surface on the lower parts of the slope. During some years and with some crops this movement of soil water exerted comparatively little effect on the crop, but there can be no doubt that in seasons of comparatively heavy rainfall during the period of most active growth, especially of crops such as corn and soy beans which require high soil temperature for best results, it was sufficient on some of the plots to keep the soil cooler and wetter than is desirable for the best yields.

RELATIVE EFFECTS OF THE TWO SYSTEMS OF MANURING ON CROP YIELDS.

Table III shows the crops grown in successive years during the period of the experiment under consideration, and for each year indicates in how many of the five different comparisons either N or S, or one of them alone, gave the larger yields. Attention is called to the fact that the period during which manure was applied annually in accordance with the two plans under comparison was twelve years, and that there were five comparisons each year, or 60 in all.

TABLE III. — *Manuring Experiment, General Character of Results.*

Year.	Crop.	North Half ahead.	South Half ahead.
1900, ...	Corn (grain), ...	1	4
1901, ...	Millet, ...	–	5
1902, ...	Corn (ensilage), ...	2	3
1903, ...	Soy beans, beans, ...	3	2
1904, ...	Corn and soy beans (ensilage), .	3	2
1905, ...	Corn (grain), ...	–	5
1906, ...	Corn (grain), ...	1	4
1907, ...	Mixed grass and clover, . .	2	3
1908, ...	Mixed grass and clover, . .	–	5
1909, ...	Mixed grass and clover, . .	3	2
1910, ...	Mixed grass and clover, . .	–	5
1911, ...	Mixed grass and clover, . .	4	1
	Totals, ...	19	41

Examination of this table shows that, as might be expected by any one familiar with the variations in our climate, results were not consistently favorable throughout the entire period, either to one or the other season of application; but the general average result was most favorable to winter application in 19 out of 60 comparisons, or practically 1 in 3.

The following points appear to be worthy of especial mention. In 1903, the crop being soy beans, the general average based upon results upon all the plots showed that plots N were ahead both in yields of beans and straw. In 1904, the crop being corn and soy beans which were ensiled, the crops were about equal. When the crop was mixed grass and clover the general average was favorable to the North half three years out of five, or in three-fifths of the trials. On the other hand, when corn for ripened grain was the crop, the South half was invariably ahead on the general average.

The general results, therefore, it may be said, appear to indicate that the common practice of top-dressing mowings with manure during the late fall or winter rather than in the spring is wise. If, however, we study Table IV, which shows the percentage results, it will be noticed that the average superiority of the North half is due to the fact that the first, or hay, crop is usually the better under that plan; the rowen crop, on the other hand, is usually better when the manure is spread in the spring, and the degree of superiority as indicated by the higher percentage shown in Table IV for the rowen crop under spring application is usually very high.

TABLE IV. — *Manuring Experiment, Percentage Results.*

Year.	Crop.		Percentage for South Half (North Half=100 Per Cent).				
			Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
1900	Corn,	Grain,	96.3	108.6	124.7	111.1	132.6
		Stover,	113.2	105.2	125.5	108.9	111.4
1901	Millet,		118.2	131.3	177.0	145.7	148.7
1902	Corn (ensilage),		103.9	97.3	150.0	91.6	108.6
1903	Soy beans,	Beans,	106.9	95.3	95.9	82.5	106.7
		Straw,	118.7	103.7	90.8	81.4	101.4
1904	Corn and soy beans,		92.2	107.4	130.1	92.9	97.2
1905	Corn,	Grain,	102.1	123.6	123.1	119.5	106.4
		Stover,	107.0	108.6	113.3	111.6	105.1
1906	Corn,	Grain,	105.9	122.9	108.4	93.2	102.2
		Stover,	105.9	114.0	107.9	99.1	100.2
1907[1]	Mixed grass and clover,	Hay,	100.3	98.7	107.0	92.9	95.2
		Rowen,	111.1	90.0	87.3	105.6	174.2
		Total,	101.6	97.3	103.5	94.5	101.6
1908	Mixed grass and clover,	Hay,	111.1	116.0	118.8	113.0	93.2
		Rowen,	113.1	115.7	111.8	86.7	143.8
		Total,	111.5	115.9	117.8	108.7	100.7
1909	Mixed grass and clover,	Hay,	81.4	99.4	105.6	86.1	92.0
		Rowen,	244.9	57.5	143.0	123.6	255.7
		Total,	85.7	95.1	107.3	88.7	102.1
1910	Mixed grass and clover,	Hay,	109.7	109.2	98.6	104.4	95.8
		Rowen,	188.9	90.6	131.6	141.0	168.1
		Total,	115.9	106.5	102.0	107.4	102.6
1911	Mixed grass and clover,	Hay,	107.6	101.2	94.6	96.3	104.2
		Rowen,	68.9	45.9	87.4	100.0	94.2
		Total,	100.0	94.1	94.2	96.4	101.5

[1] No manure was applied to either N or S on any of the plots in 1907, the reason being that the growth and general condition of the several plots which had been seeded in the corn in 1906 indicated a high degree of probability that should manure be applied the crop would lodge to a very serious extent. That the decision was wise was indicated by the results, for the crop even without top-dressing lodged considerably. The rate of yield on all plots was considerably in excess of 3 tons per acre for the first crop, and about one-half ton for the second crop on winter application, and considerably in excess of one-half ton where the manure in previous years had been applied in the spring.

Table V shows the rainfall in inches in each of the months of what may be called the growing season, together with the total for the several years. A study of the figures for the several months in the different years and the totals for these years has not sufficed to indicate any well-defined relation between rainfall and the relative standing of N and S. This, perhaps, is not surprising, because conditions affecting the amount of evaporation or loss of moisture from the land surface vary very widely in different years, especially important in this connection being the amount of sunshine, the mean temperature and the direction and amount of wind movement. The fact is we do not know them with sufficient accuracy to determine whether variations in local climate were sufficient to account for the differing results in the different years during which the experiment continued or to enable us to judge how important these climatic variations may have been.

TABLE V. — *Rainfall in Inches.*

Year.	April.	May.	June.	July.	August.	September.	Total for Year.
1899, ...	1.79	1.28	4.13	4.89	2.00	7.90	41.49
1900, ...	1.85	3.78	3.65	4.67	4.11	3.67	51.67
1901, ...	5.95	6.91	.87	3.86	6.14	4.17	49.72
1902, ...	3.31	2.32	4.54	4.66	4.65	5.83	46.99
1903, ...	2.30	.48	7.79	4.64	4.92	1.66	45.45
1904, ...	5.73	4.55	5.35	2.62	4.09	5.45	45.30
1905, ...	2.56	1.28	2.86	2.63	6.47	6.26	38.80
1906, ...	3.25	4.95	2.82	3.45	6.42	2.59	45.45
1907, ...	1.98	4.02	2.36	3.87	1.44	8.74	42.27
1908, ...	1.97	4.35	.76	3.28	4.27	1.73	30.68
1909, ...	5.53	3.36	2.24	2.24	3.79	4.99	39.12
1910, ...	3.07	2.67	2.65	1.90	4.03	2.86	36.11
1911, ...	1.87	1.37	2.02	4.21	5.92	3.41	44.21
1912, ...	3.92	4.34	.77	2.61	3.22	2.52	38.56
1913, ...	3.30	4.94	.90	1.59	2.26	2.56	39.50
1914, ...	6.59	3.56	2.32	3.53	5.11	.52	41.83
1915, ...	3.99	1.20	3.00	9.13	8.28	1.37	51.58
1916, ...	3.69	3.21	5.34	6.85	2.49	5.08	45.61
1917, ...	1.83	4.13	5.27	3.36	7.06	2.42	43.56
1918, ...	2.78	2.47	4.01	1.84	2.22	7.00	37.47
1919, ...	2.37	6.20	1.09	4.17	4.81	4.25	41.42

TABLE VI. — *Average Yields.*

Crop.	Average for Five Plots. North Half.	Average for Five Plots. South Half.	Per Cent for South Half (North Half= 100 Per Cent).
Millet (1 year),	3,847 pounds	5,414 pounds	140.7
Corn, ensilage (1 year),	15,890 pounds	16,914 pounds	106.4
Soy beans (1 year), Beans,	15.07 bushels	14.61 bushels	96.9
Soy beans (1 year), Straw,	1,212 pounds	1,193 pounds	98.4
Corn and soy beans (1 year),	22,034 pounds	21,907 pounds	99.4
Corn (3 years), Grain,	37.14 bushels	41.13 bushels	110.7
Corn (3 years), Stover,	4,452 pounds	4,844 pounds	108.8
Mixed grass and clover (5 years),	7,101 pounds	7,250 pounds	102.1
Total weight of crops removed, average of five plots.	100,517 pounds	105,694 pounds	105.2

Table VII indicates the number of times out of the twelve (the total number of years during the period when manure was generally applied annually) in which the yield on N was superior to that on S.

TABLE VII. — *General Results.*

Plot.	North Half ahead —
1,	4 years out of 12
2,	5 years out of 12
3,	2 years out of 12
4,	7 years out of 12
5,	1 year out of 12

Examination of this table shows that on plot 3, S almost invariably gave the larger yield, N being superior to it only two years out of twelve. This may be explained by the greater fertility or better physical condition of S on plot 3, as shown by the yields given in Table II. On plot 5 the general superiority of S was still more marked, N giving the larger yield only one year out of twelve. It will be remembered that the manure applied to plot 5 was from horses, whereas that applied to all the other plots was from a herd of well-fed dairy cows. As has been pointed out, this stable manure was usually comparatively fresh, yet it had without doubt undergone more fermentation previous to being taken to the field than had the cow manure applied to the other plots. The effect of this greater progress toward complete disintegration at the time of spreading must have been to increase the proportion of soluble matter in the manure, especially the proportion of soluble ammonia and nitrates. It is a conclusion which these facts render extremely probable that the winter-spread manure on plot 5 suffered greater loss than that from cows spread on the other plots.

Further, it will be remembered that the length of time during which manure on plot 1 N was exposed was greater than on plots 2 and 4, and it is probably significant that S gave yields superior to N on plots 2 and 4 more frequently than on 1, a fact which this table brings out clearly.

Varying Effect of the Systems of Manuring on the Cover Crop of Rye.

No effort was made to determine the amount of green rye turned under on the different plots, but careful observations were made on the relative condition on N and S of the several plots. Our records of such observations show that, as would naturally be expected, the growth of the cover crop of rye during the early spring on plots N was superior to that on S. As is well understood, rye grows at an extremely low temperature, and wherever the manure had been spread during the winter the cover crop of rye derived considerable advantage from it. The dates of turning the cover crop under varied quite widely in successive years, being determined in part by peculiarities of season and in part by the crop which was to follow, but the plan adopted did not, as a rule, allow a very large growth, as it was always the aim, as it should be in turning under cover or green manure crops provided the bulk of green material is considerable, to turn the crop under some little time previous to the date of planting the crop which is to follow.

Conclusions apparently justified at the End of the Period of Annual Application.

My conclusions, if based solely upon results obtained during the period of annual application of manure, must have been about as follows: —

1. The various tabulations which have been presented indicate wide variations, and do not justify sweeping conclusions as to the superiority of either one or the other of the two systems under comparison.

2. The general results, however, in my opinion, indicate quite clearly that there was considerably more wastage, which varied from year to year in amount, from manure applied to plots N than from that first piled and later spread on plots S.

3. I believe that the fact of such excess wastage from plots N would have been brought out more distinctly by comparison of results had the rate of application of manure been lower, for the results afford fairly conclusive evidence that even after such wastage as occurred the amounts

of plant food remaining in the manure applied during the winter were in many cases at least sufficient to give the maximum yields possible under the other conditions affecting the crop.

4. I believe that our results indicate that conclusions based upon relative results of the two systems of applying manure compared for a single year or for a short series of years in current farm practice are in many cases unreliable because of the fact that the rate of application has often been sufficient so that even after such losses as occurred the supply of plant food was adequate for the crop under the conditions under which it was grown.

5. Whether the results of the comparisons made would have been similar on land more nearly level is a question on which I am able simply to express a general opinion. That opinion, based upon extensive opportunities for observation of conditions existing on Massachusetts farms, is that in almost all parts of the State there is sufficient slope to the land under cultivation so that some wash over the surface during winter and consequently some transfer of soluble plant food or absolute waste must usually be expected.

Relative Lasting Effects of Winter and Spring Applications.

Manure having been applied annually, with the exception noted, under the two systems compared from 1900 to 1911, inclusive, it was thought best to continue cropping the plots for a series of years without further differing application of either manure or fertilizer to plots N and S. As a matter of fact, the only applications made to any of the plots during the period 1912–19, both inclusive, were dressings of lime applied in 1914 and again in 1917 at the rate of 1,866 pounds per acre of calcium and magnesium oxides. Different forms of lime were used on each of the plots 1, 2, 3 and 5, namely, plot 1, hydrated lime, plot 2, marl, plot 3, fine-ground limestone, and plot 5, limoid. In each case both the form and quantity of lime applied to the two halves of the original plots (N and S) were precisely the same. It would therefore seem that the lime applied cannot have any immediate bearing upon the comparison of the lasting effects of the two systems of applying manure previously used.

The crops grown in the different years now to be considered, and the yields on the several plots, are shown in Table VIII.

It will be noted that the yields on plots S are in general considerably greater than on plots N. The percentage averages for the five plots in the different years, the yields on plots N being taken as 100, are shown in Table IX, also the relative percentage standing of N and S for the several plots.

TABLE VIII. — *Yields per Acre, 1912–1919.*

Year.	Crop.	Plot 1.		Plot 2.		Plot 3.		Plot 4.		Plot 5.	
		North.	South.	North.	South.	North.	South.	North.	South.	North.	South.
1912	Mixed grass and clover (pounds),	5,857	6,391	5,679	7,618	6,114	6,569	4,946	5,144	6,866	6,984
1913	Mixed grass and clover (pounds),	4,776	5,698	4,808	5,105	4,373	4,511	3,680	3,700	5,203	4,887
1914	Soy beans (ensilage) (pounds),	13,395	13,989	13,870	13,605	10,162	9,612	9,331	9,169	10,008	10,867
1915	Soy beans, Beans (bushels),	29.9	32.5	27.3	32.7	26.3	33.7	28.0	29.7	34.2	36.3
	Soy beans, Straw (pounds),	2,541	2,427	2,376	2,494	2,075	2,642	2,271	2,275	3,061	3,357
1916	Corn, Grain (bushels),	53.3	67.2	44.1	62.7	36.7	64.7	44.7	51.7	60.7	56.8
	Corn, Stover (pounds),	3,463	4,650	2,849	4,828	2,275	4,393	2,236	3,680	4,432	5,303
1917	Corn, Grain (bushels),	37.6	58.4	37.8	49.9	28.7	51.0	39.1	45.3	56.7	51.9
	Corn, Stover (pounds),	2,790	4,551	2,078	3,957	1,919	3,878	2,770	3,621	4,333	4,690
1918	Mixed grass and clover (pounds),	2,572	3,265	3,245	3,324	3,166	2,711	2,117	2,623	2,691	4,056
1919	Mixed grass and clover (pounds),	2,513	5,224	4,076	5,144	1,662	3,364	2,157	3,482	3,977	4,630

TABLE IX. — *Percentage Results.*

Year.	Crop.	Percentages for South Half (North Half = 100 Per Cent).					
		Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Average of Five Plots.
1912	Mixed grass and clover,	109.2	134 1	107.4	104.0	101.7	111.0
1913	Mixed grass and clover,	119 3	106.2	103.2	100.6	93.9	104.6
1914	Soy beans (ensilage),	104 4	98.1	94.6	98.3	108.6	100 8
1915	Soy beans, Beans,	108.9	120 1	128.1	105.8	106.0	113.2
	Soy beans, Straw,	95.5	105.0	127.3	100 2	109.7	107.0
1916	Corn, Grain,	127 8	146.3	185.1	118 5	93.5	126.6
	Corn, Stover,	134 3	169.5	193.1	164.6	119.6	149.8
1917	Corn, Grain,	164 5	140 2	192.0	124.8	91.8	128.4
	Corn, Stover,	163 1	190 4	202.1	130.7	108.2	149 0
1918	Mixed grass and clover,	126 9	102 4	85.6	124.3	150.7	115.9
1919	Mixed grass and clover,	207.9	126 2	202.4	161.5	116.4	151.8

The general percentage average for plots 1, 2, 4 and 5 for the entire period 1912–19, inclusive, N being taken as 100, is 122.3 for S, while for plot 3 a similar comparison shows the standing of S to be 138.2.

The figures presented in the different tables bring out the fact very clearly that the lasting effect of manure piled when taken to the field and spread in the spring is much greater than that of manure spread in the winter. For confirmation of the fact just stated, the reader should compare the figures given in Table IX with those in Tables VI and VII, which refer to the period during which manure was applied annually.

The figures for successive years presented in Tables VIII and IX indicate clearly that the superiority of plots S as compared with plots N as yet shows no signs of diminution. On the contrary, it is considerably greater during the later years of the period under consideration than in the earlier. This is most clearly shown in the last column of Table IX, which gives the percentage averages of the five plots; thus, for example, during the first and second years of the period under consideration, plots S in mixed grass and clover showed a percentage superiority of 111.0 and 104.6; in the last two years, 1918 and 1919, corresponding figures were 115.9 and 151.8. A similar relation is shown between the percentage advantage of plots S in 1915 as compared with 1914, soy beans being the crop; and in 1917 as compared with 1916, corn being the crop. This advantage in the case of the corn crop is less than with the others.

Effect of the Two Systems previously followed in the Application of Manure on Growth during the Early Part of the Season and the Maturing of the Crop.

From the very first year of the period under consideration, 1912–19, it was noticed that much earlier and more vigorous growth took place on plots S than on plots N. Whatever the crop, the superiority of S was clearly shown by better color and more rapid advancement. It would have been a matter of great difficulty to determine the difference in amount of growth made at any given period by measurement, but the field was under constant careful observation, and my own judgment I feel sure is accurate. When corn was the crop, I should say that by the last of June or the first of July the average height of the plants on plots S was some 3 or 4 inches greater than on plots N. When the field was in mixed grass and clover, the degree of superiority was in my judgment about the same, and indicated in inches would, I think, equal about 3 inches by the first of June. The earlier maturity of the crops on plots S also clearly indicates an earlier start and more rapid progress. This is shown most conclusively by the figures in Table X, showing the relative proportions of hard and soft corn at the time of husking.

Table X. — *Effect on Ripening Corn (Pounds per Plot).*

Plot.	1916.				1917.			
	North Half.		South Half.		North Half.		South Half.	
	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.
1,	915	29	1,170	19	700	60	1,150	30
2,	745	35½	1,090	19	700	64	980	29
3,	605	45	1,120	25	505	75	970	60
4,	755	35	895	20	710	80	885	30
5,	1,055	20	985	20	1,115	30	1,025	25

It will be noted that plot 5 is an exception to the general rule that the proportion of hard corn is considerably greater on plots S than on plots N. A considerable number of my different experiments, confirmed, I believe, as a rule, by the experiments of others, indicates that the period of ripening is affected more by the supply of phosphoric acid in highly available form than by any other plant-food constituent. An excessive supply of potash or of nitrogen does not, I believe, favor early ripening, but quite the contrary, unless there be a very liberal supply of phosphoric acid. It seems to me highly probable that the relative high standing of plot N on 5 in the proportion of hard corn is connected with the fact, which is generally known, that the proportion of phosphoric acid in manure from horses is higher, as a rule, than in that from milch cows, but I desire to point out that a little variation in level and character of soil from the north to south perhaps helps to account for the relatively high standing of N on plot 5.

We have yet, however, to consider how the superiority of S on the other plots, 1, 2, 3, and 4, can be accounted for. It seems to me possible that variation in humus content produced by the different methods of handling the manure and consequent differences in soil temperatures or in biological activities going on in the soil may to some extent have influenced the results. I believe, however, that more important than these is probably this fact, which, as was pointed out again and again by Paul Wagner in connection with his different experiments a considerable number of years ago, had an important connection with results.[1] Wagner pointed out that in northern latitudes optimum weather conditions for growth may exist during only a small proportion of the so-called growing season. This fact is generally recognized. All those familiar with agriculture in Massachusetts understand that, especially for crops flourishing at high temperatures and to a considerable extent for others also, weather conditions during some part of the growing season are unfavorable to rapid progress. It is often too wet or too dry, or it may be too cold, and rather exceptionally too hot when the high temperature is coincident with shortage in supply of moisture. When optimum weather conditions come, then the plant is capable of extremely rapid growth, provided the other factors essential for such growth exist, and among such other factors an abundant supply of plant food is one of the most important. Where the supply of plant food is comparatively low or meager the crop may become a good one if the weather and other conditions for growth are favorable throughout the greater part of the growing season, but, in proportion as the best of weather exists only a portion of the time, the crop will come to rapid maturity only where it finds a great abundance of food. Considerable wastage evidently occurred where the manure was spread in the winter. It is clear, therefore, that the supply of food, and hence this one among the several factors essential to rapid progress when the weather conditions are right was found in highest degree on plots S. It has long been recognized that the farmer or gardener who works his land intensively (under which term in this connection I refer particularly to an abundant supply of available plant food) is less unfavorably influenced by bad weather than the farmer or gardener whose soils are relatively low in available plant food or poorly worked.

The Relative Effects of the Two Systems on the Proportion of Clover in Mixed Mowings.

Whenever the plots used in this experiment were put into mowing, a mixture of timothy, red top and medium and alsike clovers was sown. The field was in mowing in 1912 and 1913, the first two years of the period under consideration, and it was noted that the proportion of

[1] Paul Wagner: Zur Kali-Phosphat-Düngung nach Schultz-Lupitz, Darmstadt, 1889, s. 18 u. a.

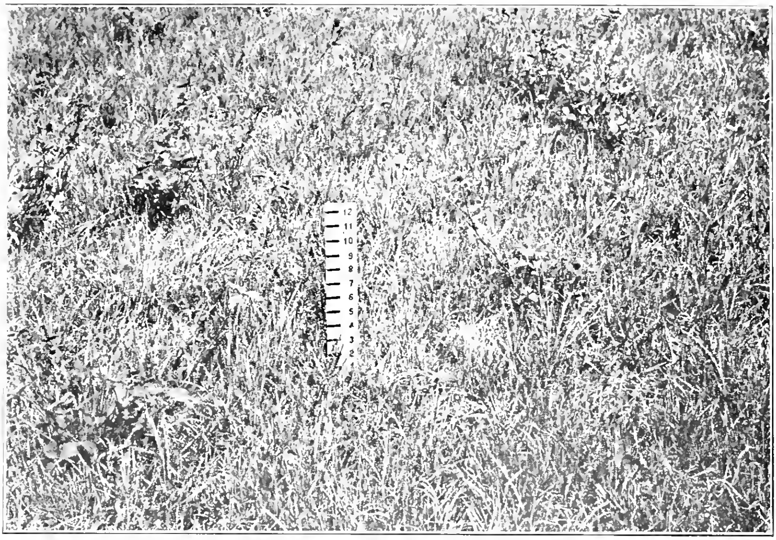


Fig. 1.—Plot 1, north half, from photograph taken Aug. 7, 1919.

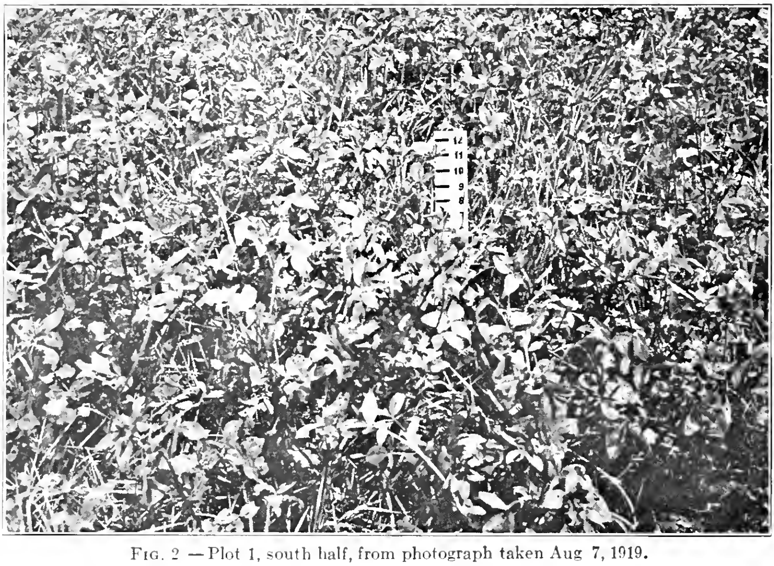


Fig. 2.—Plot 1, south half, from photograph taken Aug 7, 1919.

clovers on plots S was considerably greater than on plots N. The distribution of clovers in the different plots was not entirely uniform, some variations being apparently due to differences in moisture conditions. No photographs were taken during these two years, and the fact stated is demonstrated principally by the greater superiority of the rowen crop (made up chiefly of clovers) on plots S than of the first crop on the same plots.

The plots were put into mowing again in 1918, the seed having been sown, as is customary in this part of the State and with the type of soil on which the experiments were located, in the standing corn about the time it was waist high in 1917. We have harvested the hay crops now for two years, and Figs. 1 and 2 were made from photographs taken on Aug. 7, 1919, by a station assistant, R. L. Coffin. The difference in the proportion of clover, it will be seen at once, is very striking. The proportions of grasses and clovers on different parts of the several plots were not entirely uniform either on single plots N and S, under comparison, or on different pairs, and the excess of clover was not as great everywhere as indicated by the illustrations.

With a view to indicating in words as clearly as possible the different conditions, notes were taken on June 17, 1918, by a very careful station assistant, Mr. R. L. Coffin. I quote from Mr. Coffin: —

Plot 1. N, very little clover, mostly red.
S, seven-eighths clover, red and alsike about evenly divided.

Plot 2. N, seven-eighths clover, mostly alsike, but more red than on plot 5.
S, over seven-eighths clover, practically a dense mass of clover, more red than alsike.

Plot 3. N, almost no clover, but a little both red and alsike present.
S, nearly seven-eighths clover, more red than alsike.

Plot 4. N, about one-fourth clover, mostly alsike; a little sorrel.
S, nearly seven-eighths clover, mostly alsike; a little sorrel. Growth on plot 4 not as heavy as on plot 5.

Plot 5. N, seven-eighths clover, mostly alsike.
S, a little more clover than on N. Except for two small areas, a dense mass of clover, mostly alsike.

General condition on all plots: heads just beginning to show on timothy and red top, the proportion of red top being apparently somewhat greater than that of timothy.

Why Clover has been more abundant on Plots S.

The facts which have been for a long time known concerning the proportions of the different leading plant-food constituents and their degree of solubility in manures appear to the writer to have indicated in advance the more important wastes likely to occur from manure spread during the winter and allowed to remain upon the surface. The more important of these facts which seem to have a bearing upon the results are as follows: —

In fresh, well-made cow manure the proportion of its nitrogen content soluble is about one-third of the whole; the proportion of its potash content soluble is about four-fifths of the whole; while practically all of the phosphoric acid is insoluble. In the case of the plots, then, to which cow manure was applied in winter, one must have anticipated that such waste as occurred would have carried off more potash than of either of the other more important elements. In the case of the stable manure applied to plot 5, as has already been pointed out, some fermentation had taken place before it was taken to the field. This must have increased the solubility of the nitrogen content, but this manure, it will be remembered, was from horses, and such manure is much drier than fresh cow manure, the urine being relatively far less abundant. This must, I think, decrease the probability of a loss of potash from manure spread during the winter. Moreover, the application made to plot 5 was usually comparatively late in the winter, so that the period of exposure on the surface was shorter than the average of the other plots, which also would tend to decrease the amount of such loss of potash as may have occurred.

It is now a matter of almost universal knowledge that the proportion of clover in mowings is much affected, throughout the greater part of the soils of Massachusetts at least, if not throughout those of the greater part of the northeastern section of the United States, by the supply of potash in available form; and the much greater proportion of clover on plots S than on plots N of 1, 2, 3 and 4 tends to confirm my opinion in a striking way, — that the greatest loss which occurred from manure spread upon the surface in the winter and allowed to remain there until spring was the loss of potash. The fact that there was less difference in the proportion of clover on N and S of plot 5 than on the other plots tends also to confirm the correctness of the opinion expressed concerning the losses from the partially fermented stable manure.

Just how great may have been the losses of nitrogen from manure spread in the winter and allowed to remain on the surface, our figures showing yields fail to give a very complete index; but the fact that in the eighth year without additional manure the yield of hay even on plots N was, in general, good shows that the wastage of nitrogen was probably not very excessive. Nor would excessive loss of this element, as a rule, be reasonably expected, in view of the fact that the manure spread in the winter on most of the plots was practically entirely unfermented, and could not under normal winter weather conditions undergo fermentation while lying upon the surface, which would increase the solubility of the nitrogen compounds found in the fresh manure.

Financial Results.

The basis of the calculations upon which the tables presenting relative financial results have been computed is as follows: Value of products per ton: millet hay, \$10; mixed grass and clover hay, \$12; rowen, \$8; ensilage corn, \$4; corn and soy bean mixture for ensilage, \$4; soy beans for ensilage, \$5; corn stover, \$6; soy bean straw, \$5. Value per bushel: corn, 70 cents (1 cent per pound on the ear); soy beans, \$2.50. The calculation was made on the basis of the average for the five pairs of plots N and S, and the area for which results are computed is 1 acre. The excess cost of handling manure where it was piled when hauled out and spread in the spring has been estimated at $2 per acre where the work is done upon a large scale, for on such scale the manure spreader would be used in applying the manure from the heaps in the spring, whereas conditions when manure is hauled out and applied during the winter are by no means always such in our climate as to make the use of the manure spreader practicable. It is believed, therefore, that the figure taken — $2 per acre — is sufficient to represent the difference in cost under conditions existing on farms of sufficient size to justify the use of the spreader.

The same values have been used in the calculations throughout the entire period covered by the two tables, although prices during the past four or five years have advanced materially, so that the figures taken as applied to these years are considerably too low. The reader will perhaps at once think that so also must be the figure representing the difference in the cost of handling the manure; but in this connection it is important to remember that during the past eight years no manure has been applied to any of the plots, so that the question of the excess cost of handling does not affect the results as presented in Table XII.

TABLE XI. — *Calculated Results per Acre for the Period of Annual Application of Manure.*

Crop.	Crop Values, Yearly Average. Difference in Favor of —		Cost of Application of Manure. Difference in Favor of —	Total Yearly Average. Difference in Favor of —		Number of Years.	Total Difference in Favor of —	
	Winter (N).	Spring (S).	Winter (N).	Winter (N).	Spring (S).		Winter (N).	Spring (S).
Millet,	-	$7 83	$2 00	-	$5 83	1	-	$5 83
Soy beans,	$1 20	-	2 00	$3 20	-	1	$3 20	-
Corn,	-	3 97	2 00	-	1 97	3	-	5 91
Mixed grass and clover,	-	66	2 00	1 34	-	5	4 70[1]	-
Corn (ensilage),	-	2 05	2 00	-	05	1	-	05
Corn and soy beans (ensilage).	25	-	2 00	2 25	-	1	2 25	-
Total,	-	-	-	-	-	12	$10 15	$11 79

Balance in favor of spring, $1.64.
Average for 1 year, $0.14.

[1] No manure applied in 1907; cost of applying deducted.

Examination of Table XI shows that there was a small financial advantage due to the larger crop in favor of plots S, which represent the double handling system. Table XII shows a much larger difference. There are two reasons for this: first, the superiority of plots S during the period subsequent to that covered by annual applications of manure was much greater than during the period in which manure was applied yearly; and, second, this superiority, as already pointed out, has shown a tendency to increase with lapse of time.

While it has previously been referred to, it seems desirable again to call attention to the fact that spreading manure during the winter helps to relieve the pressure of work in the spring, and therefore possesses some advantage which cannot be shown in dollars and cents, and which of course varies with the weather and other conditions affecting the spring work.

TABLE XII. — *Calculated Results per Acre (1912–19).*

Crop.	Crop Values, Yearly Average. Difference in Favor of Spring (Plots S).	Number of Years.	Total Difference in Favor of Spring (Plots S).
Mixed grass and clover,	$2 10	4	$8 40
Soy beans (ensilage),	24	1	24
Soy beans,	10 04	1	10 04
Corn,	12 73	2	25 46
Total,	-	8	$44 14

Average for 1 year, $5.52.

FINAL CONCLUSIONS.

1. Had the experiment been brought to a conclusion in 1911, the last year of the period during which manure was applied annually, the statement would apparently have been justified that it made little difference in financial result which of the two plans of applying manure should be followed. This, however, would not have amounted to a demonstration that excess wastage had not occurred on plots N, for the reason that in spite of such wastage under the conditions which had existed throughout the experiment, the supply of plant food on plots N had probably been adequate to give yields nearly as large as all the conditions affecting the yields on plots S made possible.

2. That the manure on plots N had suffered quite serious losses has been made apparent by the relative yields as compared with plots S during the period 1912–19, in which no additional manure had been applied.

3. There must have been considerable excess wastage on plots N, even had the rate of application been smaller, although, of course, the financial loss would have been less.

4. The conclusion which appears to me to be fully justified by the results obtained to date (1919) is that the manure for the crop of the following season should be incorporated with the soil by the plow or harrow after the removal of the crop in the late fall, if practicable, rather than spread upon the surface to remain until spring.

5. There can be little doubt that the excess wastage on plots N would have been less on land which was more nearly level than that used in this experiment, but the land surface in Massachusetts and throughout a large part of the New England States is so broken that the proportion of land so level that there is no wash over the surface is comparatively small.

6. The earlier start and more rapid growth on plots S, especially during the later years of the experiment, are a decided advantage, and in many cases go far to insure a superior crop on account of the fact that the moisture supply in the early part of the season is more surely adequate to the needs of the crop, as a rule, than later.

Yet in one other way the earlier start and more rapid growth which doubtless occur in the root system as well as in the tops help to insure a good crop. I would refer also to the fact that crops which develop early and rapidly are far more likely to escape serious injury by insect enemies than those starting late or growing slowly, both because better able to resist attacks of such enemies, and because capable of quickly replacing tissues which are eaten or injured. In the case of some parasitic diseases, also, the plant making an early start and rapid growth is less likely to be seriously injured.

7. The earlier maturity of the crop on plots S constitutes an important advantage in favor of such practice as will prevent excessive loss of plant food. This of course is particularly true of crops thriving at relatively high temperatures, such, for example, as Indian corn and soy beans.

8. There can be no doubt that there is some wastage of nitrogen from winter-spread manure, and nitrogen is, as a rule, the most costly of the different plant-food elements; but reduction of the amount of wastage of nitrogen through the practice of piling and spreading the manure to be immediately incorporated with the soil in the spring is not the only nitrogen advantage connected with that practice. Particular attention has been called to the far greater proportion of clover on plots S than on plots N. Under these relative conditions it appears certain that a much greater amount of nitrogen must be taken from the air, and either made

a part of the harvested portion of the crop or left behind in the stubble and roots, on plots S than on plots N, thus reducing materially the necessity for application of nitrogen to crops in later years.

Bibliography.

Wm. P. Brooks. Reports of the Progress of the Experiment. Hatch Experiment Station annual reports: 14, p. 48; 15, p. 145; 16, p. 147; 17, p. 147; 18, p. 32. Massachusetts Agricultural Experiment Station annual reports: 19, p. 54; 20, p. 55; 21, Pt. II, p. 36; 22, Pt. I, p. 44; 23, Pt. I, p. 48; 25, Pt. I, p. 32.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 197 SEPTEMBER, 1920

THE NUTRITIVE VALUE OF CATTLE FEEDS

1. VELVET BEAN FEED FOR FARM STOCK

By J. B. LINDSEY and C. L. BEALS

This bulletin contains a study of the chemical composition, digestibility and feeding value of velvet bean feed when fed to dairy cows, horses and pigs. A summary of the results secured, together with a few suggestions, will be found on pages 61 and 62, followed by a condensed description of the several experiments.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

Publication of this Document
approved by the
Supervisor of Administration.

CONTENTS.

FOREWORD.

The writer, together with various coworkers, from time to time since 1892, has made many studies relative to the nutritive value and use of different roughages and concentrates, and the experiments have been published in the several reports and bulletins of the station. The present study, entitled "Velvet Bean Feed for Farm Stock," may be regarded as the first in a new series under the general title of "The Nutritive Value of Cattle Feeds," and is designated No. 1. Other studies along similar lines will be made as circumstances warrant. A list of the more important previous papers follows: —

1. Alfalfa *v.* Wheat Bran for Milk Production.
2. Animal Residues as a Food for Farm Stock.
3. Chicago Gluten Meal *v.* King and Atlas Gluten Meal.
4. Cleveland *v.* Old Process Linseed Meal for Early Lambs.
5. Composition, Digestibility and Feeding Value of Barnyard Millet.
6. Composition, Digestibility and Feeding Value of Wheat Bran.
7. Composition, Digestibility and Feeding Value of Molassine Meal, Cocoa Shells, Grain Screenings, Flax Shives, Mellin's Food Refuse and Postum Cereal Residue.
8. Composition, Digestibility and Feeding Value of Pumpkins.
9. Composition, Digestibility and Feeding Value of Alfalfa.
10. Compilations of Composition and Digestibility of Cattle Foods. (Four Papers.)
11. Corn Meal *v.* Hominy Meal, and Corn Meal *v.* Cerealine Feed for Growing Pigs.
12. Cottonseed Feed as a Hay Substitute for Milch Cows.
13. Cocoanut Meal.
14. Digestibility of Cattle Feeds. (Eleven Papers.)
15. Distillery and Brewery By-products.
16. Dried Molasses Beet Pulp.
17. Eureka Silage Corn.
18. Effect of Porto Rico Molasses on the Digestibility of Hay, and of Hay and Concentrates.
19. Feeding Value of Apple Pomace.
20. Molasses and Molasses Feeds for Farm Stock.
21. Nutritive Value of Bibby's Dairy Cake.
22. Oat Feed *v.* Corn Meal for Pigs.
23. Rice Meal *v.* Corn Meal for Pigs.
24. Summer Forage Crops. (Two Papers.)
25. The Feeding Value of Salt Marsh Hay.
26. The Food Value of Plain and Molasses Beet Pulp.
27. The Value of Oats for Milk Production.
28. The Value of Corn Bran for Milk Production.
29. Wheat Meal *v.* Rye Meal for Pigs.

BULLETIN No. 197.

DEPARTMENT OF CHEMISTRY.

THE NUTRITIVE VALUE OF CATTLE FEEDS.

1. VELVET BEAN FEED FOR FARM STOCK.

BY J. B. LINDSEY AND C. L. BEALS.

Summary of Results with Suggestions.

1. Velvet bean feed consists of the ground seeds and pods of the velvet bean, a leguminous plant grown quite largely in the southern States.

2. In chemical composition it resembles wheat bran, but contains rather more fiber, due to the presence of the bean pods.

3. As a result of digestion studies it was found to contain about 130 pounds, or 11.5 per cent, more digestible organic nutrients per ton than does wheat bran, and as a component of the dairy ration one would expect somewhat better results from its use.

4. Two feeding experiments were made with groups of six and four cows, in which the ration consisted of hay and a grain ration of 20 per cent cottonseed meal, 40 per cent corn feed meal, and 40 per cent velvet bean feed or wheat bran. The results show that the cows while receiving the velvet bean ration produced 2.7 and 9 per cent, with an average of 5 per cent, more milk than while on the wheat bran ration. It seems safe, therefore, to conclude that the velvet bean feed is somewhat superior to wheat bran for dairy purposes.

5. It may constitute as high as 40 per cent of a dairy ration, together with a like amount of corn or hominy meal or ground oats, and some 20 per cent of cottonseed or linseed meal, or other high-grade protein concentrate.

6. As a food for pigs a ration composed by weight of 50 parts corn feed meal, 40 parts velvet bean feed, and 10 parts digester tankage,

or one composed of equal weights of corn feed meal and velvet bean feed, did not prove as satisfactory as one composed of 90 parts corn feed meal and 10 parts digester tankage; and so large an amount of the velvet bean feed is not recommended.

7. A ration composed by weight of 20 parts velvet bean feed, 20 parts high-grade peanut meal, 50 parts corn meal, and 10 parts alfalfa meal gave as satisfactory results as one composed of 80 parts corn meal and 10 parts each of digester tankage and alfalfa meal; and such combinations are to be recommended.

8. The addition of 10 per cent ground alfalfa to the grain ration for growing pigs in order to supply the necessary vitamines did not seem to exert any marked effect in promoting growth.

9. As a feed for horses, velvet bean feed, if sufficiently dry to prevent decomposition, may comprise some 20 per cent of the grain ration, mixed together with 30 per cent oats, 40 per cent cracked corn and 10 per cent wheat bran.

10. It is important that the velvet bean feed should be well dried before being shipped, otherwise more or less decomposition is likely to set in, and the feed proves unsatisfactory for use. The writer regards a satisfactory quality of velvet bean feed as a distinct addition to the protein concentrates at the disposal of northern feeders.

11. Velvet bean meal (beans minus the pods) would undoubtedly prove more satisfactory for pigs and horses.

A. What Velvet Bean Feed is.

The velvet bean, of which there are many varieties, is a tropical legume, and is grown largely in Florida, Alabama and Mississippi. It needs a long season for its maturity, and is grown rarely north of Savannah. It is a rank grower, its vines trailing on the ground to a length of from 15 to 75 feet; they are difficult to cure for hay and have been used largely for grazing. It is now becoming common to pick the best of the beans and use them without hulling for cattle, or hulled as a food for pigs. The former is termed velvet bean feed, and the latter velvet bean meal. Machinery has more recently been devised for drying and grinding the unhulled beans, and it is said that the industry is increasing rapidly. About a year since, more or less of the velvet bean feed was placed upon the Massachusetts market, but it did not seem to give the best of satisfaction, partly on account of the feeders' lack of familiarity with the product, and partly because of its being shipped in too moist a condition.

Considerable has already been published relative to the velvet bean, particularly concerning its habitat, growth, adaptability to various soil and climatic conditions, as well as its suitability as a pasture crop, source of roughage, its value as silage and as a soil renovator.[1] Such information has a more particular value for parties residing in those States where the plant can be grown advantageously. Several experiments are also on record describing the feeding value of the ground bean and pods, and one experiment on its digestibility.

Inasmuch as the velvet bean feed (pods and beans) may become distributed in Massachusetts, experiments were undertaken at this station, particularly with reference to its digestibility and its suitability as a food for dairy stock, pigs and horses.

B. Composition of Velvet Bean Feed.

	Number of Analyses.	Water.	Ash.	Protein.	Fiber.	Extract.	Fat.
Velvet bean feed,	3	11.31	4.57	16.66	12.71	50.66	4.09
Wheat bran (for comparison),	116	10.00	6.20	16.10	10.00	53.30	4.40

The feed resembles wheat bran in chemical composition. It has slightly more protein, considerably more fiber, due to the presence of the bean pods, and somewhat less extract matter than wheat bran.

C. Digestibility of Velvet Bean Feed.

Two duplicate experiments were made with two different pairs of sheep. Two sheep were fed daily 550 grams of hay and 250 grams of the bean feed, and two other sheep 600 grams of hay and 200 grams of the feed. The results of the trials giving the amounts of the several constituents digested (digestion coefficients) are here stated, but the details of the experiments will be published elsewhere.

Results (Digestion Coefficients).

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
XII,	82.06	41.48	76.64	81.07	89.71	86.69
XIII,	71.48	28.52	73.96	51.09	81.82	74.41
IX,	70.96	22.97	68.56	46.60	80.35	72.79
XI,	81.16	33.24	78.02	71.06	86.83	85.63
Average,	77	32	74	62	85	80
Average (Georgia station),[1]	79	58	74	64	77	86
Average (all results),	79	53	74	64	78	85
Wheat bran (for comparison),	66	–	77	39	71	63

[1] Farmers' Bulletins Nos. 300 and 962; Georgia Experiment Station Bulletin No. 129; Journal of Agricultural Research, Vol. XIII, No. 12, p. 611; Florida Experiment Station Bulletin No. 102.

Our own results with four sheep show some noticeable variations. Sheep XII and XI seem to have digested the feed better than the two other sheep. This variation is noticeable in each of the several ingredients. The average results agree quite closely with those secured by Ewing and Smith[1] with steers.

Applying the average coefficients to the chemical composition of the velvet bean feed we find 2,000 pounds of the material to contain the following: —

Digestible Organic Nutrients in 2,000 Pounds.

	Protein.	Fiber.	Extract Matter.	Fat.	Total.
Velvet bean feed, ...	246.6	162.6	790.2	69.54	1,268.94
Wheat bran (for comparison), .	248.0	78.0	756.8	55.40	1,138.20

Velvet bean feed contains about the same amount of digestible protein as does wheat bran. Its content of digestible fiber, extract matter and fat is somewhat in excess of that contained in the bran, and on the basis of total digestible organic nutrients it is shown to have some 11.5 per cent more feeding value than the latter feed.

D. Velvet Bean Feed for Cows.

During the fall and winter of 1918–19 two feeding experiments with velvet bean feed were made with milch cows. In one case six and in the other four animals were used. They were divided into groups in each experiment, and were fed by the reversal method for periods of five weeks (besides preliminary periods) on a ration composed of hay for roughage and a grain mixture made up of 20 per cent cottonseed meal, 40 per cent corn feed meal (corn meal in second experiment), and 40 per cent of either velvet bean meal or wheat bran.

Before starting the experiment the cows were carefully chosen and paired off as well as possible in regard to age, breed, period of lactation, yield of milk, fat, etc.

The hay and grain rations were carefully calculated for each animal on the basis of milk and maintenance requirements according to the Haecker Standards.[2] The general care and management of the animals in no way differed from that always used in our feeding experiments, and require no discussion here. Hay and grain samples were taken at regular intervals, composited and analyzed. Milk samples were taken on the first, third and fifth weeks of each half of each experiment.

[1] P. V. Ewing and F. H. Smith in Journal of Agricultural Research, Vol. XIII, No. 12, p. 616. Results with five different steers in eighteen single trials.

[2] See Minn. Bul. No. 140, p. 56.

TABLE I. — *History of Cows.*

EXPERIMENT I.

Name.	Breed.	Age (Years).	Last Calf.	Served.	Beginning of Experiment.		
					Weight (Pounds).	Milk (Pounds).	Fat (Per Cent).
Samantha II,	Grade Holstein,	4	July 22, 1918,	- -	975	32	4.50
Peggy,	Grade Jersey,	8	Aug. 13, 1918,	- -	755	25	5.75
Red IV,	Grade Jersey,	5	Dec. 2, 1917,	June 2, 1918,	835	19	5.80
Samantha III,	Grade Holstein,	5	Aug. 26, 1918,	- -	1,140	30	4.60
Colantha III,	Grade Holstein,	4	Mar. 6, 1918,	June 12, 1918,	1,000	24	3.60
Fancy IV,	Grade Jersey,	4	July 22, 1918,	- -	700	21	4.63

EXPERIMENT II.

Name.	Breed.	Age (Years).	Last Calf.	Served.	Weight (Pounds).	Milk (Pounds).	Fat (Per Cent).
Samantha III,	Grade Holstein,	5	Aug. 26, 1918,	Dec. 5, 1918,	1,170	25	4.60
Fancy IV,	Grade Jersey,	4	July 22, 1918,	Oct. 30, 1918,	810	18	5.35
Colantha II,	Grade Holstein,	4	July 22, 1918,	Nov. 7, 1918,	1,050	30	4.25
Ida II,	Pure Jersey,	6	Oct. 27, 1918,	Dec. 9, 1918,	800	28	5.60

TABLE II. — *Total Amount and Average Daily Amount of Food consumed per Cow and per Ration (Pounds).*

EXPERIMENT I.

Velvet Bean Feed Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Oct. 1-Nov. 4, 1918,	Colantha II,	840.00	24.00	350.0	10.00	-	-
	Peggy,	697.75	19.94 [1]	315.0	9.00	-	-
	Red IV,	665.00	19.00	245.0	7.00	-	-
Nov. 15-Dec. 19, 1918,	Samantha III,	840.00	24.00	315.0	9.00	-	-
	Colantha III,	735.00	21.00	280.0	8.00	-	-
	Fancy IV,	665.00	19.00	245.0	7.00	-	-
Totals,	. . . . .	4,442.75	-	1,750.0	-	-	-
Averages,	. . . . .	-	21.16	-	8.73	-	-

Wheat Bran Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Oct. 1-Nov. 4, 1918,	Samantha III,	840.00	24.00	-	-	315.0	9.00
	Colantha III,	735.00	21.00	-	-	280.0	8.00
	Fancy IV,	642.00	18.91 [2]	-	-	245.0	7.00
Nov. 15-Dec. 19, 1918,	Colantha II,	840.00	24.00	-	-	350.0	10.00
	Peggy,	700.00	20.00	-	-	315.0	9.00
	Red IV,	665.00	19.00	-	-	245.0	7.00
Totals,	. . . . .	4,422.00	-	-	-	1,750.0	-
Averages,	. . . . .	-	21.15	-	-	-	8.73

EXPERIMENT II.

Velvet Bean Feed Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Dec. 30, 1918-Feb. 2, 1919.	Samantha III,	840.00	24.00	315.0	9.00	-	-
	Fancy IV,	665.00	19.00	245.0	7.00	-	-
Feb. 13-March 19, 1919,	Colantha II,	840.00	24.00	332.5	9.50	-	-
	Ida, II,	735.00	21.00	332.5	9.50	-	-
Totals,	. . . . .	3,080.00	-	1,225.0	-	-	-
Averages,	. . . . .	-	22.00	-	10.75	-	-

[1] Peggy left a total of 2.25 pounds of hay, or a daily average of .06 pound unconsumed.
[2] Fancy IV left a total of 3 pounds of hay, or a daily average of .09 pound unconsumed.

TABLE II. — *Total Amount and Average Daily Amount of Food consumed per Cow and per Ration (Pounds)* — Concluded.

EXPERIMENT II — *Con.*

Wheat Bran Ration.

Dates.	Cows.	Hay.		Velvet Bean Mixture.		Wheat Bran Mixture.	
		Total.	Daily.	Total.	Daily.	Total.	Daily.
Dec. 30, 1918-Feb. 2, 1919.	Colantha II,	840.00	24.00	-	-	332.5	9.50
	Ida II,	735.00	21.00	-	-	332.5	9.50
Feb. 13-March 19, 1919,	Samantha III,	840.00	24.00	-	-	315.0	9.00
	Fancy IV,	665.00	19.00	-	-	245.0	7.00
Totals,	. . . . .	3,080.00	-	-	-	1,225.0	-
Averages,	. . . . .	-	22.00	-	-	-	10.75

TABLE III. — *Analysis of Feeds (Per Cent).*

EXPERIMENT I.

Feed.	Average Moisture.[1]	Dry Matter.[1]	Dry Matter.				
			Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Hay,	12.17 10.50	87.83 89.50	6.18	8.70	30.57	51.72	2.83
Velvet bean mixture,	11.31 9.72	88.69 90.28	4.08	20.56	11.42	56.12	7.82
Wheat bran mixture,	11.37 10.32	88.63 89.68	5.23	19.09	10.71	56.59	8.38

EXPERIMENT II.

Feed.	Average Moisture.[1]	Dry Matter.[1]	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Hay,	14.00 12.70	86.00 87.30	5.89	7.48	29.74	54.41	2.48
Velvet bean mixture,	11.19 10.24	88.81 89.76	4.00	19.22	9.22	63.20	4.36
Wheat bran mixture,	11.46 10.27	88.54 89.73	4.85	18.32	8.44	63.34	5.05

[1] The two figures in each case represent the average of three samples taken in each half of the trials.

TABLE IV. — *Total and Average Daily Amount of Dry Matter consumed in Each Ration.*

EXPERIMENT I.

Velvet Bean Ration.

Dates.	Hay.		Grain.		Grain.	
	Total.	Daily.	Total.	Daily.	Total.	Daily.
Oct. 1–Nov. 4, 1918, Nov. 15–Dec. 19, 1918,	3,940	18.76	1,566	7.46	–	–

Wheat Bran Ration.

Dates.	Hay Total.	Hay Daily.	Grain Total.	Grain Daily.	Grain Total.	Grain Daily.
Oct. 1–Nov. 4, 1918, Nov. 15–Dec. 19, 1918,	3,938	18.75	–	–	1,561	7.42

EXPERIMENT II.

Velvet Bean Ration.

Dates.	Hay Total.	Hay Daily.	Grain Total.	Grain Daily.	Grain Total.	Grain Daily.
Dec. 30, 1918–Feb. 2, 1919, Feb. 13–March 19, 1919,	2,669	19.06	1,894	7.81	–	–

Wheat Bran Ration.

Dates.	Hay Total.	Hay Daily.	Grain Total.	Grain Daily.	Grain Total.	Grain Daily.
Dec. 30, 1918–Feb. 2, 1919, Feb. 13–March 19, 1919,	2,668	19.05	–	–	1,091	7.79

In each experiment the two rations contained the same amount of dry matter.

TABLE V. — *Average Dry and Digestible Nutrients in the Average Daily Ration (Pounds).*

EXPERIMENT I.

Ration.	Dry Matter.	Digestible Nutrients.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.[1]	
Velvet bean,	26.22	2.05	3.89	9.51	.77	16.22	1:7.4
Wheat bran,	26.18	1.97	3.74	9.24	.76	15.71	1:7.4

[1] Including fat multiplied by 2.2.

TABLE V. — *Average Dry and Digestible Nutrients in the Average Daily Ration (Pounds)* — Concluded.

EXPERIMENT II.

Ration.	Dry Matter.	Digestible Nutrients.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.	
Velvet bean, . .	26.87	2.24	3.87	11.87	.59	18.58	1:7.6
Wheat bran, . .	26.84	1.86	3.63	10.29	.53	16.31	1:8.1

The velvet bean ration contained rather more digestible matter than the wheat bran ration.

TABLE VI. — *Gain or Loss in Live Weight (Pounds) per Herd.*

Ration.	Experiment I.		Experiment II.		Total.
	Gain.	Loss.	Gain.	Loss.	
Velvet bean meal, . . .	81	34	28	2	+73
Wheat bran, ...	135	0	32	8	+159

In the two experiments the cows when receiving the wheat bran ration seemed to gain a little more in weight than when receiving the velvet bean ration.

TABLE VII. — *Yield of Milk and Milk Ingredients.*

EXPERIMENT I.

Velvet Bean Ration.

Dates.	Cows.	Milk (Pounds).	Solids.		Fat.	
			Per Cent.	Pounds.	Per Cent.	Pounds.
Oct. 1–Nov. 4, 1918, .	Colantha II, .	1,218.9	12.50	152.36	4.07	49.61
	Peggy, . .	885.8	14.89	131.90	6.30	55.81
	Red IV, . .	724.6	15.28	110.72	5.99	43.40
Nov. 15–Dec. 19, 1918,	Samantha III,	905.8	13.09	118.57	4.39	39.76
	Colantha III, .	830.8	12.67	105.26	3.83	31.82
	Fancy IV, .	672.0	13.82	92.87	5.21	35.01
Totals, ...	. . . . .	5,237.9	-	711.68	-	255.41
Averages, . . .	. . . . .	-	13.59	-	4.88	-

TABLE VII. — *Yield of Milk and Milk Ingredients* — Concluded.

EXPERIMENT I — *Con.*

Wheat Bran Ration.

Dates.	Cows.	Milk (Pounds).	Solids.		Fat.	
			Per Cent.	Pounds.	Per Cent.	Pounds.
Oct. 1–Nov. 4, 1918,	Samantha III,	948.7	12.89	122.30	4.47	42.41
	Colantha III,	796.0	12.47	99.26	3.90	31.04
	Fancy IV,	739.7	13.80	102.08	5.10	37.72
Nov. 15–Dec. 19, 1918,	Colantha II,	1,163.0	12.69	147.58	4.01	46.64
	Peggy,	831.8	15.54	129.26	6.44	53.57
	Red IV,	620.5	16.14	100.15	6.47	40.15
Totals,		5,099.7	-	700.63	-	251.53
Averages,		-	13.74	-	4.93	-

EXPERIMENT II.

Velvet Bean Ration.

Dates.	Cows.	Milk (Pounds).	Solids Per Cent.	Solids Pounds.	Fat Per Cent.	Fat Pounds.
Dec. 30, 1918–Feb. 2, 1919.	Samantha III,	763.8	13.49	103.03	4.64	35.44
	Fancy IV,	596.0	14.70	87.61	5.32	31.70
Feb. 13–March 19, 1919,	Colantha II,	1,260.0	13.40	168.84	4.51	56.82
	Ida II,	827.6	14.81	122.86	5.81	48.19
Totals,		3,447.4	-	482.34	-	172.15
Averages,		-	13.99	-	4.99	-

Wheat Bran Ration.

Dates.	Cows.	Milk (Pounds).	Solids Per Cent.	Solids Pounds.	Fat Per Cent.	Fat Pounds.
Dec. 30, 1918–Feb. 2, 1919.	Colantha II,	995.8	13.03	129.75	4.33	43.31
	Ida II,	862.9	14.74	127.19	5.85	50.47
Feb. 13–March 19, 1919,	Samantha III,	749.7	13.51	101.28	4.69	35.16
	Fancy IV,	556.3	14.51	80.71	5.38	29.92
Totals,		3,164.7	-	438.93	-	158.86
Averages,		-	13.87	-	4.99	-

In the first experiment an increase in milk yield of 2.7 per cent was secured, and in the second experiment an increase of 9 per cent, both in favor of the velvet bean ration.

In both experiments the velvet bean ration yielded 8,685.3 pounds, and the wheat bran ration 8,264.4 pounds, of milk, an average increase of 5 per cent in favor of the velvet bean ration.

In case of the velvet bean ration 100 pounds of dry matter produced 130 pounds of milk, and in case of the wheat bran ration, 125 pounds.

It seems evident, therefore, on the basis of digestibility and feeding experiments with dairy cows, that the velvet bean feed is somewhat superior as a dairy feed to wheat bran.

E. Velvet Bean Feed for Pigs.

Observations with two lots of pigs were made, the first in 1918 and the second in 1919.

Experiment I. — August 12–November 20.

Six pigs having reached a weight of about 50 pounds each were divided into three lots of two each, and fed on the following rations: —

Lot I. — Mixture by weight of 80 parts corn feed meal, 10 parts alfalfa meal and 10 parts digester tankage.

Lot II. — Mixture by weight of 50 parts corn feed meal, 40 parts velvet bean feed and 10 parts alfalfa meal.

Lot III. — Mixture by weight of 50 parts corn feed meal and 50 parts velvet bean feed.

The mixture fed to Lot I was considered a standard or check ration. That fed to Lots II and III was intended to demonstrate the efficacy of velvet bean feed in place of the tankage. Alfalfa was used in one ration and omitted in one to note if it aided, because of its "vitamine" content, in promoting growth.

Method of Feeding. — Ten ounces of each mixture were added to each quart of water to satisfy appetite. The grain mixture was at first mixed with a little cold water to convert it into a paste, then very hot water added, and the slop fed milk warm. The pigs were fed three times daily.[1]

Housing. — Each lot of pigs was kept in an outdoor pen, protected from rain and sun, and given the run of a small yard.

Weighing. — Each pig was weighed weekly on Monday morning before feeding.

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[1] An ash mixture composed of 20 per cent salt, 40 per cent rock phosphate, 10 per cent ground limestone and 30 per cent wood ashes was kept constantly before the pigs in all of the experiments here described. The pigs also had access to charcoal.

Record of Feeds consumed and of Growth (Pounds).

Pigs.	Days.	Dry Matter in Feeds consumed.					Growth.				Dry Matter required to produce 100 Pounds Live Weight.
		Corn Feed Meal.	Alfalfa.	Tankage.	Velvet Bean Feed.	Total.	Weight at Beginning.	Weight at End.	Total Gain.	Daily Gain.	
1	101	344.2	41.7	36.5	-	422.4	52.5	180.5	128.0	1.27	330
2, ...	98[1]	320.2	38.8	34.3	-	393.4	57.5	182.5	125.0	1.27	315
3, ...	62	90.5	18.0	-	72.3	180.8	47.5	80.5	33.0	.53	548
4, ...	101	179.3	35.6	-	143.2	358.1	49.5	118.0	68.5	.68	523
5, ...	72	119.2	-	-	119.1	238.3	44.2	83.5	39.2	.55	600
6, ...	72	115 1	-	-	114.9	230.0	52.2	82.5	30.2	.42	795

[1] Sick for three days.

Pigs 1 and 2 had the advantage in that they were fed corn meal and skim milk when very young. Pigs 3, 4, 5 and 6 were fed different grain mixtures when too young and did not get as good a start. Pig 3 was badly out of condition and did not recuperate until August. Pigs 1 and 2 were normal in every way, and on the diet of corn feed meal and digester tankage for 101 days gained daily 1.27 pounds and produced 100 pounds of live weight for 322 pounds of dry matter fed. Pigs 3 and 4, on the diet of corn feed meal, velvet bean feed and alfalfa, and pigs 5 and 6, on a corn feed and velvet bean feed diet, gained noticeably less. All appeared healthy during the experiment, and ate well. Pigs 5 and 6 did not grow quite as well as pigs 3 and 4, and did not appear to be building out as good a framework. It seemed evident that the alfalfa was furnishing something in promoting early growth that was lacking in the diet fed pigs 5 and 6.

Although the experiment was not as satisfactory as one could wish, it at least indicated that so large an amount of velvet bean feed was not desirable in the daily diet, and that it was not a satisfactory substitute for digester tankage.

Experiment II. — June 9–November 1.

Six pigs, grade Chester White, weighing from 24 to 34 pounds each, were divided into lots of two each and fed on three different rations, two of which contained 20 per cent velvet bean feed in order to test its efficacy as a component of a grain mixture.

Lot I received by weight a mixture of 80 pounds of corn meal, 10 pounds of digester tankage and 10 pounds of ground alfalfa.

Lot II received by weight a mixture of 50 pounds of corn meal, 20 pounds of peanut meal, 20 pounds of velvet bean feed and 10 pounds of alfalfa meal. On July 8 the corn meal was increased to 60 pounds, the alfalfa eliminated and different kinds of green material fed from day to day.

Lot III received by weight a mixture of 60 pounds of corn meal, 20 pounds of peanut meal and 20 pounds of velvet bean feed.

Lot I, therefore, received the so-called standard or check ration, Lot II the velvet bean ration plus alfalfa meal or green material to assist in promoting growth, while in the case of Lot III this was omitted. From September 7 to September 20 coconut meal was substituted for the velvet bean feed because of lack of supply of the latter. The method of feeding, housing and weighing was the same as in Experiment I.

Record of Feeds consumed and of Growth (Pounds).

Pigs.	Days.	Dry Matter in Feeds consumed.						Growth.				Dry Matter required per 100 Pounds of Gain.
		Corn Meal.	Peanut Meal.	Velvet Bean Feed.	Digester Tankage.	Alfalfa Meal.	Total.	Weight at Beginning.	Weight at End.	Total Gain.	Daily Gain.	
1, . . .	175	476.5	–	–	62.9	60.6	600.0	22	185	163	.93	368.1
2, . . .	175	476.5	–	–	62.9	60.6	600.0	30	195	165	.94	365.0
3, . . .	175	344.6	124.5	119.6[1]	–	4.4	593.1	27	162	135	.77	439.3
4, . . .	175	344.6	124.5	119.6[1]	–	4.4	593.1	25	189	164	.94	361.6
5, . . .	175	347.7	124.0	119.1[1]	–	–	590.8	34	185	151	.86	391.3
6, . . .	175	347.7	124.0	119.1[1]	–	–	590.8	27	173	146	.83	404.6

[1] Includes 21.4 pounds of coconut meal.

Each of the pigs remained in a thrifty condition during the entire experiment, and from their looks one would not be able to say that one ration was proving more effective than another.

Lot I, receiving the corn and tankage mixture, made an average daily gain of .93 pound each, and required 366 pounds of dry matter to make 100 pounds of gain. An average for pigs of this size is .9 pound of gain daily, and a requirement of 377 pounds of dry matter per 100 pounds of gain.

Lot II, receiving the corn, velvet bean, peanut and ground alfalfa, made an average daily growth of .85 pound each, and required 400 pounds of dry matter for 100 pounds of gain. Pig 4 of this lot gained fully as well as either of the two pigs in Lot I, but for some reason, due perhaps to individuality, pig 3 made somewhat less daily gain.

Lot III, receiving substantially the same ration as Lot II, with the exception of the alfalfa, made an average daily gain of .85 pound each, and required 398 pounds of dry matter per 100 pounds of gain. This latter lot did not do quite as well as Lots I and II, indicating possibly that the lack of alfalfa may have slightly checked growth, but the difference was so slight as not to warrant one in drawing any positive conclusions. The combination of corn meal, alfalfa, velvet bean feed and peanut meal gave as satisfactory results as corn meal and tankage, and indicates that some 20 per cent of velvet bean feed, when properly combined, can be used as a component of the ration for growing pigs.

A ration containing 40 to 50 per cent of velvet bean feed together with corn meal (Experiment I) proved unsatisfactory and its use in such amounts is not recommended.

F. Velvet Bean Feed for Horses.

Velvet bean feed of good quality was fed to two farm horses for a period of three months, comprising some 18 per cent of the daily grain ration, which was as follows: —

Grain Mixture.

	Pounds.
Oats,	100
Corn,	140
Wheat bran,	40
Velvet bean feed,	60

The horses received from 17 to 20 pounds daily of the mixture, did regular farm work and maintained their live weight. Velvet bean feed, if dry and free from mold, can be used in the amounts indicated with safety.[1]

Velvet bean meal (beans minus pods) would undoubtedly prove better suited as a feed for pigs and horses.

[1] For a fuller report, see Bulletin No. 188, pp. 259-262.

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STUDIES OF CRANBERRIES DURING STORAGE

CHEMICAL STUDIES

By F. W. MORSE and C. P. JONES

FUNGI STUDIES

By B. A. RUDOLPH and H. J. FRANKLIN

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BULLETIN No. 198.

DEPARTMENT OF CHEMISTRY.

STUDIES OF CRANBERRIES DURING STORAGE.

CHEMICAL STUDIES.

BY F. W. MORSE AND C. P. JONES.

Chemical Changes in Cranberries in Storage.

For several years the Massachusetts Agricultural Experiment Station has been studying problems connected with the storage and shipment of cranberries, during the course of which chemical data have been gathered that are here arranged to show the composition of a few well-known varieties of cranberries and some of the changes which take place in their composition while they are held in storage.

The essential qualities of a fruit that is to be used for cooking or dessert are juiciness and flavor. With our present knowledge of analytical chemistry such qualities can be measured only in terms of water, sugar and acid, since as yet there are no sure methods for determining the characteristic fruit flavors or esters. Therefore determinations of water, total sugar and total acid were made in all our samples of cranberries, while the proximate analysis of the food constituents was executed on some of them.

The analyses of varieties have been selected as far as possible to show them at their best. The Early Black and the Howes varieties were sampled in October from lots stored at natural temperatures, while the McFarlin and Centennial varieties were sampled in November from lots in cold storage. Early Black is the earliest variety shipped from the Cape Cod district. It is of good quality, but is not a good keeper. Howes is a later variety and forms the main crop on many of the bogs. It is a good keeper, but is not equal to some other varieties in quality. The other two varieties are rated among growers as "fancy" kinds, and are grown in limited quantities. The McFarlin is an excellent variety in quality, but not as good a keeper as Howes. The Centennial is a very large berry, attractive on account of its size, of good flavor, but not as juicy as the others. Cranberries, however, are not sold under their variety names, like apples, but usually bear brands, originated by the sales organizations, which are unrelated to the varieties.

Two lots of Wisconsin cranberries were sent to the laboratory from that State by Dr. N. E. Stevens. One variety was the well-known McFarlin, and the other was a fancy western variety, of attractive size and color, called Searl's Jumbo. The sugar content was a bit inferior to our Cape varieties in both samples, but the fruit was sent by parcel post in tight packages, and was probably in warm mail cars and rooms while in transit. Such conditions induce a somewhat rapid change in sugar content, as shown by our storage experiments.

The composition of the varieties is shown in the following table: —

TABLE I. — *Composition of Varieties of Cranberries in October.*

VARIETY.	Water.	Total Sugar.	Total Acid.
Early Black,	87.86	4.12	2.45
Howes (two lots),	87.44	3.95	2.31
McFarlin,	88.74	4.08	2.12
Centennial,	87.16	5.59	2.05
Searl's Jumbo (Wisconsin),	89.25	3.48	2.61
McFarlin (Wisconsin),	88.47	3.75	2.49

Proximate Food Constituents.

VARIETY.	Dry Matter.	Ash.	Protein.	Fiber.	Ether Extract.	Nitrogen-free Matter.
Howes,	12.23	.15	.35	1.51	.97	9.25
McFarlin,	11.26	.16	.35	1.18	.57	9.00
Centennial,	12.84	.17	.28	1.15	.51	10.73

It has been noted that the cranberries undergo some change in composition during the storage period, although they remain firm and sound, with no evidence of decay. The change is most pronounced when the fruit is held at the higher temperatures of storage in a warm room, and is barely noticeable at cold-storage temperatures just above the freezing point.

In the fall of 1917 changes in the fruit during storage were studied by the analysis of berries kept in the storehouse at the cranberry bog. Fruit of the Howes variety was sent to the laboratory at monthly intervals directly from the storehouse, by express or parcel post, in small, ventilated crates holding about 8 quarts. The first lot was shipped in October, soon after the fruit had been stored, and the final lot in February. No attempt was made to ascertain the shrinkage in weight of the fruit during storage, since berries were all the time decaying, and no lot of selected fruit would fail to have more or less rotten berries in a week's time, and such berries lose water more rapidly than sound ones. To have correctly determined losses in weight of sound fruit over a period of months would have required the individual weights of a large number of berries, so that decayed berries could be rejected as they developed, and only sound berries weighed individually at the end of a given period. The chemical analyses included determinations of water, total sugar and total acid.

In 1918 the work was repeated in a similar manner with samples from the bog storehouse. In addition, several lots of cranberries were placed in the cold-storage rooms of the Horticultural Department about the middle of October, and samples were analyzed at intervals to compare their rate of change with the changes in the cranberries kept at the bog. The cold-storage house was built especially for fruit storage, and the fruit in it is held almost constantly just above 0° C. (32° F.).

The composition of the berries under different conditions of storage is shown in Table II.

TABLE II. — *Composition of Cranberries in Storage, 1917–19.*

	Dry Matter.	Total Sugar.	Total Acid.
Howes Variety.			
Storehouse: —			
Oct. 5, 1917,	12.89	3.97	2.28
Oct. 17, 1917,	-	3.85	-
Oct. 31, 1917,	11.81	-	-
Dec. 3, 1917,	11.58	3.27	2.32
Jan. 3, 1918,	11.76	3.47	2.37
Jan. 28, 1918,	11.78	3.58	2.26
Oct. 16, 1918,	12.23	3.93	2.34
Nov. 21, 1918,	12.06	4.19	2.15
Dec. 19, 1918,	12.10	4.18	2.01
Cold storage: —			
December, 1918,	12.14	4.04	1.96
January, 1919,	12.50	3.89	2.14
February, 1919,	12.54	3.72	2.17
McFarlin Variety.			
Cold storage: —			
November, 1918,	11.26	4.08	2.12
January, 1919,	11.59	4.09	2.12
Centennial Variety.			
Cold storage: —			
November, 1918,	12.84	5.59	2.05
January, 1919,	13.11	5.54	2.08

The samples for analysis invariably consisted of the firm, hard berries, with no evidence of decay. Some of the analytical results make it appear possible that selected lots of berries like these do not necessarily show progressive changes in composition for the average fruit of the early part of the season, but that the later berries are resistant to decay by less active cell organization and lower rate of metabolism.

In 1917 the Early Black cranberries picked from the little bogs at the Experiment Station were sampled and analyzed on September 25, soon after picking. The remainder was divided into two portions, one of which was placed in a refrigerator, and the other was left on a shelf in the basement at a temperature a little above the outside air on the average. These lots were sampled and analyzed four weeks later. The two lots were then allowed to stand until January, 1918, when the refrigerator lot was freed from all soft berries and sampled; while the lot from the basement was divided into two portions, one consisting of firm, sound berries, and the other, while free from rotten fruit, consisting of berries that were soft and rubber-like in physical appearance. Analyses of these lots of berries showed some striking differences.

TABLE III. — *Composition of Early Black Cranberries under Different Conditions of Storage.*

	Total Solids.	Total Sugar.	Total Acid.
Recently picked, September 25,	12.14	4 12	2.45
Two weeks later, October 8,	-	4.48	2.36
From refrigerator, October 23,	-	4.17	2.49
From basement, October 23,	-	3.99	2.43
From refrigerator, January,	11.01	3 51	2.35
From basement, January, firm,	10.59	2 62	2.55
From basement, January, soft,	11.76	2.75	2.63

The character of the package in which cranberries are stored and shipped has been closely related to changes in the properties of the fruit. In the course of storage investigations, made to determine the causes of cranberry spoilage after harvesting, Shear and Stevens observed a considerable number of berries that were soft, but which contained no organisms of decay.[1] Since the more thoroughly oxygen was excluded from the fruit the larger the quantity of softened berries, the trouble appeared to be caused by the lack of ventilation, and the berries were regarded as asphyxiated.

In December, 1917, Dr. Stevens brought to the laboratory directly

[1] Proc. Amer. Cranberry Growers' Assoc. 48 (1917), pp. 6-9. Mass. Agr. Expt. Sta. Ann. Rept. 30 (1918), pp. 235-239.

from Washington several lots of Howes berries that had been stored in small cans from which the air had been displaced by carbon dioxide gas. The fruit had been held in these cans for two months at different temperatures, viz., 0°, 5°, 15° and 20° C. (32°, 41°, 59° and 68° F.). Some berries at each temperature still remained firm and sound, although at 20° C. there were not enough for a satisfactory analysis. The softened berries had been attacked by the end rot fungus in most cases, but from the lot held at 0° C. enough typically asphyxiated berries were secured for chemical examination. The analyses of the sound berries showed a slightly lower sugar content at the higher temperatures, with practically no changes in water and acidity. The asphyxiated berries, although kept at the lowest temperature, contained much less sugar than any of the sound berries, indicating a much more destructive action on the fruit sugar when oxygen was lacking.

TABLE IV. — *Howes Cranberries stored at Fixed Temperatures.*

	Water.	Total Sugar.	Total Acid.
Sound berries at 0° C.,	88.30	3.56	2.25
Sound berries at 5° C.,	88.29	3.51	2.29
Sound berries at 15° C.,	88.45	3.37	2.24
Asphyxiated berries at 0° C.,	-	2.38	2.40

A small sample of asphyxiated berries with but little evidence of rot about them was selected from the combined lots stored at 15° and 20° C. The determination of sugar in this sample showed but 2.04 per cent.

It is a common practice in the household to preserve cranberries by sealing them in jars filled with water. One experiment was tried to determine the effect of such treatment on the composition of the fruit.

Two fruit jars were filled with cranberries from the lot of Howes received from the Experiment Station bog in October. Distilled water was added to the jars until they were brimful, when the covers were put on and clamped as in canning fruit. The jars were set away in a cool room and allowed to remain until February. When the jars were opened the water was found to contain carbon dioxide which escaped in bubbles as soon as the pressure on the covers was released. The fruit showed no signs of rot, but every berry was softened and felt like rubber. The water contained acid, sugar and coloring matter that had diffused from the fruit. The berries contained 10.36 per cent dry matter, 2.85 per cent sugar and 1.87 per cent acid, — quantities considerably less than in the same kind of berries stored in a cool room. While decay had been prevented, the absence of air had produced results similar to the asphyxiated fruit previously described.

The results of these different experiments show a steady loss of sugar by cranberries during storage, and this loss is greater at the higher temperatures, while the destruction is further accelerated by a lack of air. The total acidity changes were very little, hence on account of its high proportion in cranberries they do not lose flavor on long keeping as noticeably as some other fruits.

Respiration of Cranberries.

The percentage changes in the composition of fruits produced by different storage temperatures throw little light on the real rate of change at a given temperature. A simple method of estimating the rate of chemical change in fruit at any given temperature is to determine the amount of carbon dioxide exhaled by a definite weight of the fruit in an hour. The carbon dioxide is produced by respiration of the fruit, just as it is produced in animals by the same action. The oxygen of the air penetrates the cells [1] of the fruit and unites with some of the matter in the cells, apparently the sugar, and forms carbon dioxide and water which are exhaled. There is no appearance of rhythmical action, as in the breathing of animals, but the exhalation of the carbon dioxide and water can be readily determined by chemical means.

Respiration experiments with several kinds of fruits [2] have been reported, and it has been shown that respiration varies noticeably with changes in the temperature of the fruit.

Respiration experiments with cranberries were carried out during two seasons, 1917–18 and 1918–19. One kilogram of cranberries was used in nearly every case, and whenever possible for convenience in calculation. The berries were carefully hand-sorted before weighing the desired quantity, in order to avoid any berries which had begun to rot. It was impracticable to hold the cranberries closely to a given degree of temperature during a run, and it was found necessary to maintain them for several hours before a run as closely as possible to the temperature desired to be tried in the respiration chamber, because the internal temperature of the berries was slow to adjust itself to that of the chamber if they were far apart, and the exhalation of carbon dioxide might be too high or too low accordingly. By close attention to details and to the thermometer, the range of temperature during any one run was kept within one or two degrees. Several different temperatures were tried, from about 2° to 25° C. (35° to 77° F.). The lowest temperatures were obtained by setting the respiration chamber inside a small tank which could be packed with snow. Temperatures around 10° C. were obtained at times by surround-

[1] The authors' attention has been called by Dr. Stevens to a little-known paper by Winton (Conn. Agr. Expt. Sta. Ann. Rept. 1902, p. 288), in which is noted the absence of stomata in the epidermis of the cranberry. Bergman, while studying the cranberry, rediscovered this fact, and a paper by him is in press in the bulletin of the Torrey Botanical Club.

[2] Morse, Jour. Am. Chem. Soc. 30 (1908), pp. 876–881; N. H. Agr. Expt. Sta. Bul. No. 135 (1908). Gore, U. S. Dept. Agr., Bur. of Chem. Bul. No. 142 (1911). Hill, Cornell Univ. Expt. Sta. Bul. No. 330 (1913).

ing the chamber with running water, and at others by carrying on the runs in a cool basement. A warm room, such as the laboratory, served for the higher temperatures.

The results given in the following table are selected from a large number of trials, and are those in which the fruit, before and during the experiment, underwent a narrow range of temperature.

TABLE V. — *Exhalation of Carbon Dioxide by One Kilogram of Cranberries in One Hour.*

SURROUNDINGS.	Temperature (Degrees C.).	Determinations.	Milligrams CO_2.
Packed snow,	1–3	5	3.7
Cold room,	6–7	3	7.0
Running water,	9–11	5	7.7
Running water,	11–13	6	9.7
Warm room,	17–20	4	15.4
Warm room,	19–21	3	16.9
Warm room,	22–25	2	18.7

It will be readily seen that the amount of carbon dioxide exhaled doubled with a rise of 10° C. in temperature, which is in accord with the general law for the acceleration of chemical activity.

The temperatures of practical importance are those of cold storage, cool storehouses and warm rooms, or temperatures of 1° to 3°, 9° to 11°, and 20° to 25° C. Cranberries in a warm room are respiring from four to five times as fast as fruit in cold storage, while the fruit in a cool storehouse is twice as active as in cold storage.

These respiration experiments serve to confirm and explain the disappearance of sugar in the cranberries during storage and the increase in such loss at higher temperatures. The rate of respiration helps to explain the asphyxiation of the cranberry described by Shear and Stevens.

By packing cranberries in glass jars and then measuring the amount of water required to fill the air spaces remaining, it was found that in tightly packed barrels of the fruit there could not be more than 75 cubic inches of air for each quart of berries. Since only one-fifth of the air consists of oxygen, it was calculated that in about thirty-six hours, at the cool temperature of 10° C. (50° F.), the cranberries would exhaust the oxygen and replace it with exhaled carbon dioxide. Therefore, if there were no exchange of air between the outside and the inside of a barrel of cranberries, it would be only a few hours before asphyxiation would begin. Fruit, however, does not die as quickly as animals in the absence of air. There is a form of respiration called intracellular respiration, by which sugars decompose to alcohol and carbon dioxide. This is always the result with yeast in alcoholic fermentation. Similar results are found with fruits. Carbon dioxide has been found to be exhaled by fruit in nitrogen gas[1] at about the same rate as by fruit in air. The destruction of sugar under such conditions is theoretically twelve times as great as when oxygen is available.[2]

In our work with cranberries the rate of destruction of sugar in tight packages was shown to be much greater than in well-ventilated ones. At the same time, it was noted that many berries were very resistant to the conditions, and showed little or no signs of asphyxiation. It is possible that such berries have a lower rate of chemical activity, because, as Gore[3] has shown, the varieties of fruit which may be kept a long time, like oranges and lemons, have a much lower rate of respiration than fruits like grapes and strawberries, which spoil quickly.

A third study of the rate of respiration was made in January and February, 1920, with the object of learning whether the different varieties varied in their activity at a given temperature. It was necessary to have as constant a temperature as could be maintained with the means at our disposal. Through the co-operation of the Pomology Department we were enabled to carry on the work in one of the cold-storage rooms in which the temperature changes were comparatively small and slow, and the different varieties were studied under closely comparable conditions.

The cranberries were received from the Experiment Station bog in November, 1919, and had been held in a room with apples at a temperature of 32° to 33° F., until the respiration experiment was reached in January. They were then transferred to the room in which the respiration apparatus was set up, so that they would be at the temperature of the trial at all times. Four varieties of cranberries were used. The Howes variety was studied, with especial attention to possible changes in the rate of respiration as the storage period advanced, and the other varieties were compared with the Howes and with each other, as there was opportunity. A fresh lot of berries was taken from the crate and carefully hand-sorted for each day's trial in order to exclude any unsound fruit. The experiment was conducted as in all the previous cases.

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1 Hill, Cornell Univ. Agr. Expt. Sta. Bul. No. 330.

2 Palladin, Plant Physiology, tr. by Livingston, Blakiston, 1918, p. 180.

3 Gore, U. S. Dept. of Agr., Bur. of Chem. Bul. No. 142.

Table VI. — *Exhalation of Carbon Dioxide by Varieties of Cranberries.*

Date of Experiment.	Temperature of Berries (Degree C.)	Milligrams CO_2 per Kilo and Hour.			
		Early Black.	McFarlin.	Centennial.	Howes.
January 19,	1.2	3.9	-	-	-
January 20,	.6	-	4.8	-	-
January 21,	.4	-	-	5.6	-
January 22,	1.9	-	-	-	4.8
January 27,	2.1	2.6	-	-	-
January 28,	1.7	-	4.9	-	-
January 29,	2.0	-	-	4.7	-
January 30,	1.7	-	-	-	4.2
February 3,	1.5	3.7	-	-	-
February 4,	2.3	-	4.9	-	-
February 5,	1.8	-	-	5.0	-
February 6,	3.0	-	-	-	4.7
February 11,	3.4	-	5.8	-	-
February 12,	3.2	-	-	5.7	-
February 13,	3.0	-	-	-	4.9
February 16,	3.0	-	5.0	-	-
February 17,	2.3	-	-	-	4.2
February 25,	3.9	-	-	-	4.3
February 26,	3.6	-	-	4.7	-

The table shows a pronounced difference between the Early Black and the Centennial in the rate of respiration, but very little, if any, between the Howes, McFarlin and Centennial. There is a slight indication of a decrease in activity by the Howes as the storage period lengthened. Theoretically this decrease should occur, but on account of other variables it is not readily demonstrated. Since Early Black had passed its prime for quality at the date of the experiment, it is possible that its lower activity was due to a loss of vitality.

Keeping Qualities of Cranberries in Cold Storage.

Some simple tests of the keeping qualities of cranberries in cold storage have been made in connection with the chemical studies, since it was necessary to have a considerable quantity of fruit on hand to insure plenty of sound berries throughout the season. When the cranberries were received from the substation at East Wareham, they were placed in the cold-storage house at the College under the same conditions that were maintained for apples. The cold-storage house is a modern building in which the temperature can be kept practically constant week in and week out, which for apples is just above the freezing point, or between 32° and 33° F. The cranberries were stored in ventilated crates holding a half barrel each. There was some evidence that the berries in the center of a crate decayed a little more than those near the surface, but these crates are as small as will be economical for storage and transportation.

When a sample of fruit was required for the chemical studies, a quantity of berries was removed from a crate, carefully sorted by hand, and the different portions weighed. Especial care was taken to have only perfect fruit for the chemical experiments; therefore some berries were rejected which would have been included among sound fruit by the ordinary methods of sorting for the trade. The shrinkage was consequently somewhat greater than would occur in practical storage. The relative keeping qualities of the different varieties should hold, however.

In the fall of 1918 the cranberries were received at the Experiment Station on September 26, kept in a cool room until October 3, and then placed in cold storage with apples. The first lots were removed on November 20, and others at intervals until February 18. The percentages of perfect fruit are given in Table VII.

For the season of 1919 the cranberries were received in November and placed at once in the storage room with apples. Previously they had lain in the store room at the bog in East Wareham at natural temperatures. The first lot was taken from cold storage on Jan. 13, 1920, at which time the crates were removed to a room without ice for the subsequent respiration experiments, but at no time was the temperature observed to go above 37° or 38° F. in this room, which was insulated from outside temperature changes. In this series of tests one variety was used at a time, but all were examined within a week, so in the table below the dates are given for weeks instead of definite days in which berries were sorted.

TABLE VII. — *Keeping Quality of Cranberries.* (*Per Cent Sound Fruit.*)

Date.	Early Black.	Centennial.	McFarlin.	Howes.
1918-19.				
November 20,	-	86.5	74.5	-
December 16,	38.3	-	-	-
January 14,	-	68.0	55.0	78.5
February 18,	-	-	-	75.0
1919-20.				
January 13-20,	46.3	60.6	63.7	64.9
January 27-February 4,	42.5	51.8	53.2	58.5
February 12-17,	-	44.9	52.0	62.1

It is evident from the results that Howes was the only variety that would keep well enough to make storage possible until midwinter in order to extend the marketing season. The other varieties, however, are better in eating qualities, and might be used for the manufacture of jam and jelly in seasons of abundant crops.

Cranberry Vinegar.

In September, 1918, an early frost injured many acres of cranberries, and the question was asked of the Experiment Station whether it was possible to utilize the frosted fruit as a source of vinegar. Consequently a lot of the frozen berries was secured by Dr. Franklin for the preparation of some juice for a fermentation experiment. It was found impossible with a machine to separate rotten berries from the fruit softened by the frost, and the cranberries were used without sorting.

The juice was pressed from the berries early in October by means of a hand cider mill. A lot of juice from sound fruit was prepared at the same date for comparison with regard to quality. Both lots of juice possessed a very disagreeable, bitter, acid taste. They remained under favorable conditions for fermentation until December 19, when they were received at the chemical laboratory for analysis.

Careful tests were made for alcohol in the juice by repeated distillation to concentrate it, and the application of the iodoform reaction to the final distillates. Neither juice showed more than a trace of alcohol in the final reaction, so that little fermentation had occurred.

Total acid and total sugar were determined in the different juices by the methods employed for the cranberry analyses. The results were found to be 2.3 per cent acid and .8 per cent of sugar in the juice from frozen berries, and 2.9 per cent acid and 2.6 per cent sugar in the juice from sound berries. Had the sugar all fermented to acid there would not have been sufficient strength to make a legal vinegar, while the taste would condemn its use in any case. Freezing resulted in a marked lowering of sugar in the fruit. The failure to ferment freely is probably due to the benzoic acid, which is a natural constituent of the cranberry. It does not appear practicable to utilize waste cranberries for vinegar.

Summary.

This bulletin reports the results of a chemical investigation made on the changes taking place in stored cranberries.

After the cranberries are picked from the vines they still remain living organisms. Storage conditions should be such that the life of these organisms may be prolonged instead of death being hastened.

Cranberries lose some of their sugar during storage. This loss is due to the respiration of the living berries, which respiration is less rapid at low temperatures than at high temperatures. For this reason the warmer the berries are kept the greater the loss of sugar during storage.

In order to have complete respiration, berries require a constant supply of oxygen during storage. Without this they become asphyxiated and die prematurely.

Good storage must include control of both ventilation and temperature.

Methods.

For the Determination of Chemical Composition.

In drying the cranberries for the determination of water it was necessary either to puncture the skin of the berry in numerous places with a pin, or to cut it into quarters with a knife. Fifty grams of cranberries were punctured or cut in pieces and spread in a shallow glass dish which was placed in a drying oven at a temperature between 50° and 60° C., where it remained until the fruit was brittle enough to be easily pulverized. The dish and contents were then cooled in the open air and the weight of dried material ascertained, after which it was pulverized and stored in a tightly corked bottle. Weighed charges of the air-dry material were subsequently used for moisture determinations, and the total water content of the cranberries calculated.

For the determination of sugar and acid, 50 grams of cranberries were mashed, a few at a time, in a porcelain mortar and washed with water into a 500 cubic centimeter volumetric flask by the aid of a wash bottle, short-stemmed funnel and long glass rod. The flask and contents, which amounted to 300 cubic centimeters, were set on a boiling water bath and allowed to stand about one hour. The flask was frequently shaken, and the pulp and water finally made a fairly homogeneous mass through which the sugar and acid were diffused. The liquid was cooled to room temperature and made up to 500 cubic centimeters. The flask was shaken and the contents then poured on a fluted filter large enough to hold the whole. The funnel was covered and a flask used to catch the filtrate so that evaporation would be reduced as much as possible. Aliquots of 100 cubic centimeters were used for sugar determinations, which were limited to the total sugar after inversion. Clarification was accomplished with Horne's dry lead subacetate, and the soluble lead in the cleared solution was removed by dry sodium carbonate.

Total acidity was determined in aliquots of 25 cubic centimeters of the cranberry solution, which were diluted with several volumes of water and titrated with tenth-normal sodium hydrate, using phenolphthalein as the indicator. The pink color of the cranberry solution seemed at first to make the use of an indicator almost impracticable, but the cranberry pigment proved to be a crude indicator itself. As the alkali was added the pigment changed from pink to blue, and subsequently faded to a pale green as more alkali was introduced. The end point was clearly marked by the appearance of a dark purple tint when the turning point of phenolphthalein was reached. The total acid was calculated as citric acid, though benzoic acid[1] and malic acid[2] have been shown to occur in small quantities in the cranberry.

The proximate food constituents — ash, protein, fiber, ether extract and nitrogen-free matter — were determined in the dried material by the standard methods.

Ether extract from the cranberry is a mixture of true fat from the seeds, wax from the skin and more or less of the fruit acids, — citric, malic and benzoic, — all of which are soluble in ether, the last most easily. In some of the samples the ether extract was warmed with the addition of water, and its acidity determined, but as it could be only an approximate correction it was thought best to leave the total ether extract uncorrected for acids present in it.

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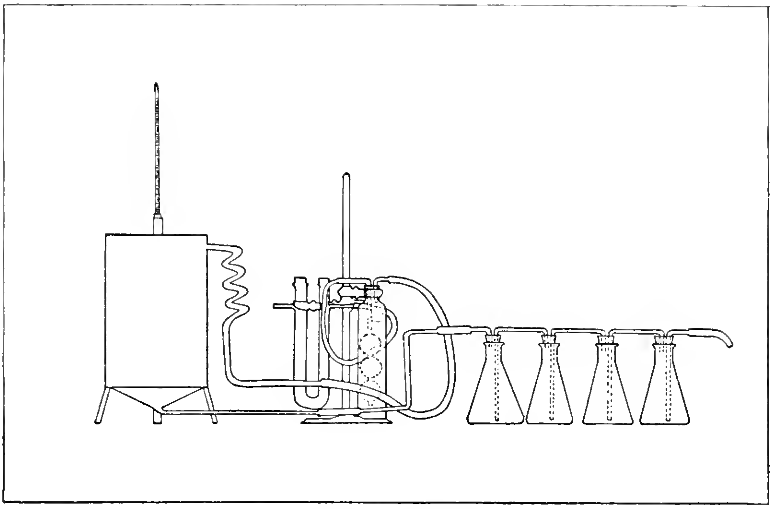
[1] Mason, Jour. Am. Chem. Soc. 27 (1905), p. 613.

[2] Bigelow and Dunbar, Jour. Indus. and Engin. Chem. 9 (1917), p. 762.

For the Determination of Rate of Respiration.

The apparatus consisted of a respiration chamber into which air freed from any carbon dioxide could be drawn, and from which the air could be conducted through a liquid which would absorb all of the exhaled carbon dioxide carried along in the current.



Respiration Apparatus.

The respiration chamber was of tin and would hold about 3 quarts. It was open at the top and was closed by a disk of tin which rested on a narrow shelf extending around the inner wall a half inch below the top. The bottom was funnel-shaped with the outlet for the exhaled gas projecting from the lowest part, so that the carbon dioxide, which is heavier than air, could be completely removed. The inlet for purified air was just below the cover of the chamber. Inside the chamber was a loose, false bottom, perforated with numerous small holes, which prevented the cranberries from settling down and blocking the outlet. The false bottom supported a tube three-eighths of an inch in diameter which rose through the center of the chamber and projected an inch above the cover. This tube was also perforated with holes in the portion below the cover, and served to hold a thermometer and to permit free circulation of air through the mass of berries. The cover was sealed in place by means of putty around the inner walls and the central tube, and a cork, through which passed the thermometer, stopped the tube. The outer end of the inlet tube was joined to the purification apparatus which consisted of a U tube containing dry soda lime, and a bulb tube containing a strong solution of sodium hydroxide. The air bubbling through the solution was moistened before entering the chamber, while the bubbles marked the movement of the air and served to indicate leaking joints. The outlet tube connected with a train of four small flasks, each of which contained a measured amount of standard solution of barium hydroxide, by which all the carbon dioxide was absorbed and precipitated as barium carbonate. A current of air was drawn through the entire apparatus by an aspirator which was regulated so that the air in the respiration chamber would be renewed about once in every hour. As a rule, each experiment was run six hours. Some were conducted for longer periods, but six hours was most convenient and satisfactory.

FUNGI STUDIES.

BY BERT A. RUDOLPH AND H. J. FRANKLIN.

Relative Prevalence of Fungi causing Rots of Cranberries at Different Periods during the Storage Season.[1]

Decay of cranberries in storage has been reported to be caused by more than ten species of fungi. The study of these storage rots and their control is complicated by the fact that the fungi causing them vary greatly in their relative abundance during different seasons. Moreover, berries from the various bogs within a given region are often found to be affected with different fungi, and there is apparently some difference in varieties on the same bog. Finally, in any given lot of berries there seems to be a more or less definite succession among the fungi causing decay during the storage period. The present paper deals especially with the last-mentioned point.

The plan of work in 1916–17 was as follows. Twelve storage boxes (1 bushel capacity) were filled with Early Black cranberries from a uniform area on the station bog at East Wareham, Mass., and placed in storage in the basement of the screen house, together with a similar lot of Howes. Beginning September 27 quart samples of sound berries were selected weekly from each variety and stored for two weeks in quart cans (which were closed but not sealed) at room temperature, after which they were sorted, and the berries which had rotted during the two weeks were sent to Washington. Here at least 60 cultures were made[2] from each lot of rotten berries by sterilizing the outside of the berry by immersing for five minutes in mercuric chloride solution (1–1000) and transferring a portion of the pulp to culture media by means of sterile forceps. In case fungi developed which did not fruit readily on the culture medium first used, subcultures were made on oat, beef, glycerine and corn-meal agar.

In the work of the season of 1917–18 the method was modified in several particulars. Closed cans were abandoned in favor of open boxes for the storage of the selected sound berries, the interval between tests was four

[1] The work summarized in this paper forms a part of the study of the spoilage of cranberries after harvest, which is being carried on jointly by the Massachusetts Agricultural Experiment Station and the United States Department of Agriculture. For further information on this general subject see Mass. Agr. Exp. Sta. Buls. Nos. 168 and 180, and U. S. Dept. Agr. Bul. No. 714.

[2] The fungi were all cultured and identified by Rudolph, whose enlistment in the navy late in 1917 prevented the completion of the work planned for that season. Mr. Rudolph was at that time scientific assistant, fruit disease investigations, Bureau of Plant Industry.

weeks, and the sound berries selected for each keeping test were divided into two lots, one of which was kept at room temperature and the other at a constant temperature of 20° C. The only considerable difference in the results due to the difference in method is that the number of sterile (*i.e.*, apparently smothered) berries was smaller during the season of 1917–18. In this respect the results of the second year are more reliable. Storing the berries at a constant temperature (20° C.) apparently changed the results little, which indicates that, in so far as concerns the kinds and abundance of the fungi which developed, those obtained in 1916 with the berries stored at room temperature are satisfactory.

More than a dozen species of fungi occurred in the cultures made during the first season. Of these, seven are known to be more or less important causes of decay of cranberries in storage, namely, *Guignardia vaccinii* Shear (early rot); *Glomerella cingulata vaccinii* Shear (bitter rot); *Fusicoccum putrefaciens* Shear (end rot); *Ceuthospora lunata* Shear (black rot); *Sporonema oxycocci* Shear (ripe rot); *Penicillium* spp. (soft rot); and *Phomopsis* sp. Table I shows the relative prevalence of the four most abundant of these fungi in terms of the percentage of the total number of spoiled berries. Occasionally the percentages recorded total more than 100, an apparent discrepancy which is accounted for by the fact that two or more fungi frequently develop from a single berry.

TABLE I. — *Most Important Fungi causing Storage Rot of Cranberries at Massachusetts State Experiment Bog, East Wareham, 1916.*

[Figures indicate per cent of total spoiled berries infected with each fungus.]

Storage Period.	Glomerella.		Phomopsis.		Sporonema.		Fusicoccum.		Sterile.	
	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.
Sept. 27–Oct. 11,	3	-	63	-	3	-	20	-	13	-
Oct. 14–18,	30	30	37	40	3	0	7	3	17	23
Oct. 11–25,	7	47	40	20	3	3	7	17	40	17
Oct. 18–Nov. 1,	15	47	36	7	15	0	33	30	0	13
Oct. 25–Nov. 8,	0	13	40	0	3	0	13	53	47	23
Nov. 1–15,	0	6	13	0	3	0	47	60	37	33
Nov. 8–22,	3	20	17	7	0	0	53	47	20	23
Nov. 16–30,	0	27	13	3	0	0	47	50	43	16
Nov. 23–Dec. 7,	0	3	17	3	0	0	40	70	47	20
Nov. 29–Dec. 13,	0	13	13	7	7	0	47	20	50	56
Dec. 6–20,	0	7	7	7	0	0	46	50	37	27
Dec. 13–27,	0	0	10	3	0	0	33	30	57	60

Comparing first the fungi found in the two varieties during this season it will be noted that Sporonema is much more abundant on the Early Blacks, though even on this variety it is not of very great importance. Phomopsis is considerably more common on the Early Blacks and Glomerella on the Howes. Fusicoccum (end rot) is an important storage rot on both varieties. Such differences as have been noted between the varieties may well be accidental. Howes usually bloom three to eight days later than Early Blacks, and thus might be in a condition of susceptibility to certain fungi at different times from the Blacks.

TABLE II. — *Cranberry Blooming Period at the Station Bog, East Wareham, Mass.*

Year.	Early Black.	Howes.
1913,	June 20–July 14	July 1–July 18
1914,	June 26–July 20	June 30–July 23
1915,	July 1–July 20	July 9–July 26
1916,	July 1–July 18	July 5–July 22
1917,	July 3–July 23	July 9–July 28
1918,	June 25–July 12	June 28–July 15

Certainly it would be unsafe to assume, without very extensive study, that either variety was especially susceptible to a given fungus.

The relative importance of the various fungi at different times during the storage season is most easily seen from the graphs, Figs. 1 and 2. In both varieties Phomopsis and Glomerella are most abundant early in the storage season, and become gradually less important. Fusicoccum, on the other hand, is relatively scarce early in the season, and becomes very much more abundant as the season advances, so that after the 1st of November end rot is more important than all the other rots combined. That this relation does not always hold is proven by the records of the succeeding year, but it seems probable that, in Massachusetts, end rot is the most serious cause of decay in stored cranberries during the latter part of the season. End rot in early stages can be identified on the fruit with a fair degree of certainty by careful observers, and its importance as a cause of loss in stored fruit has been emphasized by Mr. H. S. Griffith, chairman of the inspectors of the New England Cranberry Sales Company, in his report for 1919 (page 21).

The results of the second year's work as given in Table III show interesting resemblances to those of the previous year.

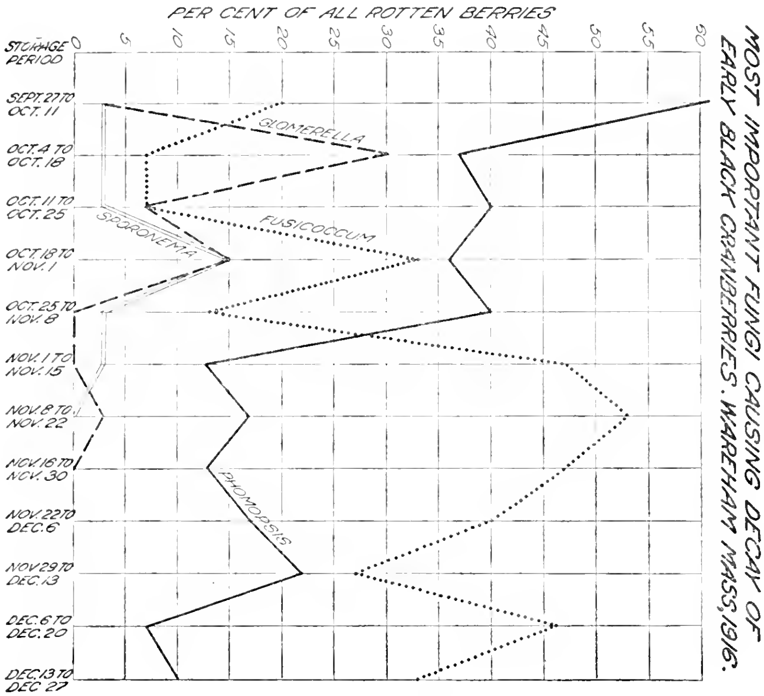

PER CENT OF ALL ROTTEN BERRIES
MOST IMPORTANT FUNGI CAUSING DECAY OF EARLY BLACK CRANBERRIES. WAREHAM MASS,1916.
STORAGE PERIOD
SEPT. 27 TO OCT. 11
OCT. 4 TO OCT. 18
OCT. 11 TO OCT. 25
OCT. 18 TO NOV. 1
OCT. 25 TO NOV. 8
NOV. 1 TO NOV. 15
NOV. 8 TO NOV. 22
NOV. 16 TO NOV. 30
NOV. 22 TO DEC. 6
NOV 29 TO DEC. 13
DEC. 6 TO DEC. 20
DEC. 13 TO DEC 27
GLOMERELLA
SPORONEMA
FUSICOCCUM
PHOMOPSIS

Fig. 1.

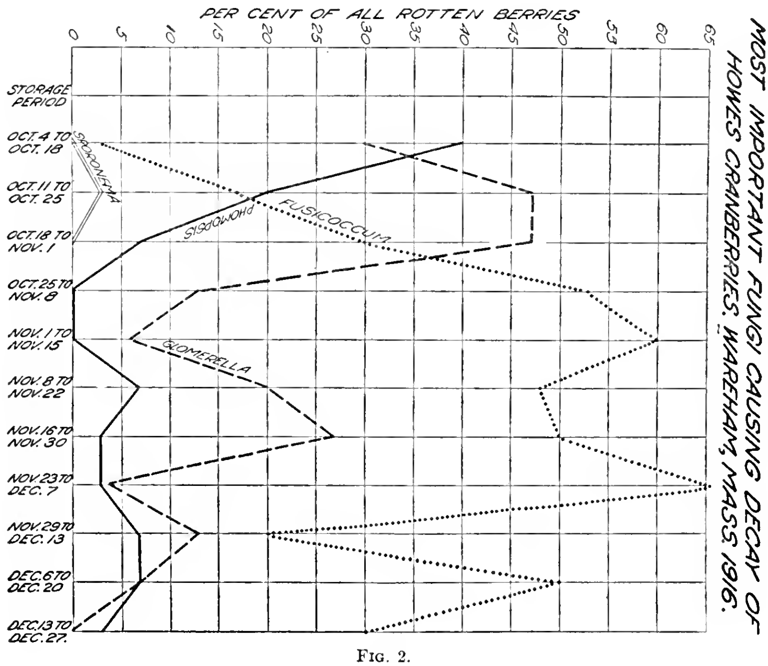

PER CENT OF ALL ROTTEN BERRIES
MOST IMPORTANT FUNGI CAUSING DECAY OF HOWES CRANBERRIES. WAREHAM, MASS. 1916.
STORAGE PERIOD
OCT. 4 TO OCT. 18
OCT. 11 TO OCT. 25
OCT. 18 TO NOV. 1
OCT. 25 TO NOV. 8
NOV. 1 TO NOV. 15
NOV. 8 TO NOV. 22
NOV. 16 TO NOV. 30
NOV. 23 TO DEC. 7
NOV. 29 TO DEC. 13
DEC. 6 TO DEC. 20
DEC. 13 TO DEC. 27.
SPORONEMA
PHOMOPSIS
FUSICOCCUM
GLOMERELLA

Fig. 2.

TABLE III. — *Most Important Fungi causing Storage Rot of Cranberries at Massachusetts State Experiment Bog, East Wareham, 1917.*

[Figures indicate per cent of total spoiled berries infected with each.]

Storage Period.	Storage Temperature (Degree C.).	Glomerella.		Phomopsis.		Sporonema.		Fusicoccum.		Sterile.	
		Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.
Before storage,	-	61	89	5	5	22	4	9	1	11	4
Storage ended Oct. 15,	20	12	76	30	3	15	0	21	3	15	7
	13[1]	23	88	40	4	20	0	13	1	11	8
Storage ended Nov. 12,	20	12	82	32	2	0	0	40	4	20	10
	18[1]	12	51	18	6	8	6	58	12	6	24
Storage ended,	20	2	43	10	3	3	3	67	18	9	23
	5[1]	1	31	3	6	2	3	58	36	11	10

[1] Estimated from outside temperature and from temperature of same room during the same periods of the previous year.

As in 1916 Sporonema is the least important of the four, and is found chiefly on the Early Blacks. Phomopsis is again more common on the Early Blacks, and Glomerella on the Howes; indeed, the contrast is more striking in 1917 than in 1916. During both years Phomopsis and Glomerella are more abundant early in the season, while Fusicoccum is rare early in the storage period and becomes more abundant later. The most unusual feature presented by the results is the very great abundance of Glomerella on Howes during 1917, and the relative scarcity of Fusicoccum.

So far as is now known infection by the various fungi causing decay of cranberries generally occurs before the berries are picked. That the development of the fungus is often delayed for some time is evident from the data here published, when it is recalled that in every case only apparently sound fruit was used for the storage test. The conditions necessary for the further development of a fungus already in the fruit or attached to the outer epidermis as a spore or appressorium are not yet determined. That it is not entirely a matter of condition of the berry is apparent from the fact that end rot, for example, becomes abundant on the Howes as soon as on the riper Early Blacks; and that it is not a matter of temperature appears (see Table III) from the fact that berries kept at 20° C. showed no marked difference in this respect from berries kept at lower temperatures.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 199 SEPTEMBER, 1920

BROODINESS

IN

DOMESTIC FOWL

DATA CONCERNING ITS INHERITANCE IN THE RHODE ISLAND RED BREED

By H. D. GOODALE, RUBY SANBORN
and DONALD WHITE

Requests for Bulletins should be addressed to the
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DEPARTMENT OF POULTRY HUSBANDRY.

BROODINESS IN DOMESTIC FOWL.

DATA CONCERNING ITS INHERITANCE IN THE RHODE ISLAND RED BREED.

BY H. D. GOODALE, RUBY SANBORN AND DONALD WHITE.

Introduction.

Broodiness, as pointed out by Herrick (1907a, 1907b), is one phase of a recurring cyclical process in birds. In the domestic fowl when kept primarily for egg production, the instinct is not allowed to run its normal course, but is checked by suitable means in its initial objective stages. Some individuals, however, never exhibit the instinct. In this study of the inheritance of broodiness two categories of birds may be recognized, viz., those that exhibit the initial stages of broodiness, which are promptly checked, and those that do not exhibit any signs of broodiness. Broodiness is intimately connected with egg production, and, other factors being equal, its presence or absence determines the number of eggs laid, since, as shown later, its presence tends towards decreased production. A knowledge of its inheritance should show the steps necessary for its complete elimination from a flock.

The character, moreover, is not a superficial and unimportant one, but is a well-defined characteristic of the class Aves, and is essential for the survival of every species in the class. If the instinct were lost in a state of nature, without being replaced by some compensating mechanism,[1] the race would become extinct. In nature selection is constantly directed in favor of the character, since those individuals that lack it will leave no progeny, yet among domestic fowl we find entire races in which the character is lacking.

Poultrymen recognize both broody and non-broody races. The American breeds, *i.e.*, Plymouth Rocks, Rhode Island Reds and Wyandottes, and

[1] It is well known, of course, that the American cowbird and the European cuckoo have developed a compensating mechanism.

the Asiatics, *i.e.*, Langshans, Cochins and Brahmas, may be cited as examples of the former, while Hamburgs and Campines, and the Mediterranean breeds, *i.e.*, Leghorns, Spanish and Anconas, furnish examples of the latter. The distinction is based on the proportion between broody and non-broody individuals in each race, for some non-broody individuals occur among the broody races, while records are lacking to show that broody individuals are entirely absent from any of the non-broody races. The Leghorns are commonly regarded as a non-broody race, but as shown in Table VI, taken from the report of the fifth laying contest at Storrs (Kirkpatrick and Card, 1917), a considerable number become broody. It is a matter of common knowledge among poultry keepers that among the broody races there are considerable differences, some races, of which the Rhode Island Reds are an example, having an intense development of broodiness compared with others, such as the Barred Plymouth Rocks, in which the amount of broodiness is relatively slight.

There are few published reports on the character in the domestic fowl, though there is, of course, a considerable amount of matter scattered through the poultry literature, in which broodiness is mentioned in a more or less general way, but which is of no importance from the standpoint of this paper. Both Bateson's (1902) and Hurst's (1905) data showed that in a cross between a broody and non-broody race, broodiness was dominant, but they have published no further observations. Pearl (1914) has published certain data relating to broodiness, with which in general our data agree. A repetition of the same sort of material is unnecessary here. His methods of collecting the data and of handling the broody birds also are essentially the same as our practices in these respects. In general, our experience with this instinct agrees with his, except that there are two points for which different interpretations may be presented. On page 285 (*loc. cit.*) he makes this statement: "It appears to be the case that in the domestic fowl the brooding instinct has to a very large degree disappeared along with the fact of domestication." Evidently this author had not encountered a strain like our Rhode Island Reds, for such a statement would be impossible after an experience with such a strain. In the second place, we entertain some doubt as to the advisability of measuring the intensity of broodiness by the length of the non-productive period associated with the objective symptoms of broodiness (*loc. cit.*, page 273), because, while the cessation of egg production coincides in nearly every instance with the onset of objective symptoms, the resumption of production is often delayed by other factors, among which may be noted the innate capacity for egg production and readiness to molt. In regard to its effect on egg production, Goodale (1918) makes the statement that the ratio between the egg production prior to the first broody period and that subsequent thereto is about 100:60.[1] Gerhartz (1914) has studied the metabolism of the broody hen in connection with his studies on the metabolism of the laying hen.

[1] The data on which this statement is based are given for the first time in Table VIII.

The Material and its Treatment.

The materials for the present study of the inheritance of broodiness are the pullet-year trap-nest records of the flock of Rhode Island Reds, bred at this station from 1913 to 1917, primarily to furnish data on the inheritance of fecundity. The usefulness of these data is limited in one important respect, since, as discussed in the section on variation, a year's record is not long enough to determine a hen's capacity for becoming broody. Limitations in housing capacity and labor have hitherto prevented the retention of non-broodies as long as was desirable. In the handling of the data, therefore, we have classified birds as broody or non-broody on the basis of the pullet-year records only, even though on this basis the non-broody class will contain more birds than it should. However, the theories of the inheritance of broodiness to which we have been led could not be substantiated from the available data, even if the difficulty under discussion were removed.

Recognition and Treatment of Broody Birds.

The recognition of a broody period is an easy matter with slight experience. The onset of broodiness is usually sudden. On the last visit to the trap nests late in the afternoon one or more birds are found that are very much disinclined to leave the nest. If they cluck and ruffle their feathers the diagnosis is certain, and the birds are removed to the broody coop to be "broken up." Sometimes part of the symptoms are lacking. In case of doubt the bird is merely removed from the nest. By the following afternoon, if she is really broody, all symptoms are well manifest. Mistakes are not easily made.

The broody coop in which the broody hens are confined, in order to prevent the instinct from running its normal course, is a box with slatted sides, top and bottom. The routine practice in dealing with broodies is to place all the broodies found in each pen in one of these coops. The same coop also receives the broodies on each of the two days following. Three days later the entire lot is released as a unit. Thus, the birds are confined from three to six days each, a period which is sufficient for the majority to "recover from the attack." A few, however, require a longer period of confinement. The confined broody individuals are supplied *ad libitum* with the same sort of food and water supplied the rest of the flock.

A bird must, as a rule, be classified either as broody or not broody, though in a few rare instances birds have exhibited a part of the broody symptoms only, as, for example, when a hen clucks and ruffles her feathers, but does not remain on the nest continuously, nor cease laying.

Variation in Amount of Broodiness.

A bird once broody may exhibit the character in various degrees which can be classified under two heads, — first, variation in the number of times a bird becomes broody in a period of given duration, usually the laying year; and second, variation in length and intensity of the individual broody periods. The latter is the less important of the two, for the length of time required by the vast majority of birds to "recover" from the attack is of comparatively small importance. To be sure, some birds take double the time that others require in "recovering," but it is an extreme case when more than a week is required, if no extraneous factors are present. Further, on forming a correlation table between number of days confined and subsequent egg production, it became evident that the coefficient of correlation (though not calculated) was so small that no relationship of importance existed between the subject and relative. The large factor in variability in broodiness is found in the variation in the number of times the broody cycle is repeated, as is shown later on.

Four sample egg records are shown here to illustrate individual variations in amount of broodiness. A numeral in a square indicates the hour at which an egg was collected; B. L., broody and placed in broody coop; A, released from broody coop; N, associated with a numeral, means that the bird visited the nest, but did not lay.

NO. 8314
PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																			12	10			10.5		8	1	2.5		8	10.5	11.5	9	
NOV.	1	4		8	10.5	1		1	1	3	11.5	12 BL			A												N9	1	N1	7.5		12	
DEC.	4.5		7.5	1	N3.5	7.5	11.5	3		9	10.5	1	4		9	1		9	3		10.5	3		4.5		BL						18	
JAN.	A												N3	N1	N11.6 1		10.5	3		10.5		1		10.5	3		10.5	1		9	1	12	
FEB.	4			10.5	3		10.5	3		10.5	3 N4.5	BL		A												N4		10.5	3			9	
																																	60
MAR.		8.5	10.5	2		9	10.5	10.5	11.5	1	12	1	2	3		7	10.5 BL				A	N5		9	1		9	N1	2		7.5	19	
APR.	8.5	9.5	10	10	10	10	10.5	1 BL		A BL						A	10.5	2		7.5	9	9	8.5	8.5	N3	9x	10	10	2	BL		19	
MAY						A		1		7.5	11									10.5	9			10				9		2 N3	BL	8	
JUNE						A							11	10	1	1	1	1	2.5		7.5	1 BL					A					9	
JULY				9	11.5	2	3		7.5	11	1		8 BL					A						9	3		1	11	11	1		14	
AUG										1		9	11	3		9	9	11	11	1		BL								A		9	
SEPT.						10	2		8.5	11	11	1	12	1	3 BL																	9	
OCT		1		9	3		9	10	11	11	11	1		1	BL																	10	
NOV.																																	

YEAR'S TOTAL 157
(365 DAYS)

FIG. 1.—Egg record of a very broody individual.

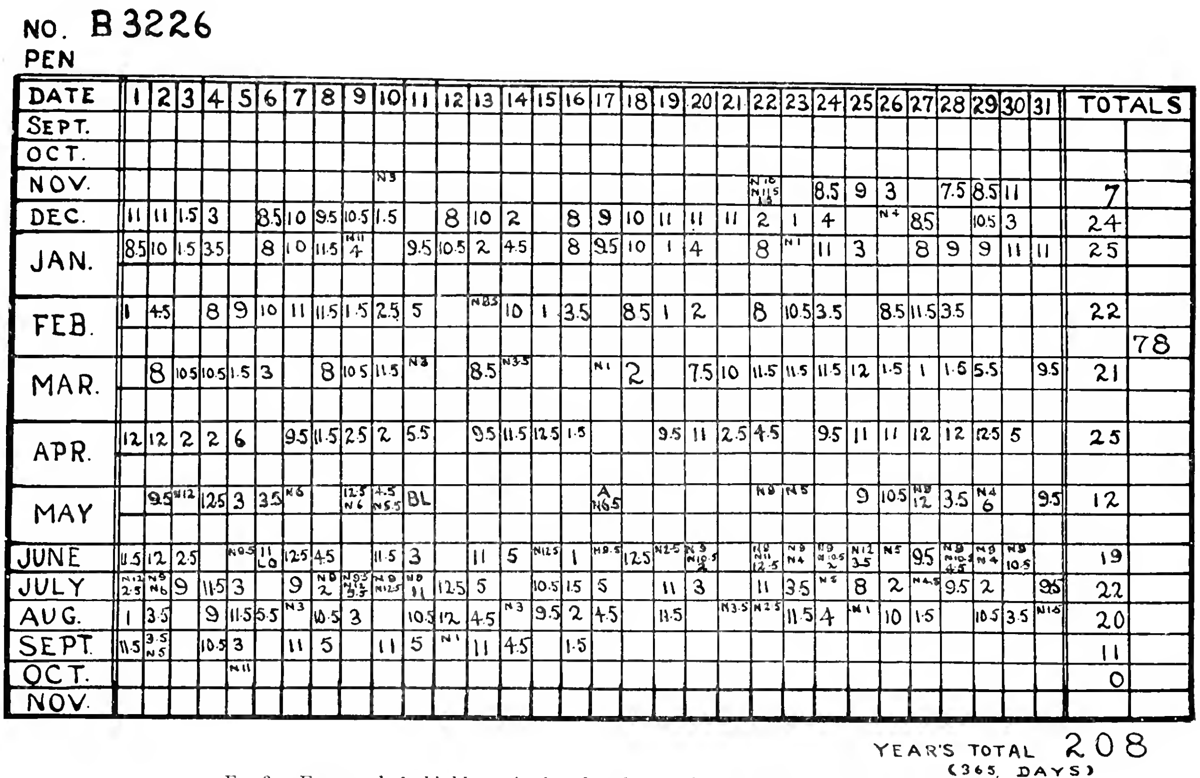
NO. B3700

PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.																					11.5		7	9.5	3		9	2		8		7	
DEC.	N3	N3.5	3		7.5	9.5	2.5		7.5	8	10	11	11.5	3			9	10	1	4			3		8	9.5	11	4		7.5	10	21	
JAN.	11.5	N3.5		7.5	8.5	10	11.5	4.5		8	9.5	10.5	2	3.5		8	11	11.5	1	4		8	9.5	11	10.5	10.5	11	N2.5	N4.5		8	23	
FEB.	11.5	12.5	4		8	10	11	N3		4		10.5	10	11.5	3.5			8.5	10	11.5	3.5		8.5	8.5	10	1	1.5	4.5				21	72
MAR.		8	2		8.5	10	N3	N3.5		8.5	1.5		8.5	10	1.5		8	9.5	12	11.5	11.5	11.5	N2	4 N5.5		8.5	10.5	4		N11	11.5	20	
APR.	3	3	N4	4		9.5	9.5	N2	N6		9.5	11	N2.5			10	11.5	2	12.5	1	2.5	4.5		N1	9.5	11	12	2.5 N5.5	BL			18	
MAY.				A		N11		N5		9.5	N3	N5.5		9	9	9.5	9.5	10.5	10.5	11.5	10	N3	11.5	10	9	2 N5.5	BL					13	
JUNE			A				N9.5	4.5		9.5	11.5	11.5	11.5	12.5	3		9.5	9.5	11	11	11	3 N5.5	BL				A	N4.5				13	
JULY		N9							2		9.5	2.5		11	12	3.5		9	10	9.5	9 N5.5	1.5 C BL				A						11	
AUG.									N9	12			9.5	9.5	10.5	N3.5	4.5			1.5		8.5	10	10	10	1.5 NS	N2 BL					11	
SEPT.				A														N9.5	3		10	11	5		NS	3		9.5	9.5	11		8	
OCT	11	11	11	1	12.5	3 N5	BL						A																			6	
NOV.																																	

YEAR'S TOTAL 172
(365 DAYS)

FIG. 2.—Egg record of a bird becoming broody about midseason.



NO. B 3226

PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.										N3												N10 N11.5 1.5		8.5	9	3		7.5	8.5	11		7	
DEC.	11	11	1.5	3		8.5	10	9.5	10.5	1.5		8	10	2		8	9	10	11	11	11	2	1	4		N4	8.5		10.5	3		24	
JAN.	8.5	10	1.5	3.5		8	10	11.5	N11 4		9.5	10.5	2	4.5		8	9.5	10	1	4		8	N1	11	3		8	9	9	11	11	25	
FEB.	1	4.5		8	9	10	11	11.5	1.5	2.5	5		N8.5	10	1	3.5		8.5	1	2		8	10.5	3.5		8.5	11.5	3.5				22	
																																	78
MAR.		8	10.5	10.5	1.5	3		8	10.5	11.5	N3		8.5	N3.5			N1	2		7.5	10	11.5	11.5	11.5	12	1.5	1	1.6	5.5		9.5	21	
APR.	12	12	2	2	6		9.5	11.5	2.5	2	5.5		9.5	11.5	12.5	1.5			9.5	11	2.5	4.5		9.5	11	11	12	12	12.5	5		25	
MAY		9.5	N12	12.5	3	3.5	N6		12.5 N6	4.5 N5.5	BL						A N6.5					N8	N5		9	10.5	N8 12	3.5	N4 6		9.5	12	
JUNE	11.5	12	2.5		N0.5	11 LO	12.5	4.5		11.5	3		11	5	N12.5	1	N8.5	12.5	N2.5	N9 N10.5 2		N8 N11 12.5	N8 N4	N8 N10.5 2	N12 3.5	N5	9.5	N8 N10.5 4.5	N8 N4	N8 10.5		19	
JULY	N12 2.5	N5 N6	9	11.5	3		9	N8 2	N9.5 N12 9.5	N8 N12.5	N8 11	12.5	5		10.5	1.5	5		11	3		11	3.5	N5	8	2	N4.5	9.5	2		9.5	22	
AUG.	1	3.5		9	11.5	5.5	N3	10.5	3		10.5	12	4.5	N3	9.5	2	4.5		11.5		N3.5	N2.5	11.5	4	N1	10	1.5		10.5	3.5	N1.5	20	
SEPT.	11.5	3.5 N5		10.5	3		11	5		11	5	N1	11	4.5		1.5																11	
OCT.					N11																											0	
NOV.																																	

YEAR'S TOTAL 208
(365 DAYS)

FIG. 3.—Egg record of a bird becoming broody only once the first year, and that at midseason.

NO. B640
PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT																																	
OCT.																											2			1		2	
NOV.	8.5	10	4.5		8	10	4.5		9	1.5	4		7.5	10	3		8	9	10	11	3		8	9	2		7.5	9.5	10			23	
DEC.	9	12				10.5	3		7.5	9	1	3		9	10	11	4		7	9	9.5	11	1	2.5		7	10.5	3.5	7		11	23	
JAN.	1	4		9	11	3		8	10	1.5	4		9	10.5	4		8.5	11	4		8	11	3.5		8.5	11	3		8.5	1.5	N3 4	24	
FEB.		10	1	4		11	3		8.5	2	2		8.5	12	4		10	3		8.5	3	4	9		11	4		9.5				20	92
MAR.	10	4		9	9.5	12	5		9.5	11	2		8	10	4		10	10			8.5	5		9	1.5		11	2		9.5	3	22	
APR.	6		12	5		11	5		3		2.5		2		12	1	4			3		12	5		10	6		2		11		18	
MAY		2		4		4		1		10	4			12		10	4	6		11	4		11	2	3	12	5		10.5	2	3	20	
JUNE		1		10	12	3		2		12	3		11		11	12	4		9.5	2		10	3				1	3				17	
JULY		5		3		N3 11	4.5		1		11		11	4		11	5		11			1		11.5	4		1.5		1		10	17	
AUG.	1		5	11	3		11		10	N10 3		11	3		10	2	5		11	1	5		10	1	5		10	3	N3 5	SNBC BL	A	21	
SEPT.	BL		A																													0	
OCT.																																0	
NOV.																							10		10	1		10	1			5	

YEAR'S TOTAL 207
(365 DAYS)

FIG. 4. — Egg record of a bird becoming broody at the end of the laying year.

Figures 1, 2 and 4 are examples of variability in number of broody cycles. It will be observed that there is a period of production of variable length before the first broody period makes its appearance. This may come soon after production begins (Fig. 1), or may be delayed till near the end of the season (Fig. 4), or even till subsequent seasons. After the first broody period subsequent periods occur in fairly regular sequence, the cycle of broody, rest and production being repeated over and over. It is obvious, then, that the number of broody periods occurring during the first year will be determined in part by the time of year the first broody period occurs. After one broody period it becomes a question of the number of additional cycles that are added before a bird stops laying for the season. In the extreme case of Fig. 4, production was not resumed after the first broody period, which came late in the season.

In later years there has been much less regularity in the recurrence of the broody periods in that part of the flock bred specifically for increased egg production, but the parallelism does not necessarily mean that the latter has caused the former. It is noticeable that the broody periods are fewer in number and limited to the height of the broody season in many individuals, which afterward may become regular producers, without further evidence of broodiness in that season. For example, instances are quite common where a single broody period occurs in mid-season, and is followed by continuous production, as shown in Fig. 3. Sometimes there are two or even three such periods followed by continuous production. Occasionally some birds have broody periods occurring at rather irregular intervals.

When birds are kept through the second season it is found that some birds that did not become broody the first season may become broody at some point in the second season. One instance occurred where the bird did not become broody till the third season. Because of the physical limitations in the matter of plant equipment we are unable to give the exact percentage of birds not broody in their pullet year that became broody later on. We have, of course, the data for such birds as were kept over, but we do not believe it gives a fair picture of what will be found in large flocks. They are, however, fairly numerous. There is, moreover, some evidence that various lines behave unlike others in this respect. On the other hand, only four instances free from complications have occurred among our records of birds that were broody the first season but failed to become broody thereafter. It is clear that the pullet year is a good index of the presence of the broody instinct for those birds that actually become broody, but not as good an index for those that do not become broody.

This brief description of variation in amount of broodiness, together with the data given in Table VIII, is sufficient to give the reader a general idea of its nature. Further details are outside the scope of this paper.

Germinal Basis of Broodiness.

The normal or wild condition is the presence of broodiness, otherwise the race could not survive. Hence, any changes from the normal condition of those parts of the germ plasm which are responsible for the existence (as distinguished from amount) of broodiness will probably result in a failure in the appearance of the broody instinct. Broodiness may also, of course, fail to become manifest from non-genetic causes, and hence some genetically broody birds are recorded as non-broody. Non-broodiness, therefore, is a comprehensive term employed to describe the phænotypic condition resulting from several sorts of genetic differences. The situation is parallel, in certain respects, to that of eye color in Drosophila. Red eye is the normal or wild color. Changes in the germ plasm result in a host of other eye colors, which are all non-red. In like manner, from the genetic standpoint, all broody birds are presumably alike in their fundamental broody mechanism, except for the homozygous or heterozygous condition, and, of course, the presence of modifiers discussed in the next paragraph. Non-broody birds, on the other hand, may belong to quite different genotypes. It is, therefore, improbable that any one scheme can be applied to the inheritance of non-broodiness in domestic fowl. Indeed, the data given in Tables II and III indicate clearly that several types of non-broodies exist in the Rhode Island Reds. The presence of these types suggests that still different genetic types of non-broodies will be discovered in other breeds.

It seems clear on general grounds that a distinction must be made between the primary factors concerned with broodiness and modifying factors. The latter may act in various ways on the primary mechanism for the manifestation of broodiness, but they cannot act unless that mechanism is present. We may expect that such modifying factors will control the intensity of broodiness in either a plus or minus direction, and, extending this reasoning to its logical conclusion, such modifying factors may prevent entirely any manifestation of broodiness. Non-broodiness, therefore, may result from some genetic change in the secondary mechanism, as well as in the primary.

There are three possible sorts of matings (the male being treated as though capable of giving phænotypic expression to his genotypic constitution), viz., both parents may be broody, both non-broody, or one broody and the other non-broody. From each of these three possible matings there are three possible groupings of the female offspring, *i.e.*, (1) all may be broody, (2) all non-broody, and (3) part broody, part non-broody, as shown in Table I.

TABLE I. — *Kinds of Offspring expected from all Possible Kinds of Matings.*

Parents.	Offspring.
Both parents broody, ...	All broody. All non-broody.* Part broody, part non-broody.
Both parents non-broody, ...	All broody.* All non-broody. Part broody, part non-broody.
One parent broody, the other non-broody, ...	All broody. All non-broody.* Part broody, part non-broody.

Of the nine possible groupings between parents and offspring, six have been realized in our experience. Those marked with an asterisk (*) have not been realized. Two of the three unrealized possibilities should be realized eventually, and the third, all non-broody offspring from broody parents, is not expected, as is explained beyond.

The preceding table, as well as the ratios in which the offspring occur, Table II, does not agree with the assumption that broodiness is a simple Mendelian dominant and non-broodiness a simple recessive in all instances as Hurst (1905) supposed. If non-broodiness were a simple Mendelian recessive, then the son of a non-broody hen should throw either all non-broodies or half non-broodies when bred to non-broodies, but this does not always happen. Moreover, the establishment of a non-broody strain should have been a much simpler matter than it has proved.

TABLE II. — *A Comparison between Observed and Theoretical Ratios, assuming that Two Factors, A and C, must both be present in order that an Individual may become Broody.*

Father's Band Number.	1915. Number of Mothers. Non-broody.	1915. Number of Mothers. Broody.	1915. Number of Mothers. Total.	1915. Offspring. Observed Ratio. Non-broody.	1915. Offspring. Observed Ratio. Broody.	1915. Offspring. Expected Ratio. Non-broody.	1915. Offspring. Expected Ratio. Broody.	1916. Father's Band Number.	1916. Number of Mothers. Non-broody.	1916. Number of Mothers. Broody.	1916. Number of Mothers. Total.	1916. Offspring. Observed Ratio. Non-broody.	1916. Offspring. Observed Ratio. Broody.	1916. Offspring. Expected Ratio. Non-broody.	1916. Offspring. Expected Ratio. Broody.	1917. Father's Band Number.	1917. Number of Mothers. Non-broody.	1917. Number of Mothers. Broody.	1917. Number of Mothers. Total.	1917. Offspring. Observed Ratio. Non-broody.	1917. Offspring. Observed Ratio. Broody.	1917. Offspring. Expected Ratio. Non-broody.	1917. Offspring. Expected Ratio. Broody.
68,	1	3	4	0	9	0	9	274	0	2	2	0	8	0	8	3003	4	1	5	23	1	$22\frac{1}{8}$	$1\frac{7}{8}$
A143,	1	2	3	1	9	0	10	3617	0	5	5	6	24	$3\frac{1}{2}$	$26\frac{1}{2}$	5470	4	0	4	13	5	13	5
228,	0	3	3	0	5	0	5	4312	0	1	1	0	8	0	8	5581	0	1	1	0	4	0	4
269,	3	10	13	7	40	6	41	4354	1	4	5	5	32	2	35	7727	0	2	2	1	3	$\frac{3}{4}$	$3\frac{1}{4}$
270,	0	2	2	0	6	0	6	4378	0	4	4	6	22	$5\frac{1}{2}$	$22\frac{1}{2}$	7745	0	3	3	4	10	$2\frac{1}{2}$	$11\frac{1}{2}$
271,	0	4	4	2	15	$\frac{7}{8}$	$16\frac{1}{8}$	4723	0	6	6	15	59	$16\frac{7}{8}$	$57\frac{1}{8}$	7931	0	1	1	2	1	$1\frac{5}{16}$	$1\frac{11}{16}$
272,	0	1	1	0	2	0	2	4786	0	2	2	2	6	$\frac{7}{8}$	$7\frac{1}{8}$	8027	2	6	8	30	39	$27\frac{1}{2}$	$41\frac{1}{2}$
274,	4	5	9	0	43	0	43	4882	0	1	1	5	20	$6\frac{1}{4}$	$18\frac{3}{4}$	8095	1	3	4	3	4	$2\frac{13}{16}$	$4\frac{3}{16}$
A323,	0	1	1	0	1	0	1	5077	0	3	3	2	10	$2\frac{1}{4}$	$9\frac{3}{4}$	8097	0	5	5	21	22	$17\frac{1}{4}$	$25\frac{3}{4}$
619,	0	2	2	0	3	0	3	5240	0	1	1	0	7	0	7	8147	2	5	7	15	33	18	30
2313,	0	5	5	1	30	$\frac{7}{8}$	$30\frac{1}{8}$	5470	0	1	1	1	2	$1\frac{1}{2}$	$1\frac{1}{2}$	8217	0	3	3	0	9	0	9
2539,	0	1	1	0	1	0	1	5477	0	2	2	0	15	0	15	8422	1	2	3	7	4	$6\frac{1}{2}$	$4\frac{1}{2}$
2914,	1	2	3	2	7	$2\frac{7}{8}$	$6\frac{1}{8}$	5581	0	7	7	2	42	$1\frac{1}{2}$	$42\frac{1}{2}$	8528	1	5	6	27	32	$28\frac{1}{4}$	$30\frac{3}{4}$
3003,	4	1	5	11	3	$11\frac{3}{8}$	$2\frac{5}{8}$	5584	0	4	4	3	35	0	38	8761	0	4	4	9	15	$7\frac{5}{16}$	$16\frac{11}{16}$
3533,	0	4	4	1	11	$\frac{7}{16}$	$11\frac{9}{16}$	5642	1	0	1	0	2	0	2	9305	0	2	2	2	5	$1\frac{1}{2}$	$5\frac{1}{2}$
3617,	1	10	11	1	38	$1\frac{1}{4}$	$37\frac{3}{4}$	5776	0	1	1	0	8	0	8	9752	6	5	11	57	16	$48\frac{3}{8}$	$24\frac{5}{8}$
4128,	0	4	4	2	10	$1\frac{1}{2}$	$10\frac{1}{2}$	6265	0	3	3	1	19	0	20	–	–	–	–	–	–	–	–
4167,	3	4	7	5	52	$5\frac{1}{2}$	$51\frac{1}{2}$	6373	0	4	4	0	22	0	22	–	–	–	–	–	–	–	–
4265,	0	3	3	2	16	$2\frac{1}{2}$	$15\frac{1}{2}$	6781	1	3	4	14	24	$16\frac{3}{8}$	$21\frac{5}{8}$	–	–	–	–	–	–	–	–
Brown,	0	1	1	0	3	0	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
McLean,	0	4	4	1	13	0	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Several factorial explanations of the observed ratios between broodies and non-broodies in the several families can be developed, but choice among such explanations cannot be made because of the small size of the individual families, *i.e.*, the offspring of a single mother. Nor are any of them of value save as working hypotheses. The one on which Table II is based is presented simply to show that a close agreement between theory and fact is possible, and this theory was chosen for presentation because it gives a slightly better agreement between observed and theoretical rations, with one partial exception, than the others. This theory assumes that the appearance of broodiness in Rhode Island Reds requires the simultaneous presence of two factors, designated A and C, in either homozygous or heterozygous condition. A better fit in the case of the partial exception can be secured by assuming that there is also a dominant factor (presumably a modifier) for non-broodiness, which may be designated as N. Non-broodies, therefore, may be of numerous genetic types, the homozygous forms being NNAACC, nnAAcc, nnaaCC; and nnaacc, where A and C, respectively, represent the factors (condition of germ plasm) necessary for broodiness. A broody bird, then, in homozygous form must be nnAACC. As shown by Table III, which gives the theoreti-

TABLE III.—*The Theoretical Ratios resulting from Matings of Different Types, arranged by Ratios.*

[A ratio appears only once under its respective theory.]

Parents.	NNAACC Theory.		AACC Theory.	
	Progeny.		Progeny.	
	Non-broody.	Broody.	Non-broody.	Broody.
Broody × broody,	7	9	7	9
Non-broody × non-broody,	55 29 15 64	9 3 1 0	16	0
Broody × non-broody,	23	9	5	3
Broody × broody, broody × non-broody,	0 1	64 3	1	3
Broody × non-broody, non-broody × non-broody.	1 13 7	1 3 1	1 3	1 1
Broody × broody, broody × non-broody, non-broody × non-broody.	5 3	3 1	0	16

cal ratios expected on both the NNAACC and AACC theories, it will be seen that matings between birds of the same phænotype may give several different ratios, including those in which the proportions between broody and non-broody birds are reversed. Thus (NNAACC theory) broody x broody may give 3 broody to 1 non-broody, or it may give 1 broody to 3 non-broody, exactly reversing the ratio, as has occurred in the detailed data from which Table II was compiled. It should be stated that while families showing the extreme ratio of 15 non-broody to 1 broody have not been encountered, several instances of the 7:1 ratio have been observed.

The only evidence at present available in support of either of these schemes is furnished by the ratios between the broody and non-broody members of the several families (Table II). N, if it represents a real condition of the germ plasm, occurs relatively infrequently in the flock at present. Practically all the observed ratios, except the partial exception mentioned, can be accounted for if N is omitted.

It is also possible to modify the AACC theory, by assuming that A is sex linked, though no evidence of sex linkage other than an agreement between the observed and theoretical ratios has been noted. Doubtless other schemes could be devised that would also account for the ratios.

Although the ratios themselves could perhaps be explained as chance deviations from monohybrid ratios (though this is doubtful in some instances), or as the result of errors of classification of individuals through failure to manifest the genotypic condition phænotypically, the moment lines of descent are established it becomes clear that a monohybrid explanation does not fit the facts. The data have been worked over in an attempt to apply the monohybrid scheme, *i.e.*, broodiness due to a single dominant factor, but without success. See, for example, the history of male No. 3003 and his offspring, page 107.

In order to establish the existence of any of the schemes under discussion certain results of critical importance must be obtained. Thus, the discovery of a family consisting of all non-broody offspring from the mating between a non-broody and a broody is required to demonstrate the presence of a dominant factor for non-broodiness, while a mating between two non-broody birds that gives all broodies is required as proof of the AACC theory (or a theory of the same order). The ratios at hand indicate the possibility that several genetic types of non-broodies coexist in our strain. One possibility only seems to be excluded if the schemes outlined represent the facts, for one need never expect to find a pair of broody birds that produces all non-broody offspring, because such a result would mean two distinct types of broodies which mutually inhibit each other.

Modifying Factors for Broodiness.

The possibility that the non-broodies dealt with in these experiments are not due to changes in the primary genes concerned with broodiness, but are due to changes in modifying genes, cannot be excluded. As we have worked over the records, the impression has been strong that we are not dealing with a real absence of broodiness so much as with delay in the appearance of broodiness. Unfortunately the present data are inadequate to settle this point. Nor is it likely that we shall have suitable data in the near future, because the somatic manifestations of broodiness, *i.e.*, the number of times a bird becomes broody as well as the ease with which she is broken up, vary considerably, as already described. Since the chief reason for this variability is found in the number of times a bird becomes broody, which in turn is so thoroughly interwoven with egg production, the same practical difficulties, *i.e.*, disease control, that at present prevent a complete analysis of the inheritance of fecundity also prevent the determination of the hereditary factors involved in degree of broodiness.

The Production of a Strain of Low Degree of Broodiness through Selection.

Two lines of selection have been under way, — one for the elimination of broodiness, the other for its development to a high degree, equal to or greater than that observed in the case of Fig. 1. Because most of our facilities were needed in other directions, little has been done with the plus line beyond its maintenance. The minus line, however, has been closely involved with the problem of securing increased egg production, since absence of broodiness tends toward higher production, other things being equal. Until 1917 this line had been also carried on in a very small way, the general policy being to mate the son of a non-broody bird to non-broodies, on the hypothesis that broodiness is a simple Mendelian dominant, and non-broodiness a recessive. As a result of the early matings a male was obtained that appeared to be a homozygous recessive, since he threw no broodies from non-broody mothers. In 1917 this male, No. 3003, with his son, No. 5470 out of a non-broody hen, and grandson, No. 9752 (mother broody once in her third year), also supposed to be homozygous recessives, were mated to all the non-broody hens available. Some of these, however, became broody the second year. The results of the experiment, given in Tables IV and V, show that non-broodiness is not always a simple Mendelian recessive, since the son and grandson failed to breed true, even with those birds that never became broody. This

Table IV. — *The Progeny of Three Supposedly Non-broody Males distributed according to their Mother's Broody History.*

Male.	Mothers not Broody.			Mothers known to be Broody after Pullet Year.			Mothers Broody in Pullet Year.		
	Number of Mothers.	Daughters not Broody.	Daughters Broody.	Number of Mothers.	Daughters not Broody.	Daughters Broody.	Number of Mothers.	Daughters not Broody.	Daughters Broody.
No. 3003, ...	4	19	0	–	–	–	1	4	1
No. 5470 (son of No. 3003),	3	9	1	1	4	4	–	–	–
No. 9752 (son of No. 5470),	6	27	9	1	1	0	4	29	7

TABLE V. — *"Non-broody" Lines, 1917–18.*

[Daughters of males No. 3003, No. 5470 and No. 9752.]

	Number of Daughters.	Daughters not Broody.		Daughters Broody once.		Daughters Broody more than once.		Total Broody Daughters.	
		Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.
Mothers not broody in pullet year.	72	58	80.55	9	12.50	5	6.94	14	19.44
Mothers broody once in pullet year.	34	28	82.35	1	2.94	5	14.71	6	17.65
Totals, . . .	106	86	81.13	10	9.43	10	9.43	20	18.87

conclusion is supported by the ratios observed in other matings which have already been commented upon. However, the amount of broodiness in the first laying year is much reduced compared with the flock from which it originated, the data on this point being given in Table VII, Table VIII, item 4, and Table IX. A comparison with the published results of the laying contest at the Connecticut Agricultural Experiment Station shows that our foundation stock had broodiness developed to a higher degree than any of the breeds studied at Storrs, and that our non-broody

TABLE VI. — *Broodiness in the Several Breeds at the Storrs Contest of 1915–16, compared with Three Flocks at the Massachusetts Agricultural Experiment Station.*

Breeds.	Number of Birds.	Broody.		Average number of Times Broody per Broody Hen.	Average Number of Times Broody for All Birds in Flock.	Average Number of Days in Broody Period.	Average Number of Days spent in Broodiness by each Broody Hen.	Average Number of Days spent in Broodiness per Hen, per Year, all Birds included.
		Number.	Per Cent.					
Storrs.								
Plymouth Rocks, .	151	67	44.4	2.8	1.2	21.2	59.9	26.6
Wyandottes, . .	151	87	57.6	2.5	1.4	19.4	47.6	27.4
Rhode Island Reds, .	183	120	65.6	2.8	1.8	21.3	60.2	39.5
White Leghorns, .	315	43	13.6	1.3	.2	22.7	29.6	4.0
Massachusetts.								
Rhode Island Reds, 1912–13.	125	112	89.6	4.4	3.9	19.7	74.8	65.8
Rhode Island Reds, 1913–14.	78	71	91.0	5.4	4.9	16.3	78.8	68.7
Rhode Island Reds, 1917–18, "non-broody" line.	106	20	18.9	1.9	.4	20.9	37.0	10.6

TABLE VII. — *Number and Per Cent of Birds Broody and not Broody in Pullet Year in Three Flocks of Rhode Island Reds.*

Date.	Total Birds.	Broody.		Not Broody.	
		Number.	Per Cent.	Number.	Per Cent.
1912-13, ...	125	112	89.60	13	10.40
1913-14, ...	78	71	91.03	7	8.97
1917-18, ...	106	20	18.87	86	81.13

lines, derived from this extremely broody stock, exhibited a low degree of broodiness surpassed only by the Leghorns (Table VI). The most significant data on this point are given in the third and last columns of Table VI. Table VII shows the relation between the number of broody birds and those not broody for the flocks of 1912–13, 1913–14 and 1917–18. The flock of 1912–13 was the foundation stock.

Tables VIII and X give a further comparison between the broody birds of the flocks of 1913–14 and 1917–18.

TABLE VIII. — *Statistical Constants for Various Broody Characters for the Flock of 1913–14, and the Non-broody Flock of 1917–18.*

		Number of Instances or Individuals.		Mean.		Standard Deviation.		Coefficient of Variation.	
		1913-14.	1917-18.	1913-14.	1917-18.	1913-14.	1917-18.	1913-14.	1917-18.
1	Number of broody periods per individual.	71	20	5.39±0.23	1.90±0.17	2.87±0.16	1.14±0.12	53 24±3.77	59 78±8 35
2	Length of broody periods (days), . .	327	34	16 28±0.34	20.91±0.95	9.04±0 24	8.22±0.67	55 60±1.85	39 32±3.68
3	Amount of broodiness in each individual (broodies only) (days).	68	20	78.84±4.03	37.00±3.63	49 27±2.85	24.06±2.57	71.68±5.90	65.02±9.42
4	Amount of broodiness in each individual (entire flock) (days).	78	106	68 73±3 28	10 63±1.08	42.95±2.32	16.46±0.76	62.49±4.50	154.83±17 27
5	Days in initial laying period, . . .	71	20	118.67±4.23	170.50±8.42	52.82±2.99	55.86±5.96	44.51±2.98	32.76± 3.85
6	Eggs in initial laying period, . . .	71	20	80.64±2.85	101.50±3.84	35.66±2.02	25.48±2.72	44.22±2 95	25.10±2.84
7	Per cent production in initial laying period.	71	20	67.89±0 99	61.00±1.68	12.38±0.70	11.17±1.19	18 24±1.07	18.31± 2.02
8	Days in each laying period, . . .	327	34	18.84±0.40	36.85±2.98	10.85±0 29	25.80±2 11	57.60±1.96	70.00± 8.06
9	Eggs in each laying period, . . .	327	34	13.96±0.19	21.26±1.52	5.21±0.14	13.12±1 07	37.32±1.11	61.72± 6.70
10	Per cent production in each laying period,	327	34	78.41±0.53	64.91±3 09	14.24±0 38	26.70±2.18	18.16±0.49	41.13± 3.89
11	Time spent in laying periods annually by each individual (days).	68	20	90.75	62.75	–[1]	–[1]	–[2]	–[3]
12	Average length of broody cycle (days), .	327	34	35.02±0.56	57.71±2.98	15.15±0.40	25.72±2.10	43.26±1.34	44.57± 4.31
13	Per cent production in broody cycle, .	327	34	41.50±0.43	35.94±1.54	11.55±0.30	13.29±1.09	27.83±0.79	36.98±3.41

[1] Standard deviation not calculated. [2] Range 9–188. [3] Range 16–114.

DEFINITION OF TERMS USED IN TABLE VIII.

2. In reckoning the number of days in a broody period the first day without production is taken as the first broody day, while the last day counted is the day before production begins again. The object here is to measure the length of the non-productive period originating with broodiness, but not the intensity of broodiness itself. This definition includes instances in which the resumption of production is delayed long after its normal time because of the interference of factors not concerned with broodiness. Some limitation to the number of days included in the non-productive period is desirable, but the only one employed thus far is the exclusion of broody periods that end the annual cycle of production, and whose length cannot be ascertained.

5, 6, 7. The initial laying period begins with the first egg laid, and ends with the last egg laid before the first broody period.

8, 9, 10. A laying period begins with the first egg laid after a broody period, and ends with the last egg laid before the subsequent broody period.

12, 13. A broody cycle is defined as a broody period plus the following laying period. The incomplete cycles formed by a terminal broody period are rejected in calculating the constants. It is, of course, possible to treat the broody cycle somewhat differently, by defining it as a laying period plus the subsequent broody period. Biometrical constants were calculated for each method of treatment, but since the results proved to be essentially the same, if the initial cycle is omitted, only one set of constants is given in the table.

Constants differing slightly from those given in the table are obtained, if, instead of employing each instance separately in the calculations, the average for each individual bird is employed. Whether the instance or the average for each individual bird should be used in calculating the constants depends on which one occupies the center of interest, but whichever method is used, the primary purpose for which this table is presented is not affected. The inconsistencies in the number of individuals occur because it is often possible to determine a character in one individual but not in another. Thus, every bird that becomes broody can be counted, but if a bird becomes broody but once, and does not lay again until the following year, the length of her broody period cannot be measured, and so is omitted in calculating the constants.

Taking the means (Table VIII) as the basis of comparison, it is clear that the birds of the "non-broody" lines becoming broody in 1917–18 had the character much less intensely developed than the broodies of the flocks of 1912–13 and 1913–14 from which they originated. The mean number of times each broody bird became broody is 1.90 against 5.39. Though the average length of each broody period is longer (Table VIII), the total time spent in broodiness by each broody bird is about one-half that of the broodies of the flock of 1913–14. If the entire flocks of each year (*i.e.*, if the non-broody birds are included in calculating the means) are compared with each other the following significant results are obtained (Table IX): —

TABLE IX. — *A Comparison of the Amount of Broodiness in the Foundation Flock, 1912–13, and their Immediate Unselected Descendants, 1913–14, with their Descendants selected for the Absence of Broodiness, 1917–18.*

DATE.	Number of Birds.	Mean Number of Days spent in Broodiness.	Mean Number of Times Broody.
1912-13, ...	125	65.81	3.88
1913-14, ...	78	68.73	4.91
1917-18, ...	106	10.63	.36

A comparison between the two flocks in respect to egg production (Table VIII) shows that while the 1917–18 flock laid somewhat less rapidly than the 1913–14 flock, the first broody period came later in life (Table X). The mean date of the first broody period is April 18 for the 1913–14 flock, and June 7 for the 1917–18 flock. The 1917–18 flock has a slower rate of production, as shown by the lower percentage production in the initial laying period as well as the later laying periods. On the other hand, the length, both of laying periods and broody periods, is longer

TABLE X. — *Seasonal Distribution of Broodiness in the Flock of 1913–14, and in the Broodies occurring in the Non-broody Lines, 1917–18.*

	Month.	Month in which Individual Broody Periods begin.				Month in which First Broody Period of Each Individual begins.				Month in which Last Broody Period of Each Individual begins.				Month in which Median Broody Period of Each Individual begins.			
		1913-14.		1917-18.		1913-14.		1917-18.		1913-14.		1917-18.		1913-14.		1917-18.	
		Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.
1	November,	-	-	-	-	-[1]	-[1]	-	-	-	-	-	-	-	-	-	-
2	December,	5	1.30	-	-	5	7.04	-	-	-	-	-	-	-	-	-	-
3	January,	4	1.04	-	-	3	4.23	-	-	-	-	-	-	-	-	-	-
4	February,	8	2.08	-	-	3	4.23	-	-	-	-	-	-	-	-	-	-
5	March,	19	4.94	-	-	10	14.08	-	-	-	-	-	-	-	-	-	-
6	April,	41	10.68	4	10.53	21	29.58	4	20.00	-	-	-	-	.5	.70	.5	2.50
7	May,	67	17.45	11	28.95	16	22.54	8	40.00	3	4.23	5	25.00	10.5	14.79	6.0	30.00
8	June,	64	16.67	6	15.79	9	12.68	2	10.00	4	5.63	3	15.00	34.0	47.89	5.0	25.00
9	July,	53	13.80	8	21.05	2	2.82	3	15.00	2	2.82	5	25.00	18.0	25.35	5.5	27.50
10	August,	48	12.50	4	10.53	-	-	3	15.00	6	8.45	2	10.00	5.0	7.04	2.0	10.00
11	September,	43	11.20	4	10.53	1	1.41	-	-	26	36.62	4	20 00	2.0	2.82	.5	2.50
12	October,	25	6.51	1	2.63	-	-	-	-	23	32.39	1	5.00	-	-	.5	2.50
13	November,	7	1.82	-	-	1	1.41	-	-	7	9.86	-	-	1.0	1.41	-	-
	Totals,	384	99.99	38	100.01	71	100.02	20	100 00	71	100.00	20	100.00	71.0	100.00	20.0	100.00

[1] Very few birds laying.

in this flock than in that of 1913–14. Just what this means is uncertain. The longer laying periods may be taken as resultant of the reduced tendency toward broodiness, but this is not true for the longer broody periods. The latter may be connected with the slower rate of production.

The experiments in eliminating broodiness are being continued, but a change in the plan of the experiment, to permit of the fusion of the non-broody line with another line known as the high-producing line, has been made. The fusion appears at date of this writing to be accomplished.

Broodiness, in its various sub-characters and in the associated periods of egg production, is decidedly variable as judged by the several coefficients of variation given in Table VIII. Some of the sub-characters are much more variable than others. While some of the characters associated with broodiness are of the same order of variability in the two flocks studied, others are quite unlike, sometimes one and sometimes the other flock being the more variable. The details are best obtained from Table VIII.

Relation between Birds of a Low Degree of Broodiness and Absence of Broodiness.

Some evidence exists that birds that become broody once during the pullet year are not genetically different from those that do not become broody, since the number of broody offspring from each sort of female is approximately the same, as is shown in Table XI. On the other hand,

Table XI. — *A Comparison between the Number of Broody Offspring from Non-broody Mothers with the Number from Mothers Broody once, the Sires being the Same for Both Lots of Offspring.*

	Number of Mothers.	Broody Offspring.		Non-broody Offspring.	
		Number.	Per Cent.	Number.	Per Cent.
Not broody,	15	14	19.45	58	80.55
Broody,	3	6	17.65	28	82.35

the daughters of birds broody once are somewhat more broody than the daughters of birds not broody at all, as shown in Table XII, which gives a comparison between 14 broody daughters of non-broody mothers and 6 broody daughters of mothers that became broody once, the sires being the same for both lots. It is shown by the per cent production, for both the initial laying period and the subsequent laying periods, that the two sets of birds are about equal in their ability to produce eggs. The daughters whose mothers became broody once were, however, somewhat more broody than the daughters of hens that did not become broody at all, as shown by the length of the initial laying period, the number of broody periods per individual, and the length of the broody periods. Though in this experiment the daughters of non-broody hens are less broody than the daughters of hens broody once, it would be unwise to generalize such a conclusion, because of the very small number of individuals involved.

TABLE XII. — *A Comparison of the Amount of Broodiness in the Daughters of Non-broody Hens with those whose Mothers became Broody once.*

	Mothers not Broody in Pullet Year.		Mothers Broody once in Pullet Year.	
	Number of Instances or Individuals.	Mean.	Number of Instances or Individuals.	Mean.
Days of broodiness per individual,	14	31.64	6	49.50
Days in each broody period,	22	18.26	12	24.25
Broody periods per individual,	14	1.79	6	2.17
Days in initial laying period,	14	181.36	6	145.67
Eggs laid in initial laying period,	14	106.93	6	85.83
Per cent production in initial laying period per individual.	14	60.86	6	60.27
Days in each laying period,	22	38.23	12	34.50
Eggs laid in each laying period,	22	21.95	12	19.83
Per cent production in each laying period,	22	65.20	12	64.70
Eggs in each laying period per individual,	14	25.44	6	21.37

Since some birds become broody in their second or third laying years that did not become broody in the first year, the question may be raised as to whether or not a hen may ever be so constituted that it is impossible for her to become broody. We have kept a few hens for four years without evidence of broodiness, but this may not mean that these birds might not have become broody if the proper stimulus had existed. There is the further question as to whether the designation "non-broody" has been accurately used for birds not broody in their pullet year. It might be better to regard such cases as instances of delayed broodiness rather than of the actual absence of broodiness. The delay in the appearance of broodiness in some individuals certainly complicates matters greatly.

The Interrelation of Several Broody Characters.

The interrelations of several of the broody characters have been studied in the 1913–14 flock by means of the coefficient of correlation. It should, perhaps, be pointed out that the coefficient of correlation does not measure the relationship between the characters as such, but relationship between the numerical occurrence of such characters in the flock studied. This limitation in the use of the coefficient of correlation is often forgotten. Thus it is found that r between number of eggs laid in a year and total days spent in broodiness is $+.1677 \pm .0742$. This value, as shown by its large probable error, is not significant statistically, but, ignoring the error, may perhaps indicate that broodiness is an advantage, since, on the average, those birds spending the most time in broodiness are the heaviest layers. On the contrary, it is known from a study of other data that the very best layers cannot spend much time in broodiness. The interpretation we give this value is that those birds whose laying year begins earliest and stops latest get in more broody periods, other things being equal, than birds whose laying year is shorter.

If an index of production of high value is desired, it is found in the initial laying period, for here the correlation between the length of the period and number of eggs produced is very high, viz., $+.8843 \pm .0210$, a value, moreover, that indicates good homogeneity in rate of production in this flock.

In this flock there is a pronounced negative correlation between egg production during the laying periods and number of broody periods, the coefficient of correlation being $-.3453 \pm .0716$, indicating that those birds that are very broody tend to lay less eggs between broody periods than those having a less number of broody periods. On the other hand, there is no relation between the average (*i.e.*, for one individual) length of laying periods or the eggs produced in such periods and average length of broody periods, since in the first case $r = -.0130 \pm .0818$, and in the second case $r = -.0013 \pm .0818$.

While the above statements hold true for average values, if the coefficient of correlation is determined between the length of a laying period or its egg production and the length of the broody period immediately subsequent thereto, a marked negative correlation is found, being $-.2899 \pm .0415$ in the first instance, and $-.3715 \pm .0345$ in the second. The disagreement between the values obtained when each laying period is correlated with its subsequent broody period, and that found when the average value for each bird is used, is due to a shortening of the laying period and a lengthening of the broody period as the season progresses. This is clearly shown on the individual records.

If, instead of taking a laying period and its subsequent broody period, a broody period is paired with the laying period following, little or no relationship is indicated, for r between length of broody period and subsequent laying period is $-.0222 \pm .0388$, while between length of broody period and subsequent egg production it is only slightly greater, being $-.0799 \pm .0372$.

The interrelationships discussed in the two paragraphs preceding may perhaps be interpreted to mean that heavy laying tends to suppress broodiness, or, at least, that in the flock studied, those birds that laid most heavily had shorter broody periods than those laying less heavily, the tendency to heavy production in such birds enabling them to get back more quickly into production than those in which the tendency was less strong. Longer broody periods, however, and their accompanying element of rest did not conduce to heavier production, a view contrary to that held by most poultrymen.

Summary and Conclusions.

The working hypothesis is adopted that —

1. Broodiness depends upon the presence of a "complete mechanism" in the individual, from which it follows that the absence of broodiness depends upon the loss of some essential part of this mechanism, or upon its inhibition by some secondary factor.

2. The inheritance of broodiness may be expected to vary from flock to flock.

3. In the flocks studied, non-broodiness appears to result from the loss of one or both of two genes from the complete germinal complex, while there is some evidence that a dominant inhibitor may also exist in the germ plasm of these flocks.

4. By suitable breeding methods it has been possible to develop quickly a strain of low degree of broodiness from a strain with a very high degree of broodiness.

5. Statistical constants for certain broody characters are given.

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BULLETIN No. 200 OCTOBER, 1920

THE NUTRITIVE VALUE OF CATTLE FEEDS

2. OAT BY-PRODUCTS FOR FARM STOCK

By J. B. LINDSEY and C. L. BEALS

This bulletin contains the results of an investigation of the composition and digestibility of oat by-products, as well as the feeding value and use of the mixture or mill run of oat hulls, middlings and dust, known as oat feed. At the end of the bulletin will be found a summary and brief discussion of the results.

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CONTENTS.

BULLETIN No. 200.

DEPARTMENT OF CHEMISTRY.

THE NUTRITIVE VALUE OF CATTLE FEEDS.

2. OAT BY-PRODUCTS FOR FARM STOCK.

BY J. B. LINDSEY AND C. L. BEALS.

A. The Process of Manufacture.

Oat feed is the residue from the oat meal mills engaged in the preparation of oat products for human consumption.

In the milling process the first step consists in separating the light and double oats and other cereal seeds, as well as sticks and straw, from the oats suitable for human consumption. These latter oats are divided into two or more grades, depending upon size, in order to gain efficiency in milling, and are then roasted or dried in open pans over fire with constant stirring, in order to drive off as much moisture as possible. From the roasters the oats are run over coolers and dusters, and then to the stones which remove the hulls. This latter process, called the first milling or hulling, does not remove all of the hulls, and the unhulled oats are subjected to a second milling to complete the process.

Mill run oat feed contains the hulls, usually reground, together with the middlings and dust removed in the first milling. The residue from the second milling contains a much larger proportion of middlings, and, together with some middlings recovered in cleaning the rolled oats, is used in calf meals and poultry feeds, and is not returned to the oat feed.[1] It is understood that *mill run oat feed*, as above described, should be a comparatively uniform product, especially as produced at the larger plants in the United States. On the other hand, small Canadian mills, because of a less efficient process of separation, are likely to put out an oat feed of better quality than the average run from the larger American mills.

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[1] One large manufacturer states that in its process the middlings and dust from the second milling are also incorporated in the oat feed, and that the material used in calf and pig meals represents the fine oat particles and chips made in cutting groats or shelled oats, together with the fine flakes that come from the rolled oat aspirators, and also the pieces of groats which are unsatisfactory for rolling on account of being broken. It seems reasonable to assume that the process of manufacture may vary somewhat in different establishments.

B. Analyses of Oat By-Products.

In view of the constant increase in the cost of hay and all kinds of concentrates, it was believed that a study of the value of oat by-products was worth while. A visit was therefore made by Mr. P. H. Smith to one of the mills of the Quaker Oats Company and of the H-O Company, the process of manufacture observed, and samples secured for analysis, which were declared by the manufacturers and believed by us to be representative. In addition, several lots of oat feed were shipped us at our request for the purpose of conducting digestion and feeding experiments. The analyses of all of these samples follow: —

Table I. — *Composition of Oat By-Products.*

(*a*) *Oat Hulls.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H-O Company (unground),	3.82	6.65	.96	33.18	54.99	.40	100
2	Quaker Oats Company (ground),	5.04	6.15	2.01	31.08	54.78	.94	100
	Average,	4.43	6.40	1.49	32.13	54.88	.67	100

(*b*) *Oat Middlings and Dust.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H-O Company (first break),	4.13	8.00	9.54	23.68	50.57	4.08	100
2	H-O Company (second break),	5.20	3.40	16.73	5.58	61.14	7.95	100
3	Quaker Oats Company,	5.54	5.94	12.30	15.60	54.97	5.65	100
4	Henry & Morrison,[1]	7.30	3.20	16.30	4.60	61.80	6.80	100

(*c*) *Oat Feed.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H-O Company, mill run,	4.24	6.34	6.04	26.65	54.05	2.68	100
2	Quaker Oats Company, mill run,	5.48	5.95	5.26	27.18	53.98	2.15	100
3	Quaker Oats Company, mill run,	5.30	6.10	4.65	26.73	55.14	2.08	100
4	Quaker Oats Company, mill run,	9.53	5.39	5.29	24.17	53.37	2.25	100
5	Quaker Oats Company, mill run,	7.75	5.91	5.22	24.85	54.04	2.23	100
6[2]	Quaker Oats Company, mill run,	7.59	6.10	7.12	22.62	53.40	3.17	100
7	Quaker Oats Company, mill run,	7.03	6.58	6.40	29.82	48.09	2.08	100
8	Quaker Oats Company, mill run,	7.25	5.86	5.91	26.05	52.80	2.13	100
9	Quaker Oats Company, mill run,	7.07	5.99	6.00	26.00	52.90	2.04	100
10	Quaker Oats Company, mill run,	5.48	6.39	5.98	31.85	48.09	2.21	100
11	Quaker Oats Company, mill run,	7.63	6.24	5.53	27.57	51.04	1.99	100
12	Quaker Oats Company, mill run,	7.90	5.84	5.04	26.14	53.10	1.93	100
	Average,	6.85	6.06	5.70	26.64	52.50	2.24	100

[1] Average of 23 analyses.

[2] Sample No. 6 evidently contains an excess of middlings, and cannot be considered representative.

The results of the analyses of the two samples of oat hulls simply emphasize their very low protein and fat, — 1.49 of protein and .67 of fat, — and their very high fiber content. The fiber percentage multiplied by 3 gives 96.4 per cent of hulls, indicating the presence of very little dust or middlings.

Oat middlings vary somewhat in composition, depending naturally upon the process of separation employed. The higher the fiber content the less completely are the hulls separated. A high grade of middlings such as results from the second break evidently ought to contain not more than 5 to 6 per cent of fiber, and at least 15 per cent of protein.

The oat feed does not vary more in composition than one would expect from a by-product of this sort. Its moisture content is low, due to artificial drying, showing an average of 6.85 per cent. It has relatively little protein, extremes of from 4.65 to 7.12 being noted, with an average of 5.70 per cent. The fiber content is high, due to the large amount of oat hulls; the average percentage of fiber was 26.64. A much higher percentage of fiber than this average would indicate an excess of hulls. Carefully conducted studies[1] have shown that in case of oat by-products the percentage of fiber present multiplied by 3 will give the percentage of oat hulls. The application of this rule to the average analyses of the twelve samples (26.64 x 3=80) shows 80 per cent of hulls and 20 per cent of fine material (oat dust and middlings). The fat percentage in the feed is low, as would be expected.

C. Digestibility of Oat By-Products.

The station has made a number of digestion experiments with oat feed, middlings and hulls. Sheep and horses were employed for the purpose. The results only of the experiments are reported in this connection. Sheep would not eat any amount of the oat feed when fed dry, and hence it was necessary to moisten it thoroughly. It was also moistened before being fed to horses.

Table II. — *Digestion Coefficients for Oat By-Products.*

(*a*) *Oat Hulls* (*Sheep*).

Series.	Experiment.	Animal.	Percentages of Ingredients digested.						Ration Fed.
			Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	
24, . . .	13	9	31	16	–	50	29	–	500 g. hay+150 g. gluten feed+150 g. oat hulls.
24, . . .	13	11	36	9	12	51	36	14	
Average, . . .			34	13	12	50	33	14	

[1] Landw. Versuchssta. Band XCIV, Heft I and II, pp. 9-40, by H. Neubauer.

TABLE II. — *Digestion Coefficients for Oat By-Products* — Concluded.

(*b*) *Oat Hulls* (*Horses*).

Series.	Experiment.	Animal.	Percentages of Ingredients Digested. Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
3,	4	Joe	24	36	123	28	10	76	8,000 g. hay+2,500 g. brewers' grains +2,000 g. oat hulls.
3,	4	Tom	20	33	105	15	11	88	
Average,			22	34	?	22	11	82	

(*c*) *Oat Middlings* (*Sheep*).

Series.	Experiment.	Animal.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
X,	14	IV	91	31	81	77	97	93	550 g. hay+300 g. oat middlings.
X,	14	V	88	30	80	21	94	94	
Average,			90	36	80	49	95	93	
Wheat flour middlings for comparison.			82	–	88	36	88	86	

(*d*) *Oat Feed* (*Horses*).

Series.	Experiment.	Animal.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
3,	5	Joe	40	13	58	51	36	36	8,000 g. hay+2,500 g. oat feed.
3,	5	Tom	43	14	54	55	39	69	
Average,			42	14	56	53	38	53	

(*e*) *Oat Feed* (*Sheep*).

Series.	Experiment.	Animal.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
24,	12	12	51	92	81	39	45	119	500 g. hay+150 g. gluten feed+150 g. oat feed.
24,	12[1]	13	19	52	5	1	19	102	
25,	11[1]	9	29	–	18	23	31	185	500 g. hay+150 g. oat feed.
25,	11[1]	11	27	–	22	21	32	100	
25,	13	9	55	26	86	56	49	43	500 g. hay+150 g. gluten+150 g. oat feed.
25,	13	11	51	26	90	43	49	46	
25,	18	12	57	69	90	57	52	16	500 g. hay+150 g. oat feed.
25,	18	13	47	23	86	53	40	67	
Average,			52	–	86	46	48	69	
Timothy hay (for comparison).			55	39	47	51	62	50	
Fine hay (extra) (for comparison).			61	44	55	63	62	48	

[1] Excluded from the average.

The results with oat hulls show that the sheep were able to digest 34 per cent of the hulls, and the horses 22 per cent. The protein and fat content of the hulls is quite small, and the coefficients for these ingredients with both sheep and horses are of no particular account. The sheep digested one-half of the fiber and one-third of the extract matter, while the coefficients obtained with the horses were noticeably less. It is possible that in case of the horses, if the hulls had been fed with a different combination than hay and brewers' grains, the results would have been somewhat more favorable. It has been established, however, that horses are not able to utilize fibrous material as well as are the bovines.

The trial with oat middlings was made at this station a number of years since, and has been published.[1] The sample was found in the Massachusetts markets, and was of excellent quality, containing 16.1 per cent of protein, 2.3 per cent of fiber, and 7 per cent of fat. The results are given here to show how well the animal is able to digest oat middlings when substantially free from fiber.

TABLE III. — *Digestible Matter in 2,000 Pounds.*

(*a*) *Sheep.*

FEED.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total Digestible Matter (Fat × 2.2).	Relative Values: Basis Digestible Matter (Oat Feed 100).
Oat hulls,	649.8	3.6	321.4	362.4	1.8	691.3	75
Oat middlings,	1,668.6	260.8	45.0	1,174.2	126.4	1,758.0	191
Oat feed,	969.6	99.0	245.4	503.6	31.4	917.7	100
Timothy hay (for comparison).	946.0	76.0	284.0	542.0	20.0	946.0	103
Fine hay (extra) (for comparison).	1,073.6	86.0	358.0	546.0	22.0	1,038.0	113

(*b*) *Horses.*

FEED.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total Digestible Matter (Fat × 2.2).	Relative Values: Basis Digestible Matter (Oat Feed 100).
Oat feed,	782.0	64.4	282.0	338.0	24.0	737.2	100
Timothy hay,	756.8	33.6	243.4	410.8	39.4	727.2	98.6

On the basis of the digestion experiments with sheep, it will be seen that oat feed contains 918 pounds of total digestible matter as against 1,758 for oat middlings, 691 for oat hulls, and 946 for timothy hay. Placing oat feed at 100, oat middlings would have a feeding value of 91 per cent more, oat hulls 25 per cent less, and timothy 3 per cent more.

On the basis of digestible organic matter, the oat feed and timothy

[1] Mass. Agr. Expt. Sta., Ann. Rept. 19, p. 114.

appear to have about equivalent feeding values for horses. In place of digestible matter as a measurement of nutritive value, Kellner and also Armsby, as a result of more recent investigations, have adopted the unit of net energy. While recognizing its superiority over digestible matter as a basis for comparison, the writers feel that sufficient data are not available to warrant its use in the case of oat by-products.

D. Oat Feed for Dairy Cows.

Experiments I, II, and III.

In addition to the numerous analyses and digestibility trials with the several oat by-products, it was thought necessary to observe the effect of oat feed upon milk production. Inasmuch as it approximated hay in digestibility, it was fed in comparison with hay. Thus fed, a larger amount could be given daily than if used as a component of a grain mixture.

The experiments, three in number, with eight, four and eleven cows, respectively, were conducted by the usual reversal method. The basal ration consisted of a uniform grain mixture and sufficient of a first quality of cow hay to meet the needs of each animal. In each half of the experiment a definite amount of oat feed *on a dry matter basis* was substituted for a like weight of hay, amounting in case of individual cows to from 6 to 8 pounds daily. It was fed well moistened with water and was readily eaten. The average daily ration fed will be found in Table VIII.

Table IV. — *History of the Cows.*

Experiment I.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Peggy,	9	G. Jersey,	Aug. 13, 1918	Dec. 26, 1918	18	6.4
190,	7	G. Holstein,	Dec. 3, 1918	Feb. 9, 1919	25	3.8
Colantha II,	4	G. Holstein,	July 22, 1918	Nov. 7, 1918	25	4.5
Red IV,	6	G. Jersey,	Mar. 7, 1919	- -	30	5.0
Fancy IV,	4	G. Jersey,	July 22, 1918	Oct. 30, 1918	16	5.5
Ida II,	6	P. Jersey,	Oct. 27, 1918	Feb. 13, 1919	23	6.0
Samantha III,	6	G. Holstein,	Aug. 26, 1918	Dec. 5, 1918	20	4.7
Betty II,	12	G. Ayrshire,	Jan. 24, 1919	Feb. 19, 1919	30	4.6

Experiment II.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
190,	8	G. Holstein,	Nov. 17, 1919	- -	31	4.4
Cecile II,	7	P. Jersey,	Oct. 12, 1919	- -	21	5.6
Ida II,	7	P. Jersey,	Nov. 22, 1919	- -	30	6.0
Peggy,	10	G. Jersey,	Oct. 9, 1919	- -	23	6.2

Experiment III.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Cecile II,	7	P. Jersey,	Oct. 12, 1919	Feb. 24, 1920	18	6.2
Diantha II,	3	G. Holstein,	Jan. 22, 1920	- -	34	3.4
Colantha II,	5	G. Holstein,	Aug. 8, 1919	Nov. 3, 1919	33	4.2
Ida II,	7	P. Jersey,	Nov. 22, 1919	Feb. 10, 1919	26	6.2
Samantha III,	6	G. Holstein,	Sept. 12, 1919	Dec. 8, 1919	29	4.0
Colantha,	6	G. Holstein,	Sept. 19, 1919	Feb. 4, 1920	21	4.3
Fancy IV,	5	G. Jersey,	Aug. 10, 1919	Nov. 15, 1919	18	5.5
Eantha,	3	G. Holstein,	Jan. 19, 1919	- -	28	3.6
Samantha IV,	5	G. Holstein,	Aug. 20, 1919	Dec. 4, 1919	32	4.6
Peggy,	10	G. Jersey,	Oct. 9, 1919	Feb. 4, 1919	24	6.4
190,	8	G. Holstein,	Nov. 17, 1919	Jan. 2, 1920	31	4.4
Red IV,	6	G. Holstein,	Jan. 14, 1919	- -	32	4.9

TABLE V. — *Duration of Experiments.*

EXPERIMENT I.

DATES.	Hay Ration.	Hay and Oat Feed Ration.	Weeks Fed.
April 3, 1919, through April 30, 1919, .	Fancy IV, . . Ida II, . . . Samantha III, . Betty II, . .	Peggy, . . . 190, . . . Colantha II, . . Red IV, . . .	4
May 11, 1919, through June 7, 1919, .	Peggy, . . . 190, . . . Colantha II, . Red IV, . .	Fancy IV, . . Ida II, . . . Samantha III, . Betty II, . .	4

EXPERIMENT II.

Dec. 24, 1919, through Jan. 27, 1920, .	Ida II, . . . Peggy, . . .	190, . . . Cecile II, . .	5
Feb. 8, 1920, through March 13, 1920, .	190, . . . Cecile II, . .	Ida II, . . . Peggy, . . .	5

EXPERIMENT III.

April 1, 1920, through May 5, 1920, .	Fancy IV, . . Eantha, . . Samantha IV, . Peggy, . . . 190, . . . Red IV, . .	Cecile II, . . Diantha II, . . Ida II, . . . Samantha III, . Colantha, ...	5
May 16, 1920, through June 19, 1920, .	Cecile II, . . Diantha II, . . Ida II, . . . Samantha III, . Colantha, . .	Fancy IV, . . Eantha, . . . Samantha IV, . Peggy, . . . 190, . . . Red IV, . . .	5

Care of the Animals. — The animals were cared for in the usual way, as described in previous experiments.

Sampling Feeds and Milk. — The hay was sampled three times during each half of the trial, by taking forkfuls here and there, running the same through a power cutter, sub-sampling, and placing the sub-samples in glass-stoppered bottles which were brought to the laboratory at once, dry matter determinations made, and composite samples analyzed. The grain mixtures were sampled each time a new lot was mixed, and the samples placed in glass-stoppered bottles for analysis. The oat feed was sampled at regular intervals during the experiment.

The milk was sampled for five consecutive days for two or three weeks during each half of the trial, preserved with formalin, and analyzed for total solids and for fat by the Babcock method. The usual method of sampling was followed as described in previous experiments.

TABLE VI. — *Grain Mixtures fed (Pounds).*

Experiment I.		Experiment II.		Experiment III.	
Coconut meal,	50	Coconut meal,	40	Coconut meal,	30
Velvet bean feed,	20	Gluten feed,	30	Gluten feed,	10
Wheat bran,	20	Wheat bran,	30	Wheat bran,	20
Linseed meal,	10			Corn meal,	30
				Peanut meal,	10

Notes of the Experiment. — In Experiment I, a preliminary test of the oat feed used showed it to contain 4.95 per cent of protein and 26.89 per cent of fiber, and it was regarded as a representative lot. The final analysis, however, made from a number of different samples, gave 7.12 per cent of protein and 22.62 per cent of fiber, indicating the presence of an undue amount of oat middlings. The results of this experiment are reported, but they are not included in the average.

In Experiment III, twelve cows were employed, but during the progress of the experiment Colantha II showed such an abnormal milk shrinkage that she could not be continued, and the experiment was completed with eleven cows.

TABLE VII. — *Chemical Analysis of Feeds used (Per Cent).*

Experiment.	Feed.	Water.	Ash.	Crude Protein.	Fiber.	Extract Matter.	Fat.
I,	Hay,	10.00-11.63 10.85	5.34	7.27	26.09	47.81	2.64
	Oat feed,	7.59	6.10	7.12	22.62	53.40	3.17
	Grain mixture,	10.24	5.62	18.71	8.90	50.19	6.34
II,	Hay,	9.50-10.25 9.72	5.62	8.42	29.49	44.22	2.53
	Oat feed,	7.63	6.24	5.53	27.57	51.04	1.99
	Grain mixture,	11.08	5.64	20.90	9.10	48.24	5.04
III,	Hay,	10.96-11.96 11.46	4.23	6.98	26.70	48.08	2.55
	Oat feed,	7.90	5.84	5.04	26.14	53.10	1.93
	Grain mixture,	11.77	4.28	18.18	5.87	53.86	6.07

The hay was of good to excellent quality. It contained a considerable proportion of the finer grasses, together with some timothy and clover, and was usually cut before it was too ripe. Its fiber percentage was not unduly high, and it contained a reasonable amount of protein. Attention has already been called to the fact that the first sample of oat feed contained too large a per cent of middlings to be representative, as is indicated by its relatively low fiber and high protein and fat.

The grain mixtures contained the desired amounts of the several ingredients, and were of satisfactory composition.

A study of Table VIII shows that the average cow received the same amount of grain daily during each experiment. In case of roughage, from 6 to 8 pounds of oat feed were substituted for a like amount of hay *on a dry matter basis.* Because of the dryer condition of the oat feed, it took .5 of a pound less of oat feed in its natural condition to replace a like amount of hay, *e.g.*, 6.5 pounds of oat feed in place of 7 pounds of hay, or 8 pounds of oat feed in place of 8.5 pounds of hay, or 7.64 pounds of oat feed in place of 8.14 pounds of hay. If 8 pounds of hay in its natural state had been fed in place of 8 pounds of oat feed in its natural state the results should have been slightly more favorable to the oat feed.

TABLE VIII. — *Average Ration Consumed per Cow (Pounds).*

EXPERIMENT I.

Number of Cows.	Character of Ration.	Hay. Total per Cow.	Hay. Daily per Cow.	Oat Feed. Total per Cow.	Oat Feed. Daily per Cow.	Grain Mixture. Total per Cow.	Grain Mixture. Daily per Cow.
8, ...	Oat feed, . .	392 00	14 00	182.00	6.50	252 00	9 00
8, ...	Hay, . . .	588.00	21 00	–	–	252 00	9 00

EXPERIMENT II.

Number of Cows.	Character of Ration.	Hay. Total per Cow.	Hay. Daily per Cow.	Oat Feed. Total per Cow.	Oat Feed. Daily per Cow.	Grain Mixture. Total per Cow.	Grain Mixture. Daily per Cow.
4, ...	Oat feed, . .	402.00	11.50	280.00	8.00	324 00	9.25
4, ...	Hay, . . .	700.00	20.00	–	–	324 00	9 25

EXPERIMENT III.

Number of Cows.	Character of Ration.	Hay. Total per Cow.	Hay. Daily per Cow.	Oat Feed. Total per Cow.	Oat Feed. Daily per Cow.	Grain Mixture. Total per Cow.	Grain Mixture. Daily per Cow.
11, ...	Oat feed, . .	447.05	12.77	270.45	7.64	308.64	8.82
11, ...	Hay, . . .	731.82	20.91	–	–	308.64	8.82

TABLE IX. — *Estimated Dry and Digestible Nutrients in Average Daily Rations (Pounds).*

EXPERIMENT I.

Character of Ration.	Dry Matter.	Digestible Nutrients. Protein.	Fiber.	Extract Matter.	Fat.	Total.	Nutritive Ratio.
Oat feed, ...	26.28	2.34	3.05	9.31	.86	15.57	1:6.06
Hay, ...	26.73	2.24	3.59	9.74	.77	16.34	1:6.71

EXPERIMENT II.

Character of Ration.	Dry Matter.	Digestible Nutrients. Protein.	Fiber.	Extract Matter.	Fat.	Total.	Nutritive Ratio.
Oat feed, ...	25.98	2.55	3.56	8.86	.61	15.58	1:54.00
Hay, ...	26.27	2.56	4.13	9.24	.60	16.53	1:57.00

EXPERIMENT III.

Character of Ration.	Dry Matter.	Digestible Nutrients. Protein.	Fiber.	Extract Matter.	Fat.	Total.	Nutritive Ratio.
Oat feed, ...	26.22	2.11	3.24	9.89	.71	15.95	1:6.96
Hay, ...	26.32	2.09	3.71	10.33	.71	16.84	1:7.52

The above figures are based upon analyses and average digestion coefficients. On this basis, in each of the three experiments, the hay ration appears to have contained a little more total digestible nutrients than the oat feed ration. The two rations in each experiment contained about the same amounts of protein and fat.

TABLE X. — *Total Yields of Milk and Milk Ingredients.*

EXPERIMENT I.

Oat Feed Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Peggy,	556.7	16.18	90.07	7.23	40.25
190,	747.1	12.89	96.30	4.53	33.84
Colantha II,	649.7	14.80	96.16	5.47	35.54
Red IV,	998.7	14.19	141.72	5.55	55.43
Fancy IV,	443.6	15.18	67.34	5.99	40.34
Ida II,	681.9	15.00	102.29	6.25	63.93
Samantha III,	560.0	13.92	77.95	5.08	39.60
Betty II,	848.1	13.37	113.39	4.93	55.90
Totals,	5,485.8	-	785.22	-	364.83
Averages,	-	14.31	-	6.65	-

Hay Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Peggy,	492.9	16.10	79.36	6.78	53.81
190,	710.2	12.75	90.55	4.39	39.75
Colantha II,	447.0	14.78	66.07	5.44	35.94
Red IV,	860.6	13.39	115.23	5.50	63.38
Fancy IV,	455.2	15.43	70.24	5.93	26.99
Ida II,	695.1	15.35	106.70	6.24	43.37
Samantha III,	591.7	14.21	84.08	5.32	31.48
Betty II,	884.0	13.78	121.82	4.93	43.58
Totals,	5,136.7	-	734.05	-	338.30
Averages,	-	14.29	-	6.58	-

TABLE X. — *Total Yields of Milk and Milk Ingredients* — Continued.

EXPERIMENT II.

Oat Feed Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
190,	1,115.4	12.53	139.76	4.33	48.30
Cecile II,	695.1	14.79	105.59	5.86	41.83
Ida II,	877.2	14.85	130.26	6.00	52.63
Peggy,	806.0	15.12	121.88	6.43	51.83
Totals,	3,512.6	-	497.49	-	194.59
Averages,	-	14.16	-	5.54	-

Hay Ration.

190,	1,060.9	12.66	134.31	4.25	45.09
Cecile II,	640.6	15.33	98.20	6.24	39.97
Ida II,	973.6	14.93	145.36	6.09	59.29
Peggy,	799.3	15.17	121.25	6.50	51.95
Totals,	3,474.34	-	499.12	-	196.30
Averages,	-	14.37	-	5.65	-

EXPERIMENT III.

Oat Feed Ration.

Cecile II,	612.0	15.37	94.06	6.37	38.98
Diantha II,	1,164.5	12.11	141.02	3.88	45.18
Ida II,	858.9	14.92	128.15	6.03	51.79
Samantha III,	873.3	13.26	115.80	4.70	41.05
Colantha,	802.7	12.78	102.59	4.50	36.12
Fancy IV,	586.0	14.83	86.90	5.65	33.11
Eantha,	833.5	12.53	104.44	4.07	33.92
Samantha IV,	963.2	13.25	127.62	4.84	46.62
Peggy,	757.7	15.19	115.09	6.30	47.74
190,	915.4	13.05	119.46	4.44	40.64
Red IV,	1,009.6	14.45	145.89	5.60	56.54
Totals,	9,376.8	-	1,281.02	-	471.69
Averages,	-	13.66	-	5.03	-

TABLE X. — *Total Yields of Milk and Milk Ingredients* — Concluded.

EXPERIMENT III — *Concluded.*

Hay Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Cecile II,	583.6	15.22	88.82	6.07	35.42
Diantha II,	1,081.1	11.67	126.16	3.52	38.05
Ida II,	791.9	14.43	114.27	5.54	43.87
Samantha III,	597.9	13.79	82.45	5.01	29.95
Colantha,	724.5	12.71	92.08	4.74	34.34
Fancy IV,	606.0	14.98	90.78	5.88	35.63
Eantha,	853.1	12.58	107.32	4.23	36.09
Samantha IV,	1,047.3	13.30	139.29	4.76	49.85
Peggy,	744.3	15.29	113.80	6.59	49.05
190,	967.3	13.08	126.52	4.52	43.72
Red IV,	1,029.5	14.04	144.54	5.56	57.24
Totals,	9,026.5	-	1,226.03	-	453.21
Averages,	-	13.58	-	5.02	-

TABLE XI. — *Summary of Yields (Pounds).*

EXPERIMENT.	Character of Ration.	Number of Cows.	Milk produced.	Total Solids.	Total Fat.
I,	Oat feed,	8	5,485.8	785.22	364.83
	Hay,		5,136.7	734.05	338.30
II,	Oat feed,	4	3,512.6	497.49	194.59
	Hay,		3,474.3	499.12	196.30
III,	Oat feed,	11	9,376.8	1,281.02	471.69
	Hay,		9,026.5	1,226.03	453.21
Totals, II and III,	Oat feed,	15	12,889.4	1,778.51	666.28
	Hay,		12,500.8	1,725.15	649.51

TABLE XII. — *Percentage Increase Oat Feed Over Hay.*

Experiment.	Milk produced.	Total Solids.	Total Fat.
I,	6.7	7.0	7.8
II,	1.1	-	0.9
III,	3.9	4.5	4 1
Totals, II and III,	3.1	3.0	2.5

The results of Experiment I have been omitted from the average because of the variation of the lot of oat feed from the recognized standard. The results of Experiments II and III with four and eleven cows, respectively, covering periods of five weeks each, show that the substitution of from 7 to 8 pounds of dry matter in the form of oat feed for a like amount of dry matter in the form of a good quality of hay (8 pounds and 7.64 pounds of oat feed in place of 8.5 pounds and 8.14 pounds of hay in natural condition) produced substantially 3 per cent more milk and milk ingredients.

TABLE XIII. — *Gain or Loss in Live Weight (Pounds).*

Experiment.	Gain.		Loss.		Net.	
	Oat Feed Ration.	Hay Ration.	Oat Feed Ration.	Hay Ration.	Oat Feed Ration.	Hay Ration.
I,	79	38	56	78	23+	40—
II,	12	15	47	53	35—	38—
III,	231	180	37	50	194+	130+
Averages, II and III,	-	-	-	-	159+	92+

During the experiments the cows on the two different rations showed little change in weight. Our object in each experiment was to feed them a little less than was required for maintenance and milk yield, in order to get, so far as possible, the full effect of each ration. In Experiment III some of the cows were considerably advanced in lactation, at which time they are prone to increase somewhat in weight.

E. Oat Feed for Horses.

Oat feed has been fed to a pair of farm horses, Joe and Chub, at intervals for a period of five months, beginning in early May. The horses had been used for digestion work during the winter, and it was necessary during the early spring to bring them on to a full day's work by degrees. They were employed in plowing, harrowing, drawing manure, mowing, and in similar work for nine hours daily during five and one-half days in each week.

The oat feed was substituted for the hay, at first in the proportion of 5 pounds, and later 6 pounds, daily.

The "grain mixture" consisted of 10 pounds of cracked corn, 1 pound of wheat bran, and 1 pound of cottonseed meal. The object of feeding the cottonseed was to furnish some extra protein in the ration, and to note if any objectionable effect occurred from its use. The wheat bran was used not only for its nutritive value, but because of its gentle laxative effect.

Table XIV. — *Daily Rations consumed (Pounds).*

Periods.	Joe.				Chub.			
	Grain Mixture.	Whole Oats.	Hay.	Oat Feed.	Grain Mixture.	Whole Oats.	Hay.	Oat Feed.
May 3–June 13,	12	5	15	–	11	5	9	5
June 14–July 11,	12	5	10	5	11	5	14	–
July 12–August 8,	12	5	15	–	11	5	8	6
August 9–September 12,	12	5	9	6	11	6	14	–

The table shows that each horse received daily 12 and 11 pounds, respectively, of the grain mixture of corn, cottonseed and bran. This amount was divided into two feeds, and given in the morning and evening. At noon each horse received 5 pounds of oats. From May 3 to June 13, inclusive, Joe received daily 15 pounds of hay and no oat feed, while Chub received 9 pounds of hay and 5 pounds of oat feed. From June 14 to July 11, inclusive, the conditions for the coarse feed were reversed, Joe receiving the hay and oat feed and Chub the hay only. Conditions were again reversed July 12–August 8, and again August 9–September 12, so that during each period from May 1 through September 12 one of the horses was receiving hay for roughage and the other a limited amount of hay and 5 or 6 pounds daily of the oat feed. The latter was well moistened before being fed, and given in three portions. The horses objected a little to the oat feed at first, but soon learned to eat it readily.

TABLE XV. — *Estimated Digestible Nutrients consumed Daily (Pounds).*

Ration fed.	Protein.	Total (Fat × 2.2).	Nutritive Ratio.
15 pounds hay, 5 pounds oats, 10 pounds cracked corn, 1 pound cottonseed meal, 1 pound wheat bran.	2.40	20.20	1:7.4
9 pounds hay, 6 pounds oat feed, 5 pounds whole oats, 10 pounds cracked corn, 1 pound cottonseed meal, 1 pound wheat bran.	2.30	19.50	1:7.5
Standards for comparison: —			
Kellner's (moderate work),	2.00	17.70	1:8.0
Kellner's (hard work),	2.80	24.50	1:7.7
Lavalard's (moderate work),	1.86	18.10	1:8.3
Grandeau's (moderate work),	2.20	17.96	1:7.9

The horses approximated 1,400 pounds each in weight. The above figures show the estimated digestible nutrients that were fed daily and the standard requirements for horses weighing 1,400 pounds, as stated by different authorities. It seems clear that the horses, which were doing moderately hard work, were receiving sufficient digestible protein and total nutrients. It is doubtful if they would have kept in good condition with less food.

TABLE XVI. — *Weights of Animals.*

Joe.

Dates.	Weeks.	Character of Ration.	Weight, Beginning.	Weight, End.	Gain or Loss.
May 3–June 13,	6	Hay,	1,430	1,410	20—
June 14–July 11,	4	Hay-oat feed,	1,410	1,435	25+
July 12–August 8,	4	Hay,	1,435	1,425	10—
August 9–September 12,	5	Hay-oat feed,	1,425	1,440	15+

Chub.

Dates.	Weeks.	Character of Ration.	Weight, Beginning.	Weight, End.	Gain or Loss.
May 3–June 13,	6	Hay-oat feed,	1,370	1,350	20—
June 14–July 11,	4	Hay,	1,350	1,375	25+
July 12–August 8,	4	Hay-oat feed,	1,375	1,390	15+
August 9–September 12,	5	Hay,	1,390	1,430	40+

General Effect of the Ration.

The animals were weighed weekly, and minor variations were noted. Weights at the beginning and end of the change of ration are here given. The weights indicate that Joe evidently was receiving sufficient food to keep him in equilibrium and to enable him to do his work in a satisfactory way, while Chub was receiving a little more than was necessary. The latter was shorter of leg and chunkier in build, and would be termed an easy keeper. During the first period of six weeks (May 3–June 13) both horses lost a little in weight, due to the work required after a winter of comparative inaction. In the second period of four weeks (June 14–July 11) each horse gained 25 pounds irrespective of the ration, due probably to the less amount of work performed. During the third period of four weeks (July 12–August 8) Joe on the hay ration lost 10 pounds, and Chub on the hay-oat feed ration gained 15 pounds, while in the last period of five weeks both horses gained somewhat, probably because of the less strenuous character of the daily work requirements.

Summary and Discussion.

The term "oat feed" does not refer to ground oat hulls, but to the so-called "mill run" resulting from the first milling of oats. The product from the large modern mills contains some 80 per cent of hulls and 20 per cent of middlings and dust. Because of the finely ground condition of the hulls as placed upon the market it is not possible to separate the hulls from the middlings by mechanical means. An average quality of oat feed contains 5 to 6 per cent of protein, about 2 per cent of fat, and not over 27 per cent of fiber. Less protein and fat and more fiber indicate an excess of hulls, while more protein and fat and less fiber show an extra amount of middlings, and consequently a superior product.

While in digestibility oat feed falls a little below hay, feeding trials with dairy cows have shown it to be slightly superior in the production of milk.

In case of horses, the feeding of 5 to 6 pounds daily of oat feed in place of a like amount of hay was productive of quite satisfactory results, and no disturbances of any kind were noted during the four and a half months of the trial. It may be possible to substitute more than 6 pounds of oat feed for a like amount of hay, but we should hardly advise it, both because of its lack of palatability and its lack of bulk as compared with hay. The feeding of 1 pound of cottonseed meal daily in the grain mixture was in no way injurious, so far as we were able to observe, and it is believed that the extra protein furnished had a favorable effect upon the animals.

The writers are of the opinion that oat feed, if placed upon the market unmixed, can best be used pound for pound as a partial hay substitute for dairy cows, young stock, fattening cattle and horses, providing the supply of hay is limited and oat feed can be bought at a reasonable price.

From 6 to 8 pounds daily can thus be fed (well moistened) to mature bovines, proportionately less to young stock, and about 5 to 6 pounds daily to horses.

While oat feed is used in considerable amounts in many proprietary grain mixtures, the best grades, whether rich in protein or carbohydrates, cannot contain large quantities for the reason that such an addition would unduly increase their fiber content and also lessen their digestibility.

The claim is made that aside from its nutritive value, oat feed possesses merit as bulk, serving to distribute and lighten the heavier concentrates. How valid this claim is has not been proved, although as a result of experience many feeders claim that the feeding of considerable amounts of a grain ration which lacks bulk is not advisable. Be that as it may, the use of a few hundred pounds (about 15 per cent) of oat feed in a ton of home-mixed ration would not be objectionable, especially if the other ingredients are highly digestible and finely ground.

In view of the ever-increasing demand for the grains as human food, it should be the aim of both the manufacturer and feeder to use the by-products to the best advantage. Methods for improving the digestibility of indigestible materials, such as grain hulls and the like, merit the careful attention of investigators.

Oat feed should bear a guarantee of composition, and the manufacturers should be careful that it is of stable composition. The purchaser will lose confidence if it shows variations from an accepted standard, or if material is offered as oat feed which consists only of ground oat hulls.

Low-grade by-products, of which oat feed is a type, must be *sold on their merits* and at a price commensurate with their feeding value. Any attempt to sell such material either by itself or in proprietary mixtures at prices unwarranted by its feeding value as compared with feeding stuffs of higher grade would quickly destroy the confidence of the purchaser and result in a slackened demand for the article. The old motto of "state what you sell and sell what you state" may be improved by the addition of the clause "at a price commensurate with its value," and would be especially applicable to this class of materials.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

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INSECTICIDES AND FUNGICIDES

FOR FARM AND ORCHARD CROPS IN MASSACHUSETTS

By E. B. HOLLAND, A. I. BOURNE
and P. J. ANDERSON

On the quality of the insecticides and fungicides used depends in large measure success in spraying and dusting plants to control insects and diseases. Quality is to a degree indicated by the guaranty; to a further degree by the methods actually used in handling the material.

This bulletin treats of the composition of insecticides and fungicides, the conditions under which the various materials and mixtures are effective, presents tables showing standard formulas for application, a diagram showing safe and dangerous mixtures of materials, and finally a table showing the guaranties of a number of proprietary articles.

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CONTENTS.

BULLETIN No. 201.

DEPARTMENTS OF CHEMISTRY, ENTOMOLOGY AND BOTANY.

INSECTICIDES AND FUNGICIDES FOR FARM AND ORCHARD CROPS IN MASSACHUSETTS.

BY E. B. HOLLAND, A. I. BOURNE AND P. J. ANDERSON.

The successful production of farm and orchard crops depends in large measure on the protection afforded against injurious insects and bacterial and fungous diseases. Obviously there is no remedy — that is, no panacea for all noxious insects and parasitic diseases of plant life — that would not also destroy the host. The method of treatment, therefore, must be essentially specific, and for convenience will be divided into three major groups: (A) Insecticides, (B) Fungicides, and (C) Combined applications.

A. INSECTICIDES.

The injurious insects that infest the crops under consideration are of two distinct types as determined by their mode of feeding: *i.e.*, biting and sucking. The former type consumes organized tissue, and the latter draws sustenance from plant juices. The respective treatment of the two types is necessarily different and warrants a division of insecticides into (I) Stomach poisons for biting insects, and (II) Contact poisons for sucking insects. The stomach poisons of to-day owe their origin largely to the Colorado potato beetle, and the contact poisons to the San José scale.

The acknowledged requisites for an insecticide are —

1. Non-toxicity as to plant.
2. Effectiveness in destroying the insect.
3. Adhesiveness or persistence under all weather conditions.
4. Fineness of particles and a light flocculent character (when insoluble) to insure a high power of suspension and uniform distribution.
5. Ability to indicate the surface covered.
6. Reasonable cost.

The factors that facilitate distribution naturally differ somewhat in soluble and insoluble products, dust and spray applications. These attributes comprise a standard for judging insecticides, and apply in principle to fungicides as well.

I. STOMACH POISONS FOR BITING INSECTS.

Nearly all stomach poisons of the present time are compounds of arsenic, and this has led to the general use of the term "arsenicals" for this group of insecticides. Very little work has been done, and still less has been published, in regard to the exact nature of the toxic action of arsenic on the physical structure of insects. The fact that this action takes place and the rapidity of its killing effect upon the insects in question have been practically the only points to which writers have hitherto given their attention.

The sprays consist of minute particles of the poison, suspended in the water or other vehicle, which are deposited upon the food of the insect and adhere to it upon drying.

1. Arsenicals.

There are two forms of arsenicals to be considered: —

1. The lower or arsenous oxide, or arsenic trioxide (white arsenic) (As_2O_3).
2. The higher or arsenic oxide, or pentoxide (As_2O_5).

When these two oxides are combined with bases, the former yields the so-called (*a*) Arsenites, and the latter (*b*) Arsenates.

Arsenites as a class are noticeably more active poisons than the arsenates, but are relatively unstable and more likely to cause injury to the plant, and for that reason they have been largely supplanted.

Depending on the form in which the arsenic may be present, arsenicals are sold on a guaranty in which the amount of arsenic (the active principle) may be stated in the following terms: —

Percentage of arsenous oxide or arsenic trioxide (As_2O_3) or white arsenic.
Percentage of arsenic pentoxide (As_2O_5).
Percentage of elemental arsenic (metallic arsenic).

The first form is used in guaranties of Paris green, whereas either the second or third form is used in stating guaranties of arsenates. Notwithstanding the fact that the killing power of arsenates and arsenites varies in rapidity, and possibly in final extent, the percentage of metallic arsenic seems to be the only common denominator by which to compare one arsenical with another.

(*a*) **Arsenites.**

A number of arsenites have been placed on the market at one time or another. Paris, Schweinfurt, or Emerald green, a well-known poisonous pigment, was first used about 1868 (1).[1] This date, therefore, marks the

[1] Numbers in parentheses indicate literature cited, which will be found on pages 35-37.

beginning of the era in which active agents supersede the old-time repellents (2), which were usually characterized by offensive (both odor and taste) or caustic rather than poisonous properties. Some, however, may have possessed value as contact poisons. In 1875 Scheele's green (3) was introduced, in 1877 London purple (4), and in 1891 calcium arsenite (5).

There are several other commercial products which are worthy of mention, although many of them contain soluble arsenic, and in some cases uncombined white arsenic may have been a constituent. Gray arsenoid was a mixture of calcium and copper arsenites. Barium arsenite or white arsenoid was essentially a mixture of barium compounds and of arsenic rather than a true salt. Zinc arsenite was employed by potato growers in certain localities for a few seasons. Laurel green was a mixture of copper arsenite, gypsum and green sand. Paragrene was a mixture of Paris green and gypsum.

Paris green, because of its quick action and comparative safeness when applied with lime, still maintains a place in the list of recommended arsenicals, but has certainly lost much of its former prominence.

(1) *Paris Green.*

Composition. — Paris green is a copper aceto-arsenite for which the formula of Eugene Ehrmann is generally accepted: —

$$(CH_3COO)_2\,Cu.3Cu\,(AsO_2)_2$$

As a double salt it may be said to consist of 1 part of copper acetate and 3 parts of copper metarsenite. The composition of the theoretical salt is as follows: —

		Per Cent.
Cupric oxide (CuO),		31.385
Arsenous oxide (As_2O_3),		58.550
Equivalent to metallic arsenic (As) (per cent),	44.350	
Ratio CuO : As_2O_3,	1 : 1.866	
Acetic anhydride $(CH_3CO)_2O$,		10.065
		100.000

Stability. — While Paris green is nominally insoluble in water, it is in reality unstable, and breaks down under continuous percolation of water, with the liberation of soluble and hence injurious arsenic. Carbonic acid, ammonia and certain alkaline salts likewise tend to increase the solubility of the arsenic. Since conditions which control the presence of these substances cannot always be foretold, it is always well to add milk of lime to Paris green to prevent arsenical injury. It does this by uniting with the free and loosely combined arsenic to form calcium arsenite, which is insoluble and hence non-injurious to the foliage.

Form of Guaranty. — The form of guaranty under which Paris green is sold is as follows: —

	Per Cent.
Total arsenous oxide, not less than	50.00
Water soluble arsenous oxide, not more than	3.50

The statement of total arsenous oxide in the above guaranty may be taken as representing the effectiveness of the material in terms of the killing principle which it contains. The statement of soluble arsenous oxide indicates the maximum amount of injurious compounds of arsenic.

The above guaranty corresponds to the Federal standard. Paris green as offered for sale in this State fully meets this guaranty.

To summarize: Paris green is of high arsenic content, and that in the form of arsenous oxide, nominally insoluble in water, but unstable, hydrolyzing readily, and likely to cause injury unless applied with lime. It is an active poison with a low power of suspension, but admitting of reasonable distribution; a poor indicator without lime of the leaf surface covered; and of fair adhesiveness and persistence under average weather conditions.

(*b*) **Arsenates.**

As a group arsenates are rapidly supplanting arsenites, because they have greater stability and are less likely to injure foliage. Of the five arsenates which at one time or another have been used in practice or have been sold in commerce, lead arsenate, developed in 1894 (6), is unquestionably the most satisfactory. Calcium arsenate, first manufactured about 1912,[1] is serviceable, but has a more limited field of usefulness. Magnesium arsenate has been on the market for but two seasons, while the arsenates of zinc and iron are of but minor importance.

(1) *Lead Arsenate.*

F. C. Moulton (7), chemist for the Massachusetts Gypsy Moth Commission, was the first to prepare arsenate of lead for insecticide purposes in 1892. The work was continued by F. J. Smith (8), who studied various matters pertaining to the manufacture, and stated that ordinary spray material was not a single salt, but a mixture of neutral and acid arsenates. Lead arsenate paste appears to have been first prepared commercially about 1895 by the Merrimac Chemical Company of Boston, under the trade name of Swift's arsenate of lead. Disparene, manufactured by the Bowker Insecticide Company of Boston, followed soon after. Dry lead arsenate (Electro) was prepared as an insecticide by the Vreeland Chemical Manufacturing Company of New York about 1909. The California Experiment Station mentioned a dry product in 1903, but gave no information as to its source. Dry, *bulky* acid lead arsenate was first prepared in 1912 by the Corona Chemical Company of Milwaukee, Wis.

There appear to be three different lead arsenate salts, as follows: —

1. Acid lead arsenate, $PbHAsO_4$. This is the lead arsenate ordinarily sold in New England.
2. Neutral lead arsenate, $Pb_3(AsO_4)_2$.
3. Basic lead arsenate (9), $Pb_5OH(AsO_4)_3$.

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[1] Correspondence from manufacturers on file.

A few writers claim that pyroarsenate, $Pb_2As_2O_7$, may occur in commercial products, but the evidence at hand does not support the assertion.

Composition. — The composition of theoretical acid, neutral and basic lead arsenates is as follows: —

	Acid Lead Arsenate (Per Cent).		Neutral Lead Arsenate (Per Cent).		Basic Lead Arsenate (Per Cent).	
Lead oxide (PbO),		64.291		74.440		75.924
Arsenic pentoxide (As_2O_5),		33.114		25.560		23.463
Equivalent to metallic arsenic (As) (per cent).	21.590		16.667		15.299	
Ratio As_2O_5 : PbO,	1 : 1.942		1 : 2.912		1 : 3.236	
Water of combination,		2.595		0.000		0.613
		100.000		100.000		100.000

From the above table it is evident that the acid lead arsenate as it is sold in New England is considerably more concentrated than is either the neutral lead arsenate or the basic lead arsenate. From economic standpoints alone this matter is of importance.

Physical Properties. — These products, whether acid or mixed acid and neutral arsenates, are usually smooth white pastes of finely divided, amorphous particles, less than 1 μ in size, with a good power of suspension and exceptional adhesiveness. The so-called neutral salt has almost invariably been a mixture of acid and neutral, and very little has been marketed. The physical structure of the neutral salt, or of mixtures containing considerable neutral lead arsenate, is rather inferior to that of the acid salt, and the basic material used in southern California is said to be relatively coarse and granular. The power of suspension is injured by drying or freezing. These pastes are compact and "greasy," but fairly miscible with water when properly handled. The acid salt is less compact, has a lower specific gravity and higher power of suspension, and is a more active poison than the neutral or basic. The specific gravity of the acid salt (amorphous form) (10) at 15/15° C. is 5.93, the neutral (10), 7.32, and the basic (11), at 20/4° C., 7.105.

More recently the dry powders have displaced the pastes in large measure at a material saving in cost of containers, transportation, possible leakage and danger of injury on storage. This product is a white, bulky (fluffy) powder of fine amorphous particles, with a very high power of suspension and excellent adhesiveness. The "old type" dry acid arsenate ran about 40 cubic inches to the pound, and the "new type" 70 to 80 cubic inches. The neutral and basic products are more dense, but actual figures are not available, as they are seldom if ever marketed in dry form. The product, as offered in Massachusetts markets, is essentially the acid arsenate. It is more readily miscible with water than the paste, and a time saver in this respect.

Stability. — Acid and neutral lead arsenates are practically insoluble in cold water, but continuous percolation may cause decomposition. Hot water is more effective, but may cause slight hydrolysis, particularly of the acid salt. Dilute solutions of sodium carbonate, sodium chloride and sodium sulfate have been shown (12, 13) to increase the solubility of the arsenic, especially where the common acid lead arsenate is used. Stability may be obtained by adding calcium hydroxide (milk of lime) to acid or neutral arsenate. The former will necessarily require more base to afford like protection. The basic salt sold in the West contains only about 20 to 22 per cent of arsenic pentoxide on a dry basis.

Form of Guaranty. — The usual form of guaranty under which dry lead arsenate is sold is substantially as follows: —

		Per Cent.
Active ingredients: —		
Lead arsenate, not less than		98.00
Total arsenic pentoxide, not less than	31.00	
Total arsenic (as metallic), not less than	20.20	
Inert ingredients, not more than		2.00
		100.00
Water Soluble.		
Soluble arsenic pentoxide, not more than		0.75
Soluble arsenic (as metallic), not more than		0.50

As in the case of Paris green, an article is desired which contains a high percentage of total arsenic with a low maximum percentage of soluble arsenic. It is well to note further that in the above guaranty the essential statements are those italicized. The other statements made simply repeat this information in different form.

The Federal standard (14) for commercial lead arsenate specifies not more than 50 per cent of water, nor less than 12.50 per cent of total arsenic pentoxide (equivalent to 8.15 per cent metallic arsenic), and not more than 0.75 per cent of arsenic pentoxide soluble in water (equivalent to 0.49 per cent metallic arsenic).

To maintain a high standard of purity the product, whether paste or powder, should be substantially free from carbonate, chloride, sulfate and acid soluble matter, and should not contain more than 2.50 per cent, on a dry basis, of water soluble by-products. The dry acid lead arsenate sold in the East is usually guaranteed to contain 30 or 31 per cent of total arsenic pentoxide (equivalent to 19.56 or 20.21 per cent metallic arsenic), and not more than 0.75 or 1 per cent of arsenic pentoxide soluble in water (equivalent to 0.49 or 0.65 per cent metallic arsenic). The paste is usually guaranteed to contain 15 per cent arsenic pentoxide (equivalent to 9.78 per cent metallic arsenic), and not more than 0.75 per cent arsenic pentoxide soluble in water.

To summarize: Lead arsenate is of low arsenic content, and that in the form of pentoxide, practically insoluble in water, fairly stable under New England weather conditions, and may be applied to most plants with little danger of injury. It is a slow-acting poison but effective; the fineness of particles and light flocculent character insure a high power of suspension and uniform distribution; the white mixture readily indicates the leaf surface covered, and dries to a film which adheres with great persistence.

(2) *Calcium Arsenate.*

Arsenate of lime was employed as an insecticide about 1912, or possibly earlier. Dry arsenate of lime appears to have been first prepared commercially by Riches, Piver & Co. of New York. The late war, with resulting high prices, brought the product into prominence.

As with lead arsenate there are three separate products to be considered, as follows: —

1. Acid calcium arsenate, $CaHAsO_4H_2O$.
2. Neutral calcium arsenate, $Ca_3(AsO_4)_2 2H_2O$.
3. Basic calcium arsenate, a product of rather variable composition, probably depending on the amount of excess lime. This is the commercial article sold under the name of calcium arsenate.

Composition. — The composition of theoretical acid and neutral calcium arsenates, and of a commercial basic calcium arsenate, is substantially as follows: —

	Acid Calcium Arsenate (Per Cent).	Neutral Calcium Arsenate (Per Cent).	Commercial Basic Calcium Arsenate (Per Cent).
Calcium oxide (CaO),	28.310	38.744	44.128
Arsenic pentoxide (As_2O_5),	58.045	52.957	45.238
Equivalent to metallic arsenic (As) (per cent).	37.848	34.531	29.497
Ratio As_2O_5 : CaO,	1 : 0.488	1 : 0.732	1 : 0.975
Water of combination,	13.645	8.299	10.634
	100.000	100.000	100.000

Physical Properties. — The calcium arsenates are soft, white powders of fine particles with a good power of suspension and adhesiveness. The specific gravity (15) of a pure acid salt at 20/4° C. was 3.09, and of a neutral salt, 3.23. The commercial dry basic calcium arsenate is a bulky, impalpable powder of 80 to 100 cubic inches to the pound.

Stability. — The acid salt is largely soluble in water, and the neutral salt appreciably so, as determined by the Hilgard method. Carbonic acid will decompose both salts with the formation of carbonate and the liberation of arsenic. Dilute solution of alkalies and their salts will increase the solubility of the arsenic, the acid salt invariably proving the more unstable. For these several reasons calcium arsenate used alone burns foliage very badly. As in the case of other arsenicals, milk of lime prevents burning by combining with any soluble arsenic which may be formed.

The basic products are more stable than the acid or neutral salts, due evidently to the higher content of lime.

The status of the dry commercial products is still rather indefinite. Carbonate of lime is present in some instances as an impurity or filler, having neither toxic nor protective action.

Form of Guaranty. — Calcium arsenate is usually sold under the following form of guaranty: —

		Per Cent.
Active ingredients: —		
Tricalcium arsenate, not less than		76.00
Total arsenic pentoxide, not less than	42.50	
Total arsenic (as metallic), not less than	28.00	
Inert ingredients, not more than		24.00
		100.00
Water Soluble.		
Soluble arsenic pentoxide, not more than		1.50
Soluble arsenic (as metallic), not more than		1.00

The remarks relative to the form of guaranty of lead arsenate hold equally well for the form of guaranty of calcium arsenate. Note particularly that the killing power of calcium arsenate is apparently greater than that of lead arsenate on account of the higher percentage of arsenic pentoxide. Therefore a smaller quantity is used in the spray, so as to give the same amount of metallic arsenic as when arsenate of lead is used.

To summarize: Both acid and neutral calcium arsenates are of relatively high arsenic content, but too soluble to warrant their use without excess lime. The basic product is of a lower arsenic content but more stable. They are effective poisons, the fineness of particles and light flocculent character insuring a fair power of suspension and uniform distribution. The white mixture indicates the leaf surface covered, and dries to a film that is persistent under average weather conditions; and is, in brief, an efficient and reasonably satisfactory arsenical for the more resistant plants.

Standard Formulas for Application.

As previously mentioned, there is a great difference in the rapidity of killing power between arsenates and arsenites. For this reason the two classes of materials cannot be compared on the basis of arsenic contained. The following table represents basic quantities of the several materials of standard or near standard composition which may be used. Naturally the amounts to be used must be varied to adapt the spray to different kinds of insects, and to make it safe when used on different kinds of plants.

Arsenical.	Composition of Arsenical.		Amount of Arsenical in Spray.		Pounds of Metallic Arsenic per Barrel of Spray.
	Arsenic Oxides (Per Cent).	Equivalent in Metallic Arsenic (Per Cent).	Per Barrel (50 Gallons) (Pounds).	Per Gallon (Ounces).	
Arsenites: —					
Paris green, . . .	50.00 (As_2O_3)	37.87	0.333	1/10	0.126
Arsenates: —					
Dry acid lead arsenate, .	30 00 (As_2O_5)	19.56	1.5	1/2	0 3–
Dry basic calcium arsenate,	40 00 (As_2O_5)	26 08	1.0	1/3	0 3–

Any arsenite of known composition may be applied in quantity to furnish metallic arsenic equal to that in an application of Paris green; whereas any arsenate of known composition may be applied to furnish metallic arsenic equivalent in amount to that used in arsenate of lead.

For most farm and orchard crops it is unwise to use any arsenical without protecting the plant against foliage damage. The addition of milk of lime affords protection against this arsenical injury. Four pounds of high-grade quicklime (95 per cent CaO) are generally sufficient for 50 gallons (1 barrel) of spray. The lime should be slaked carefully, sieved, diluted to nearly 50 gallons, and the arsenical added slowly with thorough agitation *immediately* before application.

Arsenical Injury.

It is evident from what has been stated repeatedly that the carbonic acid and ammonia of the atmosphere in conjunction with dews, fogs or light rains and high temperatures will materially increase the amount of soluble arsenic. When the arsenic is in solution in the spray liquid, or drops of rain or dew on the foliage, some of it is absorbed by the tissues of the leaf. A very minute amount of absorbed arsenic may have no injurious effect on the cell; but if, on account of a high soluble arsenic content of the spray material, or too long standing of the liquid before drying, a sufficient amount has been absorbed, the tissue is killed. Two types of injury are distinguished (16), — *acute* poisoning and *chronic* poisoning.

In cases of *acute poisoning* the leaf, or large areas of it, turns black within twenty-four hours after the application; or sometimes, when the insecticide has dried rapidly after application, the blackening may appear after the first period when water has stood on the foliage for some time. In *chronic poisoning* there are no definite lesions on the leaves, but after two or three weeks they prematurely turn yellow and drop off. Apparently in this type of poisoning not enough arsenic is absorbed to kill the cells outright, but yet enough to interfere with and finally stop the functioning of the cells.

Certain deductions seem warranted. Conditions favoring a rapid drying of the arsenical and its continuance in a dry state are propitious.

For instance, a relatively high temperature, low humidity and a good circulation of air at the time of application, followed by warm, dry weather should tend toward a minimum of arsenical injury. On the other hand, factors conducive to solubility of the arsenic and its passage by osmosis into the substance of the leaf are detrimental, as, for example, warm, "muggy" weather, or warm weather accompanied by fogs or heavy dews. Rains are not necessarily injurious if of sufficient quantity to wash off the soluble arsenic as soon as it is formed.

2. Hellebore.

White hellebore is the powdered rhizome (root) of *Veratrum album*, and green or American hellebore that of *V. viride*. Both are sold as insecticides in the form of a gray powder containing about 1 per cent of alkaloids (usually guaranteed from 0.30 to 0.42 per cent) and a varying amount of ash. Though known to possess poisonous properties, hellebore received little attention until about 1842 in England (17), and 1865 in this country (18).

The chief insecticidal action of hellebore is as a stomach poison. It appears to possess also a certain value as a repellent. The active principles which give hellebore its insecticidal value are certain alkaloids which are poisonous to insects, but in amounts usually recommended for use do not seriously affect man. These alkaloids are so volatile that the material soon loses its strength and efficiency, particularly if exposed to the air. Consequently a fresh product should always be demanded. Its non-poisonous effect on man renders hellebore a suitable material for the protection against chewing insects of fruits or vegetables that are about to ripen or are soon to be eaten. It is, however, limited to rather small-scale applications, the cost of the material prohibiting its use on large areas. The material may be applied either dry or as a spray. In dry form it is used either undiluted or mixed with five times its volume of flour or finely divided air-slaked lime. For liquid application its use at the rate of ½ ounce to 1 gallon of water is recommended.

II. CONTACT POISONS FOR SUCKING INSECTS.

Contact poisons include a large number of diversified compounds (solid, liquid and gaseous), and their effectiveness may depend upon more than one property. The compound may act in any of the following ways: —

1. Glue the insect down.
2. Attack the body, dissolving fat and even muscle, precipitating proteids, etc.
3. Act as a narcotic, paralyzant or anæsthetic.
4. Asphyxiate the insect by closing the breathing pores (spiracles or tracheæ), or, by saturating the body, prevent necessary aeration.

These indicate some of the possibilities, but the principal action and the contributory are generally difficult to define. These poisons are generally soluble or emulsified products. They kill only by contact. Liberal and thorough application is necessary to assure effectiveness, and drench spraying is usually employed. The weaker the surface tension of the spray and the thinner the chitin of the insect the more rapid the penetration.

The contact poisons that will be considered are (1) soaps, (2) sulfur sprays, (3) oil sprays, (4) nicotine, and (5) pyrethrum.

1. Soaps.

There are four different types of soap sprays, as follows: —

1. Whale-oil or fish-oil soaps.
2. Laundry soap.
3. Rosin fish-oil soap, soap "stickers."
4. Fish-oil soaps and nicotine.

(1) *Whale-oil or Fish-oil Soaps.*

Whale-oil soap was first brought forward in 1842 by the experiments of Haggerston (19), and showed an efficiency which it has steadily maintained up to the present. It is interesting to note that many of the statements made at that time in regard to its value have proved true through years of subsequent use, and the dosage first recommended is practically the same as that used to-day.

At the present time soaps made from fish oil have largely supplanted the true whale-oil soaps, but the similarity in the nature and effectiveness of the two materials has led to the habit of using these two names more or less interchangeably. Strictly speaking, however, the commercial product to-day is largely made from various fish oils.

For use as a summer spray against plant lice and other soft-bodied insects, as well as younger stages of more resistant types, it is very effective when applied at the rate of 1 pound to 6–8 gallons of water, according to the tenderness of the plant in question. It has sometimes been used for dormant treatment of scale insects at the rate of 2 pounds to 1 gallon of water, and applied while hot. The stronger, more efficient sulfur sprays have largely supplanted it for this purpose.

(2) *Laundry Soap.*

In the absence of whale-oil or fish-oil soaps, common laundry soap may be employed effectively for the same type of insects. An average soap of this type should be used at the rate of 1 pound to 2–4 gallons of water, depending on the resistance of the insects treated.

(3) *Rosin Fish-oil Soap, Soap "Stickers."*

On plants having a smooth and waxy foliage, such as cabbage and similar types, lead arsenate and Bordeaux mixture will not adhere at all well unless used with some kind of soap as a "sticker." Types of resinous soaps have come into use under the general name "Resin (Rosin) Fish Oil Soaps," and are especially adapted for such purposes. These are recommended to be used at the rate of 3–4 pounds to 50 gallons of spray (or about 1 ounce to 1 gallon), and to be added to the diluted spray material immediately before it is to be applied. In the preparation of this type of soap for a spray it is necessary to add the water a little at a time, stirring vigorously all the while, until the soap has entirely dissolved; otherwise the resinous nature of the material repels the water, making a solution almost impossible.

Except on the particular types of plants just mentioned (cabbage and similar plants), soap should not be used with arsenicals or Bordeaux mixture. Arsenicals are unstable in the presence of the alkali of the soap, with the consequent danger of the formation of soluble arsenic (20). In this particular case, however, the application is made so soon after the soap is added that there is little opportunity for breakdown; and, further, the waxy leaves seem to offer more resistance to arsenical injury than would foliage of ordinary texture. The alkalies entering into the composition of our common soaps are mainly compounds of sodium and potassium. Such soaps are the only ones soluble in water. When, however, soap is combined with Bordeaux mixture or lime-sulfur sprays, calcium soaps are formed which are insoluble in water, making a gummy, sticky mass which is apt to clog the spray apparatus. Moreover, other products of this breakdown are formed which are either actively dangerous to the plant or are of no use whatever as an insecticide.

(4) *Fish-oil Soaps and Nicotine.*

Commercial brands of fish-oil soaps combined with a small amount of nicotine are on the market and appear to have a considerable sale. These are rather expensive, and usually their nicotine content is quite low, so that in general, better satisfaction can be obtained by combining soap and nicotine solutions as needed. (See Nicotine Sprays, page 20.)

2. Sulfur Sprays.

These are efficient contact poisons for certain scale insects, and possess substantial fungicidal value as well. They are supplanting the miscible oils, probably due in large measure to the deleterious after-effects of the latter. Concentrated lime-sulfur solution, dry lime-sulfur, barium tetrasulfide (B. T. S.), and sodium polysulfide, or so-called soluble sulfur, will be considered. All of these materials seem to have the following properties in common: —

1. The amount of polysulfide sulfur present largely governs the effectiveness of the material.

2. Thiosulfate sulfur is a product of the breaking down of polysulfide as well as an original constituent of the product, and hence is present in variable amounts.

3. The free sulfur contained is usually inert as an insecticide. It does, however, have a distinct fungicidal value. (See page 26.)

(1) *Lime-sulfur.*

The efficiency of lime-sulfur-salt wash (21) for the San José scale appears to have been first demonstrated by F. Dusey of Fresno, Cal., in 1886, using a sheep dip prepared by A. T. Covell. The dip (22, 23), however, seems to have been of Australian origin. About the year 1900 it began to be used in the eastern States for the control of the San José scale.

The formulas adopted by different experiment stations showed appreciable variations. A proportion of 1 pound of lime and 2–2¼ pounds of sulfur to 1–1⅗ gallons of water assures solution of the largest proportions of lime and sulfur, the smallest amount of sludge or sediment, and a high proportion of calcium polysulfide (particularly pentasulfide) with a moderate amount of calcium thiosulfate, thus making the most efficient product with the least waste. The lime must be a high-grade caustic, substantially free from magnesia, which causes unnecessary loss of sulfur as hydrogen sulfide and increases the amount of sediment. A greater proportion of lime causes the formation of more thiosulfate, and favors the formation of crystals of oxysulfide. Boiling for thirty to sixty minutes with proper agitation should be sufficient to dissolve all of the sulfur; longer heating is detrimental. The resulting solution should be about 24° or 25° Baumé. A greater concentration is generally obtained at a sacrifice of thiosulfate, which is converted into sulfite and free sulfur which being insoluble increase the amount of sediment.

The commercial product has largely superseded the home-made except, possibly, in the case of orchard practice on a large scale. Lime-sulfur solution appears to have been first produced commercially by the Rex Spray Company (formerly Rex Stock Food Company) of Omaha, Neb., as a sheep and cattle dip, which was approved by the Bureau of Animal Industry Sept. 30, 1903. Later the product was tested as a spray at Corvallis, Ore., and largely marketed as such. The commercial concentrate is to-day practically standardized on a 33° Baumé basis. A product of greater density is more likely to crystallize on chilling.

Concentrated lime-sulfur properly prepared is a clear orange-red solution with more or less sludge, depending on the purity of the lime and sulfur, formula, and method of treatment. The clear solution consists chiefly of so-called calcium polysulfide and calcium thiosulfate in varying amounts. The sludge may contain free sulfur, together with calcium sulfite, calcium sulfate and impurities from the lime. The polysulfide is a combination of lime and sulfur, approximating a ratio of 1 : 5, or CaS_5; the thiosulfate is CaS_2O_3.

Composition. — A comparison of home-made concentrate and the commercial 33° Baumé concentrate is shown in the following table: —

	Home-made (24½° B) (Per Cent).		Commercial (33° B) (Per Cent).	
Water,		75.00		68.04
Sulfur in solution,		17.00		24.75[1]
Polysulfide sulfur,	13.75		24.00	
Thiosulfate sulfur,	3.25		.75	
Ratio thiosulfate sulfur to polysulfide sulfur,	1 : 4.23		1 : 32.00	
Calcium,		5.57		6.65
Oxygen in combination,		2.43		.56
		100.00		100.00
Water,	75.00		68.04	
Calcium polysulfide ($CaS_{4.55}$)	17.29		30.18	
Calcium thiosulfate,	7.71		1.78	
	100.00		100.00	

[1] A conservative estimate.

Stability. — Lime-sulfur is readily oxidized on exposure to air, the polysulfide being converted into thiosulfate with precipitation of sulfur, the thiosulfate into sulfite with precipitation of additional sulfur, and the sulfite into sulfate, as follows: —

$$CaS_5 + O_3 = CaS_2O_3 + S_3$$
$$CaS_2O_3 = CaSO_3 + S$$
$$CaSO_3 + O = CaSO_4$$

This necessitates full containers, well-stoppered, or a thin covering of paraffin oil to prevent decomposition of lime-sulfur in storage.

The guaranty of commercial concentrates is generally about 33° Baumé and 25 per cent sulfur in solution. The efficiency, however, is more accurately measured by the amount of polysulfide sulfur in solution, irrespective of whether the effectiveness is a result of direct action or from products of decomposition. The total sulfur in solution apparently gives the home-made product, containing a much larger proportion of thiosulfate sulfur, relatively too high a rating.

According to P. J. Parrott, of the New York (Geneva) Agricultural Experiment Station, a gallon of diluted lime-sulfur for dormant spray (San José scale) should contain about 0.297 pound of sulfur in solution, or 3.45 per cent; and for fungicidal work on foliage, 0.065 pound of sulfur, or 0.775 per cent. The following formulas are so calculated for concentrates of 15° to 36° Baumé: —

TABLE I. — *Standard Formula for Application (24).*

Density of Solution, Baumé Degrees.	Equivalent in Specific Gravity.	Sulfur Equal to 1° B. (Per Cent).	Weight of 1 Gallon of Concentrate (Pounds).	Sulfur in 1 Gallon of Concentrate (Pounds).	Sulfur in Solution (Per Cent).	Dilution for San José Scale:[1] To 1 Gallon of Concentrate add Gallons of Water.	**Dilution for San José Scale:[1] For 50 Gallons of Spray use Gallons of Concentrate.**	Dilution for Summer Spray:[2] To 1 Gallon of Concentrate add Gallons of Water.	**Dilution for Summer Spray:[2] For 50 Gallons of Spray use Gallons of Concentrate.**
36	1.3303	0.75	11 08	2 99	27.00	9	**5**	45	**1**
35	1.3182	.75	10.98	2.88	26.25	8¾	**5¼**	43¼	**1¼**
34	1.3063	.75	10.88	2.77	25.50	8¼	**5¼**	41½	**1¼**
33	**1.2946**	**.75**	**10 78**	**2 67**	**24 75**	**8**	**5½**	**40**	**1¼**
32	1 2832	.74	10.69	2.53	23 70	7½	**5¾**	37¾	**1¼**
31	1.2719	.74	10.60	2.43	22.95	7¼	**6**	36¼	**1¼**
30	1.2609	.73	10.51	2.30	21.90	6¾	**6½**	34¼	**1½**
29	1 2500	.73	10.42	2.20	21.15	6½	**6¾**	32¾	**1½**
28	1.2393	.72	10.32	2.08	20.15	6	**7¼**	31	**1½**
27	1.2288	.72	10.23	1.99	19.45	5¾	**7½**	29½	**1½**
26	1.2185	.71	10.15	1.87	18.45	5¼	**8**	27¾	**1¾**
25	1 2083	.70	10.07	1 76	17.50	5	**8½**	26	**1¾**
24	1.1983	.69	9.98	1.65	16.65	4½	**9**	24¼	**2**
23	1.1885	.68	9.90	1.55	15.65	4¼	**9½**	22¾	**2**
22	1.1789	.67	9.82	1.45	14.75	3¾	**10¼**	21¼	**2¼**
21	1.1694	.66	9.74	1.35	13.85	3½	**11**	19¾	**2½**
20	1.1600	.65	9 67	1.26	13.00	3¼	**11¾**	18¼	**2½**
19	1.1508	.65	9.59	1.18	12.35	3	**12½**	17	**2¾**
18	1.1417	.65	9.51	1.11	11.70	2¾	**13½**	16	**3**
17	1 1328	.65	9.44	1.04	11.05	2½	**14¼**	15	**3¼**
16	1.1210	.65	9.37	0.97	10.40	2¼	**15¼**	14	**3¼**
15	1.1154	.65	9.30	0.90	9.75	2	**16½**	12¾	**3½**

[1] Density of spray, 4.6° Baumé, or 1.0327 specific gravity.
[2] Density of spray, 1.0° Baumé, or 1.0072 specific gravity.

(2) *Dry Lime-sulfur.*

Dry lime-sulfur was first marketed in 1915 by the Sherwin-Williams Company of Cleveland, Ohio. The use of the dry product effects a material saving in cost of containers, transportation, storage and possible leakage. Commercial lime-sulfur solution contains nearly 68 per cent of water, while the dry product usually contains only a small amount of uncombined water. In the production of dry lime-sulfur the polysulfide apparently undergoes partial decomposition, and a portion of the sulfur formerly combined with the lime splits off and fails to redissolve on the addition of water, and is termed free sulfur.

Composition. — Dry lime-sulfur is usually guaranteed about as follows: —

		Per Cent.
Active ingredients,		80.00
Calcium polysulfide,	63.00	
Calcium thiosulfate,	5.00	
Free sulfur,	12.00	
Inert ingredients,		20.00
		100.00

A 33° Baumé lime-sulfur solution containing 24.75 per cent sulfur, concentrated to a like basis, should contain substantially 61.95 per cent total sulfur. If 12 per cent was rendered insoluble by evaporation, 49.95 per cent remains soluble. Five per cent calcium thiosulfate is equivalent to 2.11 per cent thiosulfate sulfur, which deducted from the soluble sulfur leaves 47.84 per cent polysulfide sulfur.

(3) *Barium Tetrasulfide.*

Barium tetrasulfide (25) or B. T. S. was prepared experimentally as an insecticide by the Thomsen Chemical Company of Baltimore, Md., in 1913. The product is guaranteed as follows: —

		Per Cent.
Active ingredients,		82.00
Barium tetrasulfide (BaS_4),	68.00	
Barium thiosulfate,	6.00	
Free sulfur,	8.00	
Inert ingredients,		18.00
		100.00

Barium tetrasulfide is a fairly satisfactory contact poison, yet it possesses no distinct advantages over lime-sulfur preparations. It has never replaced lime-sulfur to any great extent, and is not now widely used, largely because it is more expensive.

(4) *Soluble Sulfur.*

Soluble sulfur or sodium polysulfide was first marketed by the Niagara Sprayer Company of Middleport, N. Y., about 1912. Con-sol, a sodium sulfur compound, prepared by the American Horticultural Distributing Company of Martinsburg, W. Va., was offered about 1905, but little information has been received relative to the nature of the product.

Soluble sulfur is guaranteed as follows: —

		Per Cent.
Active ingredients,		85.00
Sodium polysulfide (Na_2S_4),	56.00	
Sodium thiosulfate,	25.00	
Free sulfur,	4.00	
Inert ingredients,		15.00
		100.00

Soluble sulfur is used considerably as a dormant spray, and is fairly satisfactory. It is exceedingly dangerous as a foliage spray unless an excess of lime is added. It has no marked superiority over lime-sulfur preparations, and has not supplanted them to any great degree.

Formulas for Application.

These various materials may all of them be applied in such quantities as to furnish approximately equivalent amounts of soluble sulfur. That this basis is not entirely sound is shown by the fact of difference in the ratio between polysulfide sulfur and thiosulfate sulfur. This difference should, of course, be considered when computing amounts of spray materials needed. On the basis of amounts of soluble sulfur equal to the standard application of 33° Baumé lime-sulfur concentrate (1–8 for dormant spray and 1–40 for summer spray), the following table is presented as showing suggested formulas for application: —

Material.	Soluble Sulfur (Per Cent).	Amount of Material in 50 Gallons of —			
		Dormant Spray.		Summer Spray.	
		Gallons.	Pounds.	Gallons.	Pounds.
Lime-sulfur concentrate,	24.75	5.556	59¾	1.22	13
Dry lime-sulfur,	50.00	–	29½[1]	–	6½
Barium tetrasulfide,	41.00	–	36[1]	–	8
Soluble sulfur,	51.35	–	28¾[1]	–[2]	–[2]

[1] These amounts are greater than are recommended by the manufacturers.
[2] Soluble sulfur should never be used as a summer spray, save with a great excess of lime.

3. Oil Sprays.

Oil sprays owe their insecticidal value chiefly to their asphyxiating effect. To a certain degree some of them may also have corrosive effect. Oil sprays likewise have a peculiar creeping power which enables the operator to cover the tree area even under unfavorable conditions. With most other contact insecticides, an insect to be killed must be actually "hit." These oils will be considered under two divisions: (1) emulsions, and (2) miscible oils.

(1) *Emulsions.*

The idea of combining soap, kerosene and water to form a stable mixture which could be safely applied to foliage undoubtedly occurred to growers very early. The first record of successful accomplishment, however, was in 1870 (26). Cook (27) records the attaining of a successful emulsion in experiments in 1877–78, and the formulas which he developed, bearing his name, were used for many years. The experiments of Riley and Hubbard, covering a number of years, carried forward this idea of a permanent mixture of kerosene and soap, and finally led to the production of the formula (28) which is used practically unchanged at the present day. This formula is as follows: —

Kerosene,	2 gallons
Water (soft),	1 gallon
Soap,	½ pound

The soap is dissolved in boiling water, and while the mixture is still hot the kerosene is added. The mixture is then churned, with a bucket pump with nozzle turned back into the liquid, until it has reached the consistency of a thick cream. Upon cooling, this thickens still further, and if properly made no free oil should separate out on the surface. This stock emulsion should last for some time, but it is much better to make it up only as needed. Where the water is hard it must be softened by the addition of borax or soda to prevent the lime or magnesium present from combining with the soap, which makes impossible an emulsion with the oil.

For spraying, dilute with 9–10 parts of water for aphids or other soft-bodied insects. Greater strengths are sometimes recommended for more resistant insects, or on trees when dormant.

Kerosene emulsion cannot be used safely in combination with other sprays (lead arsenate, lime-sulfur, etc.) owing to the breakdown of these materials in the presence of the soap, and the consequent liberation of free oil as well as other products of this double decomposition, which are dangerous to plants. This spray has now been largely superseded by the various nicotine solutions which have proved fully as efficient, are more easily prepared, can be used with safety to foliage, and, moreover, can be used in combination with other sprays, thus saving the trouble and expense of separate applications.

Carbolic Acid Emulsion. — This is a fairly effective remedy for certain root-feeding insects, such as root maggots of onion, cabbage and turnip. Its value for other purposes is somewhat limited. It is made as follows: —

Soap,	1 pound
Water,	1 gallon
Crude carbolic acid,	1 pint

This is prepared in the same way as is kerosene emulsion. It will not, however, attain the same curd-like consistency on standing as will kerosene emulsion, but remains in a more or less fluid condition. It should be diluted 1 part to 25–30 of water, and applied to the ground around the stems. Its use is restricted to small areas.

(2) *Miscible Oils.*

Miscible oils are formed from a mineral oil emulsified with a vegetable oil, with some alkali present. A stable stock emulsion is formed which mixes readily with water. These preparations are particularly adapted for use on old, rough-barked trees heavily encrusted with scale, as the oils spread over the bark more readily than do sulfur sprays. As the proportion of component parts is seldom furnished, and the manufacture of these oils is, in fact, more or less of a trade secret, the directions furnished by the manufacturer, both as to dilution and application, should be very carefully followed, whatever brand is used. In general, for dormant spraying these oils are diluted at the rate of 1 part to 12–15 parts of water.

The use of these oils has sometimes been followed by distinct injury, even where proper precautions have been taken and directions carefully followed. There are also reports of cumulative injury following repeated applications (29).

Miscible oils are relatively expensive dormant sprays in spite of the fact that the oil is said to go further in application than an equal amount of lime-sulfur. The uncertainty of the exact effect of the oils upon the health of the tree seems to favor the use of lime-sulfur, which has proved to be an efficient scale destroyer and can be used with safety.

4. Nicotine.

The value of tobacco in killing soft-bodied types of insects was discovered very early. In 1763 it was recommended in France for the control of plant lice, both tobacco powder and a water solution being applied. Its use in America was first recorded in 1814. Its effectiveness against soft-bodied insects and its safety to foliage of plants soon gave it a prominence which has continued undiminished to the present day. The most active principle of tobacco, and the one which gives it its value as an insecticide, is the alkaloid, nicotine. Soluble in water, entirely volatile, this is one of the most virulent poisons known.

(1) *Nicotine Sulfate.*

At the present time there are on the market a number of different commercial brands of nicotine, of various grades and strengths, which have to a large extent superseded the home-made preparations for general use. For garden and orchard operations the highly concentrated product containing 40 per cent of nicotine in the form of nicotine sulfate is at present extensively used. This is sold under various trade names, as "Black-Leaf 40," "Nicotine Sulfate 40%," etc. It has proved especially valuable for the control of many soft-bodied sucking insects. It can be applied at strengths required for efficient insect control without injury to foliage, and, moreover, it can be combined with other standard sprays (lime-sulfur, lead arsenate, etc.) without impairing either their efficiency or its own.

The amount of dilution recommended varies according to the resistance of the insects for the control of which it is applied. When used at a dilution of $\frac{3}{8}$–$\frac{1}{2}$ pint in 50 gallons of water (or, where only a few plants are to be treated, 1–1$\frac{1}{2}$ teaspoonfuls to 1 gallon of water), nicotine sulfate is efficient for the control of the average soft-bodied sucking insects of orchard and garden. When nicotine sprays are used alone in water, the addition of soap, 2–4 pounds to every 50 gallons of spray ($\frac{2}{3}$–1 ounce to 1 gallon), increases their spreading power and general effectiveness. Without soap the nicotine solutions show a tendency to form into drops which roll off the leaves without penetrating to and thoroughly wetting the insects. When nicotine sprays are used in combination with other insecticides the soap should *never* be added, owing to the breakdown of these chemicals in the presence of the strong alkali of the soap, with the consequent formation of compounds dangerous to foliage. (See page 12.)

Recent studies upon the effects of nicotine as an insecticide (30) have shown that, regardless of the form in which it is employed, the killing action is by paralysis, through the penetration of the nicotine vapors into the body of the insect. The effectiveness of nicotine sprays, therefore, depends on the amount of nicotine released. The experiments of Graham and Moore (31) have indicated that nicotine sulfate alone is nonvolatile, but if a solution of this material is treated with soap to render it alkaline, nicotine is at once released. Inasmuch, therefore, as the vapor of nicotine is the principal cause of the death of insects sprayed with tobacco solutions, the maximum efficiency of solutions containing nicotine sulfate can only be obtained by insuring that the spray is rendered alkaline. This is best attained by the addition of soap.

Within the last few years nicotine sulfate has been used, with lime and kaolin as carriers, in a dust application for the control of the walnut aphis and various truck crop insect pests, in California. In this form it has demonstrated a killing efficiency and rapidity of action superior to the spray applications. Furthermore, it can be applied faster and costs less than when applied in liquid form. So far as known, this has not as yet been used in Massachusetts. Its convenience of application and rather remarkable success as far as tried make it a promising form of application, especially in market gardens.

5. Pyrethrum.

Pyrethrum, Persian or Dalmatian insect powder, is the powdered flowers of *Chrysanthemum cinerariæfolium:* and Buhach, the California product, the powdered flowers of *C. coccineum*. The bright yellow powder owes its insecticidal value to the presence of certain volatile oils, contained in the flower heads, which are quite poisonous to insects, but apparently harmless to man. The material rapidly loses its effectiveness unless carefully stored in tight receptacles.

Pyrethrum is quite effective on soft-bodied insects and larvæ not protected by hairs, and is especially useful against young cabbage worms on cabbage and cauliflower plants which are soon to be harvested. It acts purely as a contact insecticide; the application must be made very thoroughly, therefore, to bring the material in actual contact with the insects to be treated. Its action is of short duration, the active principles being so volatile, and if used too sparingly some of the insects are merely numbed and eventually recover. Its usefulness is consequently very limited. It is rather costly, and is apt to vary as to purity.

Pyrethrum may be applied as a dry powder, pure or diluted with two to three times its bulk of flour, air-slaked lime, etc., which increases its adhesiveness. When diluted with any carrier it is well to keep the mixture in some tightly closed receptacle for twenty-four hours before using. It can also be applied as a spray at the rate of 1 ounce to 2 gallons of water, which should stand for twenty-four hours before using. For immediate use a decoction can be made by extracting in a quart of boiling water for from five to ten minutes, then adding the rest of the water.

B. FUNGICIDES.

Fungicides, as the term is applied in this bulletin, are substances used to kill or prevent the growth of fungi. They are applied to the host as spray, dust or fumes. For the most part, they are used as preventives and not cures, and therefore should be applied before the fungus is present on the surface of the host plant. As such, they protect by forming a poison barrier through which the threatening fungus cannot penetrate. Sometimes, however, they are used to destroy a pathogen (parasitic organism which causes the disease) which is already present; *e.g.*, powdery mildews and potato tuber organisms, in which case they are called disinfectants. In respect to use, then, we distinguish the two groups of fungicides: (I) Protective sprays or dusts, and (II) Disinfectants. In some cases, however, the same substance may be used for both purposes.

A good fungicide must have the following qualifications: —

1. It must kill or inhibit the growth of the pathogen at the concentration used.
2. It must not seriously injure the host plant at this same concentration.
3. If used as a spray it must adhere tenaciously to the surface of the host.
4. If used as a protective spray it must be practically insoluble in water after it dries on the host, but still go very gradually into solution under the influence of atmospheric conditions, host or pathogen.
5. It must be reasonably low in cost, both of material and of labor of application.

Most of the fungicides which are in general use owe their effectiveness to the presence in some form of one of three elements, — copper, sulfur or mercury. Formaldehyde, effective on account of its reducing qualities, is an exception. On this basis we shall divide them for convenience of discussion, as follows: —

I. PROTECTIVE APPLICATIONS.

1. Copper Fungicides.

This group of fungicides owes its effectiveness to the action of dissolved copper on the fungus. *Copper sulfate* was perhaps the first to come into general use. Its use for disinfection of smutted grain seed was perfected during the eighteenth century, and it is still used for that purpose in Europe and Australia.

Numerous *copper ammonia washes* have also been used with more or less success, mostly for the diseases of ornamental plants. The best known and most widely used of these washes are Eau celeste (cuprammonium sulfate) and ammoniacal copper carbonate. Since none of them has come into general use for farm or orchard crops, they need not be discussed further at this time.

The most popular and most extensively used of all copper fungicides is Bordeaux mixture. Home-made Bordeaux and commercial Bordeaux preparations are discussed separately below. Other copper fungicides have not been used enough to warrant separate discussion at this time.

(1) *Bordeaux Mixture.*

A thick paste made by mixing slaked lime with copper sulfate and applied to the grapevines of southern France for the purpose of warding off pilfering vagrants was the origin of Bordeaux mixture. Millardet, a professor of botany at Bordeaux, observed that the vines which were so treated suffered less from the downy mildew (*Plasmopora viticola*), which had been introduced from America into France about 1878. He began investigations, the results of which were published from 1882–85, and gave to the world its most widely used fungicide. The whole science of protective spraying began with his work. Soon after the effectiveness of Bordeaux mixture in controlling grape mildew had been demonstrated it was used with equal success for potato mildew and black rot of grape. In 1887 it was introduced into the United States by the United States Department of Agriculture, and its use extended to other diseases, until by the end of the century it had come to be regarded almost as a panacea for all fungous diseases of plants.

Formulas. — Bordeaux mixture as now used is still made from lime, copper sulfate (blue vitriol or bluestone) and water, but many different formulas for the proportions of the three ingredients have been proposed and used with success for various diseases. For Massachusetts crops and conditions the "4–4–50 formula" (4 pounds copper sulfate, 4 pounds quicklime and 50 gallons of water) is preferred, except in the case of the late sprays for potatoes and the spray for celery and grapes. In the latter cases 5–5–50 is recommended. Other formulas sometimes employed are 3–3–50, 5–4–50 and 6–4–50.

Chemical and Physical Properties. — When the dissolved copper sulfate and milk of lime are poured together, a reaction takes place between them resulting in the formation of a voluminous, gelatinous colloidal precipitate which does not settle rapidly to the bottom, but remains evenly distributed throughout the liquid and begins to settle only after standing undisturbed for several hours. As seen under the microscope it is a mass of very thin precipitation membranes, each in the form of a minute closed bag. After a few hours the gelatinous precipitate gradually becomes crystalline, the copper salt then appearing in the form of blue sphærocrystals (32) which do not remain afloat but settle to the bottom. In the best mixtures these membranes are most fully and abundantly formed, and as a result they "stand up" longest. In poor mixtures they settle to the bottom quickly. The ability of the mixture to perfectly cover the surface of the plant and to adhere tenaciously is dependent on the thoroughness of development of these precipitation membranes. It is therefore customary to gauge the excellency of the mixture to no inconsiderable extent by the length of time required for the precipitate to settle. Since even the best of mixtures will begin to settle after a few hours, it is essential that, to get the best results, Bordeaux be applied when freshly prepared. In the 4–4–50 Bordeaux there is a considerable excess of lime (as calcium hydroxide). When the spray dries on the leaves, the membranes which are spread over the surface conform tightly to every irregularity, much as a piece of thin wet tissue paper does when dried on a flat surface, and are not washed away readily by rains or removed by winds or other agencies. Bordeaux mixture surpasses all other fungicides in its ability to adhere to the host. Copper, its only active fungicidal agent, is in these dry membranes in a form almost insoluble in pure water. Since it cannot affect the fungus in an insoluble form, it must be brought into solution by some other agency. The following agencies have been found more or less active in this direction: —

1. Carbon dioxide from the air or from the plant, in solution in dew or rain drops, very gradually brings the copper into solution after the excess lime has been carbonated.
2. Ammonia and nitrous or nitric acids, present in small amounts in rain water, cause some solution of the copper.
3. Organic substances such as sugars, excreted in small quantities from the host cells, bring about very gradual solution.
4. There is some evidence that excretions from the fungus itself bring into solution enough copper to kill it.

Bordeaux Injury. — Bordeaux mixture falls short of the requirements of a good fungicide in that it frequently causes injury to the plant. The copper, brought into a soluble form in one or more of the ways enumerated above, enters the tissues of the plant directly through the epidermal walls by a process of osmosis, or through the stomates, lenticels or wounds. The invaded cells are killed by the toxic copper. On leaves this results in definite dead spots or irregular areas on margins or tips. More or less defoliation may result on fruit trees. On fruits, the death of some of the cells incites the production of protective cork cells, thus causing the rough russet areas which disfigure the surface of fruits such as apples or grapes. The extent of the injury varies with the hosts, being most severe on peaches and plums, and less so on apples, grapes and potatoes, but varying even here with the variety, weather conditions, stage of development and many other factors. No host seems to be immune under all conditions. Apparently, continued rainy weather increases injury. According to Hedrick (33) it is not prevented by the use of excess lime. The apple growers of Nova Scotia, however, use an excess lime Bordeaux, 3-10-50, which is found to be effective against scab, while it greatly reduces the russeting of fruit which results from use of the ordinary Bordeaux formula.

(2) *Commercial Bordeaux Preparations.*

The home preparation of Bordeaux mixture has a number of disadvantages: —

1. It involves a number of distinct operations which require considerable time.
2. The grower must keep in mind the proportions and various directions for preparation, or always have available the printed directions for the same (considered a nuisance by the average grower).
3. A number of suitable containers are required and are frequently not at hand when needed.
4. Few growers keep on hand a supply of quicklime, and even at the store it cannot always be obtained when wanted and of the quality wanted, especially in small quantities. When a barrel of lime is opened, it quickly carbonates, and the merchant in the small place is reluctant to break a barrel for a few pounds; while for the same reason the small grower does not wish to try to keep it at home.
5. The addition of a suitable insecticide in proper proportions increases the above objections.

The grower who uses large quantities of material may not hesitate to go to all this trouble, but the grower who operates on a small scale demands a fungicide which can be purchased ready-mixed, insecticide included, and which needs only to be diluted with water according to the directions on a convenient-sized package to be ready to apply. As early as 1893 — possibly earlier — Leggett & Brother of New York were putting on the market a dry Bordeaux. The Bowker Insecticide Company of Boston sold the concentrated paste "Bodo" at least as early as 1895. Since that time a great number of ready-mixed copper fungicides, usually with the insecticide included, have come into the market: *e.g.*, Pyrox, Caascu, Kiltone, Adheso, Bordo-Lead, Tuber Tonic, etc.

Guaranties. — In compliance with the insecticide act of 1910, and the various rules and regulations which have been promulgated in interpretation of it, every package of commercial copper fungicide (not materials such as copper sulfate (bluestone), etc.) has on the label a statement of (1) the percentage of metallic copper, and (2) the percentage of inert ingredients which it contains. Thus one well-known commercial brand of dry Bordeaux mixture, typical of most of them, is guaranteed as follows: —

Active ingredient, metallic copper, not less than 11 per cent.
Inert ingredients, not more than 89 per cent.

The percentage of copper varies in different brands from 1.5 per cent to as much as 25 per cent, being, of course, higher in the powdered copper fungicides than in those which contain various percentages of water.

In case an insecticide which contains copper, *e.g.*, Paris green, is included, the guaranty states the amount of copper present as copper of Bordeaux, and in addition may also state the total amount of metallic copper in both the fungicide and the insecticide. In this case the copper of Bordeaux should be used as the basis for calculating the value of the substance as a fungicide. To the purchaser who has been accustomed to thinking in terms of 4–4–50 Bordeaux mixture, this statement of ingredients may mean but little. For this reason, Table II on page 33 is presented, interpreting the guaranties in terms of the standard 4–4–50 Bordeaux.

Now, while copper is the only active fungicidal principle in many of these materials, the value of a fungicide does not vary directly as the percentage of metallic copper. The physical character after it is diluted determines its power to cover and adhere to the foliage of the plant to be protected. A fungicide which is washed from the foliage with the first rain is worthless. It is just as important that the commercial substitute shall on dilution produce a voluminous gelatinous precipitate which "stands up" well as it is for the home-made Bordeaux. Commercial fungicides which lack this physical character are deficient in adhesive quality, and are therefore inferior to home-made Bordeaux, although they may contain as much copper.

The final test of the efficiency of a fungicide, however, is its proved ability in the field or experimental plot to check the disease for which it is used. It has been demonstrated in the field that many of these commercial copper preparations have value, but we know of no case in which carefully confirmed and repeated experiments by unbiased experimenters have shown them to be equal in efficiency to freshly prepared Bordeaux mixture. They are being rapidly improved, however, and we do not despair of seeing on the market within a few years an entirely satisfactory commercial Bordeaux preparation.

(3) *Pickering Sprays.*

These fungicides, variously called Woburn Bordeaux, lime-water Bordeaux, or Pickering sprays, were devised and investigated by Bedford and Pickering (34) of the Woburn Experimental Fruit Farm in England. They are made by mixing clear saturated limewater with dilute solutions of copper sulfate. It is claimed that they are more economical than Bordeaux, in that they contain no excess lime, and the copper is more efficient. They are said to deteriorate less rapidly than Bordeaux and are more easily applied. They have been but little investigated or used in America. Cook (35), however, after three years' tests, finds them just as effective as Bordeaux 4–4–50 for control of diseases of potatoes and cranberries in Maine and New Jersey. They did not injure the foliage, possessed good covering and adhesive properties, and apparently possessed the same stimulative properties. These sprays have not been used in Massachusetts.

2. Sulfur Fungicides.

The use of sulfur for disinfection of diseased plants was a common horticultural practice many years before the discovery of Bordeaux mixture. The date of its origin has not been recorded. It was sometimes used alone as a dust, and sometimes mixed with other substances such as lime. Thus in 1833 William Kenrick (36) recommended a mixture of 1½ pints of sulfur, a piece of quicklime as large as the fist, and 2 gallons of boiling water as a remedy for mildew of grapes. "Grison liquid," first prepared by a Frenchman, Grison, in 1851, was considered at that time very effective, and is of historical interest as being a prototype of our modern lime-sulfur solution. A mixture of flowers of sulfur, freshly slaked lime, and water was boiled for ten minutes, and the supernatant liquid diluted and applied with a sponge, especially for control of mildews (37). In these early years, it should be noted, sulfur fungicides were never applied for protection, but as cures. The idea of protective spraying seems never to have been considered previous to the discovery of Bordeaux mixture.

(1) *Lime-sulfur Solutions.*

The introduction of lime-sulfur into California from Australia for the control of San José scale has been described elsewhere in this bulletin (page 13). Shortly after the peach growers of that State began using it for the scale (about 1880), they noted that peach leaf curl, a fungous disease, was also controlled by the dormant spray. It immediately began to come into general use as a fungicide, first in the West, then in the East. Its use as a protective spray for other plant diseases began about 1907, with the observation by Cordley of Oregon (38) that when the dormant spray for scale was applied so late that the apple leaves had already unfolded, the scab disease was also checked. Experiment stations in all parts of the country began to investigate it, and within a few years it had almost supplanted Bordeaux as a spray for the apple orchard and for many other crops.

Formulas for Application. — Most of the commercial brands of lime-sulfur test about 33° by the Baumé hydrometer. As a summer spray for the orchard, this should be diluted at the rate of 1¼ gallons to the barrel. If the home-made solution is used it should be tested with the hydrometer, and the rate of dilution ascertained by consulting the dilution table on page 15 of this bulletin. The dilution for dormant spray (*e.g.*, for peach-leaf curl) is the same as recommended for San José scale under insecticides on page 15.

Effect on the Fungus. — When lime-sulfur is exposed to the air on the foliage, a process of oxidation begins (see page 14 for the equations representing this process), which results in the liberation of sulfur in a very fine state of division. It is the opinion of most investigators that it is this nascent sulfur — not the sulfite, sulfate or thiosulfate of calcium — which is of fungicidal value. The free sulfur is probably gradually oxidized further to sulfur dioxide, which in water forms sulfurous, and on further oxidation, sulfuric acid. Both sulfurous and sulfuric acid are toxic to fungi. There is probably some chemical reaction between the acid and the protoplast of the fungus which results in the death of the latter.

Lime-sulfur Injury. — Lime-sulfur solutions are superior to Bordeaux mixture in that they cause less injury to foliage and rarely any fruit injury. Under certain conditions, however, which have not been very well defined, injury has resulted. Wallace (39) finds that this injury differs from that produced by Bordeaux in that it appears within a very short time after the spray is applied, and infers from this fact that it is due to the burning effect of the soluble polysulfides before the solution has dried on the leaves. It most often appears as irregular dead areas on the margins and tips of leaves where the liquid collects in larger drops and becomes more concentrated as it dries. Hence he warns against drenching the leaves. Addition of lime seems to have no effect on this injury. Injury is worse where the leaves have been previously wounded by insects, scab or other agencies, and the solution has direct access to the interior tissues. Different crops show different degrees of susceptibility to injury. Peach trees are often entirely defoliated by lime-sulfur of a strength that is entirely safe on apples. Pears show varietal differences in this respect, the Duchess being very easily injured. The orchardists of Nova Scotia have within the last few years almost abandoned the use of lime-sulfur spray because it causes a serious dropping of the fruit. Such damage has not been noted in this State.

(2) *Self-boiled Lime-sulfur.*

The use of mechanical mixtures of sulfur and lime dates far back into the history of plant-disease control. Freshly slaked lime provided a cheap base for a paste suitable for applying and distributing the flowers of sulfur. The only sources of heat in these early mixtures were the hot water sometimes recommended for mixing, and the reaction of the lime in slaking. But sulfur fungicides were almost forgotten during the quarter century which followed the introduction of Bordeaux. The use of the self-boiled mixture in its present form was revived by Scott (40) of the United States Department of Agriculture in 1907 for the control of brown rot and scab of peaches. Bordeaux mixture and sulfur fungicides which contain sulfur in solution were found to be highly injurious to peach foliage when applied at a concentration sufficient to control these diseases. Scott found that this mixture, which contains but a very small percentage of soluble sulfur at most, gave good control of the diseases and caused no burning of the foliage. Within a few years it became the most extensively used and successful fungicide for peaches and plums throughout the country. Objections to the use of self-boiled lime-sulfur are: —

1. The poor suspension of ingredients necessitates constant strong agitation and frequent cleaning of nozzles.
2. Especially in dry seasons, it leaves deposits on the fruit if applied within a few weeks of ripening.
3. The labor costs of preparation are exceedingly heavy.

Formula. — The 8–8–50 formula is now used almost exclusively (8 pounds of quicklime, 8 pounds of sulfur, 50 gallons of water).

Physical and Chemical Properties. — This is a mechanical mixture, or, at most, there is only a minimum amount of chemical union between the lime and sulfur. In explanation of the part played by the lime, Scott (41) says: "The intense heat seems to break up the particles of sulphur into about the physical condition of precipitated sulphur, and the violent boiling makes a good mechanical mixture of the lime and sulphur. The finely divided sulphur is depended upon for the fungicidal action rather than the sulphids in solution." The lime also gives adhesive qualities.

The result, then, is the same in the end, whether the commercial lime-sulfur or the self-boiled is used, — sulfur in a finely divided form is deposited on the leaves, and the fungus is killed or checked in its development as described above (page 26).

(3) *Sulfur Dust.*

The use of sulfur dust as a protective application was first begun in New York State and most energetically pushed by Whetzel, Reddick, Blodgett *et al.* of the Cornell Experiment Station. Since its beginning in New York State in 1912, experiment station workers in Michigan, Georgia, Illinois, Virginia, West Virginia, Maryland, Nova Scotia, and Ontario have conducted orchard tests with the dust as a possible substitute for the lime-sulfur and lead arsenate spray. The published results from New York, Michigan, Illinois, Nova Scotia, and Ontario indicate an efficiency equal to that of lime-sulfur and lead arsenate for the control of apple scab and codling moth. Virginia and West Virginia workers report satisfactory control of codling moth, but find it unsatisfactory for black rot, bitter rot, rust and scab of apples, and (in Virginia) for brown rot of peaches. Peach dusting experiments in Georgia and West Virginia indicate an efficiency against scab and curculio equal to that of the sulfur spray, and slightly less control for brown rot. Results in Maryland are less favorable to control of orchard fungi by dusting than by spraying. Whether it is better to dust than to spray and just what diseases can be better controlled by dusting are questions that have by no means been fully answered. Dusting has many opponents as well as advocates among both scientists and practical growers. No great body of experience has yet been developed in Massachusetts, and lacking this, the question cannot be satisfactorily answered.

Formulas. — The sulfur dust is still in the experimental stage, and the proportion of sulfur to lead arsenate or to inert "fillers" has not become standardized. The most used formula calls for 90 parts of very finely ground sulfur to 10 parts of the fluffy type powdered lead arsenate. "Fillers," such as hydrated lime, "terra alba," etc., have been used in some places. The material may be bought ready-mixed or mixed with machine at home. Various types of dusting machines for application are now on the market.

II. DISINFECTANTS.

1. Corrosive Sublimate.

This fungicide (known also as mercuric chloride or mercury bichloride) is used only as a disinfectant. Its toxicity to foliage and its solubility prevent its use as a spray. Its only use in Massachusetts on the farm or in the orchard is for disinfection of seed potatoes and of wounds on trees produced by pruning, canker removal, etc. Corrosive sublimate is a white, dry crystalline salt which may be secured in the market in the powdered form or as tablets. The tablets, which are commonly purchased at drug stores, are of such a size that one tablet produces a 1–1,000 solution when dissolved in a pint of water.

Formula. — Corrosive sublimate for all purposes is used at a dilution of 1–1,000. This dilution may be secured by dissolving 2 ounces of the salt in 15 gallons of water.

2. Formaldehyde.

Formaldehyde is a toxic gas extensively used as a disinfectant since 1888. Its ability to kill fungi and bacteria is dependent on its reducing power, that is, on its power to remove oxygen from matter with which it comes in contact. The formaldehyde (formalin) which is sold on the market is a solution of the gas in water. According to the United States standard of purity for interstate commerce, 37 per cent of the weight must be formaldehyde gas. Although commonly spoken of as a 40 per cent solution, analyses of samples in recent years have shown it to be frequently much lower, even down to 32 per cent. Also, a white sediment (paraformaldehyde) is frequently deposited in the bottom of containers. Since the formation of paraformaldehyde lowers the percentage of formaldehyde, the solution should be warmed until the white sediment has disappeared before it is used. Commercial formaldehyde also contains 5–10 per cent or more of wood alcohol, but this does not impair its fungicidal value. The fumes are very irritating to the nose and eyes, but it is a safer disinfectant than corrosive sublimate.

Uses and Formulas. — The use of formaldehyde (formalin), at a dilution of 1 part in 240 (1 pint to 30 gallons), for disinfection of seed potatoes against scab has now been almost discontinued in favor of corrosive sublimate because the latter is also effective against black scurf.

For disinfection of grain seed against smut, a dilution of 1–240 is recommended except where the spray method is used. In the latter case equal parts of commercial formaldehyde and water are used.

For onion smut the 1–128 formula has been recommended most extensively.

C. COMBINED INSECTICIDES AND FUNGICIDES.

Most farm and orchard crops suffer from both insect pests and fungous diseases. This necessitates the use of both an insecticide and a fungicide on the same plant. Frequently, also, the presence at the same time of more than one species of insect requires the application of both a stomach poison and a contact insecticide. If the crucial time for application of more than one should be approximately the same, it is usually possible and profitable to combine them in a single application. Such a combination results in the saving of one-half to two-thirds of the time required for separate applications, and since labor is usually the big item of expense in spraying, the cost is materially diminished. Unfortunately, however, it is not possible to combine indiscriminately the various substances which are used as fungicides and insecticides. Frequently, in combining two or more of them a reaction takes place which results in —

1. Complete or partial neutralization of the beneficial qualities of one or more.
2. Formation of a new compound which will injure the plant.
3. Liberation of some harmful element.

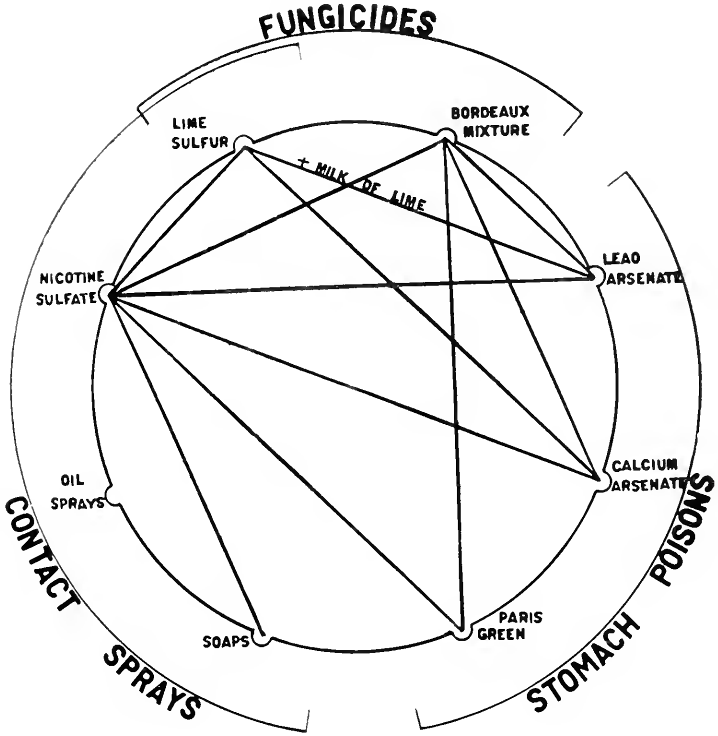
Such substances are said to be incompatible. It should not be understood, however, that chemical combinations between fungicides and insecticides are always harmful or undesirable. Sometimes the reaction is known to increase rather than decrease the fungicidal value; in other combinations the substances have no effect on each other. The possible combinations are discussed below, and the compatibilities graphically represented in the diagram opposite this page.

In making combinations, the formulas and methods of preparation should be the same as have been previously described for each material.

1. Bordeaux Mixture with Lead Arsenate or Calcium Arsenate.

Bordeaux mixture can be combined safely with lead arsenate or calcium arsenate. There is, however, some experimental evidence to show that, in such a combination, the fungicide inhibits the action of the arsenical to a considerable extent (42). On the other hand, the excess lime of the Bordeaux combines with any arsenic rendered soluble by atmospheric conditions, thus diminishing the danger of foliage injury. Owing to its superior adhesive qualities, lead arsenate is better than calcium arsenate for combination with Bordeaux. On the other hand, calcium arsenate is much cheaper. The choice between these, therefore, seems to be a matter of personal preference.

MIXING SPRAY MATERIALS.



DESIRABLE COMBINATIONS

UNDESIRABLE COMBINATIONS

ADAPTED FROM CIR. 195 CAL. EXP STA.

2. Bordeaux Mixture with Paris Green.

These two can be combined safely. The excess lime in the Bordeaux unites with any free arsenic which may be present in the insecticide, and thus protects the leaves from arsenical injury. Paris green also has fungicidal value (43); the combination, therefore, is slightly more beneficial than the fungicide alone. No injurious or neutralizing reaction occurs between the two materials.

3. Proprietary Copper Preparations.

Most of these preparations have the constituents of Bordeaux mixture with the addition of a stomach poison, usually lead arsenate but occasionally Paris green. Both are compatible with the fungicide, and the effect should be the same as previously described for combinations of these arsenicals with Bordeaux.

The tendency of manufacturers of commercial copper mixtures has been to recommend the dilution of their product to a copper content lower than that of 4–4–50 Bordeaux. Within recent years, however, they have been increasing the amount of copper and recommending a more concentrated application. The percentage of arsenic has been more nearly that recommended by entomologists for control of insects. Thus when the purchaser has mixed in his spray tank enough of a low-copper preparation to conform to the standard given in Table II, he will have the arsenical in great excess of the amount needed, and therefore is paying a very high price for his arsenic.

The manufacturer is required to state on the label the amount of arsenic which is present, either as metallic arsenic or as arsenic or arsenous oxide. As an aid to the purchaser in making dilutions and in estimating the value of the preparation, Table II shows the guaranteed arsenic content and the amount of material required to furnish arsenic equivalent to the standard formula (0.293 pound of metallic arsenic to 50 gallons of water).

4. Bordeaux Mixture with Lead Arsenate or Calcium Arsenate and Nicotine Sulfate.

These materials are compatible and make an efficient combination. Some hesitancy was felt at first in regard to the safety of such a combination, owing to the supposed reaction between copper and tobacco compounds, and the possibility of serious burning of foliage by the resulting products (44). It has been demonstrated, however, by chemical analyses and extensive field tests, that there is no objectionable reaction when nicotine in the form of sulfate is combined with Bordeaux mixture; hence this combination may be used (45).

In preparing this spray the nicotine sulfate should be added just before application, and thorough agitation should be given to insure an even distribution of the highly concentrated nicotine product throughout the mixture.

Soap should *never* be added when nicotine sulfate is used in this combination.

5. Lime-sulfur with Lead Arsenate or Calcium Arsenate.

The great extent to which sulfur compounds have supplanted copper sprays as fungicides has made this combination probably the most widely used and most important in practice to-day.

When lead arsenate is added to lime-sulfur, a chemical reaction takes place causing more or less decomposition of both materials. This reaction does not decrease the fungicidal value of the mixture. In fact, Wallace (46), in his investigation of apple scab control, found that the addition of lead arsenate increased the fungicidal action of the lime-sulfur by about 50 per cent. The fact has long been recognized that arsenate of lead alone has some value as a fungicide.

The effect of this reaction upon the value of the combination as an insecticide, however, is unfavorable. In the case of the *acid* lead arsenate (90 per cent of that on the market to-day is of this type), the reaction with lime-sulfur results in the formation of a considerable percentage of soluble arsenic, with the consequent danger of severe foliage injury. The addition of milk of lime, 5 pounds to 50 gallons of the mixture, checks this reaction and so reduces the tendency to burn foliage (47). The arsenate of lead should be added to the milk of lime, and the two thoroughly mixed together and then poured into the lime-sulfur solution so that the protective agent may be present when the two active ingredients are brought together.

When calcium arsenate is used with lime-sulfur, so far as known no chemical change takes place which decreases the value of the combination either as an insecticide or as a fungicide. The addition of milk of lime, however, as a precautionary measure seems advisable.

6. Lime-sulfur with Lead Arsenate or Calcium Arsenate and Nicotine Sulfate.

These materials can be combined successfully and effectively. The presence of nicotine sulfate is not known to modify any of the reactions mentioned under 5, and the recommendations there made apply to this combination also.

The suggestions relative to the addition of nicotine sulfate to the spray, and caution regarding the use of soap, apply here as in 4 above.

TABLE II. — *Combined and Uncombined Insecticides and Fungicides.*

Amounts required to furnish metallic copper and arsenic in quantities equivalent to those in a standard 4-4-50 Bordeaux with arsenical.

COMMERCIAL BORDEAUX.			COMMERCIAL ARSENATES.		
Guaranty of Metallic Copper (Per Cent).	For 50 Gallons of Spray (Pounds).	For 1 Gallon of Spray (Ounces).	Guaranty of Metallic Arsenic (Per Cent).	For 50 Gallons of Spray (Pounds).	For 1 Gallon of Spray (Ounces).
25 0	4 00	1 25	30 0	1 00	.25
20 0	5 00	1.50	25 0	1 25	.25
15.0	6 75	2 25	20 0	1 50	.50
12 5	8.25	2 50	17.5	1 75	.50
10 0	10.25	3 25	15 0	2 00	.75
9 0	11 25	3 75	10 0	3 00	1 00
8.0	12 75	4 00	9.0	3.25	1 00
7.5	13 50	4.25	8.0	3 75	1.00
7.0	14 50	5.00	7.0	4.25	1 25
6.5	16 00	5 00	6.0	5 00	1.50
6.0	17.00	5.50	5.0	5 75	2.00
5.5	18.50	6 00	4.5	6.50	2.00
5.0	20.00	6 50	4.0	7 00	2 50
4.5	22.50	7.00	3 5	8.00	2.75
4 0	25.50	8.00	3 0	10.00	3 25
3.5	29.00	9.00	2 5	12.00	3 75
3.0	34.00	12.00	2.0	15.00	4.75
2.5	41.00	13 00	1.5	19 50	6.25
2.0	51 00	16.00	1.0	29 00	9 50
1.5	68.00	22.00	.5	58 00	19.00

APPENDIX.

Commercial Bordeaux Mixtures.

Brands and Guaranteed Composition.

Manufacturer and Brand.	Metallic Copper (Cu) (Per Cent).
J. A. Blanchard Company, New York City: —	
Lion Brand,	4.00
Lion Brand (dry),	11.00
Corona Chemical Company, Milwaukee, Wis.: —	
Corona Dry Bordeaux Mixture,	11.00
Dow Chemical Company, Midland, Mich.: —	
No brand name given,	25.00
Grasseli Chemical Company, Cleveland, Ohio: —	
Bordeaux mixture (dry),	13.00
Sherwin-Williams Company, Cleveland, Ohio: —	
Fungi-Bordo,	11.00
Sterling Chemical Company, Cambridge, Mass.: —	
Sterlingworth (liquid),	3.00
Sterlingworth (dry),	10.00

Commercial Bordeaux with Insecticides.

Brands and Guaranteed Composition.

Manufacturer and Brand.	Metallic Copper (Cu) (Per Cent).	Metallic Arsenic (As) (Per Cent).
Bowker Insecticide Company, Boston, Mass.: —		
Pyrox,	2.30	3.42
Detroit White Lead Works, Detroit, Mich.: —		
Rogers Leaded Bordo,	10.50	2.75
Frost Insecticide Company, Arlington, Mass.: —		
Bordo Lead,	5.00	2.90
Interstate Chemical Company, Jersey City, N. J.: —		
Bordo Lead,	2.00	5.00
Sherwin-Williams Co., Cleveland, Ohio: —		
Pestroy,	10.50	2.75
Tuber Tonic,	6.00	24.00
Sterling Chemical Company, Cambridge, Mass.: —		
Sterlingworth Ar-Bo,	4.00	1.65
Thomsen Chemical Company, Baltimore, Md.: —		
Bordo Lead, Orchard Brand,	5.40	3.90
Toledo Rex Spray Company, Toledo, Ohio: —		
NuRexo,	12.70	3.60
Leggett & Brother, New York City: —		
Dry Bordeaux and Paris Green Compound,	7.00	12.50
Sterling Chemical Company, Cambridge, Mass.: —		
Sterlingworth Dry Bordeaux and Paris Green Compound,	9.00	2.00

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MASSACHUSETTS

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INSECTICIDES AND FUNGICIDES

FOR FARM AND ORCHARD CROPS IN MASSACHUSETTS

By E. B. HOLLAND, A. I. BOURNE
and P. J. ANDERSON

The successful production of farm and orchard crops depends in large measure on the protection afforded against injurious insects and diseases. For this purpose a large number of insecticides, fungicides and combinations of the two have appeared on the market. It is to aid the purchaser in interpreting the guaranties of these materials that this bulletin is issued. Tables giving standard formulas for application, a diagram showing safe and dangerous mixtures of materials, and a table showing the guaranties of a number of proprietary articles are included. The more complete bulletin will be sent on request.

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INSECTICIDES AND FUNGICIDES FOR FARM AND ORCHARD CROPS IN MASSACHUSETTS.

BY E. B. HOLLAND, A. I. BOURNE AND P. J. ANDERSON.

INTRODUCTION.

The insecticides and fungicides on the Massachusetts markets are sold under the regulations of the national insecticide act of 1910. By this act all materials of this kind must bear a guaranteed analysis. In the case of Paris green and lead arsenate the law has established certain standards of composition. In the case of other poisons containing arsenic, a regulation made under the terms of the insecticide act specifies the form of statement which must be made in the guaranty. For all other insecticidal and fungicidal materials the guaranty may take one of two forms: —

1. Either a statement of inert substances contained, that is, of materials having no value in killing or repelling insects or in controlling fungous diseases; or —

2. A statement of the active ingredients contained, expressed in terms of percentages, together with the percentage of the total inert ingredients.

In practice, manufacturers of insecticides and fungicides almost universally guarantee the percentage of each active ingredient, together with the percentage of the total inert substances present.

While there is no indication that insecticides and fungicides as sold in Massachusetts fail to live up to their guaranties, there is plenty of evidence that purchasers of such articles fail oftentimes to interpret the guaranties. This is particularly true in the case of articles for which standards have not been defined by law.

The complexity of the problem is truly marvelous. Arsenic has been used in a variety of forms, — combined with lead, with lime, with zinc, with copper; white, pink, gray or green in color; in paste, in heavy powder or in bulky powder. Soaps in great variety are used. Emulsified oils are in the market. Copper is used in a variety of concentrations; so also is nicotine (tobacco). Sulfur in a variety of forms, with lime and without lime, comes on the market. Then there is a great galaxy of commercial preparations, typically combining insecticide and fungicide in one application, and all put out for the purpose of giving to farmer or gardener, in *convenient* form, something which will do the work at least moderately well. No wonder that the government finds it difficult to fix standards, and that purchasers find it difficult to interpret guaranties!

The successful production of farm and orchard crops depends in large measure on the protection afforded against injurious insects and bacterial and fungous diseases. Obviously, there is no remedy — that is, no panacea for all noxious insects and parasitic diseases of plant life — that would not also destroy the host. The method of treatment, therefore, must be essentially specific, and for convenience will be divided into three major groups: (A) Insecticides, (B) Fungicides, and (C) Combined insecticides and fungicides.

A. INSECTICIDES.

The injurious insects that infest the crops under consideration are of two distinct types as determined by their mode of feeding, *i.e.*, biting and sucking. The former consumes organized tissue, and the latter draws sustenance from plant juices. The respective treatment of the two types is necessarily different and warrants a division of insecticides into (I) Stomach poisons for biting insects, and (II) Contact poisons for sucking insects.

The acknowledged requisites for an insecticide are —

1. Non-toxicity as to plant.
2. Effectiveness in destroying the insect.
3. Adhesiveness or persistence under all weather conditions.
4. Fineness of particles and a light flocculent character (when insoluble) to insure a high power of suspension and uniform distribution.
5. Ability to indicate the surface covered.
6. Reasonable cost.

The factors that facilitate distribution naturally differ somewhat in soluble and insoluble products, dust and spray applications. These attributes comprise a standard for judging insecticides, and apply in principle to fungicides as well.

I. Stomach Poisons for Biting Insects.

Nearly all stomach poisons employed to-day are compounds of arsenic, and this has led to the general use of the term arsenicals for this group of insecticides. The sprays consist of minute particles of poison suspended in the water or other vehicle, which are deposited upon the food of the insect and adhere to it upon drying.

There are two forms of arsenical stomach poisons, — the arsenites and arsenates. The former are more active poisons, but relatively unstable, and more likely to cause injury to the plant. Chiefly for this reason the arsenates are to-day largely used. Paris green is the principal arsenite now on the market, whereas lead arsenate and calcium arsenate are the most important members of the other class.

Composition and Properties of Arsenicals.

(1) *Paris Green.*

Form of Guaranty. — The form of guaranty under which Paris green is sold is as follows: —

	Per Cent.
Total arsenous oxide, not less than	50.00
Water soluble arsenous oxide, not more than	3.50

This corresponds to the Federal standard. Paris green as offered for sale in this State fully meets this guaranty. The statement of total arsenous oxide in the guaranty may be taken as representing the effectiveness of the material in terms of the killing principle which it contains. Soluble arsenic, however, injures the foliage; hence the statement of soluble arsenous oxide indicates the maximum amount of injurious compounds of arsenic present.

Because of its chemical nature, Paris green is liable to cause foliage injury unless applied with lime. Physically it has a low power of suspension, but admits of reasonably effective distribution. It does not color the foliage; hence without lime it does not indicate sprayed and unsprayed portions of the plant. It is fairly adhesive and persistent under average weather conditions.

(2) *Lead Arsenate.*

Form of Guaranty. — The usual form of guaranty under which dry lead arsenate is sold is substantially as follows: —

		Per Cent.
Active ingredients: —		
Lead arsenate, not less than		*98.00*
Total arsenic pentoxide, not less than	31.00	
Total arsenic (as metallic), not less than	*20.20*	
Inert ingredients, not more than		2.00
		100.00

Water Soluble.

	Per Cent.
Soluble arsenic pentoxide, not more than	0.75
Soluble arsenic (as metallic), not more than	*0.50*

The essential statements in the guaranty are those italicized. Naturally the greater the percentage of total arsenic contained in the product the less will be the amount needed to secure satisfactory results. Conversely, the greater the proportion of water soluble arsenic the greater will be the liability of foliage injury unless lime is used with the lead arsenate to prevent foliage burning.

Lead arsenate, as shown above, is of low arsenic content, and that practically insoluble in water, and is safe to apply to most plants. It is slow acting but effective, its fineness of particles and light flocculent character insuring a high power of suspension and uniform distribution. The white mixture readily indicates the leaf surface covered, and on drying it forms a film which adheres with great persistence.

(3) *Calcium Arsenate.*

Form of Guaranty. — Calcium arsenate is usually sold under the following form of guaranty: —

		Per Cent.
Active ingredients: —		
Tricalcium arsenate, not less than		*76.00*
Total arsenic pentoxide, not less than	42.50	
Total arsenic (as metallic), not less than	*28.00*	
Inert ingredients, not more than		24.00
		100.00

Water Soluble.

	Per Cent.
Soluble arsenic pentoxide, not more than	1.50
Soluble arsenic (as metallic), not more than	*1.00*

Because of the higher percentage of total arsenic contained in calcium arsenate, it is evident that a smaller quantity of this material may be used than of lead arsenate to obtain satisfactory results.

Calcium arsenate is an effective poison, its fine particles and light flocculent character insuring a fair power of suspension and uniform distribution. The white mixture indicates the leaf surface covered, and is persistent under average weather conditions.

Standard Formulas for Application.

There is a great difference in the rapidity of killing power between arsenates and arsenites. For this reason the two classes of materials cannot be compared on the basis of arsenic contained. The following table represents basic quantities of the several materials of standard or near-standard composition which may be used. Naturally the amounts to be used must be varied to adapt the spray for use against various kinds of insects and on different kinds of plants.

Arsenical.	Composition of Arsenical.		Amount of Arsenical in Spray.		Pounds of Metallic Arsenic per Barrel of Spray.
	Arsenic Oxides (Per Cent).	Equivalent in Metallic Arsenic (Per Cent).	Per Barrel (50 Gallons) (Pounds).	Per Gallon (Ounces).	
Arsenites: —					
Paris green,	50.00 (As_2O_3)	37.87	.333	1/10	0.126
Arsenates: —					
Dry acid lead arsenate,	30.00 (As_2O_5)	19.56	1.5	1/2	0.3–
Dry basic calcium arsenate,	40.00 (As_2O_5)	26.08	1.0	1/3	0.3–

Any arsenite of known composition may be applied in quantity to furnish metallic arsenic equal to that in an application of Paris green, whereas any arsenate of known composition may be applied to furnish metallic arsenic equivalent in amount to that used in arsenate of lead.

For most farm and orchard crops it is unwise to use any arsenical without protecting the plant against foliage injury. The addition of milk of lime affords protection against this arsenical injury. Four pounds of high-grade quicklime (95 per cent CaO) are generally sufficient for 50 gallons (1 barrel) of spray. The lime should be slaked carefully, sieved, diluted to nearly 50 gallons, and the arsenical added slowly, with thorough agitation, *immediately* before application.

II. Contact Poisons for Sucking Insects.

Contact poisons include a large number of diversified compounds (solid, liquid and gaseous), and their effectiveness may depend upon more than one property. The compound may act in any of the following ways: —

1. Glue the insect down.
2. Attack the body, dissolving fat and even muscle, precipitating proteids, etc.
3. Act as a narcotic, paralyzant or anæsthetic.
4. Asphyxiate the insect by closing the breathing pores (spiracles or tracheæ), or, by saturating the body, prevent necessary aeration.

These indicate some of the possibilities. These poisons are generally soluble or emulsified products. They kill only by contact; hence liberal and thorough application is necessary to insure effectiveness. The most important contact poisons are (1) soaps, (2) sulfur sprays, (3) oil sprays, and (4) nicotine.

Composition and Properties of Contact Poisons.

(*1*) *Soaps.*

Whale-oil or fish-oil soaps are those most generally used in spraying, although common laundry soap may also be used. There are also soap preparations with rosin, making a so-called "soap sticker," and mixtures of soap with nicotine, the effect of the nicotine being to make the whole spray more effective against certain types of insects, and of the soap, to volatilize the nicotine, and in this way increase the rapidity of its action. These materials are not standardized. They may be purchased merely as "soaps," and hence need not come under the provisions of the insecticide act of 1910. The guaranty of analysis, if given, has but little significance.

Standard Formulas for Application.

Product.	Use.	Quantity.
Whale-oil or fish-oil soap,	Summer spray against plant lice,	1 pound to 6 to 8 gallons water.
Laundry soap,	Summer spray against plant lice,	1 pound to 2 to 4 gallons water.
Rosin fish-oil soap,	Plants having waxy and smooth foliage (cabbages, etc.). Used with arsenical.	3 to 4 pounds per 50 gallons of spray.

Except for plants having smooth, waxy foliage, soaps should not be mixed with either Bordeaux mixture or arsenicals. In the one case "calcium soaps" are produced, which are insoluble and clog the spraying machinery; and in the other, soluble arsenic is formed, which burns the foliage.

(2) *Sulfur Compounds.*

These products are of value both as contact insecticides and fungicides. A number of brands appear on the market, which usually fall in one of two groups, — namely, lime-sulfur concentrate, in which the sulfur is carried in solution, and dry lime-sulfur, prepared as a dry powder, but applied as a spray.

Form of Guaranty, Lime-sulfur Concentrate. — The guaranty of this product is usually stated in terms of degrees Baumé, the usual strength being 33°, with about 25 per cent sulfur in solution. This statement indicates the strength of the concentrate, a low degree Baumé showing a weaker solution with a smaller amount of soluble sulfur, whereas a high test expressed in degrees Baumé shows more soluble materials. It is the soluble sulfur which is considered to have effect against insects, notably San José scale. This material, as well as other similar materials, also contains free sulfur, of practically no value as an insecticide, but of considerable value as a fungicide.

Form of Guaranty, Dry Lime-sulfur. — Dry lime-sulfur is usually guaranteed about as follows: —

		Per Cent.
Active ingredients,		80.00
Calcium polysulfide,	63.00	
Calcium thiosulfate,	5.00	
Free sulfur,	12.00	
Inert ingredients,		20.00
		100.00

The calcium polysulfide and calcium thiosulfate together represent the soluble sulfur compounds, and are about the equivalent of 50 per cent soluble sulfur. This fact is of importance in estimating the amount of this product needed as compared to the lime-sulfur concentrate.

These two materials may be applied in such quantities as to furnish approximately equivalent amounts of soluble sulfur. On the basis of amounts of soluble sulfur equal to the standard application of 33° Baumé lime-sulfur concentrate, the following table is presented as showing suggested formulas for application: —

Formulas for Application.

Material.	Soluble Sulfur (Per Cent).	Amount of Material in 50 Gallons of —			
		Dormant Spray.		Summer Spray.	
		Gallons.	Pounds.	Gallons.	Pounds.
Lime-sulfur concentrate,	24.75	5.556	$59\frac{3}{4}$	1.22	13
Dry lime-sulfur,	50.00	-	$29\frac{1}{2}$[1]	-	$6\frac{1}{2}$

[1] This amount is greater than is recommended by the manufacturers.

For the different strengths of lime-sulfur concentrate which may be prepared or which are already on the market, Table I, on page 14, gives information as to formula for application.

(3) *Oil Sprays.*

Oil sprays probably owe their insecticidal value chiefly to their asphyxiating effect. To a certain degree some of them may also have corrosive effect. Oil sprays have a peculiar creeping power which enables the operator to cover the tree even under unfavorable spraying conditions, while with most other contact insecticides an insect to be killed must be actually hit. The oil sprays, however, are not sold under any standard form of guaranty.

(4) *Nicotine.*

A number of different commercial brands of nicotine of various grades and strength are now on the market. For garden and orchard operations the highly concentrated product guaranteeing 40 per cent of nicotine in the form of nicotine sulfate is at present most extensively used. This has proved especially valuable for the control of many soft-bodied insects.

B. FUNGICIDES.

Fungicides are substances used to kill or prevent the growth of fungi. They are applied to the host as spray, dust or fumes. For the most part, they are used as preventives and not cures, and therefore should be applied before the fungus is present on the surface of the host plant. As such, they protect by forming a poison barrier through which the threatening fungus cannot penetrate. Sometimes, however, they are used to destroy a pathogen (parasitic organism which causes the disease) which is already present, — *e.g.*, powdery mildews and potato tuber organisms, — in which case they are called disinfectants. In respect to use, then, we distinguish the two groups of fungicides, — protective sprays or dusts, and disinfectants. In some cases, however, the same substance may be used for both purposes.

A good fungicide must have the following qualifications: —

1. It must kill or inhibit the growth of the pathogen at the concentration used
2. It must not seriously injure the host plant at this same concentration.
3. If used as a spray, it must adhere tenaciously to the surface of the host.
4. If used as a protective spray, it must be practically insoluble in water after it dries on the host, but still go very gradually into solution under the influence of atmospheric conditions, host or pathogen.
5. It must be reaonably low in cost, both of material and of labor of application.

Most of the fungicides which are in general use owe their effectiveness to the presence in some form of one of three elements, — copper, sulfur or mercury. Formaldehyde, effective on account of its reducing qualities, is an exception.

1. Copper Fungicides.

(1) *Bordeaux Mixture.*

The most popular and most extensively used of all copper fungicides is Bordeaux mixture. For Massachusetts crops and conditions, the 4–4–50 formula (4 pounds copper sulfate, 4 pounds quicklime and 50 gallons of water) is preferred, except in the case of the late sprays for potatoes and the spray for celery and grapes. In the latter cases 5–5–50 is recommended.

Copper is the only active fungicidal agent in this mixture. The copper sulfate as purchased is approximately of standard composition. There is often great difficulty, however, in obtaining high quality lime for the making of Bordeaux mixture, especially where spraying is done on a small scale. It is partly for this reason that commercial Bordeaux preparations have come on to the market.

(2) *Commercial Bordeaux Preparations.*

The home preparation of Bordeaux mixture has a number of disadvantages: —

1. It involves a number of distinct operations which require considerable time.
2. The grower must keep in mind the proportions and various directions for preparation, or always have available the printed directions for the same (considered a nuisance by the average grower).
3. A number of suitable containers are required, and are frequently not at hand when needed.
4. Few growers keep on hand a supply of quicklime, and even at the store it cannot always be obtained when wanted and of the quality wanted, especially in small quantities. When a barrel of lime is opened it quickly carbonates, and the merchant in the small place is reluctant to break a barrel for a few pounds, while for the same reason the small grower does not wish to try to keep it at home.

Guaranties. — In compliance with the insecticide act of 1910, and the various rules and regulations which have been promulgated in interpretation of it, every package of commercial copper fungicide (not materials such as copper sulfate (bluestone), etc.) has on the label a statement of (1) the percentage of metallic copper, and (2) the percentage of inert ingredients which it contains. Thus one well-known commercial brand of dry Bordeaux mixture, typical of most of them, is guaranteed as follows: —

	Per Cent.
Active ingredients, copper (as metallic), not less than	11
Inert ingredients, not more than	89

The percentage of copper varies in different brands from 1.5 per cent to as much as 25 per cent, being, of course, higher in the powdered copper fungicides than in those which contain various percentages of water.

In case an insecticide which contains copper, *e.g.*, Paris green, is included, the guaranty states the amount of copper present as copper of Bordeaux, and in addition may also state the total amount of copper (as metallic) in both the fungicide and the insecticide. In this case the copper of Bordeaux should be used as the basis for calculating the value of the substance as a fungicide. To the purchaser who has been accustomed to thinking in terms of 4–4–50 Bordeaux mixture, this statement of ingredients may mean but little. For this reason, Table II, on page 15, is presented, interpreting the guaranties in terms of the standard 4–4–50 Bordeaux.

2. Sulfur Fungicides.

As previously stated, sulfur compounds have both fungicidal and insecticidal values. The form of guaranty under which they are sold is the same, regardless of the purpose for which the spray is sold. In interpreting the guaranty, however, there is one important difference. The free, undissolved sulfur, of practically no value as an insecticide, is of value as a fungicide. For the same reason sulfur dust is recognized as a fungicide, although not as an insecticide.

(1) Lime-sulfur Solutions. — Formulas for Application.

Most of the commercial brands of lime-sulfur test about 33° by the Baumé hydrometer. As a summer spray for the orchard this should be diluted at the rate of $1\frac{1}{4}$ gallons to the barrel. If the home-made solution is used, it should be tested with the hydrometer, and the rate of dilution ascertained by consulting the dilution table on page 14 of this bulletin. The dilution for dormant spray (*e.g.*, for peach leaf curl) is the same as recommended for San José scale under insecticides, page 9.

(2) Self-boiled Lime-sulfur.

This is used extensively on peaches and plums. The usual formula is 8–8–50, *i.e.*, 8 pounds of quicklime, 8 pounds of sulfur, and 50 gallons of water.

(3) "Sulfur Dust."

This product has scarcely progressed beyond the experimental stage. It has been urged as a substitute for lime-sulfur and lead arsenate spray, with the usual formula recommended of 90 parts of very finely ground sulfur to 10 parts of the fluffy type powdered lead arsenate.

3. Corrosive Sublimate.

This material finds its only use on the farm or in the orchard for the disinfection of seed potatoes and of wounds on trees produced by pruning, canker removal, etc. The tablets commonly purchased at drug stores are of such a size that one tablet produces a 1–1,000 solution when dissolved in 1 pint of water. This is the standard strength at which this product is used. The same dilution may be secured by dissolving 2 ounces of the salt in 15 gallons of water.

4. Formalin.

Formalin is used for much the same purposes as corrosive sublimate, although its use on potatoes is being discontinued in favor of corrosive sublimate. According to the United States standard of purity for interstate commerce, 37 per cent of the weight of formalin must be formaldehyde gas, although the product is commonly spoken of as a 40 per cent solution. It is used at a dilution of 1 part to 240 (1 pint to 30 gallons) for disinfection of seed potatoes, and for disinfection of grain seed against smut. For onion smut the formula of 1–128 has been extensively used.

C. COMBINED INSECTICIDES AND FUNGICIDES.

Most farm and orchard crops suffer from both insect pests and fungous diseases. This necessitates the use of both an insecticide and a fungicide on the same plant. Frequently, also, the presence at the same time of more than one type of insect requires the application of both a stomach poison and a contact insecticide. If the crucial time for application of more than one should be approximately the same, it is usually possible and profitable to combine them in a single application. Such a combination results in the saving of one-half to two-thirds of the time required for separate applications, and, since labor is usually the big item of expense in spraying, the cost is materially diminished. Unfortunately, however, it is not possible to combine indiscriminately the various substances which are used as fungicides and insecticides. Frequently, in combining two or more of them, a reaction takes place which results in —

1. Complete or partial neutralization of the beneficial qualities of one or more.

2. Liberation of some harmful element.

Such substances are said to be incompatible. It should not be understood, however, that chemical combinations between fungicides and insecticides are always harmful or undesirable. Sometimes the reaction is known to increase rather than decrease the fungicidal value; in other combinations the substances have no effect on each other.

The diagram opposite page 13 shows the mixtures which may be made with safety as well as those which should be avoided.

In recent years there have come into commerce a number of proprietary articles combining an insecticide with a fungicide. Typically the fungicide is represented by a copper compound, while the insecticide is arsenic usually in the form of lead arsenate. The tendency of manufacturers has been to recommend a dilution of their product to a copper content lower than that of a 4–4–50 Bordeaux. Within recent years, however, they have increased the amount of copper and recommended a more concentrated application. The percentage of arsenic has approached more nearly to the amount recommended by economic entomologists. Even to-day, however, when the purchaser has mixed in a spray tank enough of a low copper preparation to conform to the standard, he will have the arsenic in great excess of the amount needed.

As an aid to the purchaser in making dilutions and in estimating the value of a preparation, Table II shows the guaranteed arsenic content and the amount of material required to furnish arsenic equivalent to the standard formula.

APPENDIX.

TABLE I. — *Lime-sulfur Concentrate — Standard Formula for Application.*

Adapted from New York (Geneva) Agricultural Experiment Station Bulletin, No. 329, p. 438.

Density of Solution Baumé Degrees.	Equivalent in Specific Gravity.	Sulfur Equal to 1° Baumé (Per Cent).	Weight of 1 Gallon of Concentrate (Pounds).	Sulfur in 1 Gallon of Concentrate (Pounds).	Sulfur in Solution (Per Cent).	Dilution for San José Scale;[1] To 1 Gallon of Concentrate add Gallons of Water.	**Dilution for San José Scale;[1] For 50 Gallons of Spray use Gallons of Concentrate.**	Dilution for Summer Spray;[2] To 1 Gallon of Concentrate add Gallons of Water.	**Dilution for Summer Spray;[2] For 50 Gallons of Spray use Gallons of Concentrate.**
36	1.3303	.75	11.08	2.99	27.00	9	5	45	1
35	1.3182	.75	10.98	2.88	26.25	8¾	5¼	43¼	1¼
34	1.3063	.75	10.88	2.77	25.50	8¼	5¼	41½	1¼
33	**1.2946**	**.75**	**10.78**	**2.67**	**24.75**	**8**	**5½**	**40**	**1¼**
32	1.2832	.74	10.69	2.53	23.70	7½	5¾	37¾	1¼
31	1.2719	.74	10.60	2.43	22.95	7¼	6	36¼	1¼
30	1.2609	.73	10.51	2.30	21.90	6¾	6½	34¼	1½
29	1.2500	.73	10.42	2.20	21.15	6½	6¾	32¾	1½
28	1.2393	.72	10.32	2.08	20.15	6	7¼	31	1½
27	1.2288	.72	10.23	1.99	19.45	5¾	7½	29½	1½
26	1.2185	.71	10.15	1.87	18.45	5¼	8	27¾	1¾
25	1.2083	.70	10.07	1.76	17.50	5	8½	26	1¾
24	1.1983	.69	9.98	1.65	16.65	4½	9	24¼	2
23	1.1885	.68	9.90	1.55	15.65	4¼	9½	22¾	2
22	1.1789	.67	9.82	1.45	14.75	3¾	10¼	21¼	2¼
21	1.1694	.66	9.74	1.35	13.85	3½	11	19¾	2½
20	1.1600	.65	9.67	1.26	13.00	3¼	11¾	18¼	2½
19	1.1508	.65	9.59	1.18	12.35	3	12½	17	2¾
18	1.1417	.65	9.51	1.11	11.70	2¾	13½	16	3
17	1.1328	.65	9.44	1.04	11.05	2½	14¼	15	3¼
16	1.1240	.65	9.37	0.97	10.40	2¼	15¼	14	3¼
15	1.1154	.65	9.30	0.90	9.75	2	16½	12¾	3½

[1] Density of spray, 4.6° Baumé, or 1.0327 specific gravity.
[2] Density of spray, 1.0° Baumé, or 1.0072 specific gravity.

TABLE II. — *Combined or Uncombined Insecticides and Fungicides.*

Amounts required to furnish metallic copper and arsenic in quantities equivalent to those in a standard 4-4-50 Bordeaux with arsenical.

Commercial Bordeaux.			Commercial Arsenates.		
Guaranty of Metallic Copper (Per Cent).	For 50 Gallons of Spray (Pounds).	For 1 Gallon of Spray (Ounces).	Guaranty of Metallic Arsenic (Per Cent).	For 50 Gallons of Spray (Pounds).	For 1 Gallon of Spray (Ounces).
25.0	4.00	1.25	30.0	1.00	.25
20.0	5.00	1.50	25.0	1.25	.25
15.0	6.75	2.25	20.0	1.50	.50
12.5	8.25	2.50	17.5	1.75	.50
10.0	10.25	3.25	15.0	2.00	.75
9.0	11.25	3.75	10.0	3.00	1.00
8.0	12.75	4.00	9.0	3.25	1.00
7.5	13.50	4.25	8.0	3.75	1.00
7.0	14.50	5.00	7.0	4.25	1.25
6.5	16.00	5.00	6.0	5.00	1.50
6.0	17.00	5.50	5.0	5.75	2.00
5.5	18.50	6.00	4.5	6.50	2.00
5.0	20.00	6.50	4.0	7.00	2.50
4.5	22.50	7.00	3.5	8.00	2.75
4.0	25.50	8.00	3.0	10.00	3.25
3.5	29.00	9.00	2.5	12.00	3.75
3.0	34.00	12.00	2.0	15.00	4.75
2.5	41.00	13.00	1.5	19.50	6.25
2.0	51.00	16.00	1.0	29.00	9.50
1.5	68.00	22.00	.5	58.00	19.00

TABLE III. — *Commercial Bordeaux Mixtures.*

BRANDS AND GUARANTEED COMPOSITION.

MANUFACTURER AND BRAND.	Metallic Copper (Cu) (Per Cent).
J. A. Blanchard Company, New York City:	
Lion Brand,	4 00
Lion Brand (dry),	11 00
Corona Chemical Company, Milwaukee, Wis.:	
Corona Dry Bordeaux Mixture,	11 00
Dow Chemical Company, Midland, Mich.:	
No brand name given,	25 00
Grasseli Chemical Company, Cleveland, Ohio:	
Bordeaux mixture (dry),	13.00
Sherwin-Williams Company, Cleveland, Ohio:	
Fungi-Bordo,	11 00
Sterling Chemical Company, Cambridge, Mass.:	
Sterlingworth (liquid),	3 00
Sterlingworth (dry),	10 00

TABLE IV. — *Commercial Bordeaux with Insecticides.*

BRANDS AND GUARANTEED COMPOSITION.

MANUFACTURER AND BRAND.	Metallic Copper (Cu) (Per Cent).	Metallic Arsenic (As) (Per Cent).
Bowker Insecticide Company, Boston, Mass.:		
Pyrox,	2.30	3 42
Detroit White Lead Works, Detroit, Mich.:		
Rogers Leaded Bordo,	10 50	2 75
Frost Insecticide Company, Arlington, Mass.:		
Bordo Lead,	5 00	2 90
Interstate Chemical Company, Jersey City, N. J.:		
Bordo Lead,	2 00	5 00
Sherwin-Williams Company, Cleveland, Ohio:		
Pestroy,	10.50	2 75
Tuber Tonic,	6 00	24 00
Sterling Chemical Company, Cambridge, Mass.:		
Sterlingworth Ar-Bo,	4 00	1 65
Thomsen Chemical Company, Baltimore, Md.:		
Bordo Lead, Orchard Brand,	5.40	3.90
Toledo Rex Spray Company, Toledo, Ohio:		
NuRexo,	12.70	3.60
Leggett and Brother, New York City:		
Dry Bordeaux and Paris Green Compound,	7 00	12.50
Sterling Chemical Company, Cambridge, Mass.:		
Sterlingworth Dry Bordeaux and Paris Green Compound,	9.00	2.00

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 202 AUGUST, 1921

RUST OF ANTIRRHINUM

By WILLIAM L. DORAN

Rust is the most serious disease of snapdragons under glass, and is second in importance to anthracnose in snapdragons out of doors. This bulletin presents the results of studies of the causal organism of this disease and methods of control. For snapdragons out of doors, the growing of rust-resistant varieties is recommended. For snapdragons in the greenhouse, careful control of cultural methods is suggested as a preventive measure, dusting with sulfur and regulation of the night temperature as means of controlling the disease after it appears.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

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CONTENTS.

BULLETIN No. 202.

DEPARTMENT OF BOTANY.

RUST OF ANTIRRHINUM.[1]

BY WILLIAM L. DORAN.

Introduction.

The cultivated snapdragon (*Antirrhinum majus* L.) is a biennial or perennial under culture. It is a member of the family Scrophulariaceæ. The plant was introduced here from Europe. As an escape from gardens it is rare in New England. The snapdragon has been a popular garden flower for two hundred years, but only within the last ten years has it been grown to any extent as a greenhouse crop. There has been an increasing demand for it as a cut flower, and consequently an increasing amount of glass has been devoted to its culture. As a florist's crop, the snapdragon may be classed as about equal in importance to mignonette, schizanthus, stocks, pansies and primulas (Nehrling, 1914), varying, of course, in different localities.

Growers have propagated principally for the best colored blossoms and the best formed spikes, and relatively slight attention has been paid to the susceptibility of the plants to disease. Increased and intensive cultivation seem to have weakened this once hardy plant, for it is now affected severely by at least four fungous diseases. The diseases of snapdragon, other than rust, are: anthracnose or leaf-spot, caused by *Colletotrichum Antirrhini*, Stew. (Stewart, 1900), and stem-rot and leaf-spot, caused by *Phyllosticta Antirrhini*, Syd. (Guba and Anderson, 1919).

Rust is the most serious of the diseases of snapdragon under glass; but according to the observation of the writer, anthracnose is in most years a more serious disease than rust on plants grown outdoors. The investigation of snapdragon rust was undertaken by the writer because of the economic importance of the disease, and because so little information

[1] Presented to the faculty of the Graduate School of the Massachusetts Agricultural College (May, 1917) in partial fulfillment of the requirements for the degree of master of science. Literature citations are brought up to the date of presentation for publication (January, 1921). The writer wishes to express his indebtedness to Prof. A. V. Osmun of the Massachusetts Agricultural College and to Dr. O. R. Butler of the New Hampshire Agricultural Experiment Station, under whose direction the work here described was carried on.

concerning the disease was available to the growers. Rust causes loss in at least three ways. A spike of snapdragon blossoms is useful only when it is beautiful, and the rust pustules on leaves and stem considerably mar the appearance and hence lessen the value of otherwise salable spikes. An attack of rust impairs the vitality of the host plant, and results in smaller flowers and shorter spikes than the normal. In severe cases the stems and branches are girdled, causing the death of the plant.

History and Distribution.

Snapdragon rust was found in California in 1895 (Blasdale, 1903). The causal organism was described in 1899 under the name of *Puccinia Antirrhini* Diet. and Holw. (Dietel, 1899). In 1913 the disease was found in Illinois, and in 1914 it was found in Ohio and Indiana (Rees, 1914). By 1915 the rust had appeared in Wisconsin and Iowa (Peltier, 1919). In 1915 the writer observed the disease in Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut, and it was well established in New England, both out of doors and under glass. In this year, also, it was reported from Oregon (Bailey, 1915). In 1916 it was reported from Guelph and Montreal, Can., and also from Alabama (Peltier, 1919). It was found in Nebraska in 1916–17, and is now known to occur in Missouri (Thurston, 1919). Snapdragon rust is evidently generally distributed over the United States, more especially in the northern part.

Symptoms.

Snapdragon rust may occur on plants of all ages from cuttings and seedlings just beginning to show foliage leaves up to mature blossoming plants. A severely attacked snapdragon has a most dejected appearance. The leaves hang limp and wilted as if the plant had been deprived of water, the flowers open small and prematurely, and leaves and stems bear chocolate-brown powdery pustules each edged by a yellowish ring. Leaf blades, petioles, stems and calyces are attacked. Usually the lower leaves of the plant are most affected.

In the early stages there appear on the under side of the leaves swollen yellow patches just inside the epidermis. These yellow patches are 1 to 7 mm. in diameter. At this time the leaf may curl slightly. About forty-eight hours after these yellow patches first appear the epidermis is ruptured, exposing brown powdery masses beneath. These brown spore masses, the uredinia, have been described as being usually circularly grouped (Clinton, 1915), but according to the writer's observation this circular grouping is not an especially dependable characteristic. On the upper surface of the affected leaves are yellow blotches, corresponding in position to the uredinia beneath. The spore powder in the uredinia is in an agglutinate condition at first, but after a few days it becomes dry and dusty and is easily blown about. The uredinia are not sunken. They are confluent with age. The ring of ruptured epidermis surrounding a uredinium is soon concealed by this brown spore powder.

PLATE I.

Snapdragon plant attacked by *Puccinia Antirrhini*.

The uredinia on the stem are much elongated. Here the ruptured epidermis is more noticeable than on the leaves. Uredinia on the stem usually occur at the base of a petiole, or at the crotch of two branches, or any place where water may stand. It is the girdling of the stem by uredinia which causes the branch or plant to wilt and die. It is not especially common, however, for snapdragon rust to cause the death of the host plant.

The telia are black, not brown. They are leathery, not powdery, and must be scraped off if they are to be removed. Telia are more common on stems than on leaves, but are not numerous anywhere. They are slightly smaller than the uredinia and are usually somewhat sunken, with the ruptured cuticle projecting above them. Teliospores are sometimes borne in the same sorus with the urediniospores, but the telia may be distinguished macroscopically by their blacker color and harder consistency.

In the greenhouse the disease occurs at all seasons of the year, but is more serious and conspicuous during April and May.

Causal Organism.

Morphology.

Snapdragon rust is caused by the fungus *Puccinia Antirrhini* Diet. and Holw. The mycelium of the fungus occurs chiefly between the spongy parenchyma cells of the leaf and between the cortex cells of the stem. It is more abundant in the leaf than in the stem. It is colorless, septate frequently, and branches profusely. It is intercellular and provided with haustoria (Fig. 4, Plate 2). The haustoria are constricted at the point of entrance to the cell. Within they become broader and vase-shaped, or bear short knoblike branches. A dilute solution of eosin makes the haustoria easily visible. A cross section through an infected leaf reveals beneath each uredinium a stroma of interwoven mycelium (Figs. 1 and 5, Plate 2). This stroma underlies the whole sorus, and extends in a ring around its edge. From this stroma the spore-bearing hyphæ arise.

Two types of spores are known in the life cycle of the fungus, viz., urediniospores and teliospores. The urediniospores are spherical to elliptical. They are 22 to 30 microns in length and 21 to 25 microns in diameter. They are borne on pedicels of varying length from which they become detached at maturity. The urediniospores are yellowish brown in color. Their walls are provided with short spines and have two or three germ pores. The teliospores are 36 to 50 microns in length and 17 to 26 microns in diameter. These spores vary greatly in shape (Fig. 2, Plate 2). The apex may be sharply pointed, rounded or truncate; the base is usually attenuated, but may be rounded off bluntly. There is a slight constriction at the septum. The epispores are dark brown to black, and the wall is smooth, possessing no such spines as occur on the urediniospores. Each of the two cells of the teliospore is provided with a germ tube which is apical in the terminal cell and occurs just below the septum of the basal cell.

PLATE II.

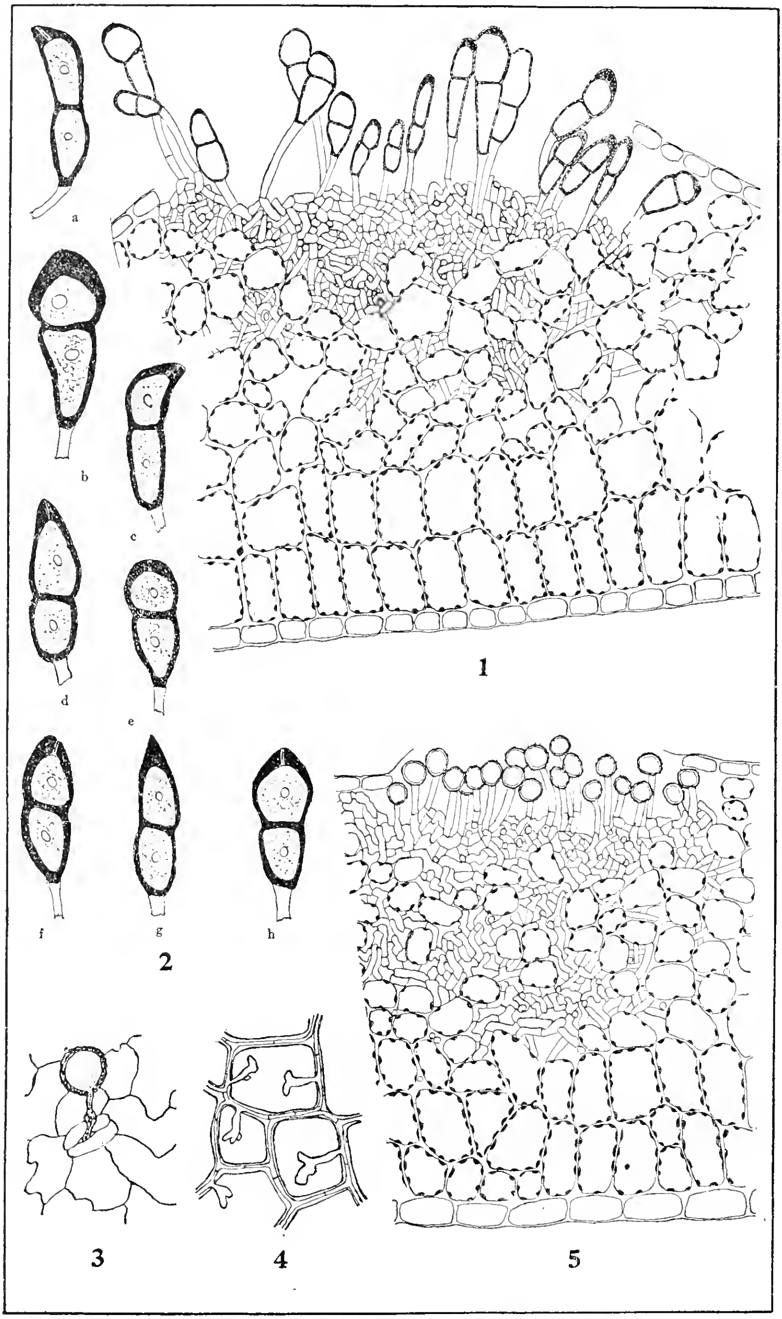


FIG. 1. — Cross section of telium and leaf.
FIG. 2. — Teliospores.
FIG. 3. — Germinating urediniospore on leaf.
FIG. 4. — Haustoria and intercellular mycelium.
FIG. 5. — Cross section of uredinium and leaf.

Occurrence of Spore Stages.

Urediniospores occur at all times on the diseased snapdragons. In the greenhouse these are normally the only type of spores produced. Teliospores occur only rarely in New England. Many infected plants bear only urediniospores, even on the advent of killing frosts. Occasionally teliospores may be found outdoors in November, occurring more often on the stems than on the leaves. In November the writer placed several snapdragons bearing uredinia in wire baskets and allowed them to winter over out of doors in this way. Examination the following March showed only one telium on all the material.

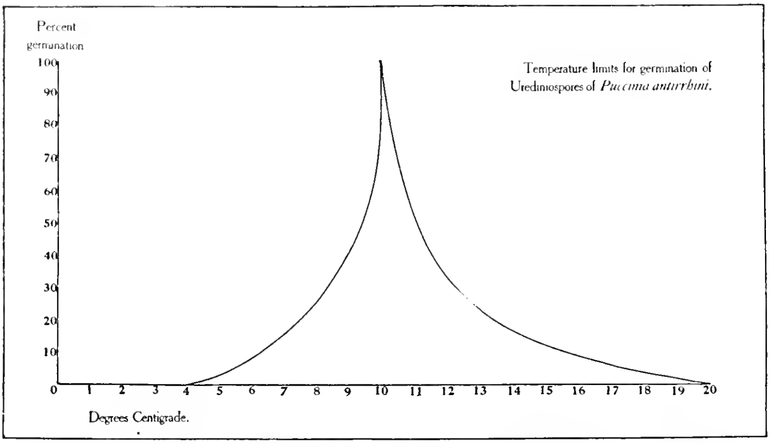
In the greenhouse there is no lowering of temperature to stimulate the formation of teliospores, but their formation is stimulated if the host plant dries out very slowly. When plants were suddenly dried out, no teliospores were formed; but when plants were gradually deprived of water, teliospores were formed in five weeks. Under normal conditions of culture the teliospore may be eliminated as a factor in the greenhouse. No greenhouse snapdragons seen by the writer showed teliospores except those plants gradually deprived of water, as above mentioned.

Spore Germination and Infection Experiments.

The first attempts made to germinate urediniospores were not uniformly successful. As it proved later, this was because the room temperature at which the tests were made was above the maximum temperature for spore germination. The method by which the minimum, optimum and maximum temperatures for the germination of these spores were determined is here described. This method has been previously described by the writer (Doran, 1919).

The spores to be used were removed from infected leaves by a stream of water from a pipette. In this way only mature spores were obtained, while scraping with a brush or wooden instrument would also detach young and immature spores. The spores were shaken in distilled water until they were uniformly distributed through it. Drops of this water containing the spores were then placed on clean slides, and the latter were placed on culture plate benches in moist chambers. These were placed in biological incubators at constant temperatures. About twelve hours later the germinated and ungerminated spores were counted. Most of the spores which germinated did so, however, in five to eight hours. Throughout these tests it was noticeable that no spores in the interior of the drop ever germinated. Only those spores in contact with the air as well as the water germinated, so spores in the interior of the drop were not counted as being present. The distilled water used was not aërated. This aërotropism was not further investigated. Throughout the tests one lot of spores was always run at 10° C. The percentage of germination at 10° C. was taken as a standard, raised to 100, and the other percentages at the different temperatures raised proportionately. This was done in order to bring the data into shape for plotting a constant curve of temperature and germination.

PLATE III.



Curve showing temperature limits for germination of urediniospores of *Puccinia Antirrhini.*

The optimum temperature for the germination of the urediniospores of *P. Antirrhini* was found to be 10° C., the minimum, 5° C., and the maximum, 20° C. When the data are plotted, a curve is obtained that is nearly symmetrical. A most striking fact is that if the temperature is varied 2° C. above or below the optimum, the germination falls off 50 per cent. In the following table each relative germination is the mean of five experiments: —

TABLE 1. — *Relative Germination of Urediniospores of P. Antirrhini Diet. and Holw., compared to the Germination at 10° C. taken as 100.*

5° C.	6° C.	7° C.	8° C.	9° C.	10° C.	11° C.	12° C.	14° C.	15° C.	18° C.	20° C.	30° C.
0	0	27	13	50	100	–	21	0	17.5	2.5	0	0
0	0	0	35	30	100	42	15	12	13	0	1	0
1	4	7	37	50	100	9	32	0	0	0	1	0
0	0	–	4	12	100	14	16	42	6	1.5	0	0
1	4	–	21	30	100	72	–	2	1	1	0	0
0	3	–	–	–	100	–	–	22	–	0.5	0	0
0.3	1.8	11.3	22	34.4	100	34.2	21	13	7.5	.75	0.2	0

Conditions affecting Longevity of Urediniospores.

The spores used in the previously described germination tests were taken fresh from growing plants. It was noticeable that their viability gradually diminished if the leaves dried out long in the room. To determine the longevity of urediniospores, rusted shoots were removed from the plants and placed at temperatures of 0° C., 10° C. and 22° C. Half of this material at each temperature was allowed to dry in open containers, and half of it was kept in closed chambers to prevent its drying out. Spores were removed every seven days and placed at their optimum temperature for germination, with the results shown in Table 2.

TABLE 2. — *Effect of Temperature and Drying on the Longevity of the Urediniospores of P. Antirrhini.*

Percentage of germination of urediniospores.

STORAGE PERIOD (DAYS).	STORAGE TEMPERATURE.					
	DRY.			MOIST.		
	0° C.	10° C.	22° C.	0° C.	10° C.	22° C.
7,	55	50	40	52	52	50
14,	35	25	28	35	20	25
21,	20	20	15	18	12	20
28,	12	15	12	18	15	15
35,	1	2	3	10	6	5
42,	0	0	0.5	3	2	2
49,	0	0	0	1	1	0
56,	0	0	0	0	0	0

When this experiment was begun, 60 per cent of the spores germinated. Some of the spores in moist air retained the power of germination forty-nine days, and in dry air, forty-two days. Some of the spores at 0° C. and at 10° C. retained the power of germination forty-nine days. It is evident that exposure to freezing temperature does not shorten the life of urediniospores. In Massachusetts the snapdragon remains green and lives through mild winters with no protection, and lives through harder winters if protected by a mulch. In January the writer obtained urediniospores from green plants growing outdoors in Massachusetts. These urediniospores germinated readily when placed at the optimum temperature for germination, but after these plants had been dried three weeks at room temperature the spores no longer germinated. Temperature is of less importance than drying in shortening the life of urediniospores.

To determine the effect of temperature on infection, twelve plants were sprayed with fresh spores distributed in distilled water. Four of these plants were placed at a temperature of 10° C., four at 15° C. and four at 18° C. The plants used were of a susceptible variety, Carter's Pink, but they were free from disease when selected, and from a disease-free bench. The plants remained in the above-mentioned temperatures twelve hours, after which they were all placed in the greenhouse at the same temperature.

Seven days later the stromata were visible. Ten days after inoculation the uredinia began to appear. One week later the number of sori on the plants was counted, with the results shown in Table 3.

TABLE 3. — *Effect of Temperature on the Infective Power of the Urediniospores of P. Antirrhini.*

Temperature at which Plants were inoculated.	Number of Sori per Plant.				Mean Infection in Relative Numbers.
	Plant A.	Plant B.	Plant C.	Plant D.	
10° C., ...	240	265	210	180	100.0
15° C., ...	9	6	15	20	7.6
18° C., ...	5	3	7	9	3.5

It is thus seen that raising the temperature 5° to 8° C. above the optimum for germination of the urediniospores causes the amount of infection to fall off more than 90 per cent.

As a further test of the effect of temperature on infection of snapdragon by *P. Antirrhini*, plants of a susceptible variety were inoculated in two different greenhouses, having a night temperature of 10° C. in one case, and 15° C. in the other. Fifteen days after inoculation the plants in the greenhouse at 15° C. bore an average number of twelve uredinia, and the plants in the greenhouse at 10° C. bore an average number of one hundred and twenty uredinia.

As indicated by the results with *P. Antirrhini*, the rusts are able to germinate best at rather low temperatures. A consideration of the literature also supports this view. Erikson (1895) discovered that low temperatures are suitable to the germination of rust spores. He found that the spores of *Æcidium Berberidis* germinate best when cooled for seven hours to 3° C., and that the spores of *Peridermium strobi* germinate best when cooled for twenty-four hours to 6.5° C. He found the optimum temperature for the germination of the spores of *Uredo glumarum* to be 4.5° C., and that the spores of *Uredo coronata* germinate best after being cooled for sixteen hours to a temperature of —10° C. In the last case it seems probable that he went below the optimum temperature, and that the spores germinated when the temperature again rose to the optimum.

Howell (1890) found that the urediniospores of *Uromyces Trifolii* (Alb. and Schw.) Wint. germinate best between 11° and 16° C. They do not germinate below 7° C. nor above 21° to 25° C. If the minimum, optimum and maximum temperatures for germination of *U. Trifolii* are taken as 7° C., 11° C. and 21° C., respectively, this fungus has about the same temperature-germination relation as has *P. Antirrhini*, the minimum, optimum and maximum temperatures for germination of urediniospores of *P. Antirrhini* having been found by the writer to be 5° C., 10° C. and 20° C., respectively.

Experiments on Germination of Teliospores.

Numerous attempts to germinate teliospores were made with fresh material, dried material, teliospores produced under glass, teliospores produced outside, and teliospores wintered over outside. These germination tests were made at 7° C., 10° C., 12° C. and 20° C., but in no case did the teliospores germinate. These spores had formed in response to the definite stimulus of cold or drying. They do not germinate when first formed; they are spores of regeneration, and they may be considered as requiring a rest period, like other spores which function to carry fungi through adverse conditions. But these teliospores do not germinate after the rest period, that is, after passing the winter out of doors, when subjected to the range of temperature in which their host normally grows. It is not unlikely that they are killed by the cold, not being able to withstand the rigors of the winters to which their host has been carried.

Peltier (*loc. cit.*) reports that all efforts to germinate the teliospores failed.

The fact that teliospores do not germinate may be explained in another way. The temperature-germination curve for urediniospores is very sharp; and if teliospores have an even narrower range of temperature through which they can germinate, it is possible that the right temperature for germination has not yet been hit upon, since a variation a few degrees above or below the optimum temperature would result in no germination.

According to our present knowledge the teliospores are not only rare, but they do not germinate. This being the case, the possibility of an alternate host is eliminated. But no alternate host is necessary for a rust fungus which passes the winter under glass. The chrysanthemum rust fungus (*P. Chrysanthemi* Roze.) in America dispenses with both an alternate host and teliospores (Atkinson, 1890). Yet this rust occurs both in the greenhouse and out of doors, and persists from year to year. *P. Chrysanthemi* also is independent of the other rusts found on nearly related Compositæ, just as *P. Antirrhini* is not a parasite on other Scrophulariaceous plants, such as Linaria (see below, experiments with Linaria). Carnation rust, *Uromyces Caryophyllinus* (Schrank) Wint. has an alternate host, *Euphorbia gerardiana*, in Europe (Fischer, 1910), but it has not been found on an alternate host in this country. If the teliospores of *P. Antirrhini* ever were functional they seem now to be useless. The urediniospores of this fungus are sufficient to propagate it through the year, as long as greenhouses in the vicinity shelter the host plant during the winter. The urediniospore is a spore of dissemination. Spores of regeneration, such as teliospores, are not a necessity for a fungus the host of which occurs both under glass and out of doors.

The original host of *P. Antirrhini* is not known. Blasdale (*loc. cit.*) concluded that either snapdragon rust originated on the wild form of Antirrhinum (*A. vagans*), or its original host plant was not a member of the Scrophulariaceæ. Peltier (*loc. cit.*) made cross inoculations with several species of Antirrhinum and with several species of Linaria, including *Linaria vulgaris* Mill. He obtained no infection on any species of Linaria. The only species of Antirrhinum except the cultivated snapdragon (*A. majus*) upon which he obtained infection was *A. maurandioides* Gray, in which case a few urediniospores were produced.

The writer made several attempts to infect *Linaria vulgaris* Mill. and *L. Cymbalaria* (L) Mill. by spraying the plants with water containing the urediniospores and placing them at the optimum temperature for their germination (10° C.). There was no infection whatever, although check plants of snapdragon similarly treated became badly rusted. It is unlikely that the rust occurs, at least in New England, on any other host plant than the cultivated snapdragon.

Dissemination.

Many growers take their cuttings at a time when snapdragon rust is at its height in the greenhouse, which is in March, April and May. There are various opinions as to the relative merits of raising plants from seeds and from cuttings, but plants raised from cuttings come true to color, and in the effort to preserve a good variety some growers take rust-free cuttings from a bench showing rust, or they take cuttings bearing spore pustules. Some growers have thought that if the cuttings show no spore pustules they are safe to use, even though they come from a bench of infected plants. The writer propagated plants by cuttings which bore uredinia and by cuttings which bore no uredinia, although taken from an infected bench. After three weeks all of the cuttings which bore uredinia were badly rusted, and 35 per cent of the cuttings which when made were apparently free from disease, although taken from an infected bench, showed the disease. It is evident, then, that cuttings bearing spore pustules may be expected to develop into rusted plants, and that cuttings free from spore pustules, if taken from a bench of infected plants, serve to aid very materially in the dissemination of the fungus. Microscopic examination of the leaf surfaces of these apparently healthy cuttings revealed numerous urediniospores which had fallen there or had been carried there from diseased plants. These spores need only the favorable environment of the cutting bench to cause them to germinate and infect the young plants, and it is therefore usually inadvisable to take cuttings from a house showing rust. Both Peltier (*loc. cit.*) and Stone (1917) consider cuttings as being among the principal means of dissemination.

Proof of the importance of greenhouse insects in the spread of snapdragon rust is not lacking. Three insects often found on snapdragon are the white fly (*Aleyrodes vaporariorum* West), the red spider (*Tetranychus bimaculatus* Harvey) and the common aphid (*Aphis gossypii*). With a binocular microscope the writer examined these insects on snapdragon foliage. They were on healthy plants, but there were rusted plants in the same bench. On the bodies of most of the insects examined were the urediniospores of *P. Antirrhini*.

The third agency by which the fungus is disseminated is watering. Carnation growers in watering make an effort not to wet the foliage any more than is necessary, usually employing a stiff piece of hose or pipe which enables them to get water into the middle of the bench without wetting the plants above. To this simple practice is due in part the decline in importance of carnation rust. The writer selected twenty snapdragon plants of the same variety, all showing uredinia in approximately equal numbers. Ten of these plants were watered only on the soil, no water touching the foliage. The other ten were treated the same, except that their foliage was kept wet. After three weeks the plants with wetted foliage showed 200 per cent more uredinia than they had at the beginning, while the plants whose foliage had been kept dry showed no increase in the number of uredinia. Water is necessary for the germination of the spores and for infection. A carelessly directed stream from a hose loosens spores from pustules, carries them to other plants, and provides them with the necessary moisture for their germination.

Pathological Anatomy.

The upper epidermis of the leaf and the palisade cells are only rarely affected by this disease. Occasionally a few palisade cells are forced apart by hyphæ. The spongy parenchyma cells are principally affected. The parenchyma cells in the immediate vicinity of a sorus do not attain their normal size. Strands of hyphæ force them apart and sometimes cause them to grow into abnormal forms. The chloroplasts fade slightly, but the yellow appearance of the area surrounding a sorus is due mostly to the presence of a stroma of mycelium. After the intercellular mycelium has become well established it develops this firm stroma in contact with the lower epidermis, and often includes scattered spongy parenchyma cells (see Fig. 5, Plate 2). This growing stroma and the rising pedicels of the urediniospores finally rupture the epidermis. The contents of cells containing haustoria do not degenerate unless the whole leaf becomes involved. Attacked cells do not swell, and any hypertrophy on the leaf is due to the development of stromata. Leaf cells of snapdragon which are normally pink lose this pigment when attacked by the fungus. When the sori occur on the stem the epidermis is ruptured, the cortical cells are forced apart, and in some cases the mycelium may be found between the cells of the fibro-vascular bundles. Ordinarily, however, cells as far in as the phloëm are not attacked. The chloroplasts fade even less in the stem than in the leaves. The cells of the cortex do not attain their normal size. Epidermal cells appear unchanged, though raised as a membrane above a sorus. Mycelium in both leaf and stem is local.

Varietal Susceptibility.

The list of commercially grown varieties of snapdragon, such as, for example, Nelrose, Silver Pink, Phelp's White and Keystone, is not large. But there is a large number of varieties listed and grown outdoors. Since there seemed to be but little information available as to which varieties are resistant and which susceptible, the writer tested forty-six varieties. The plants were grown from seed, and when the potted plants had reached a height of 6 inches they were inoculated by being sprayed with water in which urediniospores had been distributed, and placed under bell jars at 10° C. Each variety tested was represented by twelve to twenty individuals.

Two weeks after the date of inoculation the plants were examined and the number of rust pustules and infected leaves were counted. The plants were examined at weekly intervals for the next five weeks, and observations recorded as to the number of rust pustules and infected leaves. In the following table the varieties are grouped according to color, and under each color the most resistant varieties are named first, and the most susceptible varieties are named last, the intermediate varieties being so arranged that any variety is more resistant than those which follow it. Varieties equally resistant or susceptible are connected with brackets. By means of the relative numbers in the table it is possible to compare varieties of different colors as regards resistance.

Unfortunately, the most valuable commercial varieties, such as Nelrose and Silver Pink, are very susceptible to the rust.

The following table is perhaps not of great value to florists, since they must grow the varieties most in demand. But this table of relative susceptibility could be used as a basis in breeding resistant varieties, and by its use the amateur grower of snapdragons can avoid the more susceptible varieties, and still have a satisfactory garden of snapdragons.

TABLE 4.—*Relative Susceptibility of Antirrhinum Varieties to P. Antirrhini.*

Varieties.	Scale, Relative Numbers.	Varieties.	Scale, Relative Numbers.
White.		*Variegated or Mixed Colors.*	
Queen of the North,	0	Striped Variety,	0
Pure White,	0	Bronze Queen,	72
Giant White,	0	Niabe,	93
Phelp's White,	0	Fairy Queen,	93
Queen Victoria,	0	Carter's Gold Crest,	100
Mont Blanc,	0	*Red.*	
Yellow.		Crimson,	0
Giant Yellow,	0	Giant Blood Red,	0
Hephætos,	9	Fire Brand,	0
Dwarf Golden Queen,	100	Scarlet,	9
Sulphur Yellow,	100	Giant Scarlet,	16
Pink.		Dwarf Defiance,	23
Rose Dore,	0	Giant Garnet,	23
Bridesmaid,	0	Dark Scarlet,	37
Giant Rose Pink,	23	Half Dwarf Firebrand,	44
Rosy Morn,	30	Carter's Butterfly,	51
Nelrose,	51	Orange King,	58
Silver Pink,	51	Black Prince,	58
Dwarf Daphne,	65	Deep Crimson,	79
Rose,	86	Coral Red,	86
Giant Pink,	86	Ruby,	100
Dwarf Rose Queen,	93	Fiery Belt,	100
Carter's Pink,	100	Crimson Queen Victoria,	100
Delicate Rose,	100		
Venus,	100		
Chamois,	100		

Cause of Resistance.

Resistance of plants to disease has been explained in two general ways: (1) Resistance may be regarded as being related to certain morphological characteristics. Cobb (1892) considered resistance to fungous disease as being due to small stomata, waxy coating, and thick cuticle on the host. Freeman (1911) found that increase in bloom on barley leaves made the plants more resistant to rust. Valleau (1915) studied resistance of plums to brown rot, and considered resistance to be due to the production of parenchymatous plugs which fill the stomatal cavity, and to lenticels composed of cork cells through which the hyphæ cannot penetrate. (2) On the other hand, the resistance of plants to disease has often been regarded as due not to morphological characteristics, but rather to physiological or chemical factors. Myoshi (1895) concluded that many fungi respond to chemical attraction. According to Massee (1904) infection depends on the presence of positive chemotactic substances in the plant cell. Klebahn (1896) concludes that infection is a kind of conflict between host and parasite. Bolley (1908) attributed resistance to chemical agents, such as toxins, which arise as a result of the fungous attack upon the host. These few citations from the extensive literature on this subject illustrate two views as to the resistance of plants to disease.

The work done by the writer indicates that the resistance of some varieties of snapdragons to rust is due to morphological characteristics rather than to physiological differences. The relative susceptibility of forty-six varieties of snapdragon to rust has already been given. The inoculated plants developed uredinia, some in large numbers and some in small numbers. But on both resistant and susceptible plants the sori were developed in the same length of time, and there was no apparent difference in the vigor of the sori after they had once broken through the epidermis. This seems to the writer to indicate that the difference in susceptibility is not due to chemical factors within the host cells, but rather to mechanical factors preventing infection. The most susceptible plant is the one infected in the most places, that is, the one into which the most germ tubes enter.

Infection of snapdragons by *P. Antirrhini* is always through the stomata. The writer sprayed urediniospores on the living leaves, and eight hours later examined the leaf surfaces microscopically. This was done repeatedly, but at no time was infection seen to occur anywhere except through the stomata. The plants used were kept in both light and darkness, with stomata both open and closed. The germ tubes were protruded, wandered about slightly, and then bent into the nearest stoma, or, if the water on the leaf dried too soon, they shriveled up and never reached a stoma. But no germ tubes were found which had penetrated or were penetrating the walls of the epidermal cells.

The mycelium within the leaf and stem is local; therefore the number of sori on a leaf or stem depends on the number of infections, and, since infection is only through the stomata, it was interesting to determine the connection between the number of uredinia (the index of relative susceptibility) and the number of stomata.

Leaves were taken from three-months-old snapdragons of susceptible and resistant varieties. The number of stomata on the upper epidermis per unit area of leaf was determined. In each case ten countings go to make up the average given for each variety. Ten susceptible and ten resistant varieties were used. The result of these counts is given in the following table: —

Table 5. — *Average Number of Stomata per Unit Area of Leaf.*

Susceptible Varieties.	Resistant Varieties.
3.1	1.5
4.1	1.5
3.0	2.0
2.0	1.0
3.0	1.3
3.3	1.6
3.0	1.1
2.8	1.7
5.0	1.1
3.2	1.8

The averages of these figures show that there are 3.25 stomata on the susceptible varieties to 1.46 stomata on the resistant varieties. Or, stated differently, the resistant varieties have only 45 per cent as many stomata as the susceptible varieties. The susceptible varieties showed approximately 200 per cent as many uredinia as the resistant varieties. This would indicate that in the snapdragon susceptibility is directly proportional to the number of stomata; that is, doubling the number of stomata doubles the number of uredinia or the amount of infection. Such a relation is, of course, relative rather than absolute.

It may be added that the stomata on resistant and susceptible varieties are present in the same numerical relation if both upper and lower epidermis are considered. The figures in Table 5 are for the upper epidermis only, because, owing to the fact that but little water clings to the lower epidermis, infection is mostly through the upper epidermis.

The stoma is the gateway through which the fungus enters. The fewer stomata there are, the fewer infections there will be, and the plant will appear correspondingly resistant.

Control.

Laboratory Toxicity Tests with Copper Fungicides.

In all the toxicological experiments here described the general method used was that of Reddick and Wallace (1910). The fungicides used in these toxicity tests were prepared by Dr. O. R. Butler of the New Hampshire Agricultural Experiment Station. Glass slides were cleaned in potassium bichromate cleaning solution, rinsed in distilled water and dried between filter papers. The solution, the toxicity of which was to be tested, was sprayed on the slide by means of an atomizer, and the slides were then dried for twenty-four hours. Fresh urediniospores were removed from living leaves by means of a stream of water from a pipette. These spores were shaken up in distilled water, drops of which were then placed on the sprayed and dried slides, and also on other unsprayed slides used as checks. This gives conditions similar to those the spores meet on sprayed and unsprayed leaves. The slides bearing the spores were then placed on culture plate benches in moist chambers, and these were placed at 10° C., the optimum temperature for the germination of urediniospores of *P. Antirrhini*. Here they remained for at least twelve hours, when the drops were examined microscopically, the spores counted, and the percentages of spores germinating determined. If there was no germination on the check (unsprayed) slides the results on the sprayed slides were of course discarded. At least three tests were made with each strength of solution. Only dilutions near the limit of toxicity are given in the tables, although stronger and weaker solutions were also used.

Copper sulfate was tested in dilutions ranging from .0039 to .25 per cent copper. The toxicity of copper sulfate is shown in the following table: —

TABLE 6. — *Effect of Various Strengths of Copper Sulfate on the Germination of Urediniospores of P. Antirrhini.*

PER CENT COPPER.	Germination relative to Check, 100.	Remarks.
0.25,	0	Mean of three experiments.
0.125,	5	Mean of three experiments.
0.0625,	5	Mean of three experiments.
0.0312,	12	Mean of three experiments.
0.0159,	18	Mean of three experiments.
0.0079,	14	Mean of three experiments.
0.0039,	24	Mean of three experiments.

It is thus seen that copper sulfate prevents germination of the uredin-iospores of *P. Antirrhini* at a strength of solution of 0.25 per cent copper. Melhus (1915) found copper sulfate toxic to the spores of *Phytophthora infestans* (Mont.) DeBary when the solution contained .0157 per cent copper. The indications are that the Uredinales are much more resistant to copper than are the Phycomycetes.

To determine the toxicity of copper sulfate to foliage of snapdragon, plants were sprayed with copper sulfate solutions containing from 0.25 to .0312 per cent copper. The sprayed plants were then dried slowly; that is, they were allowed to remain six hours in a moist chamber after spraying. The results are given in the following table: —

Table 7. — *Toxicity of Copper Sulfate Spray to the Foliage of Snapdragon.*

Per Cent Copper.	Injury to Foliage.
0.25,	Markedly injured.
0.125,	Markedly injured.
0.0625,	Slightly injured.
0.0312,	No injury.

It is evident from this that a copper sulfate solution which will prevent germination of urediniospores, a solution which must contain at least 0.25 per cent copper, is toxic to the foliage of the host. Copper sulfate therefore cannot be used as a control for snapdragon rust.

Cuprammonium sulfate (Eau celeste), $CuSO_4.4NH_3.H_2O$, was the next fungicide tested. On drying, this gives rise to basic copper sulfate which on further weathering passes to copper sulfate. In these toxicity tests it was used in strengths of solution containing from 0.008 per cent to 0.5 per cent copper sulfate, with results shown in Table 8.

Table 8. — *Effect of Various Strengths of Cuprammonium Sulfate on the Germination of Urediniospores of P. Antirrhini.*

Per Cent Copper.	Germination relative to Check, 100.	Remarks.
0.1300,	0	Mean of three experiments.
0.0650,	0	Mean of three experiments.
0.0325,	4	Mean of three experiments.
0.0162,	22	Mean of three experiments.
0.008,	45	Mean of three experiments.

As here shown, a solution of cuprammonium sulfate containing 0.065 per cent copper prevents germination of urediniospores of *P. Antirrhini.*

The toxicity of this solution to the foliage of snapdragon was tested as in the case of copper sulfate. Solutions containing 0.25 or 0.125 per cent copper injured the foliage markedly, and a solution containing 0.065 per cent copper produced some injury. Cuprammonium sulfate at the strength toxic to the fungus is injurious to the host plant, and cannot therefore be used.

Other copper salts were not tested, for Melhus (*loc. cit.*) has found cupric sulfate ($CuSO_4.5H_2O$), cupric nitrate ($Cu(NO_3)_2.3H_2O$), cupric acetate ($Cu(C_2H_3O_2)_2.H_2O$) and cupric chloride ($CuCl_2.2H_2O$) to be about equally toxic if they contain the same amounts of the toxic principle, — copper.

Hammond's Copper Solution, a commercial preparation which has been used by florists in attempts to control greenhouse rusts, was next tested. The stock solution as purchased was analyzed by Mr. T. O. Smith, assistant chemist at the New Hampshire Agricultural Experiment Station, and found to contain 0.018 gms. copper in 1 c.c. of solution. The manufacturers recommended that it be applied at the rate of 1 quart of the stock solution to 25 gallons of water, that is, a solution containing 0.018 per cent copper. The results of the tests are given in Table 9.

TABLE 9. — *Effect of Various Strengths of Hammond's Copper Solution on the Germination of the Urediniospores of P. Antirrhini.*

PER CENT COPPER.	Germination relative to Check, 100.	Remarks.
0.18,	5	Mean of three experiments.
0.144,	8	Mean of three experiments.
0.12,	19	Mean of three experiments.
0.072,	18	Mean of three experiments.
0.036,	17	Mean of three experiments.
0.014,	40	Mean of three experiments.
0.018,	72	Mean of three experiments.

It is evident that Hammond's Copper Solution, even when used at ten times the recommended strength, does not prevent germination of urediniospores of *P. Antirrhini*. In connection with this work the action of Hammond's Copper Solution on carnation rust was also tested, and at the recommended strength it was not toxic, the germination of the urediniospores of *U. Caryophyllinus* (Schrank) Wint. relative to check, 100, being 56.

Bordeaux mixture was next tested. The Bordeaux mixture used contained copper sulfate and calcium oxide in the approximate ratio of 1 : 0.3; that is, calcium oxide was added to slight alkalinity. This formula was used for the sake of convenience, but the same results would be obtained with any current formula, for the unit copper is equally toxic in acid, neutral and alkaline Bordeaux mixtures (Butler, 1915). The Bordeaux mixture used in the tests was diluted to various strengths, so as to contain the following percentages of copper sulfate: 0.0156, 0.0312, 0.0625, 0.125, 0.25, 0.5, 1, 2 and 4. The results are shown in Table 10.

TABLE 10. — *Effect of Various Strengths of Bordeaux Mixture 1 : 0.3 on the Germination of the Urediniospores of P. Antirrhini.*

Per Cent Copper Sulfate.	Per Cent Copper.	Germination relative to Check, 100.	Remarks.
4.0,	1.0	24	Mean of three experiments.
2.0,	0.5	25	Mean of three experiments.
1.0,	0.25	15	Mean of three experiments.
0.5,	0.125	32	Mean of three experiments.
0.25,	0.0625	33	Mean of three experiments.
0.125,	0.0312	23	Mean of three experiments.
0.0625,	0.0159	20	Mean of one experiment.
0.0312,	0.0079	20	Mean of three experiments.
0.0156,	0.0039	40	Mean of three experiments.

The urediniospores of *P. Antirrhini* are able to germinate in all the strengths of Bordeaux mixture employed by the writer. They germinate as readily in the mixture containing 1 per cent copper as in the mixture containing only 0.0039 per cent copper. There was a 10 per cent difference in favor of the weaker mixture, but this has no significance when we consider the irregular fluctuations shown by the intermediate strengths. It is probable that at the lesser strength the sprayed slide or leaf offers the maximum surface of solute to the solvent. An increased strength, as 1 per cent copper, means that the particles on the slide or leaf merely overlap each other, and do not offer an increased surface proportional to the added amount of substance. Having found a certain strength of Bordeaux mixture non-toxic to the urediniospores, increasing the strength of the Bordeaux mixture results in no toxic effect.

To confirm the results of the toxicity tests of Bordeaux mixture against *P. Antirrhini*, snapdragon plants all of the same variety were sprayed with Bordeaux mixture 1 : 0.3 containing 1 per cent copper sulfate. After spraying, the plants were allowed to dry, then with other plants of the same variety, not sprayed, were inoculated with snapdragon rust, the urediniospores being applied to the plants in distilled water by means of an atomizer. All inoculated plants, both sprayed and unsprayed, were then placed for twelve hours in an incubator at a constant temperature of 10° C., after which they were placed together in a greenhouse under the same conditions. Fifteen days after inoculation all the plants which had been inoculated were examined and the uredinia on the leaves were counted. The sprayed plants showed on the average two hundred uredinia each, while the unsprayed plants showed on the average two hundred and ten uredinia each; that is, there was an approximately equal amount of infection on the sprayed and unsprayed plants. Bordeaux mixture cannot, therefore, be recommended for the control of snapdragon rust. Peltier (1919) also came to the conclusion that Bordeaux mixture 4–4–50 will not control snapdragon rust.

Continuing the study of the toxicity of Bordeaux mixture to members of the Uredinales, the writer tested the effect of this fungicide on the germination of the urediniospores of carnation rust, *U. Caryophyllinus* (Schrank) Wint. It is realized that growers do not often spray for carnation rust now, being able to control this disease by cultural methods and varietal selection. But Bordeaux mixture has often been recommended for the control of this rust. Bordeaux mixture 1 : 0.3 was used in these tests in various strengths, so as to contain 0.5, 1, 2 and 4 per cent copper sulfate. The method employed was the same as that described for *P. Antirrhini*, except that the spores were germinated at 14° C., which temperature was found by the writer (Doran, 1919) to be the optimum temperature of germination for the urediniospores of *U. Caryophyllinus*. These urediniospores, like those of *P. Antirrhini*, germinated only when in contact with both air and water, spores in the interior of the drop of water never germinating.

The toxicity tests conducted by the writer showed that Bordeaux mixture is not toxic to the urediniospores of *U. Caryophyllinus*, which indicates that the behavior of the urediniospores of *P. Antirrhini* toward this fungicide is not exceptional. If carnation plants sprayed with Bordeaux mixture failed to rust, it must have been due to other adverse conditions, such as temperature, which prevented spore germination and infection.

It would appear from data obtained by others as well as from the results here reported that the Uredinales are much more tolerant of copper than are the Phycomycetes. Melhus (*loc. cit.*) found Bordeaux mixture toxic to *Phytophthora infestans* (Mont.) De Bary at 0.0039 per cent copper sulfate. But the writer did not find Bordeaux mixture toxic to the two members of the Uredinales studied at 4 per cent copper sulfate. It may be that the thick wall of the spore secretes some chemical substance which prevents the copper in the Bordeaux mixture from going into solution.

The literature contains numerous references to the use of copper solutions as a control of diseases produced by members of the Uredinales, but there is a variance of opinion as to the effectiveness of copper on rust diseases.

The experiments performed by earlier investigators were mostly of the field rather than the laboratory type. Dudley (1890) recommended a saturated solution of potassium permanganate as a control of hollyhock rust. Maynard (1893) found Bordeaux mixture to give good results as a control of carnation rust. Hitchcock and Carleton (1893) found the spores of *P. graminis* Pers. able to germinate in solutions of thirty chemical compounds of various strengths, including 0.1 per cent solutions of mercuric chloride, copper acetate, potassium bichromate, potassium cyanide, acetic acid and sulfuric acid. Pammel (1893) attempted to control rusts on oats and wheat by spraying with Bordeaux mixture, but found no appreciable difference in the amount of the disease on the sprayed and unsprayed plants. Stuart (1894) found that Bordeaux mixture of standard and half strength solutions gave best results in the control of carnation rust. Bailey and Lodeman (1895) sprayed carnations with a mixture of Bordeaux mixture and soap. They also used a mixture of copper chloride, lime and soap. They concluded that the copper fungicides were most efficient in the control of carnation rust. Stewart (1896) recommended spraying with weak copper sulfate for the control of carnation rust. He found that the spores of *U. Caryophyllinus* can germinate in a copper sulfate solution containing 0.0025 per cent copper, and that there is slight germination in copper sulfate solutions containing as much as 0.083 per cent copper. He found these spores unable to germinate in 0.033 per cent solution of potassium sulfide. This investigator found that if copper sulfate is applied to carnation cuttings in a solution strong enough to control the rust the plants are injured. He found that Bordeaux mixture would not control carnation rust, and recommended spraying carnations with a 0.56 per cent copper sulfate solution, or with a 0.78 per cent solution of potassium sulfide. Sturgis (1896) recommended potassium permanganate for the control of hollyhock rust. Halstead (1897) sprayed hollyhocks with Bordeaux mixture, and found rust on all the check plots, while but one sprayed plot showed any rust. Kinney (1897) sprayed carnations with Bordeaux mixture, and concluded that this treatment did not control the rust. Abbey (1898) recommends Bordeaux mixture as an efficient fungicide in the control of chrysanthemum rust.

A survey of the literature on rust control by fungicides is not very helpful. Some of the statements made are misleading and few are very convincing; for instance, it is hard to see how potassium permanganate could be of any great value in combating a rust. Potassium permanganate destroys organisms by oxidizing them, and if in contact with oxidizable material it very soon loses its power; hence it would be of no avail against spores which subsequently fell upon the sprayed surface. Some investigators found Bordeaux mixture efficient and some found it inefficient as a fungicide for the control of rust. The narrow range of temperature in which the spores can germinate may have been exceeded, and the credit for no germination given to the fungicide instead of to a faulty temperature which reduces or prevents germination. But the literature does indicate that the rusts are very resistant to fungicides in general, especially to copper fungicides.

Sulfur Fungicides.

Dusting with sulfur has been used successfully as a control of *P. Asparagi* Dec. (Smith, 1905 and 1906). Butler (1917) described a sulfur dust control for rust of snapdragon. Stone (1917) recommended for the control of snapdragon rust that plants be dusted with powdered sulfur every ten days, or sprayed with lime-sulfur 1 : 35.

The writer began his study of the toxicity of sulfur by testing the toxicity of sulfur applied in water. Powdered sulfur, washed and freed of sulfur dioxide, was added to drops of distilled water in which urediniospores of *P. Antirrhini* were placed. These spores in water with sulfur and the checks (spores in water without sulfur) were then placed at a temperature of 10° C. Subsequent examination showed that the spores in water with sulfur germinated quite as well as the spores in water without sulfur. This result is not surprising, for sulfur, being insoluble, would hardly be expected to have a fungicidal effect when applied in water. This result agrees with that of Melhus (*loc. cit.*), who found that the spores of *Phytophthora infestans* germinated as easily in water containing sulfur as in pure water.

The toxicity of dry sulfur to urediniospores of *P. Antirrhini* was next determined. Dry urediniospores were placed on slides and dusted with powdered sulfur. These were then put into desiccators and kept for three and one-half hours, some at a temperature of 12° C. and some at a temperature of 21° C., then placed in drops of distilled water and set away for twelve hours at their optimum temperature for germination, 10° C. They were accompanied by unsulfured spores as checks. The following table shows the relative germination of the spores sulfured at 12° C., and those sulfured at 21° C.: —

TABLE 11. *Effect of Dry Sulfur and Temperature of Application on the Germination of the Urediniospores.*

Germination of Spores exposed to Sulfur Three and One-Half Hours at the Temperatures stated. (Relative to Check, 100.)		Remarks.
12° C.	21° C.	
90.1	0	Mean of ten experiments.

It is thus shown that spores dusted with powdered sulfur and kept three and one-half hours at a temperature of 21° C. do not germinate. Spores similarly treated, but kept during the sulfuring at a lower temperature, 12° C., germinate as well as unsulfured spores. Sulfur at the lower temperature is comparatively inert, but at the higher temperature it reacts slowly with the oxygen of the air to form sulfur dioxide.

The experiment just described shows that sulfur as such is not toxic to the spores of this fungus. It is rather the sulfur dioxide generated by the exposure of dry sulfur to warm air that is toxic to the spores of the fungus. The more surface a substance exposes the more rapidly it reacts chemically. Hence the necessity of having finely divided, that is, finely powdered, sulfur rather than a coarser grade.

As a continuation of this experiment urediniospores were taken from snapdragon plants which had been dusted with powdered sulfur at a temperature not less than 21° C. These plants bore many spore pustules, and the fungus was to all appearances vigorous. But these spores failed to germinate when placed under optimum conditions for germination.

Fungine is a commercial preparation which has been used by some growers in their attempts to control snapdragon rust. As stated by the makers, it contains potassium polysulfide 6 per cent, and potassium thiosulfate 4 per cent. The writer tested the toxicity of this preparation to the spores of *U. Caryophyllinus* and of *P. Antirrhini* at various strengths and at the strength recommended by the makers. Fungine proved toxic to the spores of both of these fungi.

TABLE 12. — *Effect of Various Strengths of Fungine on the Germination of the Urediniospores of P. Antirrhini and of U. Caryophyllinus.*

Strength of Solution (Per Cent Thiosulfate).	Germination relative to Check, 100.		Remarks.
	P. Antirrhini.	U. Caryophyllinus.	
0.25, ...	0	0	Mean of four experiments.
0.50, ...	0	0	Mean of four experiments.
1.0, ...	0	0	Mean of four experiments.

Fungine, though toxic to the spores of these fungi, has certain disadvantages. It is no more efficient than powdered sulfur, but it costs more than the sulfur, and the sulfur dust reaches parts of the plant which a liquid spray would not. Fungine when sprayed on a slide or leaf has a physical character resembling a soap film, and this soapiness makes it wash off the leaf too easily, which may in part account for Peltier's conclusion (*loc. cit.*) that snapdragon rust in the field cannot be controlled by Fungine.

Temperature Regulation.

It has been shown that the urediniospores of *P. Antirrhini* cannot germinate below 5° C. nor above 20° C., and that they germinate best at 10° C. (50° F.); 50° F. is the night temperature at which the snapdragon is usually grown under glass; it is frequently grown in the house with carnations. This temperature results in a maximum amount of rust on the snapdragon. The carnation, on the other hand, is grown at a night temperature of 4° C. below the optimum for germination of the spores of carnation rust, and this may in part explain why carnation rust is so much less serious than snapdragon rust. Day temperatures of the houses are not important in the study of snapdragon rust, for those temperatures are usually too high for germination of the urediniospores, so we may consider infection as taking place only in the night.

If growers would raise or lower the night temperature of the snapdragon house to 52° F. or 48° F., the rust would decrease in amount about 50 per cent. This is indicated in the constant curve showing the relation between temperature and germination. It must be remembered that this temperature change prevents infections and prevents the spread of the disease, but it does not kill the spores. So if the temperature approaches the germination optimum even for a few hours, the disease may break out again. Rise of temperature as a control is further considered under treatment with sulfur. Growers may object to raising the temperature very much above 50° F. because of the danger of shortening the blossom spikes, but a rise of even two or three degrees will check the rust, and is not likely to diminish the value of the blossom spikes.

Selection of Resistant Varieties.

Forty-six varieties of snapdragon have been observed by the writer, and their relative resistance to *P. antirrhini* has been determined. The most susceptible varieties are Half Dwarf, Rose Queen, Fiery Belt, Crimson Queen Victoria, Ruby, Carter's Pink, Delicate Rose, Dwarf Golden Queen, Sulphur Yellow, Venus, Carter's Gold Crest and Chamois. It is recommended that the above varieties be not grown at all. The most resistant varieties are Queen of the North, Pure White, Rose Dore, Giant White, Crimson, Giant Blood Red, Giant Yellow, Striped Varieties, Hephætos, Phelp's White, White Queen Victoria, Firebrand and Mont Blanc. It is recommended that outdoor gardeners confine themselves principally to these varieties. These varieties, while not absolutely resistant, are the nearest approach to it among snapdragons. Florists grow only a few varieties, as a rule, notably, Keystone, Silver Pink, Buxton's Pink, Phelp's White and Nelrose. None of these varieties is really resistant. Florists can control this disease less by the selection of resistant varieties than can outdoor gardeners, but the florist can propagate from resistant individuals if any appear, and meanwhile safeguard his crop by the sulfur treatment.

Regulation of Moisture.

It has been shown that although temperature does not kill the urediniospores of *P. Antirrhini*, six weeks of drying does kill them. The teliospore may be eliminated as a factor; and as the urediniospores cannot germinate after six weeks of drying, there is no danger of the disease being transmitted on dry seed; also it is evidently impossible for urediniospores to live from season to season in a greenhouse if the snapdragons are removed and the house deprived of water for a period of at least eight weeks. A case of this kind has recently come to the attention of the writer. A house of snapdragons was severely attacked by rust last year. This year mignonette is being grown in the space occupied by last year's rusted snapdragons. Among the mignonette plants are many seedling snapdragons, the descendants of the rusted plants, but these seedlings are absolutely clean and free from rust. Here we have a case of seed from infected plants producing seedlings free from disease, although they are growing in the space occupied by the diseased plants the previous year. Apparently their only protection is the drying out of the urediniospores.

Use of Fungicides.

The copper salts and copper mixtures, the toxicity of which to *P. Antirrhini* was tested in the laboratory, are copper sulfate, cuprammonium sulfate (Eau celeste), Bordeaux mixture (cupric sulfate to calcium oxide in the ratio of 1 to 0.3 present), and Hammond's Copper Solution. It is shown that Bordeaux mixture is absolutely useless for the control of this disease, for at no strength suitable for use on plants does it prevent germination, and sprayed plants when inoculated develop quite as much rust as plants similarly inoculated but not sprayed. The toxic constituent of Bordeaux mixture is copper sulfate, and this used alone has a toxic effect on the spores of *P. Antirrhini*, but in principle does not dissolve with sufficient rapidity to be efficient against either *P. Antirrhini* or *U. Caryophyllinus*.

Copper sulfate solution, 0.25 per cent copper, is toxic to the urediniospores of *P. Antirrhini*, but the use of this strength of copper sulfate on snapdragon is precluded because of its toxic effect on the foliage. Cuprammonium sulfate (Eau celeste) is toxic to the urediniospores of *P. Antirrhini* at 0.0625 per cent copper, but this strength of Eau celeste is liable to result in a toxic action to the foliage of snapdragon, unless the foliage can dry off in less than one hour. This nearly precludes the use of Eau celeste on thick crowded plants, for the bottom foliage would dry off too slowly. Eau celeste can be used only when the principle toxic to the foliage can be volatilized by rapid drying. Hammond's Copper Solution is not toxic to the urediniospores of *P. Antirrhini*, and is therefore of no use for the control of snapdragon rust.

A method for the control of snapdragon rust by dusting of the plants with sulfur has been described by Dr. O. R. Butler (1917). During the winter of 1916–17 the writer inspected, at intervals of two weeks, greenhouses of snapdragon which had been thus treated. When the treatment began the plants were in very bad shape, leaves and stems were fairly covered with rust pustules. The first thing done was to cut out those shoots so badly infected as to be hopeless. Many of them were girdled and dying. The sulfur used was obtained from the Union Sulphur Company and from Corona Chemical Company. It is powdered finely enough to pass through a sieve having 40,000 holes to the square inch. It was applied with a good bellows that filled the air of the greenhouse with dust, which settled as a thin even film on the foliage. For plants 10 inches high, 4 ounces of sulfur were applied to 150 square feet of bench. The sulfuring was repeated at intervals of two to three weeks, as necessitated by new growth of plants. Exposed blossoms were injured, but there was no injury to the leaves. For two days after sulfuring the night temperature was kept between 60° F. and 70° F. Spores from these sulfured plants were tested from time to time and were uniformly unable to germinate. The mycelium in the plant remained alive, and occasionally produced new sori near the old ones. But new infections were impossible, and the spread of the disease was checked. In one case some young plants which had been sulfured became infected, but the explanation was soon found. They had been grown since sulfuring at a temperature not over 50° F. To be successful, the sulfur must be accompanied by some rise of temperature.

Fungine, a potassium polysulfide preparation, is toxic to the urediniospores of *P. Antirrhini*. It controls snapdragon rust under glass if applied to the plant frequently, but its use is not recommended, for it has no advantages over powdered sulfur, while it costs more and cannot be applied as thoroughly as a dust.

Summary of Control Measures.

Many of the experiments already described contain suggestions as to the control of snapdragon rust. They may be summed up as follows: —

1. There is only very slight chance of rust entering a house on the seeds. The urediniospores would not live on the seeds. Teliospores are not formed till after seed is harvested, and are of no use to the fungus when formed.

2. A house which has contained snapdragon rust should not be used for snapdragons the following year if any plants have remained alive during the interim, nor unless the house has been dried out.

3. Cuttings should not be taken from a bench showing rust. If such cuttings must be used, dust them with powdered sulfur, and give them a high temperature for a few nights.

4. Varieties showing resistance to rust should be selected. The list of varieties showing relative susceptibility should be of assistance here.

5. Water should be kept off snapdragon foliage. In watering, only the soil should be wet. If syringing becomes necessary it should be done on a sunny morning so that the foliage will dry off quickly.

6. Insects should be kept down; they serve to spread the rust. But cyanide must be used carefully, as snapdragons are easily injured by it.

7. If rust appears the plants should be dusted with finely powdered sulfur. If only a few isolated leaves are infected they should be removed by hand picking. The sulfur should be applied with a good bellows that will throw clouds of dust. The temperature should be kept up for a few nights. (For more detail on sulfuring, see the article by Dr. O. R. Butler, 1917.)

8. A solution of cuprammonium sulfate containing 0.065 per cent copper will control the fungus, but because of its toxic effect on the foliage it can be used with safety only when the sprayed foliage will dry within one hour.

9. Bordeaux mixture is absolutely ineffective.

10. If rust appears the temperature should be run up to 60° F. at night for a few nights, till the rust has been placed under control by sulfuring or hand picking.' It should be borne in mind that 50° F. is the temperature most favorable to the fungus.

Summary.

Puccinia Antirrhini Diet. and Holw. is known to occur only on *Antirrhinum majus.*

This rust is the most serious disease of snapdragons under glass, and is second in importance to anthracnose on snapdragons out of doors.

The urediniospores germinate moderately well with an optimum temperature of 10° C.; the teliospores have not been germinated.

Dry urediniospores do not retain the power of germination more than six weeks.

No varieties of snapdragon are absolutely resistant to the parasite, but some are relatively resistant. The varietal resistance is dependent on the relative number of stomata per unit area of leaf surface.

The urediniospores are disseminated by cuttings, insects, water and wind.

A 0.25 per cent solution of copper sulfate is toxic to the urediniospores of *P. Antirrhini.*

A 0.25 per cent solution of cuprammonium sulfate is toxic to the urediniospores of *P. Antirrhini.*

Bordeaux mixture is not toxic to the urediniospores of *P. Antirrhini.*

The SO_2 generated by dry sulfur at a temperature of 21° C. is toxic to the urediniospores of *P. Antirrhini.*

The method of control recommended consists in growing resistant varieties, controlling cultural conditions carefully, dusting with powdered sulfur at a temperature of 70° F., and keeping the night temperature of the snapdragon house above 52° F. or below 48° F.

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TOBACCO WILDFIRE

PRELIMINARY REPORT OF INVESTIGATIONS

By G. H. CHAPMAN and P. J. ANDERSON

Wildfire, a bacterial disease of tobacco which has appeared in Massachusetts during the past two seasons, will unquestionably become a source of serious loss to growers unless it is controlled. In nearly all, if not in all, cases where the disease has been noted in the field it was found that the infection originated in the seed-bed. The production of healthy seedlings is therefore a matter of prime importance.

This bulletin describes the symptoms of the disease, its causes, and reports results of investigations on control.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

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BULLETIN No. 203.

DEPARTMENT OF BOTANY.

TOBACCO WILDFIRE.

PRELIMINARY REPORT OF INVESTIGATIONS.

BY G. H. CHAPMAN AND P. J. ANDERSON.

INTRODUCTION.

Wildfire is the name of a bacterial disease of tobacco which was first reported in 1916 in North Carolina. It may possibly have been present in previous years, but was not noted until Wolf and Foster (4) described the trouble in that year, when it caused losses in some fields. Since 1916 it has been found in a number of the tobacco sections of the country, more particularly in Kentucky, Virginia and South Carolina. It was first noted in Connecticut in 1919, but was not reported in any amount until 1920, when Dr. Clinton of the Connecticut Agricultural Experiment Station found it to be serious locally. During the same season it was found in three localities in Massachusetts.

In 1921 a very serious seed-bed infection was reported from both Connecticut and Massachusetts, and at a somewhat later date the disease was also reported from seed-beds in Pennsylvania and Ohio.[1] The disease has not been serious in the South this year, but in Massachusetts and Connecticut there was not only a wide seed-bed distribution, but also severe infection, particularly in the broadleaf, where diseased plants were set in the field. It is estimated that in Massachusetts approximately 20 per cent of the seed-beds, including those of all types of tobacco, had more or less wildfire infection. In some cases there was only a slight infection, and in others up to 90 per cent of the seedlings were infected.

The importance of the disease to the tobacco industry is great because leaves which are badly spotted are practically valueless; and furthermore, in the fields the infection works from the bottom of the plant towards the top, as a rule, and the best-quality leaves are the ones first infected.

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[1] Plant Disease Bulletin, 5:19, 37. 1921.

Last year, when to the best of our knowledge the disease appeared in rather widely separated localities in Massachusetts, it was felt that the spread might not be rapid, but in 1921 the infection was quite general throughout the State, with apparently local centers of heavy infection, the only beds or sections free from the trouble being those in outlying districts.

Unless the disease is controlled there is no question but that it will become a serious matter and the cause of considerable loss to the tobacco growers. It is apparent from data collected this year that nearly all, if not all, of our field infections originate in the seed-beds; hence the production of healthy seedlings becomes a matter of prime importance.

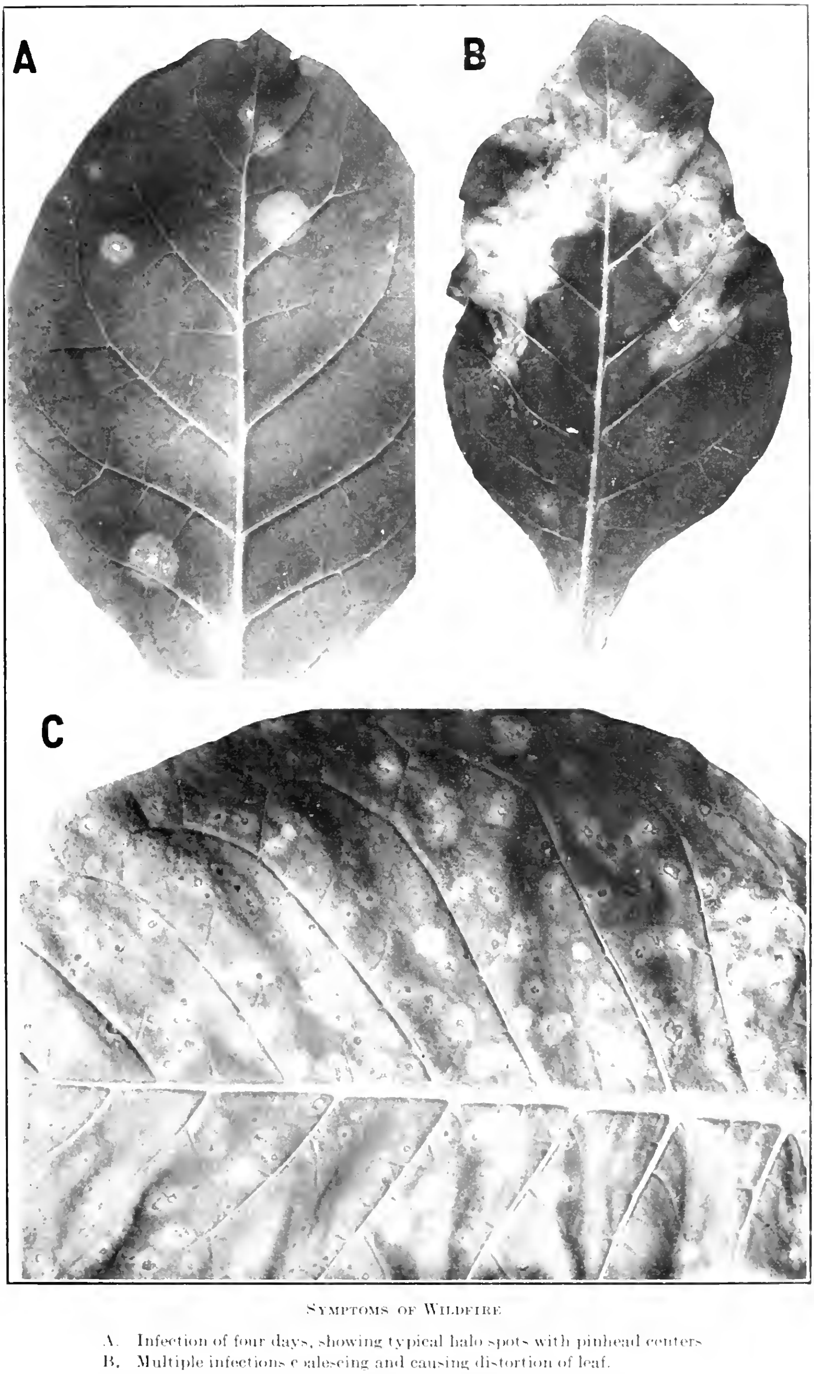
Weather conditions have a great deal to do with the spread of the trouble, as has been shown not only in the South but in Massachusetts as well. But even under favorable conditions timely control measures are necessary to combat the trouble.

It is not known how in 1921 wildfire became so generally distributed throughout the different sections, nor why we apparently had two or three successive infections during the seed-bed period. In order to determine these points, and to find, if possible, some methods of prevention, eradication or control, investigations were begun by the writers in the spring of 1921. These investigations are by no means completed, but sufficient data, especially on seed-bed control, have been secured to warrant a preliminary report.

APPEARANCE OF THE DISEASE.

The symptoms or signs of the disease are prominent and very easily recognized. The spots may be found on the leaves at any stage in the development of the plant from the time the first seed-leaves appear to full maturity. They are sometimes found on the seed-pods, but have not been observed on stalks or roots. They are usually noticed first in the seed-bed. The typical spot on the leaf in its first recognizable stage is a circular chlorotic area, yellowish green, of a lighter color than the surrounding leaf surface, and less than a quarter of an inch in diameter. Within the next twenty-four hours a small brown or whitish dead speck of less than pin-head size marks the center of the lesion which, under conditions favorable for the disease, has now increased to a quarter of an inch or more, is of a more decided yellow color, and forms a prominent halo about the central dead area (Plate I, Fig A). Both the central brown dead spot and the yellow halo now increase in size, and within a few days the affected part may be a half inch or more in diameter. The central brown dead part may or may not be surrounded by a water-soaked translucent band, depending apparently on moisture conditions. In very humid times the entire spot is sometimes soft and water-soaked. The most constant and dependable character is the yellow halo which persists in all stages of development. Any number of spots may occur

PLATE I.



Symptoms of Wildfire

A. Infection of four days, showing typical halo spots with pinhead centers.
B. Multiple infections coalescing and causing distortion of leaf.
C. Typical infection of leaf in field seven days after heavy rain.

on a single leaf (Plate I, Fig. C), and when numerous they usually run together to produce large irregular dead areas. Frequently, when a leaf is attacked while it is rapidly developing, the affected part becomes distorted and uneven (Plate I, Fig. B). Spots may be located on any part of the leaf, but a great number of them are marginal with a semi-circular halo. During dry weather the dead areas remain intact, but in stormy weather they may be broken out and result in a ragged appearance of the leaf. Severely attacked plants, especially in the seedling stage, may die, but more often the plant continues to grow and is only stunted by the injury or loss of a part of its leaves. In the field the lower leaves are most affected. No lesions are found at the top of the plant on the very young leaves which are just unfolding. Badly affected leaves are practically worthless on the market, as they cannot be used for wrappers or binders.

In the very early seedling stage, when the plants are no larger than the thumb nail, the symptoms may be atypical and not readily recognized as wildfire by the inexperienced. Superficially, affected plants have much the appearance of being attacked by ordinary damping-off. The leaves are usually affected from the margins inward and the lesions are more typical of a wet rot, and in this condition the water-soaked, translucent line is particularly noticeable between the living and dead tissue. Very often the entire leaf is withered, and nothing but the dried midrib is observable. In such plants the stem, however, is usually not affected, and this character differentiates the trouble from the ordinary damping-off, for in the latter disease infection starts in the stem and the entire plant rots down.

CAUSE OF WILDFIRE.

When the disease first came under investigation in North Carolina, Wolf and Foster (4) demonstrated by isolations and inoculations that it is produced by a parasitic species of bacteria which they named *Bacterium tobacum*. In Massachusetts the writers have made numerous isolations from all the types of lesions described above, and have invariably obtained pure cultures of an organism which gave the same cultural tests as described by Wolf and Foster (5). The same organism has never failed to produce the typical disease when healthy plants were inoculated with it from pure cultures.

An individual bacterium of this species is so microscopically small ($3.3 \times 1.2\mu$) that over 7,500 of them placed end to end would form a chain only one inch long. Its body is cylindrical with rounded ends, and two or three times as long as broad. In fresh cultures the organisms may be seen under the microscope actively darting about, the motion being produced by vibrating the long tail-like flagella (1 to 4 in number) which are attached to one end of the body. The body increases in length and divides into two individuals by the process of fission. After repeated division short chains of bacteria may be observed before they break apart.

Life History of the Causal Organism.

Although there is very little to learn about the structure of this very simple organism, there are many things which it is important that we should know about its life history. Control measures can be developed only after determining important life-history facts, such as the manner and place of overwintering, method of entrance to host, methods of spreading in the seed-bed and in the field, and longevity of the organism in various environments. About some of these life-history phases little or nothing is known as yet; concerning others we now have more definite information. It is hoped that experiments now in progress, but not completed at the date of issue of this bulletin, will clear up some of the places in the life history about which we are now ignorant. At this time we can only summarize the progress which has been made up to the present by investigators in other States, and by the writers in Massachusetts.

Infection. — Infection may occur at any stage in the development of the tobacco plant. The bacteria thrive and cause injury by rapid propagation inside the tissues of the leaf. The method by which they pass from outside the leaf through the epidermis into the interior tissue is not yet definitely known. The only openings through which they can pass are the stomates (breathing pores), the hydathodes (openings on the margins of the leaves for the exudation of water), and accidental abrasions or wounds. The writers have frequently demonstrated, however, that visible wounds are not necessary. Healthy plants of various ages have been inoculated by spraying with a suspension of the bacteria in water. Almost without exception infection has resulted, although the most careful examination has failed to reveal any wounds in the leaves. If the stomates were the only avenues of entrance, one would expect a greater percentage of infection when the lower surface of the leaves was inoculated, but the amount of infection has been about the same, irrespective of whether the upper or lower side was inoculated. The rather high percentage of marginal infection points toward the hydathodes as important infection courts. Moisture has an important role to play in infection, although perhaps more important in dissemination. Infection occurs in the field principally during rainy periods. It is not essential that the water should remain on the leaves for any long time. Successful infections are secured by spraying water suspensions on the leaves even when they become dry within a few hours.

Incubation Period. — This period covers the time between the passage of the bacteria into the interior tissues and the appearance of the first symptom of disease. The length of this period as determined by carefully watched experiments at this station is three to eight days. In the field growers usually begin to notice increased infection in five to seven days after a rain, but since the first symptoms are inconspicuous, and the casual observer does not notice the spots until they have been developing for two or three days, this confirms our conclusion as to the length of the period.

According to Wolf and Foster (5) the bacteria at first propagate only between the cells of the leaf. The cells soon begin to collapse, and one finds not only the intercellular spaces, but the cells themselves filled with dense masses of bacteria. Enzymes secreted by the bacteria apparently break down the cell contents, and some of the decomposition products are used as food for further multiplication of the parasites. As the tissue collapses the bacteria either ooze out to the surface or are exposed by rupture of the epidermis.

Dissemination.

This disease was called "wildfire" because of the extreme rapidity with which it spreads. It has been noted by all investigators of the disease and by tobacco growers that rapid spread invariably follows heavy rains. When the rain drops fall on the diseased spots, the bacteria float out into the water and successive drops splash them to other leaves of the same plant or to neighboring plants. If the rain is accompanied by wind the drops are carried farther and the spread is greater to the windward of diseased plants. A number of cases have been observed by the writers where the spread from a single diseased plant or diseased row resulting from wind-driven rain has been carefully followed. Invariably the area of new infection has been from two to ten times as great to windward as to leeward. These two agents (wind and rain) are undoubtedly the most potent of all the factors involved in dissemination. A number of experiments with various agents suspected of disseminating the disease have been conducted at this station and are summarized below.

Splashing Rain. — In order to corroborate field observations, dropping water from a rose nozzle in the greenhouse was allowed to fall onto diseased leaves and then splash to healthy young plants. The splashing was continued for five hours. Wind, insects and all other agents were excluded. Within five days lesions were observed on the plants where the water had splashed. Check plants in the same bed, which were separated from the splashed plants only by a glass partition and which had been splashed with uncontaminated tap water at the same time, remained entirely healthy. The results confirm in every way the conclusion from field observations that this is a very important agent of dissemination.

Wind. — That wind may be important in carrying the infested rain drops to greater distances has been previously mentioned and needs no further demonstration. But on the other hand, it seemed to be important to determine whether wind alone, without rain, could carry the bacteria from a diseased to a healthy plant. Therefore five diseased plants in pots were placed before an electric fan, and twelve healthy potted plants set at distances ranging from three to twenty-four inches, so placed that the air current passed from the diseased to the healthy plants. The fan was turned on for three hours on four successive days, the plants were sprinkled between times and kept under favorable conditions for infection. Since no infection resulted, even after several weeks, it seemed apparent that wind alone cannot spread the disease.

Leaf Contact. — Since in the seed-bed, and to some extent in the field, the leaves of adjacent plants come into contact, it seemed possible that the bacteria might thus pass from a diseased to a healthy plant. In order to determine whether this is possible, two diseased plants in pots were placed under a closed bell jar with two healthy plants in such a position that healthy leaves were in contact with diseased leaves in a natural way without any device for keeping them together. They were not watered, but moisture soon accumulated inside the bell jar. In a second bell jar the same experiment was repeated, but the jar was open at the top except for a thin piece of cheesecloth used to exclude insects. Infections resulted in both cases. There can be no question then but that wildfire may spread by contact. This factor is probably of more importance in seed-bed dissemination than in the field. When plants have been pulled and piled together in boxes or baskets until ready to be set in the field the moisture conditions are very favorable for the spread of the disease to healthy plants. Occasionally such plants are kept thus for days before planting, and, if diseased plants are present, no better opportunity for spreading wildfire by contact could be found.

Handling by Workmen. — Do workmen, in weeding, transplanting, hoeing, plowing and topping help to spread the disease? In order to answer this question diseased leaves were crushed between the fingers and then leaves of a healthy plant drawn through the fingers without rupturing the leaves. The plants were then kept protected under a bell jar. A few of the leaves thus treated developed typical lesions of the disease. Check plants treated in the same way after healthy leaves had been crushed in the hand remained free from disease. There is no doubt, then, that wildfire may be spread by workmen during the ordinary manipulations of the crop. The danger of spread is much greater while the plants are wet, and if there is any disease at all present, all operations while water is on the leaves should be avoided.

Insects. — It would seem almost impossible for insects to work alternately on diseased and healthy leaves without spreading the bacteria. Wolf and Moss (6) state that "flea beetles are to be regarded as carriers of infection, since the wildfire organism has been isolated from individuals which had been feeding on diseased plants." Flea beetles were the most common insects found on tobacco both in seed-bed and field in this State during the present year, and it was suspected that they carried the bacteria. To determine whether such was the case, large numbers of flea beetles were caged with diseased plants; then, after they had fed on these plants for several days, they were transferred to healthy plants, where they riddled the leaves. No wildfire lesions ever developed on these plants. Thinking that possibly the beetles had not eaten from the diseased spots in the infected plants the writers caged another lot in tubes in which only diseased bits of leaves were placed. Most of the diseased pieces were entirely consumed and all of them more or less eaten. The insects were then transferred to cages in which healthy plants were growing. Although numerous holes were eaten through the leaves, no wildfire lesions developed. The flea beetle experiments variously modified were repeated five times, but always with negative results. Wolf and Foster (5) had the same results with thrips. Other insects have not been found on tobacco in sufficient numbers to indicate that they could be the agents of dissemination. From all evidence which has been secured up to the present time we may conclude that insects are of little or no importance in the spread of the disease. This conclusion is also corroborated by a study of field conditions. If insects were responsible, one would expect to find scattered throughout the field plants which had only one or a few infections on the upper leaves, and spread from a single infected plant would be more rapid. But such is not the case. As will be explained below, most of the infections can be traced from the lower leaves, and can be readily explained by splashing and wind-borne rain.

Origin of the Disease in the Seed-beds.

Wildfire makes its first appearance in the seed-beds when the plants are yet very small. It is very essential that we should know the source of the bacteria which start this initial infection. This involves the whole problem of the overwintering of the bacteria. The possibilities are that the bacteria pass the winter on (1) the seed, (2) the chaff with the seed, (3) in the soil, (4) in the sash, frames, covers, etc. Experiments are now in progress to solve this problem by determining the longevity of the bacteria in various environments, but since these experiments have not as yet reached their conclusion, nothing can be stated as demonstrated. Fromme (2) in Virginia believes that the bacteria overwinter with the seed. The fact that infections are not positively known to start in the field from soil which is splashed onto the leaves leads one to suspect that the soil is not the source of early infection in Massachusetts. In North Carolina, however, Wolf and Moss (6) found that soil or the cloth covers which had been used the previous season could serve as carriers in overwintering the bacteria. We expect to have more definite information in regard to this point before next season. When once started in the bed, the bacteria are easily spread by splashing during watering, contact of plants, weeding, etc.

Source of Infection in the Field.

Careful field observations have been made during the past season on the origin of the field infections and the spread in the field. In the vast majority of cases it has been found that the plants came from infested seed-beds, and in all other cases the seed-bed has been suspected, but it has not been possible always to prove that it was the source. Almost always, throughout the season, when a diseased plant was found the spots could also be found on the lower leaves of the same plant which were present when the plant was set out. If not on the same plant, then they could be found on a plant which was very close by. In all the field observations we have seen nothing to indicate any other independent source of the inoculum.

OTHER HOSTS.

Up to the present the causal organism of wildfire has been found actively parasitic only on tobacco. The possibility is not excluded, however, that it may occur on other hosts. Wolf and Foster (5) isolated the organism from spots on cow peas, and were able to produce the typical disease on tobacco with the strain taken from cow peas. Only occasional small spots developed on inoculated cow peas, and they are of the opinion that the organism is not parasitic on this host, but developed only in the weakened tissues about injuries produced by leaf hoppers. They also inoculated bell peppers, potatoes, tomatoes, eggplants, horse nettle and jimson weed but were unable to produce the disease.

The writers have inoculated petunia, eggplant and pokeweed (*Phytolacca decandra*) by spraying them with suspensions of bacteria in water in the same way in which tobacco plants were usually inoculated. Some of the leaves in each case were wounded by punctures with a sterile needle.

Petunia. — Within four days after inoculation typical wildfire lesions appeared about all the punctures and on some of the leaves where no punctures were made. These increased to the usual size and the centers died. Reisolations gave the organism in pure culture, and, when tobacco plants were inoculated from these cultures, wildfire resulted. The tobacco wildfire organism is thus parasitic on the closely related genus Petunia.

Eggplant. — These plants were kept under humid conditions in bell jars. After six days necrotic lesions developed about all the punctures, but none where punctures had not been made. The lesions were 5 to 10 millimeters in diameter. Thus, although the bacteria are able to spread from wounds, apparently they are not actively parasitic on eggplant.

Pokeweed. — After a week a few lesions developed about the punctures and showed the typical broad halo. Parasitism is thus about the same as on eggplant.

Tomato. — While examining a seed-bed of infected tobacco plants at Southwick, the writers found lesions of the same type on some tomato plants which were growing among the diseased tobacco seedlings. Microscopic examination showed bacteria of the same kind in the lesions, and pure cultures were obtained. Tobacco plants inoculated from these cultures developed typical wildfire lesions. The spots on the tomato leaves appeared to have started around injuries of some kind. Undoubtedly, however, the bacteria were able under natural conditions to spread from these wounds into healthy tissue.

Further investigations of host relationships are in progress. Probably the same species of bacteria does not cause a serious disease of any of our common plants, yet it may occur rather commonly in a semi-parasitic inconspicuous condition, and this fact may prove to be of some importance in the dissemination or overwintering of the organism, and thus indirectly, also, in the control of wildfire.

CONTROL.

Necessity of starting with the Seed-bed.

It has been shown that nearly every field infection originates in the seed-bed, and that as yet there is no positive evidence that the disease has originated in the field, at least in Massachusetts. In every case that came to our attention where healthy seedlings were set, no infection was found except that brought in afterward by partial resetting. Therefore it is evident that if the seed-beds can be kept free from disease, the fields will be free from it also. All control measures should start in the seed-bed.

Sterilization of Soil.

It is the practice of many growers to steam sterilize the seed-beds in order to destroy disease-producing organisms and also to kill weed seeds. With regard to liability of wildfire infection, our observations have been that it has made little or no difference whether or not the seed-beds have been sterilized. It is, however, a good practice, and will minimize the chances of infection from material containing the organisms which may have remained in the beds. No precautionary measures should be overlooked; therefore, where it can advantageously be done, it is well to change the location of the seed-beds, particularly if sterilization is not practiced.

Seed Disinfection.

Fromme (2) has found that the organism overwinters on the seed, and has devised a method for the sterilization of seed which is apparently satisfactory, and, if carried out exactly according to the recommendations, will not injure the seed. We have sterilized several lots of seed this year, and in none of them has germination been injured. Some bad results have been reported, but these have resulted from faulty technique. Two of the most important points in seed sterilization are thorough washing out of the formaldehyde and rapid drying of the seed. Fromme in principle recommends for sterilization of seed the following procedure: Soak the seed for fifteen minutes in a solution made by adding one fluid ounce of formaldelyde (commercial strength) to a pint of water. Stir the seed all the time that they are in the solution. At the end of the time cover the pail or jar with cheesecloth and wash in running water, or wash in several changes of water until all trace of formaldehyde odor has disappeared. Spread the seed in a thin layer and dry as rapidly as possible at room temperature. Do not heat during the drying.

This treatment will not eliminate the possibility of the occurrence of the disease in the seed-bed, for some of our seed-bed infection this past season occurred after the plants were well developed, but it will eliminate one source of infection, and if the other recommendations are followed will reduce the chances of infection.

Sterilization of Sash, Cloth Covers, etc.

In the South it has been shown that the covers used on the beds are sometimes a source of infection, and it is recommended as an additional precaution that the sash, covers and side plank be washed or sprayed with a solution of formaldehyde, 1 part to 50 by measure, and dried before being used. So far, in Massachusetts, we have no positive proof that the disease is carried over in this way, but possibly it may be.

Spraying or dusting Plants in the Seed-bed.

Although the bacteria when once inside the tissues of the leaf cannot be destroyed by application of any substance to the surface, the possibility of preventing them from entering in the first place is not precluded. Spraying and dusting experiments were therefore undertaken with the object of covering the leaves with a poisonous coat which would kill the bacteria while on the surface and before they had an opportunity to pass through the epidermis.

A cloth-covered seed-bed 40 feet long and 6 feet wide was divided into 18 equal plots, and the fungicides applied for the first time when the plants were about 1 inch high and again a week later. The substances applied, rates of application and results are indicated in the table below. Four of the plots received no applications and were used as checks for comparison. No infection was present at the time of the first application, but on the following day the entire bed was sprinkled equally with a gallon of water suspension of the bacteria. Five days later infection was noted in abundance on the checks. The beds were inoculated again after the second application of the fungicides, although frequent rains in the meantime were causing satisfactory spread. One week after the second application the plants were all pulled, examined one at a time, and data recorded as to number of infections. At that time the plants were of about the right size for setting in the field. The amount of control is probably indicated more nearly by the number of spots than by the percentage of infected plants. A hand-operated 2-gallon compressed air sprayer was used for applying the liquids, and a D and B No. 100 powder blower, manufactured by the Dust Sprayer Manufacturing Company of Kansas City, Mo., was used for dusting.

Tabulation of Spraying Results.

Spray Material.	Plot Number.	Total Number of Plants.	Number of Diseased Plants.	Per Cent of Plants infected.	Average Per Cent of Infection.	Number of Lesions per Plot.
None, ...	5	300	196	66.0	48.25	936
None, ...	2	251	140	55.0		549
None, ...	16	265	96	36.0		223
None, ...	12	263	95	36.0		215
Lime-sulfur, ...	9	298	168	56.0	56.0	562
Sulfur, ...	18	301	19	6.0	6.0	26
Pyrox, ...	6	300	5	1.6	4.1	9
Pyrox, ...	10	270	18	6.7		28
Bordeaux, ...	1	207	2	1.0	1.25	8
Bordeaux, ...	14	266	4	1.5		4
Sanders dust, ...	2	232	2	.8	.55	2
Sanders dust, ...	17	302	1	.3		1
Bordeaux and lead, . . .	7	300	0	.0	.5	0
Bordeaux and lead, . . .	11	298	3	1.0		8
Pickering, ...	8	300	1	.3	.35	1
Pickering, ...	13	256	1	.4		1
NuRexo, ...	3	300	1	.3	.48	1
NuRexo, ...	15	300	2	.66		2

Notes on Substances used, and Results.

Lime-sulfur. — The ordinary commercial liquid diluted at the rate of 1 part to 40. Very severe burning of the leaves occurred within an hour after application. Since, in addition, no control was secured, it is apparent that lime-sulfur should never be used.

Pyrox. — A commercial Bordeaux paste (arsenical included) prepared by the Bowker Insecticide Company of Boston. Applied at the dilution of 10 pounds to 50 gallons of water. This fungicide was washed from the leaves by the rain to a greater extent than any of the others.

NuRexo. — A Bordeaux preparation (arsenical included) in form of a powder prepared by the Toledo Rex Spray Company of Toledo, Ohio. Diluted at rate of 8 pounds in 50 gallons of water. Adhered to leaves much better than Pyrox, but not so well as freshly prepared Bordeaux. There was a slight trace of burning, but not serious.

Freshly Prepared Bordeaux Mixture. — The ordinary 4–4–50 formula. This was washed away by rain least of all the substances which were tried, and was still to be found on the leaves after repeated heavy rains. No burning occurred.

Bordeaux Mixture and Lead Arsenate. — The Bordeaux as above, but the powdered arsenical added at the rate of 2 pounds to 50 gallons of water. Some of the leaves were burned. There seems little if any benefit to be derived by addition of the lead arsenate.

Pickering's Lime-water Bordeaux. — The clear limewater and copper sulfate solution were mixed in the proportions recommended by Cook in United States Department of Agriculture Bulletin No. 866. Considerable burning was observed, especially after the first application.

Sulfur Dust. — This remained on the leaves very well. This plot did not seem to grow as well as the others and the plants were "off color." Since the percentage of control was not so high as for some of the others, it is not to be recommended.

Sanders Dust. — A very finely ground lime-copper sulfate dust mixture prepared by Riches Piver & Co. of New York. Spreads well, adheres well and causes no burning. Both this and the sulfur dust were applied while the plants were wet with dew or rain.

Spraying Results by Growers.

Three tobacco growers followed our recommendations and sprayed with Bordeaux mixture or commercial substitutes of the same. No careful counts of results were made, but observations showed good control, and confirmed our results on the station plots.

Conclusions as to Spraying and Dusting.

Lime-sulfur and sulfur dust do not give sufficient control; Pickering's mixture and the Bordeaux with the addition of lead arsenate cause burning; Pyrox gave less control than some of the others and washed from the leaves too easily. There seems to be little choice between freshly prepared Bordeaux mixture, NuRexo and Sanders Dust. The percentage of control is about the same with all, and there is very little injury. The dust can be more quickly and easily applied, and the writers believe that it can be made to more nearly cover the lower surfaces of the leaves. They prefer the dust to the liquid. For those who prefer the liquid the home-made Bordeaux has the advantages of cheapness and better adhesion. NuRexo, as well as other commercial Bordeaux pastes and powders, has the advantage of being already prepared.

These conclusions are based on one year's experiments, and therefore should not be accepted as absolute. The experiments will be repeated for several years before final conclusions are drawn.

Aeration and Watering of Beds.

As a result of observations and experiments conducted during the season, it is recommended that the watering of the beds be done as seldom as possible, as the splashing of the water drops from plant to plant was found to spread the disease rapidly. Most of the beds are watered too much and the humidity is often very high under the sash. Water of condensation dripping from the sash to the plants also appears to be responsible for some spread. The beds should be run as dry and with as much air circulation as possible. This tends to dry off the leaves, and helps reduce the spread of the disease. In many instances where this was practiced after infections were found, spread was much slower than when the beds were closed tightly and very little if any air circulation permitted. Careful attention to this matter will result also in stronger, better plants.

Fertilizer Relations.

While fertilizer materials are not directly responsible for the disease, there is apparently a relation between the rapidity of spread in the seed-bed and the application of excessive amounts of some materials. This was particularly noted in the case of nitrogen. Where excessive amounts of nitrogen were applied to infested beds, the disease was much more serious on the parts so treated than on those sections to which no additional nitrogen was applied. It was also noted that where growers applied potash to infested beds the spread of the trouble was less than on sections of the beds where none was applied. There have been no careful experiments on the relation of fertilization to susceptibility, but it is known that excessive nitrogen applications force rapid succulent plant growth, with little resistance to any change in environment or disease invasion. Potash is said to cause strengthening of the green parts of the plant, and make it stockier and less susceptible to disease and change in environment. This question cannot be considered settled, and experiments are under way to check up on this point as related specifically to wildfire.

Selecting Plants from Disease-free Beds.

Plants from infested seed-beds should never be set in the field, even though the infection is slight. During the past season it was observed that although plants in and around the infected areas were killed out with formaldehyde, some infection, undeveloped at the time, appeared later, and subsequently many of these beds became heavily infected. Many of the lesions are so small and inconspicuous that they escape any but the most careful observation. A single observation of the seed-bed in the early part of the season is not an indication that the beds will remain free from disease. This was shown by the fact that there were two and possibly three recurring epidemics this past spring, the last occurring almost at the end of the setting season. It was the experience of many growers that while the early set plants from their beds showed none of the disease in the field, the late set plants developed the disease, and it was also noted that many of the plants used for restocking showed the trouble even when pulled from the same beds from which the field was set, and that the disease occurred only on these plants.

Relative Susceptibility of Varieties.

In the seed-bed the different varieties of tobacco seem to show no difference in susceptibility to the disease, but under field conditions the spread of the disease seems to be governed somewhat by the manner and type of growth of the variety. Shade Cuban seems to be but little affected with the trouble after setting in the field. Here the protection afforded by the tent undoubtedly has something to do with it, as the rain and wind is broken; also the open habit of growth, with the leaves relatively far apart, minimizes the chances for a rapid spread. The same is true of the Havana to a less extent, the leaves of this variety, also, having an upright habit of growth, and touching but little.

The practice of priming the leaves of the Shade Cuban and some of the Havana is also an important factor in reducing the spread of the disease, as the first priming is made early, and this includes usually the infected leaves. In this way, as will be noted under the subject of removal of diseased leaves, a large amount of field infection probably is prevented. Perhaps Broadleaf suffers most of all the varieties, as, when the leaves get their growth, they droop and touch each other and also leaves of near-by plants, and thus infection occurs more easily.

During this past season a great deal of late infection in the field has been observed, *i.e.*, many fields of Broadleaf showed practically no infection prior to topping, but after a few days, as the plants were maturing, showed a rapid spread of the disease. Cases have been called to the attention of the writers where the typical halo spots were found on all leaves of the plant. During this past season there was a large amount of "rust" on Broadleaf in some sections, and this has been confused by growers and others with true wildfire. The writers wish to point out the possibility that part of this spotting was caused by excess of nitrogen and deficiency of potash, not sufficient in the case of the latter to show symptoms of potash hunger, but enough to cause a rusting. This rusting occurs on some of the tobacco in Carolina, and has been demonstrated to be a result of the above-mentioned conditions; and this *may* be true of some of the spotting of Broadleaf, and possibly the other varieties, since very little potash has been used during the past four or five years. There is, however, no experimental evidence to warrant this statement as a fact so far as our Massachusetts conditions are concerned.

Removal of Diseased Plants or Leaves from the Field.

When the disease has become established in the field, spraying operations are not practicable. The only promising method of control at this stage seems to be the elimination of diseased plants or leaves. If infection in a field is found to be pretty general early in the season, it is perhaps best to remove all the plants and replant from a bed known to be free from the disease, if such can be found. In two fields containing thirty-five acres of tobacco, entire removal and replanting in this way was practiced with complete success. Practically no infection was found in either field at the close of the season. If the infection is light and the season is not far advanced, only the affected plants should be removed and destroyed, and healthy ones from disease-free beds substituted. When a light infection occurs late in the season there is a fair chance of keeping it under control by careful removal of the diseased leaves only. Good control was secured in this manner in a number of fields which came under the writers' observation during the past season.

Working only with Dry Plants.

In the previous pages the connection of water with dissemination and infection has been explained. If wildfire is known to be present and one wishes to keep it under control, obviously all operations should cease when the leaves are wet from dew or rain.

CONDENSED RECOMMENDATIONS FOR CONTROL.

1. Save seed only from disease-free plants.
2. Sterilize seed.
3. Sterilize seed-beds with steam or formaldehyde, or, when the disease has been in beds the previous year, change the location if practicable.
4. Spray or wash sash, plank or cloth with formaldehyde.
5. Spray or dust the beds with a fungicide weekly from the time the plants are the size of the thumb nail until setting is completed.
6. Water beds only sufficiently to keep plants growing. Ventilate thoroughly.
7. Set plants from disease-free beds only.
8. If badly diseased plants are found in the field, remove and destroy them.
9. If infection in the field is light or occurs late in the season, pick and destroy the diseased leaves when they are not wet from dew or rain.
10. As far as possible avoid working in the tobacco when the leaves are wet.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 204 SEPTEMBER, 1921

THIRTY YEARS' EXPERIENCE

WITH

SULFATE OF AMMONIA

By F. W. MORSE

Sulfate of ammonia is now the most important domestic source of fertilizer nitrogen. During the late war its production in this country, by means of by-product coke ovens, was increased to three times its previous volume. It is apparently one of the most promising sources of nitrogen to which we must look in the future. It is necessary that we should know the conditions under which it is used most effectively. Experiments in the use of this product have been under way for many years at the Massachusetts Agricultural Experiment Station. Sometimes the effects have been excellent; at other times positive injury to crops has apparently been caused by its use. This bulletin reports a study of the various conditions under which these results were secured.

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CONTENTS.

BULLETIN No. 204.

DEPARTMENT OF CHEMISTRY.

THIRTY YEARS' EXPERIENCE WITH SULFATE OF AMMONIA.

BY F. W. MORSE.

Sulfate of ammonia has been used for many years at the Massachusetts Agricultural Experiment Station in field experiments with fertilizers. Sometimes the effects have been excellent and at other times positive injury to crops has apparently been caused by its use. The object of this bulletin is to show the conditions under which sulfate of ammonia has been used, and to point out the way that seems likely to give favorable results when it is applied as a fertilizer. No attempt is made to show its effect in comparison with the other nitrogenous fertilizers used on adjacent plots in the same field. The comparative results have been reported from year to year in the publications of the Experiment Station, and nitrate of soda has been superior to the sulfate of ammonia in crop production per unit of nitrogen.

In determining the significance of the data herein presented, the following suggestions may be of value: —

1. Sulfate of ammonia as a source of nitrogen was used year after year in a single arbitrary quantity. It is fair to assume that had the application been varied in amount, as indicated by the probable need of nitrogen of the crop to be grown, better average results would have been secured. Present averages include years in which sulfate of ammonia could not have been expected to bring marked response.

2. It is possible, and in fact probable, that to depend on a single source of nitrogen is unsound fertilizer practice. What would have happened had the sulfate of ammonia been combined with other sources of nitrogen is of course a question.

3. The amount of fertilizer nitrogen applied as sulfate of ammonia was in no way dictated by the value of the crop to be grown. This being the case, any computation as to the profits derived from the use of this material is absolutely meaningless. It was not applied on any profit-making basis.

History of Plots.

The plots on which the sulfate of ammonia has been employed were laid out in 1883 as a part of the first experiment field prepared by the late C. A. Goessmann after the founding of the State Agricultural Experiment Station in 1883. During the first six years the field was used as a soil test, and corn was grown every year. In 1889 the plans were rearranged to permit a comparison of standard nitrogenous fertilizers, which has continued to the present time. The experiments have been described with more or less detail in the annual reports of the Experiment Station, under the headings Field A, and Experiments with Nitrogenous Fertilizers. The earlier reports were prepared by the late Director Goessmann,[1] and the later ones by Director W. P. Brooks.[2]

Soil Conditions.

The surface of the field has a slight, uniform slope toward the east and south. The soil and subsoil are a sandy loam classified in the soil survey of the Connecticut Valley as Norfolk, but later reclassified as Merrimac.[3] At a depth of 4 to 5 feet, as shown by the excavation for drains, the field is underlain by the boulder clay of glacial till. The geological formation is that of a river delta,[4] and excavations for buildings in the vicinity of the plots have shown no stratification in the underlying earth, but irregular masses of coarse and fine material so hard and compact as to require constant use of the pick in excavating. Although the surface soil is quite uniform, there is considerable variation in the depth to the till, which possibly causes some of the differences between plots handled uniformly alike.

Fertilizer and Lime Treatment.

The field is laid out in 11 plots of one-tenth acre each, separated from one another by strips 5 feet in width. A drain of 2-inch tile runs lengthwise through the center of each plot at a depth of 3 feet, and empties into a well formed of 24-inch tile, 4 feet deep, at the bottom of which runs the main drain along the eastern border of the field.

The plots compared in this report are numbered 4, 5, 6, 7, 8 and 9. Sulfate of ammonia has been applied to 5, 6 and 8 at the rate of 225 pounds per acre, while 4, 7 and 9 have received no nitrogen since 1882, and probably a number of years preceding that.

During the preliminary soil test, 1883–88, plots 6 and 8 were unfertilized, while 5 received sulfate of ammonia. Since 1889 all the plots have received per acre 80 pounds of available phosphoric acid in superphosphates, and 125 pounds of potash in potash salts. Plots 4 and 5 have

[1] Mass. Agr. Expt. Sta., Ann. Repts., 1883 to 1896, inclusive.
[2] Mass. Agr. Expt. Sta., Ann. Repts., 1897 to 1917, inclusive.
[3] Soils of the United States. Bul. No. 55, Bureau of Soils, U. S. Dept. Agr., p. 158.
[4] B. K. Emerson. Geology of Old Hampshire County.

received low-grade sulfate of potash-magnesia, while 6, 7, 8 and 9 have had muriate of potash applied to them.

The plots have had applications of lime at irregular intervals. In 1894, plot 8 alone received a small application of air-slaked lime at the rate of 500 pounds per acre, because it had been persistently inferior to all others in production. The lime produced a favorable effect. All the plots were dressed with hydrated lime in 1898 and again in 1905, at the rate of 1 ton per acre each time. The east half of each plot received an application of hydrated lime in 1909 at the rate of 5,000 pounds per acre, and again in 1913 at the rate of 4,000 pounds per acre.

The east half of the field is positively moister than the west half, so that a fair comparison between the yields produced with lime and those without it cannot be made; but the effects of liming on the relations of the plots to each other can be determined.

The arrangement of the plots permits the comparison of yields from the plots treated with sulfate of ammonia with the yields from plots without nitrogen lying directly beside them.

Scheme of Fertilization of Plots.

NORTH.

9.	No nitrogen, superphosphate, muriate of potash.	
	Lime.	
	1898, 1905.	1898, 1905, 1909, 1913.
8.	Sulfate of ammonia, superphosphate, muriate of potash.	
	Lime.	
	1894, 1898, 1905.	1894, 1898, 1905, 1909, 1913.
7.	No nitrogen, superphosphate, muriate of potash.	
	Lime.	
	1898, 1905.	1898, 1905, 1909, 1913.
6.	Sulfate of ammonia, superphosphate, muriate of potash.	
	Lime.	
	1898, 1905.	1898, 1905, 1909, 1913.
5.	Sulfate of ammonia, superphosphate, sulfate of potash-magnesia.	
	Lime.	
	1898, 1905.	1898, 1905, 1909, 1913.
4.	No nitrogen, superphosphate, sulfate of potash-magnesia.	
	Lime.	
	1898, 1905.	1898, 1905, 1909, 1913.

SOUTH.

Yields on No-nitrogen Plots.

The yields of the plots without nitrogen, 4, 7 and 9, have been closely studied to ascertain whether there were any consistent differences in their production which might be due to variations in soil; but no uniform relations have been found. During the thirty years, 1889–1918, there was but one season, 1892, when the yields of the three were closely alike. Sometimes one plot has been the best and at other times the poorest. Plot 7 has been the highest in twelve years and the lowest in seven, while plot 4 was highest in eleven and lowest in fifteen years; therefore 7 may be a little the best, while 4 has been possibly a bit poorer than 9. But the differences are slight and cannot be used to explain the variations in yields on the plots receiving sulfate of ammonia. Previous to 1910 the divergences between the highest and the lowest yields on these plots without nitrogen were often from 25 to 30 per cent, and even more, while after the somewhat heavy liming in 1909 — though it covered only one-half the area — the divergences were nearly always less than 10 per cent.

Yields on Sulfate of Ammonia Plots.

The yields on the plots which receive sulfate of ammonia have been somewhat erratic, with first one plot and then the other showing marked inferiority to the other two, and also to the adjacent plots which receive no nitrogen. There is an indication from the flow of drainage water that plot 8 may have soil slightly more open in texture than the soil of 5 and 6; otherwise there is no apparent reason for the variations that have occurred in the yields of these plots in different seasons, by which 8 has oftenest been the lowest producer.

Tables of rainfall and crop yields are given on pages 88 and 89. The gross weights of crops for the individual plots are used without division into grain and straw when the cereals are listed. Nitrogen is definitely known to be a promoter of plant growth rather than maturity, hence the total weight per plot is a proper measure of the crop-producing power of a nitrogenous fertilizer.

Crops Grown.

Eight different kinds of crops have been grown in the period of thirty years covered by the tables. Each kind of crop is taken up separately in discussing the comparative yields from the plots with sulfate of ammonia and from those without it.

Corn. — Corn has been grown in five of the seasons included in this summary. The first crop was in the first year of the experiment. Corn had been grown continuously since 1883, and soil conditions had become such that the yield was smaller than in any of the subsequent years; therefore this year will not be considered in the discussion. The four crops to be compared were grown under somewhat varied conditions of soil and previous cropping.

The crop of 1906 followed the 1905 crop of oats and peas when the land was limed. The sulfate of ammonia plots produced about 20 per cent more weight than the plots without nitrogen. In 1911 the corn followed four successive years of hay production, including some clover, and an application of lime over the east half of the plots in the fall of 1909. The yields without nitrogen exceeded those with ammonia by a small amount, between 2 and 3 per cent. Corn was raised again the next year, and the results were changed, the ammonia plots producing about 7 per cent more weight. The spring months of 1911 were dry, also June and July of 1912. In 1918 corn was the last crop of this period. It had been preceded by potatoes in 1917, millet in 1916 and clover in 1915, previous to which (in 1913) the east half of the plots had been heavily limed. The crop from the limed and unlimed areas was harvested separately. In the presence of lime, the ammonia plots produced an increase of 28 per cent over the no-nitrogen plots, while without lime they were slightly inferior to the plots without nitrogen.

TABLE III. — *Average Yield of Corn (Ears and Stover) (Pounds per Acre).*

	1889.	1906.[1]	1911.[2]	1912.	1918.[3]	
					Unlimed.	Limed.
No nitrogen,	4,600	8,940	10,150	9,980	8,680	11,380
Sulfate of ammonia,	4,630	10,690	9,880	10,720	8,420	14,640
Percentage increase,	–	19	–	7	–	28

[1] After oats and peas with lime.
[2] After clover with lime applied to half area.
[3] Last limed in 1913 over half area.

Oats. — Seven crops of oats were grown during the years covered by the experiment. The first crop (1890) followed the continuous corn culture practiced for seven years. The next three crops (1893, 1895, 1897) alternated with crops of soy beans. In 1898 the crop followed the oats of 1897, but the land was limed before seeding at the rate of 2,000 pounds per acre of air-slaked lime, and the oats were sown as a nurse crop for clover. In 1905 oats were combined with field peas and followed a crop of potatoes, and the land was again limed at the rate of 2,000 pounds of air-slaked lime per acre. Up to this point the land had been plowed every year since 1883, except 1899. In 1914 oats were sown as a nurse crop for clover, after three years of tilled crops, — two of corn and one of Japanese millet. The east half of the plots had been limed in 1909 and 1913. The last two crops of oats were cut for hay and the others were permitted to ripen the grain. The rainfall in 1890, 1893 and 1895 had been well distributed during the months of growth, and was about normal in amount.

Table I. — *Rainfall in Inches.*

Year.	April.	May.	June.	July.	August.	September.	Total for Year.
1889,	2.87	4.71	5.01	7.55	**2.35**	**2.36**	40.37
1890,	**1.35**	4.56	**1.42**	5.23	4.06	4.86	**39.48**
1891,	**1.55**	**1.64**	4.36	4.93	3.43	**1.78**	**34.82**
1892,	**.54**	4.73	2.61	3.28	5.23	**1.29**	40.35
1893,	**2.20**	3.17	**2.42**	**1.77**	**2.10**	**1.88**	46.94
1894,	9.85	2.92	**1.69**	**.99**	**.19**	**2.38**	**32.64**
1895,	5.56	**2.07**	2.76	3.87	3.46	5.04	44.46
1896,	**1.32**	2.58	2.57	4.96	3.84	5.41	**39.66**
1897,	**2.42**	4.38	6.65	14.51[1]	4.29	**1.94**	57.05
1898,	3.73	5.61	3.69	4.09	6.85	3.65	53.89
1899,	**1.79**	**1.28**	4.13	4.89	**2.00**	7.90	41.49
1900,	**1.85**	3.78	3.65	4.67	4.11	3.67	51.67
1901,	5.95	6.91	**.87**	3.86	6.14	4.17	49.72
1902,	3.31	**2.32**	4.54	4.66	4.65	5.83	46.99
1903,	**2.30**	**.48**	7.79	4.64	4.92	**1.66**	45.45
1904,	5.73	4.55	5.35	2.62	4.09	5.45	45.30
1905,	2.56	**1.28**	2.86	2.63	6.47	6.26	**38.80**
1906,	3.25	4.95	2.82	3.45	6.42	2.59	45.45
1907,	**1.98**	4.02	**2.36**	2.87	**1.44**	8.74	42.27
1908,	**1.97**	4.35	**.76**	3.28	4.27	**1.73**	**30.68**
1909,	5.53	3.36	**2.24**	**2.24**	3.79	4.99	**39.12**
1910,	3.07	2.67	2.65	**1.90**	4.03	2.86	**36.11**
1911,	**1.87**	**1.37**	**2.02**	4.21	5.92	3.41	44.21
1912,	3.92	4.34	**.77**	2.61	3.22	2.52	**38.56**
1913,	3.30	4.94	**.90**	**1.59**	**2.26**	2.56	**39.50**
1914,	6.59	3.56	**2.32**	3.53	5.11	**.52**	41.83
1915,	3.99	**1.20**	3.00	9.13	8.28	**1.37**	51.58
1916,	3.69	3.21	5.34	6.85	**2.49**	5.08	45.61
1917,	**1.83**	4.13	5.27	3.36	7.06	**2.42**	43.56
1918,	2.78	**2.47**	4.01	**1.84**	**2.22**	7.00	**37.47**

[1] Eight inches the 13th and 14th.

Black-face type shows a rainfall much less than normal. It may be noted that from 1907 to 1913 there was a period of deficient rainfall, and the soil grew drier and drier each succeeding year. A short period of spring or summer drought during these years was responsible for pronounced ill effects from the sulfate of ammonia, although the liming of one-half the area conceals the injury in the averages. The period following, as a whole, had a high rainfall, and toxic effects from the ammonia salt were not noticeable on the unlimed area. In 1918 another period of low rainfall occurred, running over into the spring of 1919, when corn was particularly affected by the sulfate of ammonia on the unlimed sections of plots 5 and 6, as described in detail toward the end of this bulletin.

TABLE II. — *Crop Yields (Pounds per Plot).*

Year.	Crop.	Plot 4. No Nitrogen.	Plot 5. Sulfate of Ammonia.	Plot 6. Sulfate of Ammonia.	Plot 7. No Nitrogen.	Plot 8. Sulfate of Ammonia.	Plot 9. No Nitrogen.
1889	Corn (ears and stover),	381	488	541	525	359 [1]	475
1890	Oats (grain and straw),	260	360	385	320	220 [1]	290
1891 [2]	Rye (grain and straw),	390	530	400	450	–	425
1892	Soy beans, green,	1,440	1,935	1,970	1,430	1,450 [1]	1,460
1893	Oats (grain and straw),	590	630	600	550	420 [1]	480
1894	Soy beans, green,	405	645	615	480	680	470
1895	Oats (grain and straw),	343	550	560	428	450	430
1896	Soy beans, green,	1,130	1,582	1,870	1,240	1,980	1,060
1897	Oats (grain and straw),	189	477	372	197	477	205
1898 [4]	Oats (grain and straw),	136	238	269	167	278	171
1899	Clover hay,	325	340	340	342	420	390
1900	Potatoes,	1,387	1,343	1,247	1,268	1,215	1,108
1901	Soy beans (seed and straw),	428	393 [1]	485	385	423	382
1902	Potatoes,	1,011	1,002	1,218	1,114	978	1,013
1903	Soy beans (seed and straw),	269	246	183	177	225	125
1904	Potatoes,	758	1,059	694	694	876	1,066
1905 [4]	Oats and peas (hay),	435	565	660	480	690	390
1906	Corn (ears and stover),	957	1,048	1,044	850	1,115	875
1907	Clover hay,	340	295	222 [1]	300	260	260
1908	Clover hay,	340	358	215 [1]	463	505	465
1909 [5]	Clover hay,	395	437	420	315	450	375
1910	Hay,	640	722	700	675	630 [1]	705
1911	Corn (ears and stover),	1,047	996 [1]	1,010	956	958 [1]	1,042
1912	Corn (ears and stover),	950	1,056	1,043	1,034	1,118	1,010
1913 [5]	Japanese millet (hay),	730	1,020	1,120	670	1,220	670
1914	Oats (hay),	190	230	290	205	335	200
1915	Clover hay,	845	770 [1]	835	783	820	800
1916	Japanese millet (seed and straw),	585	580 [1]	675	645	675	640
1917	Potatoes,	1,890	1,664	1,669	1,459	1,614	1,463
1918	Corn (ears and stover),	936	1,045	1,123	1,055	1,291	1,018

[1] Sulfate of ammonia was apparently injurious.
[2] Crop on plot 8 destroyed by insects.
[3] Plot 8 received an application of lime.
[4] All plots limed on their entire area.
[5] The east half of every plot was limed.

Of the plots receiving ammonia, No. 8 made the poorest yield year after year without regard to kind of crop. In 1897 and 1898 the seasons were excessively wet, and plot 8 equaled or exceeded the other plots. It has been mentioned that this plot has appeared to be a little drier than the remainder of the field, which accords with its variable yields in the different seasons.

The sulfate of ammonia was beneficial in each year, but in 1893, a year of well-distributed average rainfall, the plots without nitrogen yielded their maximum crop and nearly equaled the yields of the ammonia plots. In 1897 and 1898 the ammonia produced marked increases in yields under adverse conditions of heavy rainfall and wet soil.

TABLE IV. — *Average Yield of Oats (Grain and Straw) (Pounds per Acre).*

	1890.	1893.	1895.	1897.	1898.[1]	1905.[1]	1914.[1]	
							Un-limed.	Limed.
No nitrogen,	2,900	5,400	4,000	1,970	1,580	4,350[2]	1,420[2]	2,530[2]
Sulfate of ammonia,	3,220	5,500	5,200	4,420	2,620	6,380[2]	2,160[2]	3,530[2]
Percentage increase,	11	2	30	124	65	46	52	39

[1] Limed in 1898 and 1905 over whole area, and in 1909 and 1913 over half area.
[2] Harvested as hay.

Soy Beans. — Five crops of soy beans were grown in this experiment. Three of them (1892, 1894 and 1896) alternated with grain crops and were cut and weighed green. The season of 1894 was extremely dry, with but 9 inches of rain from April 1 to October 1; consequently the yield in this season was much less than in the other two, when the rainfall was about normal. Plot 8 was given a light dressing of lime in 1894, which resulted in maximum yields on this plot in both 1894 and 1896.

The other two crops were grown in 1901 and 1903 and followed potatoes in each case. In 1898 the field had been limed over its entire area. The two crops ripened their seed, and the weights of the combined straw and beans are given. The rainfall was abundant as a whole, but June, 1901, and May, 1903, were each dry months, and may have influenced the yields somewhat.

In the earlier period sulfate of ammonia produced a marked effect on the crops, reaching a maximum of nearly 60 per cent increase in 1896. The crops of the second period were benefited but little by the ammonia. Probably by this time the soil had become naturally inoculated with the soy bean bacteria for fixing nitrogen from the air, for the soy beans grew nearly as well on the plots without nitrogen as on those which received sulfate of ammonia. In 1901 it was recorded that nodules were abundant on the roots.

PLATE I.—CHARACTER OF VEGETATION ON UNLIMED PLOTS, 1920.

Photo. by R. L. Coffin.

With sulfate of ammonia. Yield per acre, 2,620 pounds.

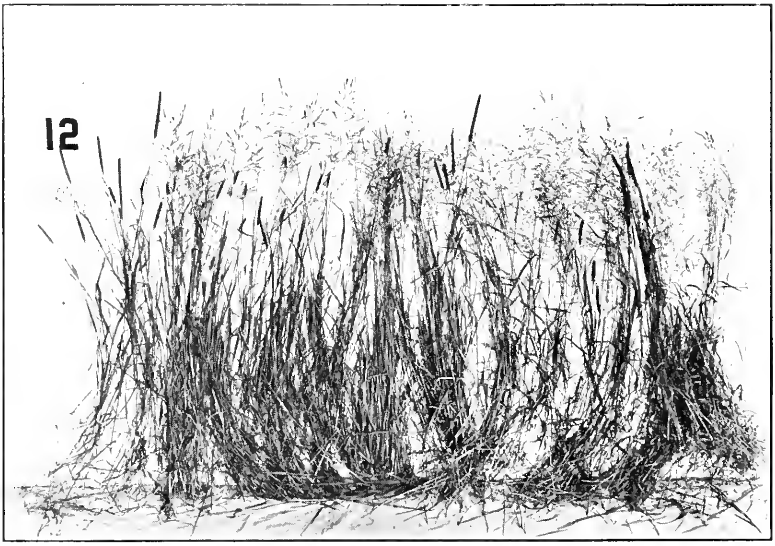

Photo. by R. L. Coffin.

With nitrate of soda. Yield per acre, 4,180 pounds.

PLATE II. — CHARACTER OF VEGETATION ON LIMED PLOTS, 1920.

Photo. by R. L. Coffin.

With sulfate of ammonia. Yield per acre, 6,095 pounds.

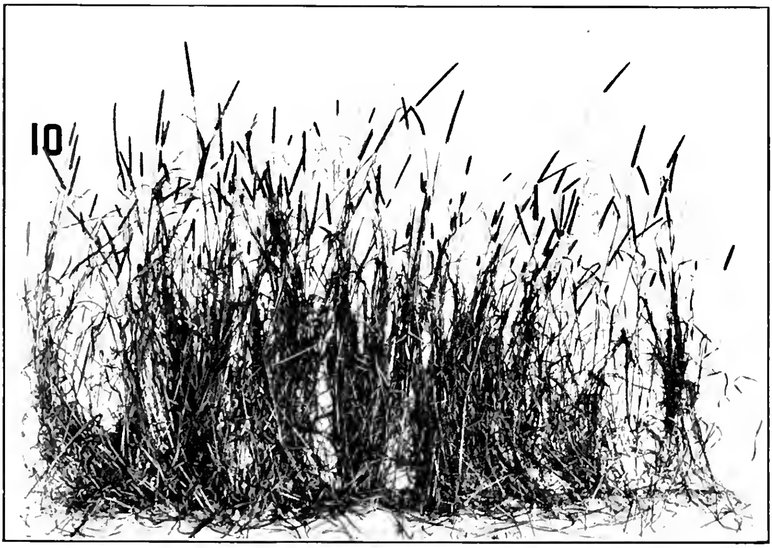

Photo. by R. L. Coffin.

With nitrate of soda. Yield per acre, 6,130 pounds.

TABLE V. — *Average Yield of Soy Beans (Pounds per Acre).*

	1892.[1]	1894.[1]	1896.[1]	1901.[2]	1903.[2]
No nitrogen,	14,430	4,520	11,430	3,980	1,900
Sulfate of ammonia,	17,850	6,470	18,110	4,340	2,180
Percentage increase,	23	43	58	9	14

[1] Weight in green state. [2] Weight dry and ripe.

Potatoes. — Potatoes have been grown four times, three of them in alternate years, 1900, 1902 and 1904, in which period the first crop followed clover and the other two followed soy beans. The soil had been limed in 1898. The seasons were all normal in rainfall. In these three years it is noticeable that the crop steadily diminished year by year on all plots, and in no year was there any appreciable benefit from the sulfate of ammonia; neither can it be said to have injured the crop, as the soil gradually lost the effects of the lime of 1898. It must be considered that either clover or lime had a more positively favorable result than soy beans or sulfate of ammonia.

In 1917 potatoes followed millet, which in turn was preceded by clover in 1915. The east half of each plot had been heavily limed in 1913. On the limed areas there was no advantage from the sulfate of ammonia. On the unlimed areas there was a small gain from its use. The unlimed areas had received no lime since 1905, while the limed had been dressed in 1909 as well as in 1913. Under the conditions of this experiment, which are in no case abnormal, sulfate of ammonia was of little benefit to potatoes.

TABLE VI. — *Average Yield of Potatoes (Pounds per Acre).*

	1900.[1]	1902.[2]	1904.[2]	1917.[3]	
				Unlimed.	Limed.
No nitrogen,	12,540	10,690	8,390	12,060	20,020
Sulfate of ammonia,	12,680	10,660	8,760	12,900	19,340
Percentage increase,	1	-	4	7	-

[1] After clover. [2] After soy beans. [3] Lime last applied in 1913 over half area.

Grass and Clover. — A hay crop consisting largely of clover has been grown in six of the years, but not in any systematic rotation.

The first crop was red clover in 1899. It had been sown the previous year with oats as a nurse crop, and the land received a dressing of lime over the whole area. The clover was winterkilled somewhat, and was unevenly distributed. There was a small gain on the plots receiving the sulfate of ammonia.

The crop of 1915 was produced under similar conditions. The plots were seeded in the spring of 1914 with oats as a nurse crop. The soil had been heavily limed in 1913 on the east half of the plots, but the west half had received none since 1905. The clover was sown in a mixture with redtop and timothy. After the oats were cut the rainfall was sufficient to start the clover promptly, and it grew faster than the timothy and redtop except on the unlimed parts of the sulfate of ammonia plots, where redtop became the principal crop. No cutting was made that season, and the clover and redtop wintered in perfect condition. The two halves of each plot were harvested and weighed separately. On the unlimed half the clover without nitrogen outyielded the redtop with sulfate of ammonia, but on the limed half the sulfate of ammonia produced about 10 per cent more clover than was produced without it. The rainfall was well distributed during the growing periods of 1899 and 1915.

Four of the clover crops, consisting of alsike clover, were grown in four successive years (1907, 1908, 1909 and 1910) as annual crops. The first crop was sown in the corn in the summer of 1906. It did not winter satisfactorily, and after the hay had been removed in 1907 the land was plowed and reseeded with clover. Conditions repeated themselves in 1908 and again in 1909. In no season was there a good stand of alsike clover, but the vacant spaces filled up with weeds or volunteer grasses. The rainfall in 1906 and 1907 was normal; in 1908, 1909 and 1910 it was continuously below normal, but in general was well distributed, and the soil grew steadily drier. The crop of 1909 was from one-fourth to one-half weeds by actual weights. It was the only year of the four in which the plots receiving sulfate of ammonia considerably exceeded in yield those without nitrogen. In the fall of 1909 the east half of the plots was top-dressed with hydrated lime, and in 1910 the crop consisted of much more timothy than clover, with a slight gain on the ammonia.

TABLE VII. — *Average Yield of Hay (Pounds per Acre).*

	1899.[1]	1907.[1]	1908.[1]	1909.[1]	1910.[2]	1915.[2]	
						Unlimed.	Limed.
No nitrogen,	3,520	3,000	4,230	3,620	6,730	8,130	8,050
Sulfate of ammonia,	3,670	2,590	3,590	4,360	7,010	7,300	8,870
Percentage increase,	4	-	-	20	4	-	10

[1] Lime applied in 1898 and 1905 over whole area.
[2] Lime applied in the fall of 1909 and in 1913 over half area.

Japanese Barnyard Millet. — This has been grown twice and the two crops have been produced under quite different conditions. The first crop was grown in 1913 and followed two successive corn crops. The soil had been limed on the east half of the plots in 1909 and 1913. The millet was cut for hay when the seed had formed but had not filled out. The crop of 1916 was a catch crop. The land had produced an excellent crop of clover the preceding year, and the stubble had been plowed under. Potatoes were planted early in the spring of 1916, but the stand proved too uneven to be satisfactory for the experiment, and the land was plowed and seeded to millet in the early summer. The crop was ripened and cut for seed.

In 1913 continuous tillage with corn for two years had used most of the organic nitrogen in the soil, and the sulfate of ammonia plots yielded 60 per cent more than those without nitrogen. In 1916, when there was a lot of organic nitrogen from the clover stubble, the no-nitrogen plots produced almost as well as those with ammonia.

TABLE VIII. — *Average Yield of Japanese Millet (Pounds per Acre).*

	1913.[1]	1916.[2]
No nitrogen,	6,900	6,230
Sulfate of ammonia,	11,200	6,430
Percentage increase,	62	3

[1] Limed over half area. Crop harvested as hay.
[2] After clover. Crop ripened for seed.

SUMMARY OF RESULTS BY CROPS.

Corn was benefited by the sulfate of ammonia in 1906, 1912 and 1918 where lime was present and the land had not recently been in sod. In 1911, following four years of grass and clover, the ammonia was ineffective. Without lime, on old ground, in 1889 and 1918, ammonia was ineffective.

Oats responded to sulfate of ammonia every year in which they were grown. The crop was least responsive in 1893, which was a season of favorable rainfall, and the plots without nitrogen gave a maximum yield.

Soy beans were benefited by the sulfate of ammonia, but its effectiveness grew less as natural inoculation of the soil developed.

Potatoes received little benefit from the ammonia under the conditions of the experiment.

Clover was discouraged by sulfate of ammonia in the absence of lime. Redtop was benefited by the ammonia without lime. Grasses in general require lime with the sulfate of ammonia.

Japanese millet was much increased by the sulfate of ammonia on old ground; but following clover the ammonia had but little effect.

History of the Plots in 1919 and 1920.

Corn and hay have been produced in the two years succeeding the period that has been included in the tables and summary. In 1919 the plots received an application of ground limestone at the rate of 2,000 pounds per acre. The lime was applied on the north half of each plot, lengthwise of the area, instead of on the east half crosswise of the plots, as heretofore. Plot 6 received no lime at this time, while its duplicate, plot 8, was limed throughout. This rearrangement, it is believed, will lead, as time passes, to a fairer comparison between the results obtained with lime and those without lime.

In the preparation of the preceding tables it was deemed best not to include the crop of 1919, while that of 1920 had not yet been produced. Now it seems proper to place them by themselves and amplify the results already shown.

The crop in 1919 was corn, which was grown as a preliminary step to seeding with grass in the summer. Hay from mixed timothy, redtop and clover was produced in 1920. The rainfall for the two years and the crop yields are tabulated below.

Table IX. — *Crop Yields of 1919 and 1920 (Pounds per Acre).*

	1919.		1920.	
	Corn (Ears and Stover).		Hay from Mixed Grasses.	
	Unlimed.	Limed.	Unlimed.	Limed.
No nitrogen,	7,520	8,060	2,760	3,540
Sulfate of ammonia,	8,480	10,120	4,620	6,480
Percentage increase,	12	25	67	83

Table X. — *Rainfall, Seasons of 1919 and 1920.*

	April.	May.	June.	July.	August.	September.	Total for Year.
1919,	**2.37**	6.20	**1.09**	4.17	4.81	4.25	41.42
1920,	4.71	3.65	6.26	**2.06**	3.62	6.74	50.09

The value of lime in conjunction with sulfate of ammonia is well shown in these two crops. Although the ammonia produced an increase without lime, the gain with lime was much greater. The absence of clover from the unlimed areas in 1920 was striking, and redtop was the main crop instead. On unlimed areas, with both corn and grass, sulfate of ammonia showed injurious effects which are discussed later.

Peculiar Effects of Sulfate of Ammonia.

A comparison of the crop yields from the plots receiving sulfate of ammonia with those from the plots without nitrogen reveals some striking extremes in the effects of the ammonia compound on plant growth. The largest percentage of gain produced by the sulfate of ammonia was on oats in the years 1897 and 1898, when rainfall was unusually high and the actual yields were among the lowest of the entire period. There are frequent instances, on the other hand, when the crops on the plots without nitrogen were better than those with sulfate of ammonia, which in some cases appeared to have been positively injurious. These ill effects were irregular, and seldom occurred on all three ammonia plots in one season. A study of the rainfall has shown that these apparently injurious effects occurred in seasons when there was a drought in May or June. Applications of lime have remedied the injurious action, but at the same time have tended to bring up the yields on the plots without nitrogen, so that the percentages of increase due to the ammonia are seldom large.

Examination of the soils from the different plots of Field A has shown that, in the absence of lime, the sulfate of ammonia forms soluble sulfates of manganese, aluminium and iron, sometimes one, sometimes another, and again all three.[1] Any one of these substances, if present in comparatively small amount, has been shown to be poisonous to plants, especially to clover.

The rearrangement of the limed areas in 1919 resulted in four distinct gradations of limed soil, as follows: —

Last limed in 1905, ...	Plots 4, 5, 7, 9, Southwest quarter. Plot 6, West half.
Last limed in 1913, ...	Plots 4, 5, 7, 9, Southeast quarter. Plot 6, East half.
Limed in 1905 and 1919, ...	Plots 4, 5, 7, 9, Northwest quarter. Plot 8, West half.
Limed in 1913 and 1919, ...	Plots 4, 5, 7, 9, Northeast quarter. Plot 8, East half.

In 1919 there was a very striking injury to corn on the long unlimed parts of plots 5 and 6. Injury was not apparent on plot 8, as the entire plot had been limed that spring. The plants were stunted in size; the lower leaves were light colored, reddish and yellowish in streaks, and ultimately turned brown and became dry and brittle. Samples of these leaves were dried and incinerated, and the ash gave a bright greenish blue reaction when fused with sodium carbonate, showing that manganese was present in noticeable amount. This was undoubtedly the cause of the injury.

The field was seeded with a mixture of timothy, redtop and clover in the late summer. The areas long unlimed on plots 5 and 6 were bare of

[1] Ruprecht and Morse. Mass. Agr. Expt. Sta. Bulls. Nos. 161, 165, 176.

vegetation, as the seed either did not germinate or the plantlets soon died. In the spring of 1920 these barren areas were twice reseeded, and finally the redtop grew and developed normally.

In July and in October, 1920, samples of soil were taken from the different sections of plots 5 and 6, the soluble manganese extracted by water, and its weight carefully determined by Mr. C. P. Jones.

TABLE XI. — *Manganese Sulfate in the Surface Soil of Plots 5 and 6.*

[Weight of one acre of soil 6 inches deep assumed to be 1,500,000 pounds.]

PLOT.	Lime Treatment.	Manganese Sulfate (Pounds per Acre).
5, Southwest quarter,	Limed, 1905,	235
5, Southeast quarter,	Limed, 1913,	17
5, Northwest quarter,	Limed, 1905 and 1919,	107
5, Northeast quarter,	Limed, 1913 and 1919,	24
6, West half,	Limed, 1905,	177
6, East half,	Limed, 1913,	19

The application of 225 pounds of sulfate of ammonia is theoretically capable of forming 257 pounds of manganese sulfate. There were found small quantities of aluminium sulfate, but only a trace of iron in the soils that were longest without lime.

The weight of evidence indicates that the injurious results were due to the quantity of manganese sulfate present. The actual concentration of the manganese in the soil solution is mere guesswork, but it is interesting to note that its striking injury occurs in seasons of droughts or following a dry period, while plenty of rainfall appears to remove the poison or to dilute it to a harmless concentration.

The effect of lime in preventing the formation of the manganese sulfate is shown by the marked reduction in the amount found where lime had been used as long ago as 1913. The actual quantities found have much less significance than the wide difference between the amounts where lime is lacking and where it is present.

When lime is applied to prevent the injurious effects of sulfate of ammonia, it should be borne in mind that the lime is not a quickly soluble substance but is very slow to dissolve in water. Hence it must be thoroughly distributed throughout the surface soil so that the sulfate of ammonia is reasonably certain to come in contact with it. Long-continued fertilizer experiments clearly show that soil water has no appreciable movement sideways, and the boundaries between limed and unlimed areas are sharply defined.

An experiment where lime to the amount of four times the calculated chemical equivalent of sulfate of ammonia was applied to a small plot showed that it was not enough two successive seasons. Therefore it is best to apply the lime generously in form of finely ground limestone or the fine hydrated lime, as has been done in Field A.

Comparative Effects of Nitrate of Soda, Sulfate of Ammonia and no Nitrogen.

As stated in the beginning of this bulletin, it was not planned to include the results obtained with other nitrogenous fertilizers, but it has seemed best at this point to present the summary of the comparative effects produced by nitrate of soda and sulfate of ammonia which was last published in 1916,[1] the figures in which were as follows: nitrate of soda, 100; sulfate of ammonia, 88.8; no nitrogen, 73.4. This summary includes all the yields on the respective groups of plots.

It has been shown in the preceding pages that liming the soil produces marked benefit with sulfate of ammonia. Therefore a special summary has been calculated in which the yields for the years 1898, 1899, 1900, 1905 and 1906, when the effects of liming were due to applications over the entire plots, have been combined with those of the limed portions obtained in 1914, 1915, 1917 and 1918. This combination produced the following comparison: nitrate of soda, 100; sulfate of ammonia, 91.6; no nitrogen, 70.

The comparative effects in 1919 and 1920 were: nitrate of soda, 100; sulfate of ammonia, 100; no nitrogen, 70. The improvement in the production by sulfate of ammonia is possibly due to the nature of the crops. Under favorable conditions and in the presence of lime, both corn and timothy respond to sulfate of ammonia; and with its long growing season, corn is especially adapted to use the substance.

Conclusions.

Sulfate of ammonia has been effective as a fertilizer when accompanied by an application of lime. In the absence of lime it has sometimes been injurious, due to the formation of soluble compounds of manganese, aluminium and iron. Injury has been greatest in dry periods when the lessened soil moisture becomes more concentrated with soluble salts.

Sulfate of ammonia has been particularly effective on the cereals — corn, oats, rye and millet — when these crops have not followed a clover crop. Potatoes have not been benefited by the sulfate of ammonia in these trials. Soy beans, when uninoculated, responded well to the ammonia; but its effects grew less as the root nodules increased in the later years. Clover has not been much benefited by the sulfate of ammonia, but mixed grasses in 1920 were much increased by it.

In general, the sulfate of ammonia has been about nine-tenths as effective as nitrate of soda, per unit of nitrogen.

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[1] Mass. Agr. Expt. Sta., 28th Ann. Rept.

APPENDIX.

Comparative Yields of Sulfate of Ammonia and no Nitrogen, 1889–1918.

Year.	Crop.	No Nitrogen.		Sulfate of Ammonia.	
		Grain (Bushels).	Straw or Fodder (Pounds).	Grain (Bushels).	Straw or Fodder (Pounds).
1889	Corn,	9 4	3,952	20 2	3,213
1890	Oats,	31 3	1,897	33 7	2,137
1891	Rye,	19.3	3,133	22.0	3,415
1892	Soy beans, green,	–	14,430	–	17,850
1893	Oats,	40 5	4,103	28 7	4,580
1894	Soy beans, green,	–	4,520	–	6,470
1895	Oats,	38 4	2,473	45 5	4,077
1896	Soy beans, green,	–	11,430	–	18,110
1897	Oats,	23 0	1,233	37.6	3,217
1898	Oats,	21.4	900	34 9	1,500
1899	Clover hay,	–	3,520	–	3,670
1900	Potatoes,	209 0	–	211 0	–
1901	Soy beans,	27 6	2,383	29.3	2,633
1902	Potatoes,	178 0	–	177.6	–
1903	Soy beans,	12 3	1,192	14.4	1,343
1904	Potatoes,	139.8	–	146.0	–
1905	Oats and peas (hay),	–	4,350	–	6,383
1906	Corn,	46 0	5,717	73 2	5,560
1907	Clover hay,	–	3,000	–	2,590
1908	Clover hay,	–	4,230	–	3,599
1909	Clover hay,	–	3,620	–	4,360
1910	Clover hay,	–	6,730	–	7,010
1911	Corn,	71 7	5,133	74.5	4,666
1912	Corn,	69 5	5,116	79.9	5,133
1913	Japanese millet (hay),	–	6,900	–	11,200
1914	Oats (hay) (unlimed),	–	1,420	–	2,160
1914	Oats (hay) (limed),	–	2,530	–	3,530
1915	Clover hay (unlimed),	–	8,130	–	7,300
1915	Clover hay (limed),	–	8,050	–	8,870
1916	Japanese millet,	28.5	5,234	26.5	5,506
1917	Potatoes (unlimed),	201.0	–	215.0	–
1917	Potatoes (limed),	333 7	–	322.3	–
1918	Corn (unlimed),	28.7	2,433	27.0	2,317
1918	Corn (limed),	31.3	3,400	39.3	4,566

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 205 NOVEMBER, 1921

THE NUTRITIVE VALUE OF CATTLE FEEDS

3. DRIED APPLE POMACE FOR FARM STOCK

By J. B. LINDSEY, C. L. BEALS AND J. G. ARCHIBALD

Apple pomace is the residue left from the manufacture of cider. Experiments show that it can be dried in such a way as to insure its preservation and greatly enhance its economic value. As an animal feed, it may be fed to dairy cows as a component of the grain ration, or when moistened as a substitute for corn silage. It must be supplemented with rich protein feeds, however, in order to insure satisfactory production. This bulletin reports the experimental evidence on the basis of which the above statements are made.

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AGRICULTURAL EXPERIMENT STATION

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CONTENTS.

BULLETIN No. 205.

DEPARTMENT OF CHEMISTRY.

THE NUTRITIVE VALUE OF CATTLE FEEDS.

3. DRIED APPLE POMACE FOR FARM STOCK.

BY J. B. LINDSEY, C. L. BEALS AND J. G. ARCHIBALD.

Introduction.

Apple pomace is the residue after the extraction of the juice from apples. This has usually been done by many small cider mills located in the various country towns, but of late years the business of cider and vinegar manufacture has become more centralized in large plants employing the most modern machinery. The large establishments in Massachusetts are those of W. W. Cary & Son, Lyonsville; the E. F. Gerry Company, Lynnfield Centre; F. E. Jewett & Son, Lowell; New England Vinegar Works, Somerville; and the Sterling Cider Company, Sterling. After the extraction of the juice, the pomace has been thrown away or used more or less by farmers in the vicinity of the mills. One large concern reports that much of the pomace is taken by the farmers, well packed in silos, and fed during the winter. More recently, two manufacturers (Sterling Cider Company and W. W. Cary & Son) have dried the pomace, the latter company reducing its water content from 63.5 to less than 10 per cent. The value of this dried pomace for feeding purposes has been the subject of our study, and the results are presented in this bulletin. The material for the work was received from W. W. Cary & Son, whose plant we have visited and inspected on two occasions.

The number of cider apples produced in Massachusetts naturally varies much from year to year and no exact data on the subject are available. Munson of the Massachusetts Department of Agriculture states that the difference between the total crop of apples and the commercial crops for the last five years was as follows: —

	Bushels.				
	1916.	1917.	1918.	1919.	1920.
Total crop, ...	3,450,000	2,186,000	2,430,000	3,240,000	3,680,000
Commercial crop, . . .	1,551,000	675,000	900,000	1,005,000	1,125,000
Difference, ...	1,899,000	1,511,000	1,530,000	2,235,000	2,555,000

This difference, according to Munson, represents the apples which were not sold in the larger markets but remained on the farm and were wasted or used for by-product purposes, including cider. W. W. Cary & Son use an average of about 60,000 bushels a year; the New England Vinegar Works used 90,000 bushels obtained in Massachusetts in 1920, but are getting none this year (1921); while the Sterling Cider Company use an average of from 8,000 to 10,000 bushels of Massachusetts apples yearly, most of their supply coming from Maine. It is evident that a very large amount of non-marketable apples goes to waste, but it is believed that as time passes more of them will be saved and utilized.

Composition of Dried Apple Pomace.

Table I. — *Composition of Dried Apple Pomace, with Other Carbohydrate Feeds for Comparison.*

No. of Samples.	Feed.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
6	Dried apple pomace (W. W. Cary & Son).	5.30	1.47	5.57	18.20	65.00	4.46	100.00
6	Apple pomace (local product),[1] .	5.30	3.34	5.57	16.16	64.62	5.01	100.00
38	Dried beet pulp,[2]	9.00	3.00	9.00	18.70	59.60	.70	100.00
193	Corn meal,[3]	12.00	1.30	9.50	2.00	71.50	3.70	100.00

[1] Compilations of analyses. Mass. Agr. Expt. Sta. 1919, p. 11. Reduced to same moisture content for comparison.

[2] *Ibid.*, p. 18.

[3] *Ibid.*, p. 20.

The results of the different analyses showed the product obtained from W. W. Cary & Son to be of quite uniform composition. It is clear that the dried pomace is quite low in protein, containing scarcely 6 per cent, and very high in carbohydrates, approximately 83 per cent, of which some 18 per cent are fiber. The fat indicated by the analyses is more of the nature of waxes and gums than true fat. The ash content of the pomace is comparatively low. The dried pomace compares quite closely in chemical composition with dried beet pulp, except that the latter contains several per cent more protein. It is a carbonaceous feed similar to corn meal, although the latter contains more protein and decidedly less fiber. Although of the same type of composition, the corn meal should be more efficient as a source of energy.

Fuller investigation of the nature of the carbohydrates and protein showed the absence of starch and the presence of considerable amounts of reducing and cane sugars and the hemi-celluloses or pentosans. It was also found that about one-third of the total protein is in the amido form.

A study of the mineral constituents of the dried apple pomace showed that it contains less ash than does beet pulp, and that it is particularly deficient in lime, in which constituent the beet pulp is relatively rich, but contains a fair amount of phosphoric acid and potash.

In calorific value the dried apple pomace compared very favorably with corn meal, sugar and corn starch. Probably the calorific value of the pomace is enhanced by the presence of nearly 5 per cent of waxy material.

Digestibility of Dried Apple Pomace.

In addition to composition, the rate of digestibility is found to throw considerable light upon the nutritive value of a foodstuff, hence eight trials with four different sheep were made, of which seven trials proved to be satisfactory. Four tests were made with the dry, coarse, or unground, pomace; in two cases the pomace was fed with hay, and in two cases with hay and gluten feed, as the basal ration. Three tests were made with the finely ground pomace in which it was fed with hay and gluten feed. The dry, coarse pomace was the product just as it came from the presses; the fine-ground pomace had been passed through an ordinary grist mill and was almost in the form of a powder.

The results showed that the sheep were able to digest on an average 68.5 per cent of the total dry matter in the apple pomace, the fiber and nitrogen-free extract being quite well utilized, the fat to a much less degree,[1] while the protein was apparently not digested at all. We say *apparently* because this peculiarity of indigestibility of protein is often met with in feeds of quite low protein content, and is due to the excretion of nitrogenous material in the form of digestive juices and intestinal wastes. The probability is that the pomace protein, although small in amount, is fairly well utilized.

The trials were not sufficient in number to indicate positively any difference in digestibility between the coarse and the finely ground pomace, and it is doubtful from a nutritive standpoint whether any advantage would be gained in grinding it fine. Compared with other feeds of a similar type, the pomace is shown to be not quite as digestible as dried beet pulp, and much less so than corn meal.

Table II. — *Digestible Matter in 2,000 Pounds.*

Feed.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total Digestible Matter (Fat × 2.25).	Relative Values on Basis of Digestible Matter (Corn meal =100).
Dried apple pomace,	1,298.0	0	248.8	991.2	32.0	1,312.0	81
Dried beet pulp,	1,365.0	93.6	310.4	989.4	-	1,393.4	87
Corn meal,	1,548.8	127.4	17.6	1,315.6	66.6	1,610.4	100

[1] The fat or other extract is largely in the form of waxy matter and has little nutritive value.

This table shows the dried apple pomace to have almost as much total digestible matter as dried beet pulp, but, as would be expected, considerably less than corn meal. Taking the latter as 100, the pomace has a feeding value of 81 and the beet pulp of 87 per cent. In other words, on the basis of digestibility, if properly fed, one would expect slightly better results from the dried beet pulp and noticeably better results from the corn meal than from the dried pomace.

Net Energy Values.

In place of digestible matter as a measurement of nutritive value, Kellner and also Armsby have adopted the unit of net energy. Net energy means the total energy in the feed minus that excreted in the urine and feces, as well as that lost in heat radiation due to the processes of digestion and assimilation. Armsby expresses it in therms, the therm being the amount of heat required to raise 1,000 kilograms of water 1 degree Centigrade.

Feed.	Net Energy in 100 Pounds (Therms).
Corn meal,	85.17
Dried beet pulp,	75.87
Dried apple pomace,	61.39[1]

[1] Estimated according to Armsby's data for beet pulp and corn meal.

On this basis, with corn meal as 100, beet pulp has a relative value of 89 and apple pomace of 72. Both the figures for digestibility and the net energy values show the apple pomace to be slightly inferior to beet pulp as a source of nutrition.

Dried Apple Pomace for Dairy Cows.

The value of dried apple pomace for milk production was carefully studied during a period extending from Nov. 10, 1920, to May 10, 1921. The material was compared first with dried beet pulp and later with corn meal, on an equal dry-matter basis. The dried pomace was fed moist in both experiments, and was mixed with the grain ration shortly before feeding. It was much relished by the cows. The beet pulp was also moistened.

The experiments were conducted by the usual reversal method, eight cows being used in the first trial and twelve in the second.[1] The animals received the usual care as described in earlier publications of the station. The hay was sampled three times during each half of each experiment by taking forkfuls here and there, running the same through a power cutter and subsampling. The subsamples were placed in glass-stoppered con-

[1] One cow was taken sick halfway through the experiment, and her record is therefore omitted.

tainers and brought at once to the laboratory where moisture determinations were made and composite samples analyzed. The grain was sampled each time a new lot was mixed, and the samples preserved as in the case of the hay. The apple pomace and dried beet pulp were sampled at regular intervals during the experiments. The milk was sampled for five consecutive days three times during each half of each experiment, preserved with formalin, and total solids and fat determined in the usual manner on the composite samples.

The basal ration consisted of a uniform grain mixture plus sufficient hay for the needs of each individual cow. The hay was of only fair quality, some of it being too coarse for good cow hay. With the exception of the corn meal fed in the last experiment, all the concentrates fed were up to the usual standards. The corn meal was unusually low in fat (1.69 per cent), and although bought for meal from whole corn could not have been such, probably having had the germs removed. A definite amount of either apple pomace, beet pulp or corn meal was substituted for a like amount of the basal grain ration, this amount varying with the different individuals in the herd. The basal grain rations fed in the two experiments are shown in the following table: —

TABLE III. — *Grain Mixtures Fed (Pounds).*

Experiment I. Apple Pomace *v.* Beet Pulp.		Experiment II. Apple Pomace *v.* Corn Meal.	
Bran,	20	Bran,	40
Corn meal,	30	Cottonseed meal,	60
Coconut meal,	30		
Cottonseed meal,	20		

A definite amount of each mixture was given to each animal, — in the first experiment from 6 to 10 pounds daily of I, with from 6 to 7 pounds of either apple pomace or beet pulp; in the second experiment from 5 to 7 pounds daily of II, with from 4 to 5 pounds of either apple pomace or corn meal.

Somewhat less of the basal grain ration was fed to each cow in the second experiment than in the first, and the amount of hay per animal increased, for the reason that it was not considered advisable to feed too large an amount of grain in the corn meal half of the trial.

TABLE IV. — *Average Ration consumed per Cow (Pounds).*

EXPERIMENT I.

Number of Cows.	Character of Ration.	Hay.		Apple Pomace.		Beet Pulp.		Grain Mixture.	
		Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.
8	Apple pomace,	590.63	16.88	231.88	6.63	–	–	284.38	8.13
8	Beet pulp,	590.63	16.88	–	–	231.88	6.63	284.38	8.13

EXPERIMENT II.

Number of Cows.	Character of Ration.	Hay.		Apple Pomace.		Corn Meal.		Grain Mixture.	
		Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.
12	Apple pomace,	625.00	19.00	157.50	4.50	–	–	218.75	6.25
12	Corn meal,	625.00	19.00	–	–	167.65	4.79[1]	218.75	6.25

[1] As the corn meal contained 9 per cent more moisture than the apple pomace, 17 ounces of the former were fed to each pound of the latter.

TABLE V. — *Estimated Dry Matter and Digestible Nutrients in Average Daily Ration (Pounds).*

EXPERIMENT I.

Character of Ration.	Dry Matter.	Digestible Nutrients.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.	
Apple pomace,	28.49	1.86	4.14	11.64	.61	18.25	1:9.22[1]
Beet pulp,	28.26	2.17	4.37	11.57	.50	18.61	1:7.87

EXPERIMENT II.

Character of Ration.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total.	Nutritive Ratio.
Apple pomace,	26.33	2.10	4.33	9.07	.53	16.03	1:6.95[1]
Corn meal,	26.16	2.38	3.87	9.94	.53	16.72	1:6.30

[1] Assuming that the protein in apple pomace is 50 per cent digestible, these ratios would be lowered to 1:8.4 and 1:6.4, respectively.

The above figures are based upon analyses and average digestion coefficients. They show that the beet pulp and corn meal rations contained slightly more total digestible nutrients than the corresponding apple pomace ration, and also had narrower nutritive ratios. The former fact is due to the less degree of digestibility of the apple pomace, and the latter fact to its low protein content.

TABLE VI. — *Summary of Yields of Milk and Milk Ingredients (Pounds).*

EXPERIMENT.	Character of Ration.	Number of Cows.	Milk produced.	Total Solids.	Total Fat.
I,	Dried apple pomace,	8	7,530.1	973.96	330.19
	Dried beet pulp,		7,775.9	1,020.59	351.54
II,	Dried apple pomace,	11	9,371.8	1,226.52	430.52
	Corn meal,		9,570.4	1,271.73	454.42

TABLE VII. — *Percentage Increase, Beet Pulp or Corn Meal Ration over Apple Pomace Ration.*

EXPERIMENT.	Character of Ration.	Milk produced.	Total Solids.	Total Fat.
I,	Dried beet pulp,	3.26	4.79	6.47
II,	Corn meal,	2.12	3.69	5.55

The slightly increased yield produced by the beet pulp over the apple pomace is in no way surprising. It was expected, however, that the corn meal would show a larger increase than did the beet pulp. On the basis of digestibility and net energy estimation it certainly should have proved more effective. If it had been possible to have a larger amount of the total ration composed of the feeds under comparison the results would undoubtedly have been more pronounced.

In Experiment I the cows on both rations showed slight gains in weight. In Experiment II the gain or loss was so insignificant as to be unworthy of consideration.

The general effect of the apple pomace ration was good. At the close of the experiments there was considerable pomace still on hand, and a number of the cows not needed for other work were continued for several months on the same ration as fed in Experiment II. All but one continued in good flesh and gave a satisfactory flow of milk.

HOW TO FEED DRIED APPLE POMACE.

The dried pomace contains very little protein, and if fed in combination with hay, corn silage and corn meal the results are bound to prove unsatisfactory and the feeder will at once conclude that the pomace "dries up the cows." Because it is so ill balanced — that is, so rich in carbohydrates and so lacking in protein — it must be combined with protein feeds in order to secure satisfactory results. It may be fed in two ways, as follows: —

As a Component of the Grain Ration.

I.	Pounds.	II.	Pounds.
Wheat bran or mixed feed,	10	Gluten feed,	30
Cottonseed meal,	50	Cottonseed meal,	30
Dried apple pomace,	40	Dried apple pomace,	40

III.	Pounds.
Corn or corn and cob meal,	10
Cottonseed meal,	50
Dried apple pomace,	40

Feed 1 pound of any of the above mixtures for each 3 pounds of milk produced. It is considered safe to feed at least 4 pounds of the pomace daily in dry condition, providing the cows have frequent access to water.

As a Substitute for Corn Silage.

Seven pounds of kiln dried apple pomace may be fed daily, after being well moistened with water, as a substitute for a bushel of corn silage weighing 30 pounds. It is not advised to feed too large quantities at first, but to begin with 2 or 3 pounds of the dried pomace daily and gradually increase to 7 pounds. It is doubtful if, pound for pound on the same moisture basis, the pomace will prove fully equal in feeding value to well-preserved and well-eared corn silage, but it certainly will approach it. This amount of dried pomace, together with what hay the animal will clean up daily, — 10 to 16 pounds, — may constitute the roughage ration; and in addition the cow should receive from 4 to 10 pounds of a suitable grain mixture, depending upon the ability to profitably utilize it. The following grain mixtures are suggested: —

I.	Pounds.	II.	Pounds.
Cottonseed or linseed meal,	300	Cottonseed or linseed meal,	100
Gluten feed or coconut meal,	300	Corn or corn and cob meal, or hominy feed or ground oats or barley,	100
Corn or corn and cob meal or hominy feed or ground oats or barley,	300	Wheat bran or mixed feed,	100
Wheat bran,	200		
Wheat middlings,	100		

III.	Pounds.	IV.	Pounds.
Gluten feed or coconut meal,	300	Cottonseed meal,	100
Wheat bran or wheat mixed feed,	200	Corn or corn and cob meal,	100
Corn or corn and cob meal or hominy feed or ground oats or barley,	100		

Ration IV is rather less bulky than the other rations, and may be fed mixed more or less with the moistened pomace as a precaution against digestive disturbances.

The Economy of Dried Apple Pomace.

The writer has emphasized for a long time that the farm is primarily the carbohydrate factory upon which maximum amounts of corn and hay should be grown as roughages, supplemented whenever possible with clover, alfalfa and possibly with soy beans. These latter furnish more protein and ash than do the non-legumes, and are favorable to milk production, growth and soil fertility. Purchased feed should be in the form of the protein concentrates; and carbohydrates such as corn, barley, hominy, beet pulp and apple pomace, especially for growth and milk production, should be purchased only when the supply of home-grown feed runs low.

To all intents and purposes, however, apple pomace is a home-grown carbohydrate feed. Through drying, waste of this food resource is prevented. The economy of attempting this conservation depends on its cost. Ultimately the carbohydrate feed produced in this way must be sold at as low a price as is asked for other carbohydrates. Whether this will be possible cannot yet be stated, for the process is still new and the cost factors not fully worked out.

Summary.

Apple pomace is now kiln dried in limited amounts, which insures its preservation and greatly enhances its economic value. It is brownish in color, of a mechanical condition resembling fine shavings, and has a slightly acid taste. Chemical analyses show it to be a strictly carbohydrate feed with a high sugar content and lacking in true starch. It is likewise high in fiber, but quite low in both protein and total ash. Phosphoric acid and potash make up fully 40 per cent of the ash.

Experiments with sheep show it to be fairly well digested, especially with respect to total dry matter, fiber and extract matter. Protein and fat are rather poorly digested, an explanation for this being offered in the text.

For dairy cows, it may be fed to the extent of 4 pounds daily as a component of the grain ration, or 7 pounds daily of the dry material may be well moistened with water and fed as a substitute for a bushel of corn silage.

Experiments herein reported show it to be but slightly inferior to both dried beet pulp and corn meal when fed to dairy cows as a component of the daily ration. No objectionable flavor was noted in the milk, nor was there any bad effect upon the health or condition of the animals.

Fed only with other carbohydrate feeds such as hay, silage and corn, dried apple pomace will prove unsatisfactory. The ration must always be supplemented with rich protein feeds such as cottonseed meal, gluten feed and coconut meal.

The chief use of apple pomace will be as a feed for dairy cows, young stock and sheep. It is of doubtful value for pigs, and as a food for horses it is not recommended.

APPENDIX.

Table VIII. — *Nature of Carbohydrates and Protein of Dried Apple Pomace.*

[Dry matter basis.]

	Per Cent.
Pentosans,	16.09
Galactan,	3.32
Reducing sugars,	13.88
Sucrose,	6.93
Starch,	None.

Total nitrogen,	.93 = 5.80 per cent crude protein.
Albuminoid nitrogen,	.68 = 4.25 per cent true protein.
Amide nitrogen,	.24

Table IX. — *Mineral Constituents of Dried Apple Pomace and Beet Pulp.*

[Dry matter basis.]

	Dried Apple Pomace[1] (Per Cent).	Beet Pulp (Per Cent).
Total ash,	1.607	3.954
Insoluble matter,	.221	.830
Phosphoric acid,	.260	.196
Iron and alumina,	.113	.168
Calcium oxide,	.157	1.007
Magnesium oxide,	.100	.502
Sulfur dioxide,	.034	.465
Potassium oxide,	.506	.301
Sodium oxide,	.037	.140

[1] Analyses made by L. S. Walker of this station.

Table X. — *The Calorific Value of Dried Apple Pomace.*

[Dry Matter Basis.]

	Small Calories per Gram.	Large Calories per ~~Gram.~~ Pound.
Dried apple pomace,	4,589	2,082
Corn meal[1] (for comparison),	4,430	2,011
Sugar, guaranteed[1] (for comparison),	3,958	1,753
Corn starch[2] (for comparison),	3,692	1,675

[1] United States Department of Agriculture, Farmers' Bulletin No. 346, by H. P. Armsby, p. 13.
[2] Journal of Agricultural Research, Vol. VII, No. 7, p. 305.

Table XI. — *Digestion Coefficients for Apple Pomace.*

Sheep.

Series.	Experiment	Animal.	Percentages of Ingredients Digested. Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
26, ...	4	9	63.48	-	0	71.41	73.88	28.35	500 grams hay + 250 grams coarse dry apple pomace.
26, ...	4	11	68.11	56.25	0	72.93	75.78	40.33	
26, ...	5	17	71.41	2.53	0	87.08	79.01	43.85	550 grams hay + 150 grams gluten feed + 200 grams coarse dry apple pomace.
26, ...	5	19	59.45	14.01	0	60.98	71.03	36.10	
Average for the coarse dry or unground pomace,	-	-	65.61	24.26	0	73.10	74.93	37.16	- -
26, ...	6	9	77.02	94.03	0	80.21	83.87	37.14	500 grams hay + 150 grams gluten feed + 200 grams fine dry apple pomace.
26, ...	6	11	65.49	53.84	0	58.61	75.45	25.22	
26,[1] . . .	8	19	71.82	107.14	0	52.13	73.39	41.38	550 grams hay + 150 grams gluten feed + 200 grams fine dry apple pomace.
Average for the fine dry or ground pomace, . .	-	-	71.44	84.67	0	63.65	77.57	34.58	- -
Average of above seven single trials,	-	-	68.53	54.47	0	68.38	76.25	35.87	- -
Average of six previous single trials (wet pomace),[2] .	-	-	72.00	49.00	0	65.00	85.00	46.00	- -
Dried beet pulp, .	-	-	75.00	26.00	52.00	83.00	83.00	-	- -
Corn meal, . .	-	-	88.00	-	67.00	44.00	92.00	90.00	- -

[1] Sheep No. 17 did not eat well in this trial and had to be rejected.

[2] Seventeenth annual report, Hatch Experiment Station, Amherst, Mass., p. 86.

Tabulated Data of the Experiments with Dairy Cows.

Table XII. — *History of the Cows.*

Experiment I.

Name.	Age.	Breed.	Calved.	Served.	Daily Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Fancy V, . . .	3	Grade Jersey, .	Aug. 23, 1920	Jan. 6, 1921	22	4.9
Samantha III, .	7	Grade Holstein,	Sept. 18, 1920	Dec. 15, 1920	34	4.6
Samantha IV, .	6	Grade Holstein,	Sept. 11, 1920	Nov. 13, 1920	34	4.0
190, ...	-	Grade Holstein,	Oct. 15, 1920	Jan. 15, 1921	27	3.8
Fancy IV, . .	6	Grade Jersey, .	Aug. 15, 1920	Jan. 6, 1921	18	5.0
46, ...	8	Grade Holstein,	Sept. 18, 1920	Nov. 10, 1920	41	3.7
Colantha II, .	6	Grade Holstein,	Aug. 10, 1920	Nov. 18, 1920	34	4.4
Colantha IV, .	3	Grade Holstein,	Oct. 18, 1920	Feb. 7, 1921	25	3.7

TABLE XII. — *History of the Cows* — Concluded.

EXPERIMENT II.

NAME.	Age.	Breed.	Calved.	Served.	Daily Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Fancy IV,	7	Grade Jersey,	Aug. 15, 1920	Nov. 17, 1920	16	5.9
46,	8	Grade Holstein,	Sept. 18, 1920	Nov. 10, 1920	35	3.2
Colantha II,	6	Grade Holstein,	Aug. 10, 1920	Nov. 18, 1920	32	4.9
Colantha IV,	3	Grade Holstein,	Oct. 18, 1920	Dec. 11, 1920	24	3.7
Ida II,	8	Jersey,	Nov. 14, 1920	Jan. 6, 1921	24	5.5
Red IV,	7	Grade Jersey,	Dec. 31, 1920	–[1]	32	5.3
Fancy V,	4	Grade Jersey,	Aug. 23, 1920	Jan. 6, 1921	21	6.0
Samantha III,	7	Grade Holstein,	Sept. 18, 1920	Dec. 15, 1920	30	4.9
Samantha IV,	6	Grade Holstein,	Sept. 11, 1920	Nov. 13, 1920	33	4.6
190,	–	Grade Holstein,	Oct. 18, 1920	Jan. 21, 1921	28	3.9
Peggy,	10	Grade Jersey,	Nov. 11, 1920	Dec. 9, 1920	25	5.6
Cecile II,	8	Jersey,	Nov. 30, 1920	–[1]	25	5.1

[1] Not bred.

TABLE XIII. — *Chemical Analyses of Feeds Used (Per Cent).*

EXPERIMENT.	Feed.	Water.	Ash.	Crude Protein.	Fiber.	Extract Matter.	Fat.
I,		9.25–12.75					
	Hay,	11.38	5.17	6.59	29.15	45.78	1.93
	Apple pomace,	5.45	1.48	5.48	17.90	65.26	4.42
	Beet pulp,	8.87	3.96	9.10	18.95	58.41	.69
	Grain mixture,	10.75	4.43	19.45	8.20	52.12	5.04
II,		11.53–16.88					
	Hay,	13.44	5.25	7.22	30.03	42.08	1.98
	Apple pomace,	6.21	1.46	5.49	16.69	65.72	4.44
	Corn meal,[1]	15.54	1.29	8.61	2.01	70.85	1.69
	Grain mixture,	9.44	6.16	27.68	11.52	39.71	5.49

[1] The corn meal was unusually low in fat (1.69%), and although bought for meal from whole corn, could not have been such, probably having had the germs removed.

TABLE XIV. — *Duration of Experiments.*

EXPERIMENT I.

DATES.	Basal Ration+Apple Pomace.	Basal Ration+Dried Beet Pulp.	Weeks fed.
Nov. 22, 1920, to Dec. 26, 1920, inclusive,	Fancy V, Samantha III, Samantha IV, 190,	Fancy IV, 46, Colantha II, Colantha IV,	5
Jan. 6, 1921, to Feb. 9, 1921, inclusive,	Fancy IV, 46, Colantha II, Colantha IV,	Fancy V, Samantha III, Samantha IV, 190,	5

Table XIV. — *Duration of Experiments* — Concluded.

Experiment II.

Dates.	Basal Ration+Apple Pomace.	Basal Ration+Corn Meal.	Weeks fed.
Feb. 20, 1921, to March 26, 1921, inclusive,	Fancy IV, 46, Colantha II, Colantha IV, Ida II, Red IV,	Fancy V, Samantha III[1], Samantha IV, 190, Peggy, Cecile,	5
April 6, 1921, to May 10, 1921, inclusive,	Fancy V, –[1] Samantha IV, 190, Peggy, Cecile,	Fancy IV, 46, Colantha II, Colantha IV, Ida II, Red IV,	5

[1] Samantha III was taken sick halfway through the experiment and had to be discontinued. Her record is therefore omitted for the entire experiment.

Table XV. — *Gain or Loss in Live Weight (Pounds).*

Experiment.	Gain.		Loss.		Net.	
	Apple Pomace.	Beet Pulp.	Apple Pomace.	Beet Pulp.	Apple Pomace.	Beet Pulp.
I,	156	195	3	0	153+	195+

Experiment.	Gain.		Loss.		Net.	
	Apple Pomace.	Corn Meal.	Apple Pomace.	Corn Meal.	Apple Pomace.	Corn Meal.
II,	94	90	73	113	21+	23–

Table XVI. — *Total Yields of Milk and Milk Ingredients.*

Experiment I.

Apple Pomace Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Fancy V,	742.4	14.87	110.39	5.86	43.50
Samantha III,	1,014.6	13.74	139.41	4.94	50.12
Samantha IV,	968.8	12.74	123.43	4.54	43.98
190,	971.8	12.28	119.34	3.84	37.32
Fancy IV,	548.8	15.15	83.14	5.74	31.50
46,	1,279.7	10.93	139.87	3.04	38.90
Colantha II,	1,110.2	13.58	150.77	4.73	52.51
Colantha IV,	893.8	12.04	107.61	3.62	32.36
Totals,	7,530.1	–	973.96	–	330.19
Averages,	–	12.93[1]	–	4.38[1]	–

[1] Average percentage of solids and fat obtained by dividing total pounds of each by total milk yield.

TABLE XVI. — *Total Yields of Milk and Milk Ingredients* — Concluded.

EXPERIMENT I — *Concluded.*

Beet Pulp Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Fancy V,	726.7	15.59	113.29	6.24	45.35
Samantha III,	1,033.1	13.98	144.43	4.99	51.55
Samantha IV,	1,144.0	13.10	149.86	4.70	53.77
190,	1,014.5	12.64	128.23	4.13	41.90
Fancy IV,	610.1	15.15	92.43	5.82	35.51
46,	1,413.4	11.12	157.17	3.17	44.80
Colantha II,	877.8	13.61	119.47	4.81	42.22
Colantha IV,	956.3	12.10	115.71	3.81	36.44
Totals,	7,775.9	-	1,020.59	-	351.54
Averages,	-	13.12[1]	-	4.52[1]	-

EXPERIMENT II.

Apple Pomace Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Fancy IV,	524.6	14.52	76.17	5.33	27.96
46,	1,079.1	11.18	120.64	3.29	35.50
Colantha II,	1,065.8	13.01	138.66	4.44	47.32
Colantha IV,	824.6	11.83	97.55	3.66	30.18
Ida II,	829.3	14.02	116.27	5.12	42.46
Red IV,	1,083.0	13.16	142.52	4.80	51.98
Fancy V,	677.6	14.55	98.59	5.51	37.34
Samantha IV,	987.8	12.80	126.44	4.51	44.55
190,	814.4	12.54	102.13	4.17	33.96
Peggy,	747.9	14.12	105.60	5.45	40.76
Cecile II,	737.7	13.82	101.95	5.22	38.51
Totals,	9,371.8	-	1,226.52	-	430.52
Averages,	-	13.09[1]	-	4.59[1]	-

Corn Meal Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Fancy IV,	547.3	14.91	81.60	5.63	30.81
46,	912.6	12.03	109.79	3.51	32.03
Colantha II,	893.1	12.83	114.58	4.74	42.33
Colantha IV,	839.5	12.12	101.75	3.51	29.47
Ida II,	800.0	14.03	112.24	5.33	42.64
Red IV,	1,022.3	13.69	139.95	5.13	52.44
Fancy V,	728.7	14.78	107.70	5.68	41.39
Samantha IV,	1,166.1	12.77	148.91	4.48	52.24
190,	930.7	12.26	114.10	4.08	37.97
Peggy,	871.5	14.10	122.88	5.60	48.80
Cecile II,	858.6	13.77	118.23	5.16	44.30
Totals,	9,570.4	-	1,271.73	-	454.42
Averages,	-	12.29[1]	-	4.75[1]	-

[1] Average percentage of solids and fat obtained by dividing total pounds of each by total milk yield.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 206 DECEMBER, 1921

EIGHTH REPORT

OF THE

CRANBERRY STATION

By H. J. FRANKLIN

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
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CONTENTS.

BULLETIN NO. 206.

REPORT OF THE CRANBERRY STATION FOR 1919 AND 1920.

BY H. J. FRANKLIN.

The cranberry industry in southeastern Massachusetts, particularly in Barnstable and Plymouth counties, is the most marked feature of the agriculture of that region. It has given large value to some 14,000 acres of peat and muck soils which previously had little or no value, having made mosquito-breeding swamps into agriculturally productive land. It gives seasonal employment to many hundreds of workers, and it adds from two to three million dollars to the value of the agricultural products of the section annually. The cranberry is the most important export crop of the State.

It is thus apparent that anything which injures the cranberry industry affects not only the sections in which the berries are grown but also the Commonwealth as a whole. Partial crop failures, whatever the cause, result in severe loss, both to the bog owners and operators and to the laborers who are accustomed to secure a part of their livelihood by work on the bogs. Reduction of the crop lessens the ability of the community to meet its taxes; it also decreases the purchasing power of the section and so affects other industries. It was to develop methods of avoiding such partial crop failures that the State in 1910 established the Cranberry Station of the Experiment Station.

For ten years the Cranberry Station has been in operation. It has given major attention to the study of the insects which injuriously affect the cranberry crop. It has also investigated the problems of plant disease control, bog fertilization, berry storage, frost protection, cranberry varieties, and even the possibilities of the blueberry as a companion crop to cranberries. In addition, the Cranberry Station has served as a center for growers' meetings, and the services of the specialist in charge in an advisory capacity have been widely sought by the growers. The following report is the eighth of the Cranberry Station, and is a discussion of the more important results of the work of 1919 and 1920.

Field Meetings.

In early June, 1920, five field meetings were held (in Rochester, Carver, Plymouth, Wareham and Sandwich) with cranberry growers to demonstrate the use of the insect net in discovering and gauging certain insect infestations in their early stages. These meetings were planned as a special effort in the control of the gypsy moth, but the other open-feeding caterpillars often harmful to bogs, such as spanworms and false army worms, were also discussed. A supply of nets had been prepared and sixty were sold to growers.

Frost Predictions.

In both 1919 and 1920 much progress was made in perfecting methods of frost predicting. Most of the results of this study and of the frost investigations of previous years are given in a paper lately published.[1] In 1920 arrangements were made with the New England Telephone and Telegraph Company for distributing frost predictions to be sent out by the station in the early afternoon and early evening. This service began in the fall.

Study of Cranberry Varieties.

The study of the characteristics of the Cape cranberry varieties was continued, special attention being given to seed counts. Small plantings of the Pride and Wales Henry varieties were made at the station in the spring of 1920.

Additions to Station Equipment.

In 1919 a lean-to shed, 41 by 20 feet, with a concrete floor, corrugated iron sides, and board and paper roof, was added to the station building. In one end of this, a part $11\frac{1}{2}$ by 20 feet was made into a garage, the larger room being for box and barrel storage. This addition had long been needed, for when the bog produced a large crop the building was too crowded for storage tests.

A screening belt and a Ford runabout truck also were added to the station equipment in 1919. The latter, presented by the Cape Cod Cranberry Growers' Association, was especially helpful, making it possible to visit bogs in distant towns more freely. This extension of the field of operations not only made the station more serviceable to the growers, but also yielded valuable results in the way of new observations.

Yields in 1919 and 1920.

The station bog yielded scantily in 1919 for reasons given below, only about 80 barrels of berries being sold, and this fruit of poor quality. On this account, keeping tests were mostly omitted that year. In 1920 the bog

[1] Monthly Weather Review Supplement No. 16: 20–30, 1920.

produced 909 barrels of unusually sound berries which sold for about $7,300.

The spring and early summer of 1920 on the Cape were wet and backward. Because of the rains, there were a few hundred acres from which it was impossible to remove the winter water early enough to grow a crop, the importance of adequate drainage thus being emphasized again.

In 1920 most of the Cape bogs bloomed very heavily and so aroused the anticipation of a record crop, but there was a marked and widespread failure to set fruit, and the total Cape yield was only about 277,000 barrels. The weather and blossom conditions and the fruiting failure paralleled those of 1916,[1] except that thin vines were not relatively more fruitful.

Fungous Diseases.

The "Rosebloom" Disease.

As the "rosebloom" disease (*Exobasidium oxycocci*) had greatly reduced the crop of Howes and McFarlin berries on the station bog for three successive years, treatment by flooding was tried in 1919. The winter flood was let off March 23, and the shoots enlarged by the disease became partly grown and abundant by May 25 when the first reflooding was done. The water was held sixty hours, the weather being mostly clear. The diseased shoots collapsed and dried up within a day after the flood was let off. More such shoots grew later and were killed by the mid-June flowage mentioned below. Little evidence of the disease appeared on the bog the rest of the season, and comparatively few of the enlarged shoots grew in 1920, the treatment thus seeming to have been largely successful. The early destruction of the diseased growths probably reduced the spore production of the fungus greatly, and thus lessened the infection of the new axillary buds.

Wisconsin False Blossom.

False blossom (the Wisconsin disease) has previously been reported[2] as found on five Cape bogs, the infestation being due to planting Wisconsin vines in every case. All these infestations have been wiped out by destroying the infected vines. In the fall of 1919 six heretofore unnoticed infestations were found by Dr. Stevens of the Bureau of Plant Industry and the writer on Holliston[3] vines in Pembroke, Carver and Wareham. The histories of the plantings strongly suggested that all the infections had had a common origin on a bog in Wareham, where the variety had been known as "Small's No. 1." Holliston vines on ten other bogs, in Plymouth, Carver, Middleborough, Lakeville, South Hanover and Holliston, the planting in the last-named town being the original one of the variety, showed no sign of the disease. This suggests that the Holliston variety, as grown on the Cape, may be a double one, the infected strain

[1] Mass. Agr. Expt. Sta., Bul. No. 180, 1917, p. 184.

[2] Mass. Agr. Expt. Sta., Bul. No. 160, 1915, p. 100; and Bul. No. 168, 1916, p. 5.

[3] This variety is widely known as "Mammoth" or "Batchelder," but the name of its place of origin seems preferable.

perhaps having come from Wisconsin. The Bennet Jumbo variety resembles the Holliston. The fact that Holliston vines are widely infected warns against further planting of the variety.

Early Black and Howes vines much affected by false blossom were found on two bogs in Marion. The vines of these plantings came from several sources and the origin of the infection is uncertain. This disease evidently is more widely prevalent on the Cape than has been supposed. Those who start new plantings should be careful not to use vines harboring it.

Fungous Injury to Small Berries caused by Submergence.

In late July and early August, 1919, numerous tests were conducted to determine the effect of submergence on the small berries. Pieces of cranberry turf, with the vines bearing berries, were immersed in Spectacle Pond (East Wareham) in clear or mostly clear weather. The periods of submersion were one to four days long. Early Black and Howes berries from various bogs were tested comparatively in this way several times. Pride and Perry Red berries also were tried. In all cases the Howes fruit was hurt less by the submersion than that of the other varieties. It appeared that this variety usually can be flooded forty-eight hours in clear weather, while the berries are small, without serious immediate harm. Such treatment probably would impair keeping quality, however. The results with the Early Black berries varied greatly, some lots being much harmed by twenty-four hours of submersion, while others seemed little hurt after forty-eight hours; but generally this variety was the most susceptible to injury of those treated, the Pride and Perry Red being intermediate. The water did most harm when its temperature was relatively high. Some Howes lots showed but little softening when submerged in cool weather four days.

Injury incidental to submergence seemed due to rapid development of putrefactive fungi. The softening of the berry always started in a small spot which kept enlarging as long as the immersion continued, until it included the whole fruit. The softened tissue examined microscopically was found always full of mycelium.

Dr. C. L. Shear, of the Bureau of Plant Industry, and his assistants, made cultures from the softened tissues of various lots of berries from these tests. The fungi found and their relative abundance are shown in Table 1.

TABLE 1. — *Fungi found in Fruit of Summer Immersion Tests.*

FUNGI.	Early Black.	Perry Red.	Pride.	Howes.	Totals.
Dematium,	2½	2	2	1	7½
Fusicoccum putrefaciens Shear,	2½	0	0	2½	5
Phomopsis,	½	0	3	0	3½
Sporonema oxycocci Shear,	2½	1	0	0	3
Penicillium sp.,	0	1	2	0	3
Pestalozzia guepini vaccinii Shear,	1	1	0	0	2
Glomerella cingulata,	1	0	0	½	1½
Acanthorhynchus vaccinii Shear,	0	0	1	0	1
Altenaria,	½	0	0	0	½
Undetermined,	1½	5	2	5	13½

The totals of the table show that most of the softening of the berries was caused by the first five fungi, and that the first two were the most active.

Spraying for the Control of Fungous Diseases.

Tables 2, 3 and 4 show the results of spraying Early Black vines with "Corona" lead arsenate used at the rate of 4 pounds to 50 gallons of water, without soap. The plots of Tables 2 and 3 were the same areas, respectively, so numbered in 1918.[1] In 1919, plots A. L. 3 and A. L. 4 were treated on June 24 and July 11; A. L. 5 on June 23, July 12 and 31; and A. L. 7 on June 24, July 11 and 24. All the plots of Tables 3 and 4 were sprayed on June 23, July 26 and August 20. The quantity of fruit stored in 1919 varied from 1 to 4 bushels for each plot or check. In 1920, 6 or 7 bushels were stored for each area of Table 3, and from 2 to 7 bushels for each area of Table 4. The effect of this spraying, shown by the percentages in the tables, except possibly those of plot B, confirms the results of like tests in previous years.[2]

[1] Mass. Agr. Expt. Sta., Bul. No. 192, 1919, p. 107.

[2] Mass. Agr. Expt. Sta., Bul. No. 180, 1917, pp. 189–192; Bul. No. 192, 1919, pp. 106, 107.

Table 2. — *Station Bog Early Black Spraying Plots (Fungous Diseases) treated with Lead Arsenate, 1919.*

Plots and Checks.	Area (Square Rods).	Yield per Square Rod (Bushels).	Storage Period.	Percentage of Berries showing Decay at End of Storage.
A. L. 3,	9	.41	Sept. 16 to Dec. 12	34.39
Check 1,	6	.56	Sept. 16 to Dec. 12	47.34
Check 2,	9	.53	Sept. 16 to Dec. 12	48.11
A. L. 4,	8	.38	Sept. 16 to Dec. 11	37.14
Check 1,	8	.50	Sept. 16 to Dec. 11	41.38
Check 2,	8	.38	Sept. 16 to Dec. 13	49.98
A. L. 5,	–	–	Sept. 16 to Dec. 12	43.01
Check 1,	–	–	Sept. 16 to Dec. 12	57.82
Check 2,	–	–	Sept. 16 to Dec. 11	63.65
Check 3,	–	–	Sept. 16 to Dec. 11	65.07
A. L. 7,	8	.25	Sept. 16 to Dec. 11	47.11
Check 1,	8	.13	Sept. 16 to Dec. 11	63.56
Check 2,	8	.22	Sept. 16 to Dec. 11	60.04

Table 3. — *Station Bog Early Black Spraying Plots (Fungous Diseases) treated with Lead Arsenate, 1920.*

Plots and Checks.	Area (Square Rods).	Yield per Square Rod (Bushels).	Storage Period.	Percentage of Berries showing Decay at End of Storage.
A. L. 1,	9	1.30	Sept. 18 to Dec. 3	12.06
Check 1,	6	1.33	Sept. 18 to Dec. 4	18.09
Check 2,	6	1.44	Sept. 18 to Dec. 3	24.56
Check 3,	6	1.61	Sept. 18 to Dec. 3	19.02
A. L. 2,	9	1.50	Sept. 27 to Dec. 7	18.26
Check 1,	6	1.42	Sept. 27 to Dec. 7	28.30
Check 2,	6	1.63	Sept. 27 to Dec. 7	26.35
Check 3,	6	1.92	Sept. 27 to Dec. 7	32.02
A. L. 3,	9	1.74	Sept. 27 to Dec. 6	9.88
Check 1,	6	1.86	Sept. 27 to Dec. 6	22.73
Check 2,	6	1.96	Sept. 27 to Dec. 6	25.13
A. L. 4,	8	1.70	Sept. 27 to Dec. 4	9.39
Check 1,	6	2.21	Sept. 27 to Dec. 6	25.04
Check 2,	8	2.04	Sept. 27 to Dec. 6	23.55
A. L. 5,	9	1.31	Sept. 18 to Dec. 3	8.74
Check 1,	9	1.37	Sept. 18 to Dec. 4	18.45
Check 2,	6	1.11	Sept. 18 to Dec. 3	17.96
Check 3,	6	1.15	Sept. 18 to Dec. 2	17.78
A. L. 7,	8	1.06	Sept. 18 to Nov. 30	5.27
Check 1,	8	1.06	Sept. 18 to Nov. 29	20.47
Check 2,	4	.81	Sept. 18 to Nov. 29	15.34
Check 3,	8	1.13	Sept. 18 to Nov. 30	19.17

TABLE 4. — *Eagle Holt Bog Early Black Spraying Plots (Fungous Diseases) treated with Lead Arsenate, 1920.*

PLOTS AND CHECKS.	Storage Period.	Percentage of Berries showing Decay at End of Storage.
Plot A,	Oct. to Nov. 27,	9.61
Check,	Oct. 1 to Nov. 29,	19.96
Plot B,	Sept. 10 to Nov. 26,	20.88
Check 1,	Sept. 10 to Nov. 26,	21.89
Check 2,	Sept. 10 to Nov. 26,	22.23
Check 3,	Sept. 10 to Nov. 26	22.71

The plots of Table 5 were treated in the same way and on the same dates as those of Tables 3 and 4. The results with the first plot were like those with the Early Black variety, but the fruit of the second plot showed no effect from the spraying.

TABLE 5. — *Station Bog Howes Spraying Plots (Fungous Diseases) treated with Lead Arsenate, 1920.*

PLOTS AND CHECKS.	Area (Square Rods).	Yield per Square Rod (Bushels).	Storage Period.	Percentage of Berries showing Decay at End of Storage.
Howes A. L. 1,	9	.74	Oct. 2 to Dec. 9	5.92
Check 1,	6	.42	Oct. 2 to Dec. 9	8.78
Check 2,	4½	.74	Oct. 2 to Dec. 9	8.61
Check 3,	9	.93	Oct. 2 to Dec. 8	8.80
Howes A. L. 2,	9	1.43	Oct. 2 to Dec. 9	14.66
Check 1,	9	1.07	Oct. 2 to Dec. 9	13.69
Check 2,	6	.94	Oct. 2 to Dec. 8	14.98
Check 3,	9	1.22	Oct. 2 to Dec. 9	10.09

Table 6 shows that two Early Black plots gave a reaction to calcium arsenate like that produced by lead arsenate. These plots were sprayed June 22, July 27 and August 20, the insecticide being used at the rate of 4 pounds to 50 gallons of water, without soap. Five or 6 bushels of fruit from each of these plots and each check were stored.

TABLE 6. — *Station Bog Early Black Spraying Plots (Fungous Diseases) treated with Calcium Arsenate, 1920.*

Plots and Checks.	Area (Square Rods).	Yield per Square Rod (Bushels).	Storage Period.	Percentage of Berries showing Decay at End of Storage.
A. Lime 1,	6	1.63	Sept. 27 to Dec. 6	20.85
Check,	6	1.94	Sept. 27 to Dec. 7	28.06
A. Lime 2,	6	1.39	Sept. 27 to Dec. 4	10.63
Check,	6	1.58	Sept. 27 to Dec. 1	16.52

With all the spraying plots having more than one check, the checks bordered different sides of the plot. The berries were all scoop-picked and stored in bushel crates as they came from the bog. At the end of the storage the fruit was examined by the "seven-sample" method[1] by the screeners employed at the station, under the writer's supervision, the inspector's cup of the New England Cranberry Sales Company being used for sampling. The Sales Company's hand grader was used to facilitate the work.

In both 1919 and 1920 the vines sprayed repeatedly with lead arsenate for three or more years had such a growth of runners that they were hard to scoop. As the surrounding bog showed no such development, this was clearly a reaction to the insecticide. The sprayed vines seemed to show a slight reduction in number of uprights. On the whole, the effect of the spraying on the vines was distinctly undesirable.

In 1920 Dr. Shear and his assistants made cultures of the fungi in twenty rotten berries taken at random at the end of the storage period from among the fruit of each of three of the lead arsenate plots and the fruit of the checks on each of these plots. Table 7 shows what fungi were found. Apparently the spraying had reduced both Phomopsis and *Fusicoccum putrefaciens* greatly, and had affected Glomerella, Sporonema and Dematium little, if any. These conclusions are supported by the fact that mostly negative results have been obtained in spraying Howes vines with lead arsenate, for studies in previous seasons[2] showed that on the station bog Glomerella was relatively a much more important disease of the Howes variety than of the Early Black.

[1] In this method seven samples from each crate are examined, one being taken from the surface berries of each half of the crate halfway between the middle and end; one from each half of the crate halfway between the top and bottom and halfway between the center and end; one from the very center; and one from the very bottom of each half of the crate halfway between the middle and end.

[2] Mass. Agr. Expt. Sta., Bul. No. 198, 1920, pp. 88–92.

TABLE 7. — *The Number of Cultures of Different Fungi obtained from Decayed Berries from Sprayed Areas and their Unsprayed Checks.*

Fungi.	Number of Berries giving Cultures of the Fungi.[1]							
	Sprayed Plots.				Check Plots (not sprayed).			
	A. L. 2.	A. L. 5.	A. L. 7.	Totals of the Three Plots.	Checks on A. L. 2.	Checks on A. L. 5.	Checks on A. L. 7.	Totals of the Checks.
Fusicoccum,	2	8	8	18	8	11	15	34
Glomerella,	11	9	7	27	3	5	2	10
Phomopsis,	0	1	1	2	2	3	5	10
Sporonema,	0	2	7	9	0	4	1	5
Penicillium,	2	0	3	5	2	1	0	3
Dematium,	2	1	1	4	1	0	0	1
Alternaria,	0	0	0	0	2	0	0	2

[1] In each case cultures were made from twenty rotten berries.

Keeping Tests with the Pride Variety.

As the Pride is the most productive cranberry variety and is not widely grown, knowledge of the keeping quality of its fruit is desirable. In a test made in a previous year this variety seemed superior to the Early Black and not greatly inferior to the Howes. In 1919 a shipping test was conducted, Early Black berries being provided by the station, three Pride lots by B. F. Vose, L. B. Handy and the Federal Cranberry Company, respectively, and two Howes lots by C. R. Rogers. Each lot consisted of one barrel of berries. All the fruit was separated, screened and packed under uniform conditions at the Carver packing house of the New England Cranberry Sales Company. It was shipped to Washington, D. C., and there stored and examined under the direction of Drs. Shear and Stevens. The results appear in Table 8.

TABLE 8. — *Results of Keeping Test of Cranberries, 1919.*

[The berries were screened at North Carver October 16, received at Washington, D. C., October 24, and stored at a temperature of 40 to 50° F. until the date given. Note that the Early Blacks and the first lot of Prides were sorted a week before the rest.]

Barrel Samples.	Percentage of Sound Berries.					
	Station **Early Blacks** (Sorted Nov. 15).	Handy **Prides** (Sorted Nov. 15).	Federal **Prides** (Sorted Nov. 22).	Vose **Prides** (Sorted Nov. 22).	Rogers **Howes** (Sorted Nov. 22).	Rogers **Howes** (Sorted Nov. 22).
Top,	41	80	56	70	72	84
¼,	39	65	52	70	77	85
¼,	33	65	58	84	75	84
Middle,	41	69	55	70	79	80
Middle,	52	73	50	63	76	88
¾,	36	60	61	63	80	82
¾,	39	69	58	68	89	82
Bottom,	49	71	60	76	83	81
Average,	41	69	56	71	79'	83

INSECTS.

The Green Spanworm (*Cymatophora sulphurea* (Pack.)).

This species was unusually prevalent in 1920, the moths appearing abundantly on many bogs and the worms wiping out a fine crop promise on several bogs in Duxbury.

The moths were flying in clouds on the Duxbury bog on July 22 and also on August 2. On the former date the males outnumbered the females fully 200 to 1, while on the latter they seemed only slightly more numerous. This indicates that the species is strongly protandrous in emerging from the pupa. The males are more active than the females, but both sexes rest much among the vines. The males fly much less than those of *Epelis truncataria*, but they are flushed up easily. Several females reared in confinement and dissected before they oviposited contained from 103 to 117 eggs. The greater egg capacity of *Epelis*[1] may explain its greater prevalence. Green spanworms captured August 2 were found to be mostly through laying. The greenish-white eggs are laid singly on the old fallen leaves under the vines, and winter under the water (if the bog is flooded), hatching in the spring.

The injury done on the Duxbury bog was much like the work of the blossom worm[2] (or bud worm), the flowers being nipped off and dropped.

The Brown Spanworm (*Epelis truncataria var. faxonii* Minot).

This species was found in great numbers on twelve different bogs in 1919, and the moths appeared abundantly on even more in 1920. It was so much more prevalent than usual that it demanded as much attention as any cranberry pest except the gypsy moth. The writer attended to many requests for advice in checking infestations in 1920, and the insect did little harm except on a few neglected bogs, lead arsenate (3 pounds of powder to 50 gallons of water) being very effective wherever used.

The worms began hatching June 30, 1919, and July 1, 1920, probably being about normal in this respect both years. In 1919 they worked on some bogs until into August. Uncounted hundreds over a thousand of the small worms to 50 sweeps of an insect net were obtained on parts of one bog two days after hatching began there. This bog was sprayed with lead arsenate at once. It was examined again sixteen days later and 75 nearly mature worms to 50 sweeps of the net were obtained on the area most infested. These caterpillars were doing little harm, for the only notable injury on the vines was the work of the multitude of small worms that had been checked by the spraying soon after they began. The tips of the vines had made much new growth after the spraying. This was lighter green than the earlier growth of the season and showed little worm-eating. This and other observations have shown that an infestation of this insect giving less than 50 worms to 50 sweeps of the net will not do much harm

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[1] Mass. Agr. Expt. Sta., Bul. No. 150, 1914, p. 50.

[2] U. S. Dept. Agr., Farmers' Bul. No. 860, 1917, p. 23.

when not treated. With such a light attack, it may not pay to spray if the bloom is heavy and the crop prospect good, because of the mechanical injury done in spraying. If the crop promise is poor, however, it is best to treat even a light infestation to save trouble the next year. The writer observed a case in which an infestation giving 275 worms to 50 sweeps of the net destroyed fully three-fourths of a fine prospective crop. One experienced with this pest can gauge a coming attack fairly well by the numbers in which the moths appear in mid-June.

The spraying should be done when the eggs begin to hatch, for the worms are poisoned most easily in their first stages, and they are sometimes numerous enough to destroy a fine crop promise within four days after hatching begins. Therefore an infested bog should be examined with an insect net daily from June 20 until the worms are found. If the infestation is severe and the area involved is so large that it will take several days to treat it, the spraying should begin a few days before the worms are expected, and the less heavily infested vines should be treated first. Under such conditions the work usually should start about June 26 on bogs from which the winter water has been let off before May 5.

The small worms seem usually to attack the flower buds as soon as anything, a hole commonly being eaten through the ovary. Often in moderate infestations they work like the blossom worm mentioned above, the flowers being nipped off and dropped to the ground.

When this species attacks severely enough to turn the vines brown it always destroys all chances of a crop in the following year, even if it is completely controlled that season, and sometimes patches of vines fail to recover for two or three years.

The period of activity of the green spanworm moths coincides with that of the worms of this insect, and as both species often abound on the same area, they are much confused in the minds of growers.

The Cranberry Girdler (*Crambus hortuellus* Hübner).

This pest was much more prevalent, especially in 1920, than it had been for many years. Its increase was pretty certainly due to the general neglect of resanding during and since the war.

Hitherto unreported parasites of the girdler were reared, as follows: —

1. *Cremastus facilis* (Cress.).[1] This species makes a delicate brownish-gray cocoon inside that of its host. Apparently no girdler cocoon ever contains more than one of these parasites. The adult parasites emerged June 6 and 7, 1919, from cocoons collected on a bog the former day. About 10 per cent of the cocoons harbored this parasite.

2. *Macrocentrus* sp.[1] Several cocoons of this species were found together in each of two host cocoons collected on a bog May 31, 1919. The adults emerged from one to four days later.

3. *Phygadeuon* sp.[1] The cocoons of this parasite are yellow and astonishingly tough. As with *Cremastus*, there is but one in a host cocoon.

[1] Identified by R. A. Cushman of the Bureau of Entomology.

Girdler cocoons containing cocoons of this species were collected on a bog June 6, 1919, and the adult parasites emerged May 10 and 11, 1920, their cocoon stage thus being remarkably long. It was estimated that about 10 per cent of the girdler cocoons on the bog from which these specimens came contained this parasite.

The girdler cocoons from which these three parasite species emerged were collected at South Wareham, on a bog which always is flooded in the winter and usually is flowed for a day or two in June. They were taken from an area, about 80 yards from the bog margin, from which the vines had been burned off in early May, before the thick accumulation of old fallen leaves on the ground had dried out. The burning had been done to destroy the girdler infestation, but it had not killed either this pest or the brown spanworm (*Epelis*), pupæ of which were present in some numbers.

The writer often finds barn swallows capturing large numbers of girdler moths.[1]

It was found in 1920 that 1 part of Black-Leaf 40 in 400 parts of water, with 2 pounds of soap to 50 gallons added, kills girdler moths readily. While this spray may not control the pest entirely, it probably will help greatly where other means are lacking. It probably should be used about four times, at three-day intervals, for the moths emerge from their cocoons in large numbers for a week or two. The insecticide, tried in this connection at strengths of 1 to 600 and 1 to 800 with soap, and 1 to 400 without soap, proved unsatisfactory.

The Cranberry Root Grub (*Amphicoma vulpina* Hentz.).

On July 21, 1917, some wash boilers with the bottoms removed were driven into the station bog until the vines came within a few inches of their tops. Grubs of this species gathered from another bog were put in them as follows, after which the boilers were covered tightly with cheesecloth for the rest of the summer.

TABLE 9. — *Root Grubs put in Boilers at Station Bog July 22, 1917.*

Boiler No.	Number of Grubs.	Length of Grubs[2] (Millimeters).
1,	17	8–10
2,	60	12–15
3,	21	15–20
4,	97	20–28
5,	60	28–30

[1] Forbush: Useful Birds and Their Protection, p. 346, 1907. U. S. Dept. Agr., Bul. No. 554, 1917, p. 12.

[2] The grubs of various sizes were found working together, as is common with this species, broods started in two or three different years probably being represented.

On July 8, 1919, the vines inside the boilers were removed and the sand down to the peat, about 7 inches deep, was taken out and carefully sifted. Amphicoma grubs were found as follows: —

Table 10. — *Root Grubs found in Boilers at Station Bog July 8, 1919.*

Boiler No.	Number of Grubs found.	Length of Grubs (Millimeters).
1,	2	24–25
2,	5	21–25
3,	1	26
4,	5	9–11
5,	0	–

The grubs from the first three boilers were evidently what were left of those put in in 1917, larger grown. Those from boiler 4 probably were a new brood produced by beetles of the grubs put in in 1917. Grubs of the smaller sizes probably were a year or more old when put in the boilers in 1917, and the size of those taken from boilers 1, 2 and 3 in 1919 suggests that they required another year to mature. Evidently, therefore, the grub stage lasts three or four years.

On July 1, 1920, the grubs were found in numbers among the fine cranberry roots of bogs, within 3 or 4 inches of the surface. On July 28, in the same places, they hardly could be found among the roots, but were abundant 6 to 10 inches below the surface, many being in the peat under the sand. One was 4 inches deep in the peat. On December 3, in the same locations, they were 3 to 5½ inches below the surface, the lowest being near the water table. It seems from this that the insect works deeper into the soil as a bog dries out in summer and comes up again with a rise of the water.

The Army Worm (*Cirphis unipuncta* Haw.).

In previous reports,[1] the fall army worm (*Laphygma frugiperda* S. & A.) and the greasy cutworm (*Agrotis ypsilon* Rott.) were mentioned as harming bogs after removal of the winter flowage in July. In 1919 a destructive visitation of the army worm under like circumstances on a bog at Mays Landing, N. J., was reported, worms of the infestation one-third to one-half grown being brought to the writer on August 8. Moths reared from these worms emerged September 9 and 10. The winter water had been let off from this bog about July 5.

On July 20, 1920, army worms, many nearly mature, were found damaging a bog at Assonet, bared of its winter flowage June 16, and on July 24 they were found abundant on a bog in Carver, bared of its flowage July 2, the largest being one-fifth to one-quarter grown. It is noteworthy, in connection with these infestations, that this pest was prevalent in most of the Mississippi Basin in both 1919 and 1920. The former year it was

[1] Mass. Agr. Expt. Sta., Bul. No. 180, 1917, p. 232; Bul. No. 192, 1919, p. 133.

reported as injuring corn or grass in the following towns in eastern Massachusetts: Wilmington, Canton, Bourne, Falmouth, Barnstable, Brewster and Chatham. That year it destroyed 20 acres of corn on one farm in Bourne. In 1920 it seriously hurt several acres of corn in Bourne.

The army worm and the fall army worm are the two more common of the three harmful insects known to infest the bogs as a result of letting off the winter water in midsummer. The outbreaks of both species nearly always start in the southern States. They are noted there by the Bureau of Entomology which forecasts their spread into the North. Such forecasts were published in both 1919 and 1920. Cranberry growers contemplating holding winter flowage very late should consult the Bureau as to the prospective abundance of these pests. The army worm probably never greatly harms cranberry bogs reasonably free of grasses except in infestations following very late removal of the winter flood.

The Cranberry Fruit Worm (*Mineola vaccinii* Riley).

In 1919 this pest did less harm than in any previous year of the writer's experience. Its reduction was to be expected from the mildness of the previous winter and the wetness of the growing season.[1] The egg parasitism (*Trichogramma*) examined ranged from 16 to 88 per cent on dry bogs, and from 0 to 37 on flowed ones.

In 1920 the insect did much more harm than in 1919, the winter before having been severe. The egg parasitism ranged from 14 to 50 per cent on dry bogs, and from 0 to 25 per cent on flowed ones.

The Black-head Fireworm (*Rhopobota vacciniana* (Pack.)).

This pest was less harmful in 1919 than in any previous year of the writer's experience. The second brood seemed to be entirely suppressed on some bogs; on others it began hatching freely, but for some cause, perhaps disease, as a rule faded out without doing much damage. In 1920 this worm was less harmful than usual, but more so than in 1919.

Results of spraying tests in 1920 support previous experience in indicating that while 1 part of Black-Leaf 40 in 800 parts of water, with 2 pounds of soap to 50 gallons added, is fairly effective in killing the worms, it is probably better economy, all things considered, to use the insecticide at the rate of 1 part to 400 parts of water. One part to 800, with the soap, kills the moths satisfactorily. At either strength the spray is safe to use when the vines are in bloom. Lead arsenate may be used with Black-Leaf 40 if the soap is left out,[2] but it should not be so used unless other pests, such as the gypsy moth or spanworms, are also to be treated, for the soap makes the Black-Leaf 40 more effective.

As cloudiness or dark water, by reducing the light reaching the plants and so lessening photosynthesis, causes a marked decrease of oxygen in the water of a cranberry bog flooding to be maintained, it seems that,

[1] Mass. Agr. Expt. Sta., Bul. No. 180, 1917, p. 227.

[2] The arsenate and soap make a burning mixture.

under such conditions of light reduction, the forty-eight-hour flooding period hitherto advocated for treating this insect may be much reduced, for the oxygen deficiency should affect the worms as well as the plants.

The Gypsy Moth (Porthetria dispar L.).

In 1919 this insect hurt the bogs more than any other. In 1920 it did little harm, as it was generally less prevalent and was treated much more effectively by the growers.

In 1920 Mr. Walter F. Holmes, the gypsy-moth division superintendent for Cape Cod, and the writer tested the open nozzle for treating this pest on the bogs. This is the nozzle used in the gypsy-moth work to spray tall trees from the ground. As tested it proved unsatisfactory for bog spraying, as it was hard to spray at such long range without skipping considerable areas; but it should be tried further, with smaller nozzle holes and lower pressures.

Experience and experiments in recent years have shown that this insect can be controlled readily on the bogs by —

1. *Holding the winter flowage until May 25.* This will kill the eggs laid on the bog the season before, and in most years it also will catch most of the worm wind-drift.

2. *Reflowing about May 29 for thirty-six hours.* The wind-drift is about over then, and the water will kill the worms before they do much harm unless they are unusually numerous. This flooding also will destroy other pests that may be at work, such as the false army worm (*Calocampa*), blossom worm (bud worm) and fireworm. After the gypsy caterpillars are one-third grown, a fourteen-hour flooding kills them, few getting ashore with life enough to eat afterward. They seem to thrash themselves to death in the water, as do apparently all other growing foliage-eating worms of the cranberry, except those that sew the leaves together. If the worms are very numerous, however, it is better not to delay the flooding after the above date in average seasons. The date for the earliest springs is May 24 and for the latest June 3.

3. *Spraying with lead arsenate (3 pounds of powder or 6 pounds of paste to 50 gallons of water) about May 24.* Well applied, this treatment is sure death to the worms when they are small. They are hard to poison when over half grown. In very early springs the spraying should be done about May 18; in very late ones about May 30.

4. *Keeping the maturing worms from getting onto the bogs. This is done best by:* —

(*a*) *Removing the trees, especially the oaks, for some distance back from the bog margin.* The removal of the underbrush (scrub oaks, etc.) also would help, but this seems too costly.

(*b*) *Keeping the marginal ditch cleaned out and partly full of water, and maintaining a film of kerosene or crude oil on the water during the worm-crawl period.*

Bog Management.

Experience and the results of recent experiments lead to the conclusion that winter-flowed bogs not reflowed in June should be sprayed once regularly, a few days before the vines blossom, with this mixture: —

Black-Leaf 40,	1 gallon
Water,	400 gallons
Fish-oil soap,	16 pounds

This treatment largely takes the place of the June reflow in reducing various harmful pests, especially —

1. The black-head fireworm (*Rhopobota vacciniana* (Pack.)).
2. The spittle insect (*Clastoptera vittata* Ball).
3. The girdler (*Crambus hortuellus* Hübner).
4. Leaf hoppers (mainly species of *Euscelis* [1]) and spring-tails (*Collembola*). These forms abound among the vines of bogs not reflowed, and must drain their vitality considerably. Cranberry vines often seem stimulated in growth by nicotine sprays. Probably this is usually due to the reduction of insect drains.

Resanding.

The results with two plots on the station bog that have not been sanded since 1909 are shown in Tables 9 and 10. The check areas in each case bordered different sides of the plot. The berries were Early Black and were picked and stored in 1920 on September 18. They were stored in bushel crates, 6 bushels being used in each case, and were examined November 26 to December 2 by the "seven-sample" method. No distinct effect on keeping quality from resanding was revealed.[2] These plots yielded as well as the surrounding bog until 1916.[3] Table 10 shows how since 1915 their average productiveness has fallen below that of their checks. The last five years these plots have been more thinly vined than the surrounding bog.

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[1] Identified by W. L. McAtee of the Bureau of Biological Survey.

[2] Mass. Agr. Expt. Sta., Bul. No. 180, 1917, p. 219, Table 18; Bul. No. 192, 1919, p. 134, Table 14.

[3] Mass. Agr. Expt. Sta., Bul. No. 168, 1916, p. 27, Table 15.

TABLE 11. — *Sanding Plots in 1920. Effect of Resanding on Keeping Quality of Cranberries.*

Plots and Checks.	Area (Square Rods).	Resanded.	Percentage of Berries showing Decay at End of Storage.
V,	9	Not since 1909,	15.63
V (check 1),	9	Spring of 1912, fall of 1914, spring of 1917 and spring of 1919.	14.85
V (check 2),	6	Spring of 1912, fall of 1914, spring of 1917 and spring of 1919.	13.85
V (check 3),	9	Spring of 1912, fall of 1914, spring of 1917 and spring of 1919.	17.41
O,	9	Not since 1909,	13.61
O (check 1),	6	Fall of 1911, fall of 1914, spring of 1917 and spring of 1919.	18.83
O (check 2),	6	Fall of 1911, fall of 1914, spring of 1917 and spring of 1919.	17.28
O (check 3),	9	Fall of 1911, fall of 1914, spring of 1917 and spring of 1919.	12.86

TABLE 12. — *Productiveness of Sanding Plots V and O from 1916 to 1920, inclusive.*

Plots and Checks.	Resanded.	Yields per Square Rod (Bushels).						
		1916.	1917.	1918.	1919.	1920.	Average, 1916-20.	Average, 1912-15.
V,	Not since 1909,	.93	.60	1.59	.24	1.22	.92	1.250
V (checks),	Four times since 1909,	1.39	.65	2.37	.16	1.41	1.20	1.052
O,	Not since 1909,	.93	.63	1.39	.19	1.07	.84	.864
O (checks),	Four times since 1909,	1.24	.63	1.95	.15	1.19	1.03	.895

Relation of Weather to Cranberry Flooding Injury.

The station bog began the season of 1919 with fair prospects, the vines having a good supply of blossom buds. Partly to check the fireworm and partly as a test treatment of the "rosebloom" disease (*Exobasidium oxycocci*), it was flooded the night of June 16, the water being held about forty-eight hours. A day or two after the water was let off, most of the buds were found to have been killed by it. This was puzzling, as the bog had been flowed with the vines in the same stage of growth in previous years without material harm. Very hot weather had accompanied some of the former June floodings, the water temperature sometimes reaching 86° F. As the first day of this flooding (June 17) was cloudy and the second (the 18th) was not very warm, the injury hardly could have been due to temperature alone.

The writer tried in every way to find the cause of the disaster. The effects of that June's floodings on many other bogs were investigated, and it was found that no notable injury had resulted anywhere except on bogs that had been under water June 17. That day's flooding had done much harm in all the five other cases found. It seemed, therefore, that there was something peculiarly harmful about the weather of the 17th. As that day had been darkly cloudy, comparative experiments in immersing vines in water under shade and in sunshine suggested themselves. Many such tests were made, pieces of cranberry turf with the vines being submerged in some cases in tubs and in other cases in a pond. These tests took place in late June and in July, the first vines being budded and partly in blossom, and the last lots with the bloom gone and bearing small berries. The immersion periods ranged from two to four days. The degree of shade over the shaded lots varied in the different experiments, but in no case did the light seem reduced as much as it is on a real cloudy day. In all these tests the tender parts of the shaded vines were much hurt by the submersion, while the vines immersed without shading were injured little, the contrast between the shaded and unshaded vines in the tests in which the shade was heaviest being striking.

The uniform result of these experiments seems ample proof that the continued reduction of light by cloudiness is harmful to cranberry vines under water during their rapid summer growth. This being so, dark swamp water is more likely to do harm than clear water, for it reduces the light reaching the plants more; also deep flooding must be worse than shallow, for the deeper the water the more light is cut off. These conclusions accord with effects of cranberry flowage commonly observed. Bogs flooded with dark water are oftener hurt than others, and whenever a bog is hurt either by late holding of the winter water or by reflooding, the parts most deeply submerged suffer most.

Dr. H. F. Bergman of the Bureau of Plant Industry determined from time to time the oxygen content of the water used in the immersion experiments in tubs. In his papers on this work lately published,[1] he gives what is probably the true explanation of the harmful effect of shading, by cloudiness or otherwise, in summer cranberry flooding. Apparently the injury is due to drowning of the more rapidly growing parts of the plant, the oxygen in the water being reduced below the respiratory needs of these parts too long.

As Dr. Bergman shows, photosynthesis tends to keep up the oxygen content of a bog flowage. One has only to see the many bubbles of oxygen that form on the leaves of the flooded vines in clear summer weather to appreciate this. As photosynthesis depends on light, cloudiness greatly reduces it or stops it entirely. On the other hand, respiration, the process that uses up oxygen, goes on without regard to light. Apparently for this reason cloudy weather is much more dangerous than clear weather for flooding the bogs in their season of active growth. The days of the June

[1] Ann. Rept. Cape Cod Cranb. Gr. Assoc., 1919–20, pp. 19–30. Amer. Journ. of Bot., 1: 50–58, January, 1921.

floodings are about the longest in the year. In clear weather they allow photosynthesis to go on about fifteen hours of the twenty-four, the oxygen in the water thus being replenished three-fifths of the time.

From what is known about the effect of temperature with other species,[1] a rise of 18° F. must more than double the rate of respiration in the new growth of cranberry. Therefore a combination of very cloudy weather with a high water temperature seems especially dangerous in the flooding of actively growing vines: for, while the stopping of photosynthesis allows the oxygen in the water to become much reduced, the high temperature greatly increases the need of the plants for oxygen. This was the weather combination of June 17. As already stated, the day was darkly cloudy. It was also warm for a cloudy day, the temperature at the station bog reaching 77° F.; also, as the 14th, 15th and 16th had been warm days with warm nights, the water must have become quite warm before it was put on the bog. That warm water is not notably harmful in cranberry flooding in clear weather is explained by the fact that a rise in temperature, with light abundant, increases the rate of photosynthesis almost as much as that of respiration.[2]

Water Injuries to Cranberry Buds.

When, in flooding, cranberry blossom buds are hurt by drowning (lack of oxygen) they usually are either entirely killed, the whole bud turning brown and never opening, or they are injured only on one side, in which case the point of the bud soon bends toward the hurt side, and one or two lobes of the corolla commonly turn brown. When but one side of the bud is hurt it usually opens to form an imperfect blossom, but rarely develops a berry.[3] When this drowning injury occurs it is severest in the deepest water and on the sides of the ditches.

Another bud injury was observed in 1919 in connection with the flooding of three bogs located near together. The berries on these bogs are Early Black, and the water for flooding them all has the same source. All three bogs were flooded before sunrise June 12. The water was let off the two lower ones on the night of June 13, the flooding having lasted about forty-two hours and both days having been clear. The night of June 13 was cold, the temperature at near-by bogs falling to 33° F. The water on the upper bog was held until the night of June 14, the flooding period being about seventy-two hours.

These bogs were examined a few days later. Most of the buds on the two lower ones showed a peculiar injury, their tips having turned dark red or blackish and having opened somewhat. In this condition they had

[1] Van't Hoff: Studies in Chemical Dynamics, trans. by Ewan, 1896, p. 126. Kuijper: Rec. Trav. Bot. Néerl., 7: 131–239, 1910. Gore: U. S. Dept. Agr., Bur. of Chem., Bul. No. 142, 1911, pp. 5–28.

[2] Matthaei; Phil. Trans. Roy. Soc., B, 197: 47–105, 1905.

[3] As might be expected, for the pistil respires faster than any other part of the flower. Maige: Ann. Sci. Nat., Bot., Ser. 9, 14: 1–62, 1911.

a distinctive appearance, with none of the marks of drowning injury. Many of the buds on the upper bog (where the water was held for seventy-two hours) showed drowning injury, but none looked like those hurt on the other bogs. These bogs were examined again late in August, and the lower ones (where the water was held forty-two hours) had little fruit, the crop being plentiful only in low places and along the ditches. On the other bog the crop was heaviest on the high parts.

The buds on the lower bogs may have been hurt by exposure to the cold when the water was let off, though no frost was seen in the vicinity that night. The fact that the buds were hurt less in the low places, as evinced by the heavier fruiting there, shows that the water tended to prevent the injury.

Blueberry Work.

To control the gypsy moth, different parts of the blueberry plantation were sprayed on June 3, 1919, with these mixtures: —

1. Three pounds of lead arsenate powder to 50 gallons of water.
2. Three pounds of lead arsenate powder and 2 pounds of Good's Caustic Potash Fish-oil Soap No. 3 to 50 gallons of water.

Both sprays killed the worms, but the one with soap burned the foliage and blossom buds badly.

No budding was done in 1919 because of a lack of good sprouts to bud into, but in 1920 it was done as follows: —

Pioneer (620A) variety, 82 buds.
Cabot (834A) variety, 208 buds.

Gypsy-moth caterpillars showed a special fondness for the growth from inserted buds, giving so much trouble that it seemed impossible to continue the work, until it was found that the caterpillars were stopped by tree tanglefoot around the bases of the sprouts.

Sixty-eight small Pioneer plants from the Bureau of Plant Industry were added to the station planting, 2 in 1919 and 66 in the spring of 1920.

The drainage of the plantation was improved by new construction in 1920.

The plantation produced 98 quarts of berries in 1919, and 147 in 1920, the bearing area being about a quarter of an acre. The fruit was sold locally at moderate prices. Most of the bearing plants are untested seedlings (four years old in 1920) provided by the Bureau of Plant Industry. A few of these seem promising, — one in 1919 yielding over 2 quarts of berries which averaged about 15 mm. in diameter, the largest measuring 18 mm. The largest berries from the plantation in 1920 were 20 mm. (about eight-tenths of an inch) through.

The proper development of the blueberry work and of the cranberry variety work requires several additional acres of rough land, and an early appropriation should be made for it.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 207 APRIL, 1922

INJURY TO FOLIAGE BY ARSENICAL SPRAYS

I. THE LEAD ARSENATES

By H. T. FERNALD and A. I. BOURNE

It has long been known that arsenical poisons sprayed upon foliage will at times produce injury or a "burning" of the leaves. To find out why this burning takes place was the purpose of the experiments reported in this bulletin. The investigation has shown that injury from the use of reliable arsenicals is due to a combination of temperature, light and humidity factors, and that spraying is safer in clear than in cloudy weather. It has also established certain limits of temperature and humidity within which spraying with the lead arsenates seems to be entirely safe.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
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CONTENTS.

BULLETIN No. 207.

DEPARTMENT OF ENTOMOLOGY.

INJURY TO FOLIAGE BY ARSENICAL SPRAYS.

I. THE LEAD ARSENATES.

BY H. T. FERNALD AND A. I. BOURNE.

It has long been known that arsenical poisons sprayed upon foliage will at times produce injury, or a "burning" of the leaves. For this, four explanations have been offered, viz., (1) that the arsenic (either As_2O_3 or As_2O_5, as the case might be) was present in the material, uncombined with any base; (2) that it was so loosely combined with the base as to become liberated from it during the addition of water in preparing it for application to the foliage; (3) that this liberation took place more or less gradually on the leaves after the spray had been applied, as a result of influences acting upon the material through the air; and (4) that injury was due to the presence of injurious impurities in the material.

Faulty methods of manufacture might easily result in producing a substance containing some arsenic, either free or so poorly combined that upon the addition of water the combination would break up, at least to some extent. The use of poor materials from which to make the lead arsenate might very possibly result in the presence of injurious substances. The liberation of arsenic upon the tree by atmospheric influences, however, comes distinctly in a different class; and the statement sometimes made, that spraying a tree with water under the right conditions may result in burning, if true, also suggests that atmospheric conditions must not be overlooked. The entire problem, therefore, of ascertaining what factors are really responsible for foliage injury following arsenical spraying has been investigated during a period of about ten years.

This bulletin reports the results of this work with the various lead arsenates. Similar reports upon arsenates of lime and Paris green are nearly ready for publication, together with notes on a number of other arsenicals which have been tested more or less.

The planning of the project, the plotting and analysis of the results, and the preparation of the material for publication are the work of the senior author; the preparation and application of the sprays, and the observations to determine their effects, were carried out by the junior author; the chemical analyses and all the chemical work involved were done by Dr. E. B. Holland and his assistants of the Department of Plant and Animal Chemistry of the Experiment Station, and to him and to those who worked with him the authors desire to express their appreciation of the efforts made to establish this work on a firm chemical basis.

Materials.

To eliminate the possibility that injury was caused by impurities in the spray materials, pure arsenates were first sought. A definite knowledge of the action of these appeared to be desirable, as, if injury resulted from their use, it seemed probable that the factors causing it would be indicated, uncomplicated by the presence of injurious impurities, uncombined arsenic or too loosely combined arsenic. In fact, such knowledge would provide a basis or standard with which to compare results obtained from the use of commercial materials. Accordingly, the attempt was made to obtain pure acid lead arsenate and pure neutral lead arsenate.

To get these seemed at first to be almost impossible. A number of manufacturers were willing to supply them, but the samples received proved on analysis to be far from pure, and nearly two years passed before materials were found so nearly pure that it was believed they would be satisfactory.[1]

Pure Acid Lead Arsenate Paste. — The material used in these experiments analyzed as follows: —

	Per Cent.
Water, H_2O	46.99
Water in combination and occlusion	1.33
Lead oxide, PbO	34.58
Arsenic pentoxide, As_2O_5	17.11
Chlorine, Cl	.04
Insoluble matter	.01
	100.06

The probable original composition of the paste, reconstructed from this analysis, was substantially as follows: —

	Per Cent.
Water, H_2O	46.99
Water occluded	.09
Acid lead arsenate, $PbHAsO_4$	47.87
Neutral lead arsenate, $Pb_3(AsO_4)_2$	4.93
Lead chloride, $PbCl_2$	.16
Insoluble matter	.01
	100.05

[1] See Holland and Reed: The Chemistry of Arsenical Insecticides, Twenty-fourth Annual Report, Mass. Agr. Exp. Station, Part I, pp. 180–182, 1912, for a fuller discussion.

The impurities present here — the lead chloride and insoluble matter — occur in such infinitesimal amounts and are of such a nature that they certainly could not cause any injury on foliage.

As the purpose of using this material was to test acid lead arsenate, the presence of nearly 5 per cent of the neutral salt was unfortunate; but, as will be shown in studying the results following the use of the neutral salt, its presence here would, if anything, tend to increase the safety of the spray rather than reduce it. The substance, then, was rather more than half arsenates of lead and rather less than half water.

This material, mixed with water at the rate of 1 part of the dry matter of the paste to 1,000 of water and kept twenty-four hours, gave .03 per cent of arsenic pentoxide (As_2O_5) as entering into solution during that time. As the Federal law permits .75 per cent of solubility under such conditions, it is evident that the sample was of excellent quality from this standpoint.

The rate at which lead arsenate settles when mixed with water is also an important factor, those brands which settle most slowly being distributed most evenly over the tree in spraying. This sample had completely settled eighty-one minutes after a thorough mixing, which is excellent for paste lead arsenates.

Commercial Lead Arsenate Paste. — This material, purchased from a dealer, was of a brand commonly used. Analyzed, it gave: —

	Per Cent.
Water, H_2O	46.32
Water in combination and occlusion	1.26
Lead oxide, PbO	35.44
Arsenic pentoxide, As_2O_5	16.29
Ferric and aluminum oxides	.19
Chlorine, Cl	.31
Nitric acid, HNO_3	trace
Insoluble matter	.04
	99.85

The probable original composition of this paste was substantially as follows: —

	Per Cent.
Water, H_2O	46.32
Water in occlusion	.19
Acid lead arsenate, $PbHAsO_4$	37.96
Neutral lead arsenate, $Pb_3(AsO_4)_2$	13.50
Iron and aluminum as ferric arsenate	.54
Lead chloride, $PbCl_2$	1.22
Nitric acid, HNO_3	trace
Insoluble matter	.04
	99.77

In this material less than 2 per cent could be termed impurities, and these were of such a nature as to make it practically certain they could not cause any injurious effect on foliage. Rather more than half of the whole consisted of arsenates of lead, but the neutral salt formed a much greater part of the total than was the case with the pure material. About the same amount of water was present as in the pure substance. Or, the total amount of arsenate in the two did not differ greatly, but there was more than three times as much of the neutral arsenate in the commercial salt as in the pure one, the acid arsenate being correspondingly decreased. Any marked difference in the results following spraying by these materials, then, might possibly be explained by this difference in composition. In fact, the results did not differ greatly.

This paste, mixed with water as described for the pure paste, gave .09 per cent of arsenic pentoxide as entering solution in twenty-four hours. This, though more than with the pure paste, is also far below the amount permitted by the Federal law. Complete settling after mixing with water required only thirty-four minutes, showing that this commercial material was rather poor in this regard as compared with the pure paste.

Commercial Acid Lead Arsenate Powder. — The appearance on the market during the progress of these experiments of lead arsenate in powder form led to the addition of this material to the list of substances to be investigated. Samples from a brand on sale were obtained, analyzed and tested like the others. The analysis gave: —

	Per Cent.
Water, H_2O	.45
Water in combination and occluded	3.20
Lead oxide, PbO	63.25
Arsenic pentoxide, As_2O_5	32.22
Ferric and aluminum oxides	.40
Insoluble matter	.38
	99.90

From this the original composition of the powder was probably substantially as follows: —

	Per Cent.
Water, H_2O	.45
Water in combination and occluded	.68
Acid lead arsenate, $PbHAsO_4$	89.93
Neutral lead arsenate, $Pb_3(AsO_4)_2$	7.28
Iron and aluminum as ferric arsenate	1.16
Insoluble matter	.38
	99.88

This material as used for spraying, therefore, contained a little more than 1 per cent of water, about 90 per cent of acid lead arsenate, rather more than 7 per cent of neutral lead arsenate, and about 1½ per cent of impurities, none of them of a nature or present in sufficient amount to be liable to cause any injury.

The amount of arsenic pentoxide which had entered into solution after twenty-four hours of treatment was .16 per cent, which, though more than with either of the other materials already considered, was still far below that permitted by the Federal law. The time required for the powder to settle was 255+ minutes, which places this sample far ahead of either of the pastes in this regard.

Pure Neutral Lead Arsenate Paste. — This material has been highly recommended as being safer on foliage than the acid lead arsenates, and an investigation of it was therefore also made. To obtain it in a pure or nearly pure form was very difficult, however,[1] and the best sample obtainable analyzed as follows: —

	Per Cent.
Water, H_2O	70.97
Water in combination (calculated)	.08
Lead oxide, PbO	21.10
Arsenic pentoxide, As_2O_5	7.33
Acetic anhydride, $C_4H_6O_3$	.10
Sodium oxide (calculated to combine with last)	.06
Carbonic acid, CO_2	.15
Insoluble matter	.01
	99.80

The original composition of this sample was therefore substantially as follows: —

	Per Cent.
Water, H_2O	70.97
Water occluded	–
Acid lead arsenate, $PbHAsO_4$	3.14
Neutral lead arsenate, $Pb_3(AsO_4)_2$	24.61
Lead carbonate, $PbCO_3$	.91
Sodium acetate, $NaC_2H_3O_2$	.16
Insoluble matter	.01
	99.80

This sample contained a very large amount (71 per cent) of water, was nearly one-quarter neutral lead arsenate, and contained a little over 3 per cent of acid lead arsenate and rather more than 1 per cent of impurities of such a nature as to indicate that it had not been sufficiently washed to remove all the acetic acid, and that impure sodium arsenate containing some carbonate had been used from which to obtain the arsenic. None of these materials was apparently present in sufficient amount to cause any foliage injury, — a view sustained by the results later.

The solubility of the sample in water was .07 per cent on standing twenty-four hours, and it required an hour for complete settling.

None of the materials showed on analysis the presence of impurities of such kinds and in such amounts as to make injury to the foliage from this cause at all probable.

As a commercial neutral lead arsenate could not be obtained which did not contain a large amount of the acid arsenate also, tests of such a material were not made.

[1] See Holland and Reed, *loc. cit.*, p. 203.

Application.

The trees used were the apple, cherry, peach, pear, plum and elm. The materials were applied in the same way in all cases, being thoroughly mixed with the proper amount of water just before using. With the acid pastes, 3 pounds in 50 gallons of water, and with the powder, $1\frac{1}{2}$ pounds, were used, the powder containing approximately twice as much arsenic pentoxide as the pastes. As the neutral arsenate contained much less pentoxide than the acid pastes, 5 pounds 7.6 ounces of it were mixed with 50 gallons of water to provide an amount of arsenic pentoxide in the spray equal to that present in the others. Practically an equal amount of poison was therefore applied in every case.

It has been suggested that injury might be caused by the poison entering the leaf through the stomata. As these are usually more numerous on the lower than on the upper surface, branches were held by the hand in such a position that the spray would reach only one surface of the leaf. Parallel tests for both surfaces were made, one test immediately following the other and on the same tree. The main lines of investigation, though, were with reference to variations of temperature and humidity and of light. Two series were made, one in bright, clear weather, and the other on cloudy days.

The temperature and humidity were obtained from a Hygrodeik manufactured by Andrew J. Lloyd & Co. of Boston, giving both the temperature and relative humidity. These were taken at the tree immediately before applying each spray. The attempt was made to spray each surface of the leaves, both in clear and cloudy weather, for at least every 5° interval between 65° and 95° of temperature, and between 50° and 90° of humidity. To obtain all these combinations, however, proved difficult, and some of them were not obtained until several years had elapsed, though fairly complete series were finally secured.

Application of the sprays was begun in June, continued during July, and a few sprays were put on the trees early in August. The tests were begun in 1912 and ended in 1920. After the spray had been applied, its effect was observed about twice a week for at least two weeks, so that any injury appearing late might not be overlooked.

Adequacy of Experimental Methods.

Three possible sources of error, at least, may have affected this experiment. First, there is the difficulty of a uniform estimation of the amount of injury found. As a check upon this we have the very uniform agreement in observations made at identical and nearly identical temperatures and humidities, not only in the same, but also in different years. The personal equation was reduced as much as possible by having the observations all made by one person. Then, after all, the main dividing line was between injury and no injury, determination of the exact degree of injury being of less importance.

A second source of error was the necessity of using different varieties of the fruit trees, in some cases, in different seasons. If different varieties of the same kind vary in their degree of resistance, the results might be expected to vary also, to some extent. This could not hold for the plum, all tests with this being of the Bradshaw variety, and for the elm, which was always the American elm. With the other trees the results do not indicate, at least, that varietal difference was a factor, though it is generally believed that the Baldwin, for example, burns more easily than the McIntosh. How much the results of these experiments were affected by varietal differences cannot be determined.

The third source of error is the possibility of a difference in the leaves as the season progresses, the later sprays having, perhaps, been applied to leaves which had already begun to "harden." Here, too, the results fail to indicate that this was a factor. Burning occurred as frequently after the late July and early August sprays as following the earlier ones, under similar conditions of temperature and humidity, and it would seem that this possible source of error was of little if any importance.

General Results.

Some general conclusions from the investigation were: —

1. The difference in sensitiveness between the upper and under surfaces of the leaves is so slight as to be negligible. Not more than a dozen cases of difference were observed out of nearly 1,600 applications. In these few the under surface showed the greater injury. Apparently in cases of spray injury, it is not caused by the poison entering the leaf through the stomata.

2. Where insects or fungi had produced holes in the leaves, spray injury was frequently observed around the edges of these holes, while the rest of the leaf was not affected. Whether this injury resulted from a freer access of the poison to the inner leaf cells, or would have resulted in any case, is perhaps uncertain. Such injury was not rated as injury by spraying where the unattacked remainder was not affected.

3. It was frequently the case that injury did not appear until nearly a week after spraying (longer in some cases), and increased in severity later. A branch graded as showing a trace of injury at the end of the first week often increased to "slight" after two or three days, and even to "bad," in a few cases, by the end of the second week. In general, though, the final degree of injury had been reached after about twelve or thirteen days.

4. It is well known that some kinds of foliage are more sensitive to arsenical sprays than others, but details as to this have hitherto been lacking. These tests show that the pear and elm are the most resistant of the trees used in the experiments; that the apple comes next, but is much less resistant; that the cherry comes considerably below the apple in this regard; and that the Bradshaw plum and the peach come some distance below the cherry, and are about equally sensitive, the peach being probably rather the more sensitive of the two.

5. No injury either from the pure or commercial materials was obtained with a combination of the lower temperatures and humidities, but traces of it began to appear as these factors became higher. This indicates that one or both of these affect the leaf in some way so that it becomes more sensitive the higher either one goes, and also that medium high temperatures and medium high humidities act together. The results of this work show that with reasonably good materials injury caused is determined by temperature, humidity and perhaps light. The effects of these are therefore given in greater detail below.

The Effects of Temperature, Humidity and Light.

Pear and Elm. — No case of injury to either of these trees was produced by any of the sprays, even at the highest combinations of temperature and humidity (hereafter written T and H) obtained in the course of the work. It may be remarked, however, that this was not true with Paris green and calcium arsenate, the results with which are not included in this bulletin, both materials seriously injuring the leaves under certain T and H combinations. Combinations as high as T91 H71, T80 H84, and T84 H82 resulted in no injury from lead arsenate, and the conclusion is reached that under any usual combinations of T and H obtainable during the summer months, spraying these trees with any reliable brand of lead arsenate should be entirely safe.

Apple. — Fig. 1 shows the results obtained by using pure acid lead arsenate paste in clear weather. The dots show the T and H points obtained for each test; a circle around the dot indicates that there was no injury; *t* indicates a trace of injury, and *s* indicates slight or "some" injury. Figures in parentheses give the number of tests at the same T and H. A line AB can be drawn across the chart somewhat below the *t* spots, which may be termed the safety line under the conditions of this test. Spraying above the TH limits of this line may not result in injury, as four cases on the chart show, but neither can safety be assured above the line.

Fig. 2 shows the results obtained with the same material applied in cloudy weather. It will be noticed that the lowest humidity was 68°, and that only one high temperature (91°) was met with under the required conditions during the six years the tests were carried on. Apparently, cloudy weather is hardly possible (as is to be expected) with low humidities, and also high temperature tends to dissipate clouds.

So far as can be judged from these tests, there is little real difference in results between clear and cloudy weather, except perhaps at the high humidity end of the safety lines. It would seem that injury begins a little sooner in cloudy than in clear weather at medium T and H, but only slightly so with low T. This is made evident by Fig. 3, where the safety lines only are shown together. Here the cloudy weather line diverges from the other toward the high H end of the diagram, though, after all, only by about 5° at H90.

APPLE — RESULTS OF SPRAYING WITH PURE ACID LEAD ARSENATE.

AB, safety line.

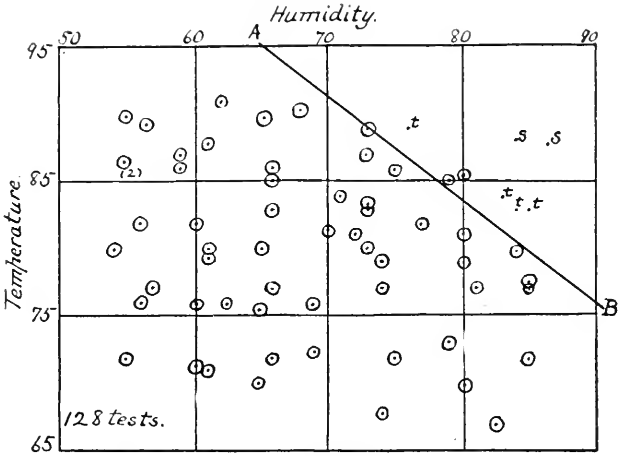

FIG. 1. — Clear weather.

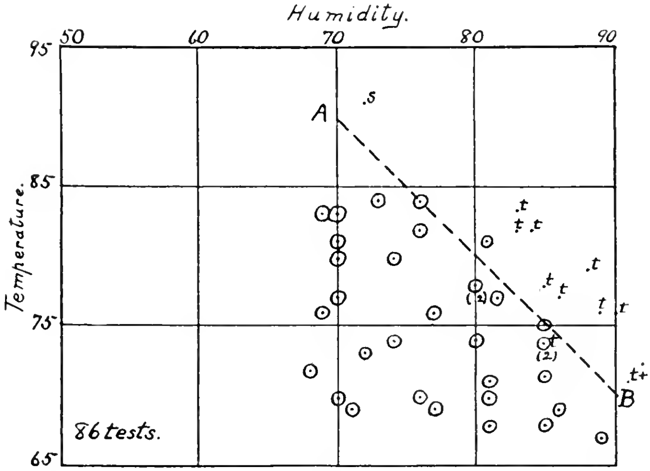

FIG. 2. — Cloudy weather.

With commercial lead arsenate paste the results as shown in Fig. 4 are much the same, though on the whole injury occurs before T and H get quite as high as with the pure paste, particularly at the higher humidities. The clear and cloudy weather lines are more nearly parallel than in the other case.

APPLE — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

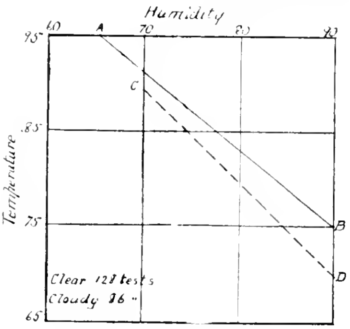

FIG. 3. — Pure acid lead arsenate paste.

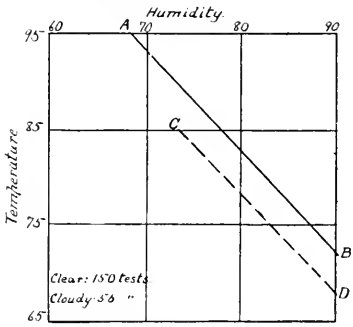

FIG. 4. — Commercial acid lead arsenate paste.

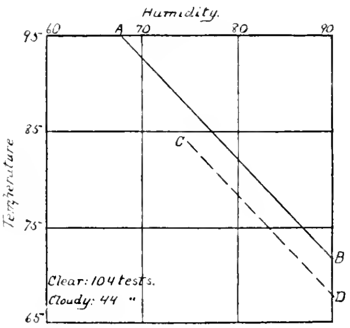

FIG. 5. — Commercial acid lead arsenate powder.

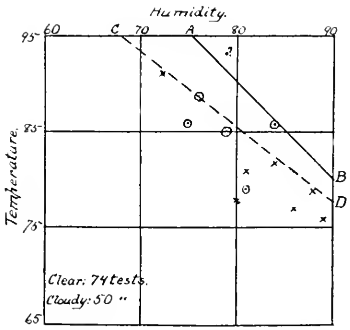

FIG. 6. — Pure neutral lead arsenate paste. Crosses indicate cloudy weather tests with no injury; circles, clear weather tests with no injury.

In the case of commercial lead arsenate powder (Fig. 5), the results differ somewhat, the clear weather safety line beginning at a higher H than in the other cases, but crossing these and running out on H90 at a lower temperature. The total difference, however, is only 4°, so that, after all, there is no great significance in this. The cloudy weather line nearly parallels the clear weather one, and runs about 1° above the commercial paste cloudy weather line.

Results from the use of neutral lead arsenate were rather different from those following the other lead arsenates, this material being apparently the safest of those used. No injury except one doubtful case was found, either

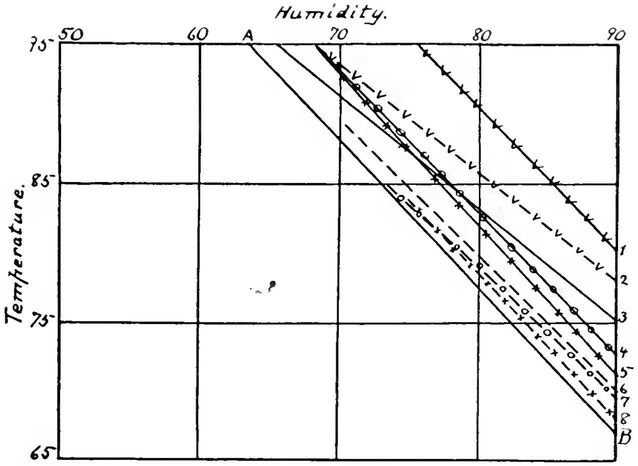

FIG. 7. — APPLE — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, same, cloudy weather; 3, pure acid paste, clear weather; 4, commercial acid paste, clear weather; 5, commercial acid powder, clear weather; 6, pure acid paste, cloudy weather; 7, commercial acid paste, cloudy weather; 8, commercial acid powder, cloudy weather.

in clear or cloudy weather, at the combinations of T and H obtained, and the safety lines were finally placed near the highest records taken. Fig. 6 shows these records and the placing of the safety line with reference to them. So far as can be judged, then, this material is safe to apply under any ordinary combinations of T and H up to the line AB of Fig. 6.

A general conclusion on the apple is that apple foliage is quite resistant to lead arsenate at high temperatures if the humidity is low, and at high humidities if the temperature is low. Thus, spraying appears to be safe at T90 or higher if the H is below 66. With intermediate T and H, however, the two appear to combine, so that at T82, for example, H should not be above 76.

Cherry. — The cherry appears to be much less resistant to injury than the apple. Fig. 8 gives the safety lines for clear and cloudy weather with pure acid lead arsenate paste. Comparing this figure with Fig. 3, we see that temperature is a more active agent with the cherry than the apple, and that this is even more marked in cloudy weather, though with less difference at low temperatures and high humidity.

CHERRY — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

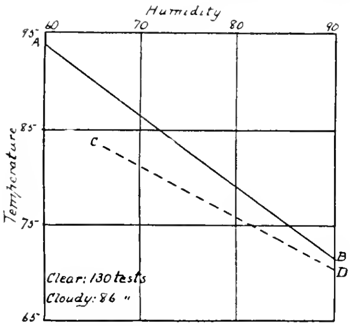

FIG. 8. — Pure acid lead arsenate paste.

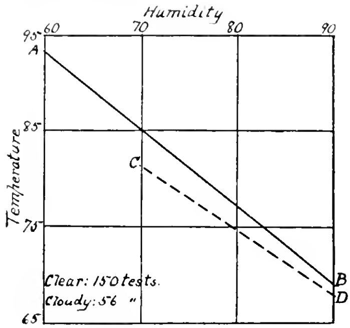

FIG. 9. — Commercial acid lead arsenate paste.

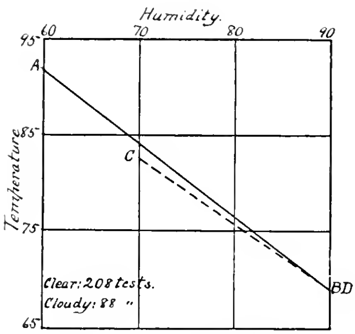

FIG. 10. — Commercial acid lead arsenate powder.

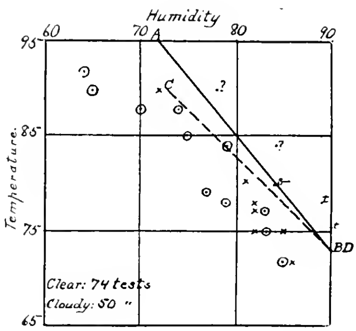

FIG. 11. — Pure neutral lead arsenate paste. Crosses indicate cloudy weather tests with no injury; circles, clear weather tests with no injury.

With commercial acid lead arsenate paste (Fig. 9) the safety lines are very similar to those given in Fig. 8, though a little lower. The difference is insignificant, however. With the commercial acid lead arsenate powder (Fig. 10) the results are also similar, but there seems to be less difference between clear and cloudy weather in producing injury.

The tests with the neutral lead arsenate paste support those on the apple in indicating higher T and H as necessary to cause burning. In Fig. 11 a few of the actual tests are recorded, those marked by circles being clear weather tests and those by crosses, cloudy weather ones. The two interrogation mark tests were clear weather tests, and whether they were really spray injuries is at least doubtful. The two marked "t" and the "s" were cloudy weather tests.

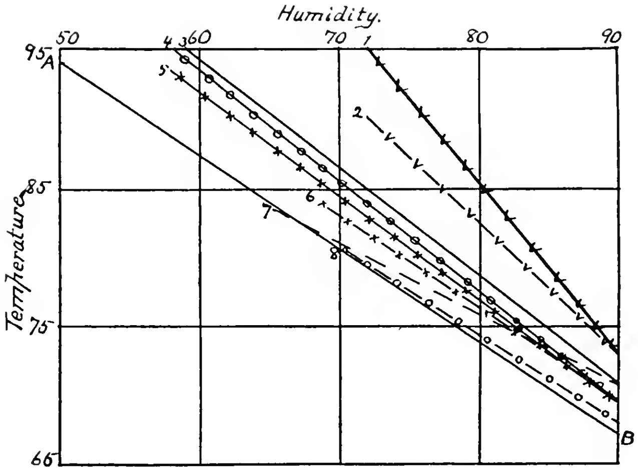

FIG. 12. — CHERRY — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, same, cloudy weather; 3, pure acid paste, clear weather; 4, commercial acid paste, clear weather; 5, commercial acid powder, clear weather; 6, same, cloudy weather; 7, pure acid paste, cloudy weather; 8, commercial acid paste, cloudy weather.

A combination of all the safety lines is given in Fig. 12. The convergence of the lines, in many cases almost to a common point, produces a rather confusing diagram, the significant features being the detached position of the neutral arsenate (1 and 2), the practical parallelism of the other materials in clear weather, and the fact that these are all located at higher H than the same materials in cloudy weather. The arbitrarily placed line AB may be regarded as the safety line for the cherry with any reliable lead arsenate, either in clear or cloudy weather.

A general study of the results obtained by spraying the cherry indicates that this tree is more sensitive to high temperatures where H is low than the apple, while at high humidity with low T it is, on the whole, more resistant. In both fruits the general agreement in each case of the various acid pastes and the noticeable way in which the neutral arsenate stands apart from the others are very marked.

PLUM — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

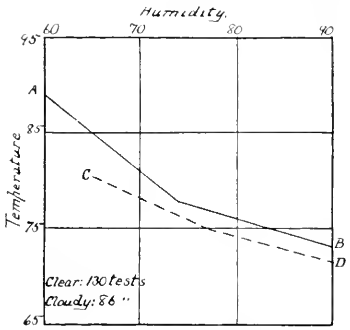

FIG. 13. — Pure acid lead arsenate paste.

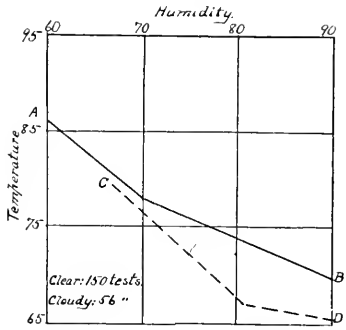

FIG. 14. — Commercial acid lead arsenate paste.

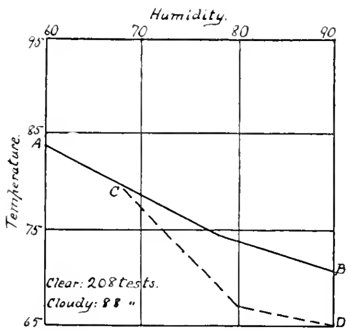

FIG. 15. — Commercial acid lead arsenate powder.

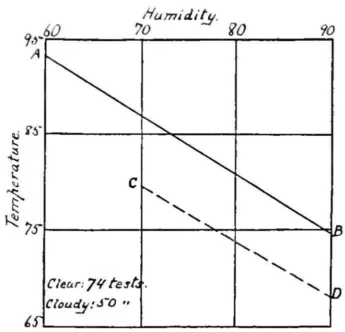

FIG. 16. — Pure neutral lead arsenate paste.

Plum. — The facts obtained here apply only to the Bradshaw plum. The results of the tests of pure acid lead arsenate paste in clear and cloudy weather are given in Fig. 13, and show at once that the resistance of this tree to arsenical sprays is much less than that of the cherry. An additional feature, here first met with in the work, is the fact that the safety lines are not straight but "elbowed." It would seem from the evidence available that in the case of the plum a combination of medium high T and H becomes dangerous more quickly as these increase than with the cherry or apple. This "elbow" is also shown in Fig. 14 giving the safety lines with the commercial paste. Here the lines run on lower T and H, and in cloudy weather humidities above 80, even with low T, are dangerous. A somewhat similar result following the use of the powder is given in Fig. 15 in the case of cloudy weather. The clear weather results differ only slightly from those with the paste.

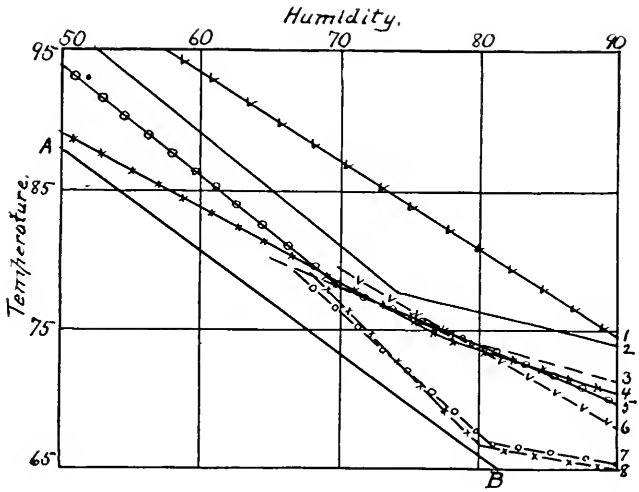

Fig. 17. — Plum — Safety Line for All Lead Arsenates. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, pure acid paste, clear weather; 3, same, cloudy weather; 4, commercial acid powder, clear weather; 5, commercial acid paste, clear weather; 6, neutral lead arsenate, cloudy weather; 7, commercial acid paste, cloudy weather; 8, commercial acid powder, cloudy weather.

The neutral arsenate, as in the case of the other trees, is much safer than the acid arsenates, though the cloudy weather line (Fig. 16) for the first time drops to run about along with those of the acid pastes in clear weather. No "elbow" appears for the neutral arsenate.

In Fig. 17 the various safety lines are brought together on one chart. The striking point shown here is that in the high humidities of cloudy weather the commercial paste and powder, closely following each other, drop far below the other lines. On the whole, the line AB should mark a safety line, however, at or below which spraying on the plum should be safe under any combinations of T and H with any reliable material.

General conclusions as to the plum, so far as the evidence goes, are: first, that this tree is far less resistant to arsenicals under certain conditions of T and H than the cherry; second, that in clear weather it is less sensitive to high humidities than to high temperatures when the other factor is low; third, that this last does not hold for the acid paste and powder in cloudy weather; and fourth, that again the neutral lead arsenate is the safest of the materials used.

PEACH — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

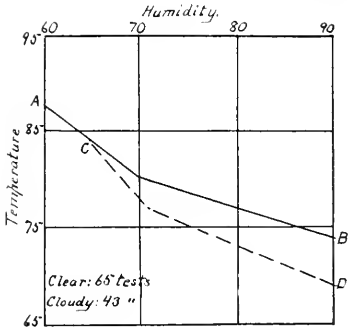

FIG. 18. — Pure acid lead arsenate paste.

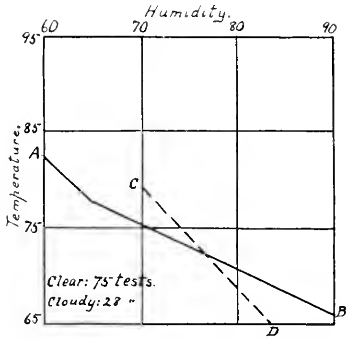

FIG. 19. — Commercial acid lead arsenate paste.

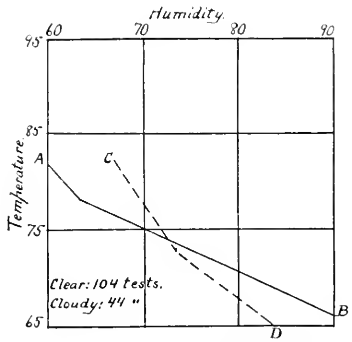

FIG. 20. — Commercial acid lead arsenate powder.

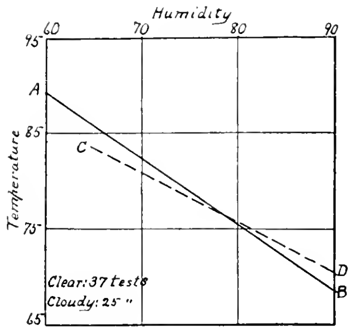

FIG. 21. — Pure neutral lead arsenate paste.

Peach. — The results of the experiments on the peach are, on the whole, very similar to those obtained from the plum. In general, the safety lines are very close, and the conclusion reached that the plum is somewhat more resistant than the peach is based mainly upon experiments with other arsenicals. There seems to be less difference at the T and H limits of the charts than was shown for the plum. In three sets of tests (Figs. 19, 20 and 21) the clear and cloudy weather lines cross, but the difference is not very great. The neutral arsenate fails to make quite as good a showing as with

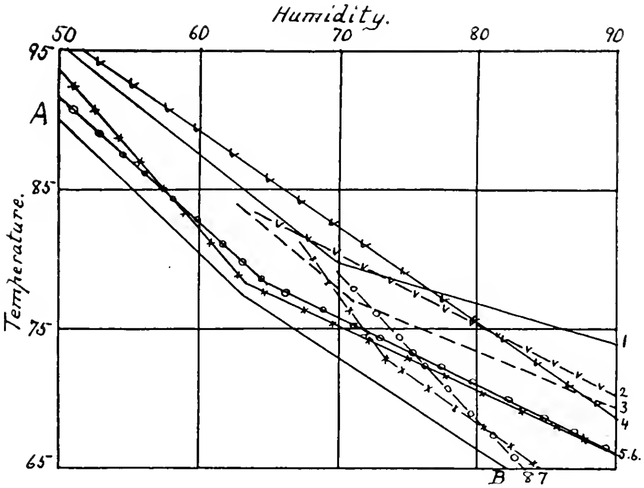

FIG. 22. — PEACH — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, pure acid paste, clear weather; 2, neutral lead arsenate, cloudy weather; 3, pure acid paste, cloudy weather; 4, neutral lead arsenate, clear weather; 5, commercial acid paste, clear weather; 6, commercial acid powder, clear weather; 7, same, cloudy weather; 8, commercial acid paste, cloudy weather.

the other trees, but is, nevertheless, still the best for the greater part of its range. "Elbowing" of the safety lines is again in evidence except with the neutral arsenate and the commercial acid paste in cloudy weather. Perhaps in this last case a larger number of tests (it was not possible to make very many) might change the path of this line somewhat. Comparison of Figs. 17 and 22 shows that the peach appears to resist injury slightly better than the plum at high T and low H, while at high H and low T the two are about alike.

It should be noted that in Figs. 7, 12, 17, 22 and 23 the chart is extended 10° lower in humidity than the others to show the paths of the safety lines in this added area. To make comparisons with the others, reading of these charts should begin, not at H50, but at H60.

In order to obtain some idea of the relative resistance of the apple, cherry, plum and peach to arsenical sprays, Fig. 23 has been prepared, the material used in each case being the pure acid lead arsenate paste applied in clear weather. The elm and pear are not included, for as already stated, no injury points were obtained. If their safety lines come into the chart at all, they would only cross the upper right square, and probably would not occur unless close to H90 T95.

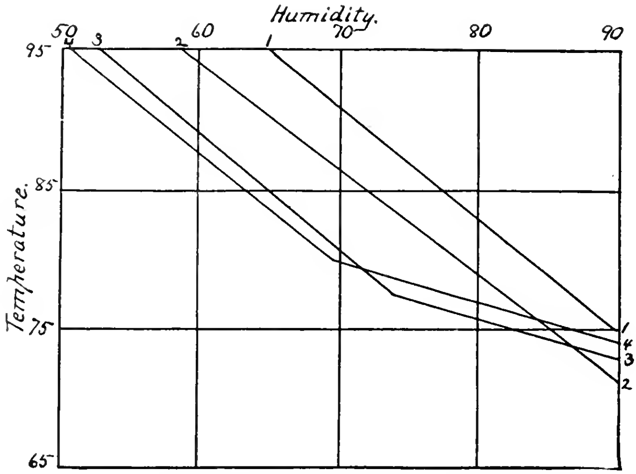

Fig. 23. — Safety lines for spraying with pure acid lead arsenate in clear weather: 1, apple; 2, cherry; 3, plum; 4, peach.

General Conclusions.

An analysis of the effects of temperature, humidity and light given in detail above brings out several features of interest: —

1. The neutral lead arsenate used, even though it was not entirely pure, proved the safest of the materials in clear weather, and in most cases was better even in cloudy weather than the others.

2. The clear weather spraying is safer than the cloudy weather, though the difference generally is not great.

3. The indication is that spraying at high temperatures can be done safely if the humidity is low.

4. Spraying can be carried out safely at high humidities if the temperature is low, though the humidity cannot run up as high as the temperature can at the other end of the line. Thus spraying the apple seems to be safe at T90 when H is not over 69, but is not safe at H90 when T is above 67.

5. Between the ends of the safety lines of the charts, *i.e.*, with medium T and H, both seem to have an influence.

6. With the apple and cherry the safety lines are straight, while in the plum and peach most of them "elbow," indicating that the T and H fac-

tors are more powerful at medium values, or when both act in medium amounts, than where either one is low, even though the other be high.

7. In the case of the plum the elbow is between H70 and H80, while with the peach it tends to move back toward lower humidities; or, in other words, the plum seems to be more sensitive to higher humidities than the peach, and also at the extremes of the safety lines to both T and H.

8. From the tests with lead arsenate, the peach and the Bradshaw plum at least appear to have about the same degree of resistance to arsenical sprays.

From the evidence at hand it would seem that, with reliable arsenicals properly made, mixed and applied, injury results from the combination of temperature, humidity and light factors. A high value for either of the first two factors, provided the other is low, indicates probable safety, particularly on sunny days.

Why divergence from these requirements should cause burning has not been brought out by this work. It may be that, as the injury generally appeared only after a week or more, there was some chemical factor at work. With some carbonic acid in the air and heavy dews at night it might be possible that a slow decomposition of the arsenate on the leaves took place, gradually liberating the arsenic and resulting after a time in injury. If this were correct, however, it would seem as though the decomposition of the arsenate would take place when sprays were applied at T and H combinations below the safety line, and cause burning in those cases also. Possibly the leaf differs in its physiological activities under different conditions of light, temperature and humidity, and under some of these is susceptible to influences not effective under others.

The most that can now be said is that this work has failed to answer the question why arsenical sprays sometimes injure foliage, though it has shown that of the four explanations given at the beginning, the first, second and fourth can be rejected, and that the problem is apparently one for the plant physiologist, the chemist, or both working together, to solve. The demonstration of safety limits for spraying can hold good, however, even though the question of why they are located where they are remains unanswered.

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LEAF CHARACTERS OF APPLE VARIETIES

By J. K. SHAW

Not the least of the problems with which orchardists must contend is that of nursery stock sometimes failing to come true to the name under which it is sold. In the majority of cases, probably, this difficulty has been due to error in the nursery rather than deliberate misstatement on the part of the seller of the planting stock. This bulletin reports the results of seven years' work in attempting to establish a basis on which trees can be identified previous to fruiting. In this work the leaves are used as the taxonomic character. In future work it is expected to continue the study with reference to tree form, appearance of bark, and growth habits.

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CONTENTS.

BULLETIN No. 208.

DEPARTMENT OF POMOLOGY.

LEAF CHARACTERS OF APPLE VARIETIES.

BY J. K. SHAW.

It is as easy to recognize varieties of apples by their tree characters as by their fruit, yet all fruit growers know varieties by the fruits much better than by the trees. This is doubtless because they come into closer contact with the fruit. They pick, handle and eat the fruit, while contact with the trees is less frequent and intimate. Nurserymen are more familiar with the tree, and many old nurserymen know varieties by the nursery trees better than by the fruit. As trees have been studied less than the fruit, there has been less written about them. Variety descriptions deal mostly with the fruit. John J. Thomas, himself a nurseryman of many years' experience, discussed tree characters at some length in his "American Fruit Culturist," but his work along this line has been given little attention by other writers.

In recognizing varieties, especially with nursery trees, one depends largely on the leaves, and it is our purpose here to discuss the leaf characters by which we may know one variety from another. Characters of the bark, buds, branches and general habit of the trees are very useful, perhaps equal to the leaves, but they will receive only incidental mention here, being reserved for further study and later discussion.

In order to talk understandingly about the leaves we must have names for their different parts. These are shown in Fig. 1, which is largely self-explanatory. The leaf is first divided into three parts: stipules, petiole and blade. About one-third of the blade next to the petiole is called the base, and similarly about one-third of the other end, the apex; beyond this is the narrow point called the tip. The midrib is a continuation of the petiole to the tip of the leaf. The saw-like notches along the edge of the leaf are called serratures or serrations, and are of the greatest importance, being rarely exactly alike in two varieties.

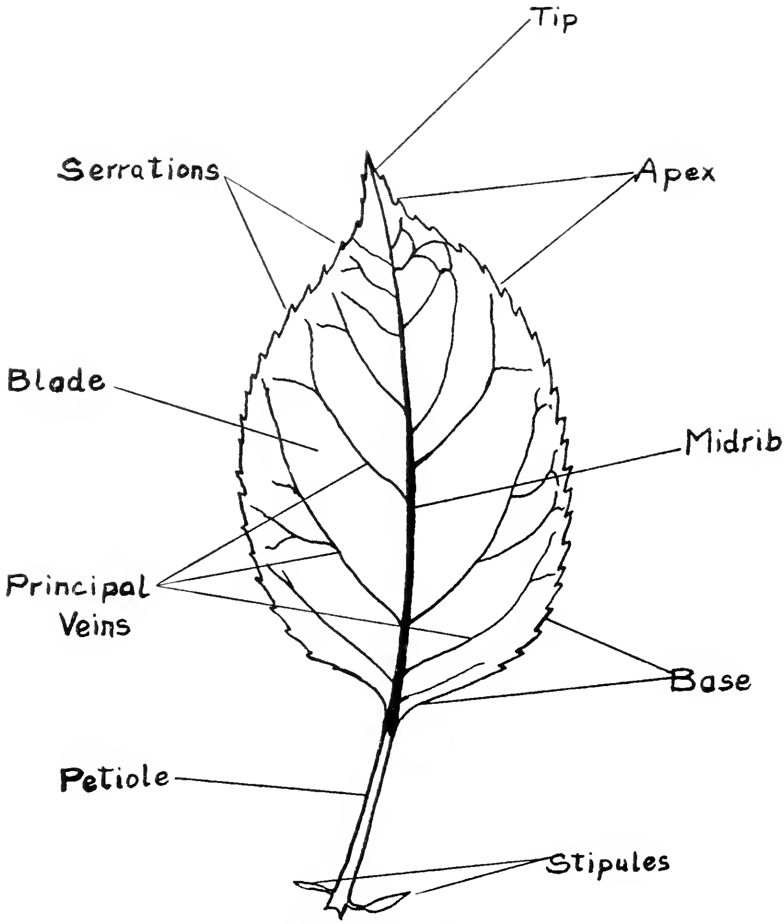

Fig. 1.—Diagram of apple leaf, showing parts.

Which are the Characteristic Leaves.

The leaves on any tree can be divided into two groups: (1) the single leaves coming out on the current season's growth; and (2) the rosette leaves coming out of buds formed the previous season, *i.e.*, on wood of last year's growth. *The latter should be discarded, and study and attention centered on the single leaves on the current season's growth.* Leaves that have been injured by lice or other insects or by scab spots are of little value for identification purposes. Leaves on shoots in the interior of the tree should be avoided. *Study the well-developed uninjured leaves usually found along the middle of the season's growth.* Leaves on trees that are poorly nourished are often undersized and yellowish. Such leaves are not typical and should be observed with caution.

Typical leaves are found on healthy uninjured trees that are making vigorous but not excessive growth. Inasmuch as one requires the leaves of the current season's growth, little progress can be made in leaf study until considerable growth has been made. The most favorable period is from July 1 until October 1. To one familiar with leaf characters this period may be extended somewhat.

What to Look at.

To the beginner in leaf study the leaves of all varieties will look alike. Close and repeated observation will reveal differences that are peculiar to the different varieties. It is our purpose here to discuss the various parts of the leaf and how they differ in different varieties. (See Fig. 1.)

The Petiole.

The petiole or stem of the leaf is sometimes characteristic of the variety, though it is of minor importance. Wealthy has a rather long, slender petiole, while that of McIntosh is usually short and stout. The angle which the petiole forms with the shoot on which it grows is often helpful in recognizing varieties. In the Spy the angle is sharp, that is, the leaf is said to be upright; while in the Rhode Island Greening it is broad or spreading. This character is correlated in all varieties with the form of the top. The Spy has an upright head, while the Rhode Island Greening is distinctly spreading. This character of the head or form of the tree is quite well known to fruit growers, but few are aware that in an unknown variety the form of the top can be foretold with considerable accuracy from the leaf angles on a one-year whip.

The Stipules.

The stipules located at the base of the petiole have a certain value in variety identification. They vary in size and shape and in the degree to which they persist. In all or nearly all varieties they are likely to fall by late summer or early fall, especially if there is a good deal of dry weather.

The Blade.

Size. — Coming now to the blade we find the most dependable characters for variety identification. Let us first consider the size of the leaf blade. This, of course, varies considerably with the vigor of the tree. Trees in a sod orchard making little growth will have much smaller leaves than will the same variety growing under cultivation and making a vigorous growth. Leaves well exposed to the sun will be smaller than those growing in shade, as in the interior of the tree. With these reservations in mind, we may say the Jonathan (Fig. 17) has a small leaf, while Rhode Island Greening (Fig. 4) and King (Fig. 24) have large leaves; Wealthy (Fig. 7) is a little smaller than Baldwin (Fig. 8); and McIntosh (Fig. 3) a little larger than Wolf River (Fig. 12).

Shape. — Next we may consider the shape or outline of the leaf. This may vary in different varieties in two ways: in relative length and width, and in the width of the base and apex. Winter Banana (Fig. 10) is relatively long and narrow, while Baldwin (Fig. 8) is relatively short and broad. An example of the second is found in comparing Wolf River (Fig. 12), which is narrow at the base and apex, with McIntosh (Fig. 3), which is broad at the base and apex. This difference is especially valuable in distinguishing between Oldenburg (Fig. 6) and Wealthy (Fig. 7), the former being much broader at the base and apex than the latter.

Tip. — The narrow tip called the point is of some value, being larger and more slender in some varieties, usually those with a narrow apex, than in others.

Folding. — Next we may consider the various types of bending and folding which may appear in the leaf blade. The blade may be flat as in Gravenstein (Fig. 2) and Wealthy (Fig. 7), or it may be folded to a greater or less degree as in Baldwin (Fig. 8) or Wagener (Fig. 15). The last two varieties exhibit different types of folding, it being broad, saucer-shaped or boat-shaped in the Baldwin, and much narrower and more pronounced in the Wagener. Leaves of a given variety may show this character in varying degree according to condition; the folding is more pronounced in periods of dry, sunny weather than it is during cloudy or rainy periods. Jonathan, as shown in Fig. 17, shows only moderate folding, but at times it may show very pronounced folding, — sometimes more than any variety illustrated here. Nevertheless, it is a most valuable character in the identification of varieties. The peculiar saucer-shaped folding of the Baldwin is always seen in greater or less degree in a considerable proportion of the single leaves on the tree, and with one or two other peculiarities will serve to distinguish this variety from all others.

Next we may consider the bending or waving of the leaf edge. Flat leaves do not often show this, although it appears quite noticeably in Oldenburg and Wealthy, neither of which are folded very much. Some folded leaves are very distinctly waved, as Wagener (Fig. 15), Hubbardston (Fig. 22) and Tolman (Fig. 27), while others show it but little, as Baldwin (Fig. 8), Roxbury Russet (Fig. 9) and Winter Banana (Fig. 10).

A third type of bending or folding of the leaf blade is seen in the bending backward or reflexion of the midrib. Pronounced reflexion of the midrib is not common in flat leaves, but is the usual thing in strongly folded leaves if the folding is of the narrow type. Thus Baldwin (Fig. 8) and Roxbury Russet (Fig. 9) are not reflexed, while Grimes (Fig. 20) and Wagener (Fig. 15) are strongly reflexed.

Serratures. — Probably the most dependable leaf character for identifying varieties is the nature of the serratures along the edge of the leaf. They are sharp in Rhode Island Greening (Fig. 4) and dull in Wolf River (Fig. 12) and Wealthy (Fig. 7). Other varieties are intermediate between these extremes, but every variety is peculiar to itself and different from other varieties. In Rhode Island Greening (Fig. 4) the serratures are distinct or well separated, while in Gravenstein (Fig. 2) and Baldwin (Fig. 8) they are set close together or indistinct. They vary in depth also, and in some varieties they are straight, as in Rhode Island Greening, while in Baldwin they are more or less curved or sickle-shaped. The last peculiarity, together with the saucer-shaped folding referred to above, serves to distinguish Baldwin from all other varieties known to the writer. If one leaf is laid upon another so that the serratures of both can be seen and carefully compared, the observer with some experience can very often tell quite positively whether the leaves represent one variety or two varieties.

Texture. — The veins of the leaves divide and subdivide until they form a network all over the surface of the leaves. This network is coarser in some varieties than in others. There are other peculiarities in the veining hard to describe in words, but evident and distinct in the leaves. These peculiarities taken together are spoken of as texture. The texture of Rhode Island Greening (Fig. 4) is very different from that of McIntosh (Fig. 3). Comparisons of other varieties will show differences in texture difficult to picture in words, but of much value in recognizing varieties.

Pubescence. — All varieties have more or less growth of short hairs over the under surface. Those having an abundant growth of these hairs are said to be pubescent or "woolly." This is not shown very clearly in the figures, but may be seen by observing the leaves themselves. Ben Davis and Jonathan are examples of "woolly" leaves, while Rhode Island Greening shows very little of this growth. This hairy growth is sparse on Baldwin and more abundant on Hubbardston and McIntosh.

In some varieties the surface of the leaves is smooth and shining, while at the other extreme are some varieties that appear rough or dull. This is correlated with hairiness or woolliness of the surface, the smooth and shining leaves having few hairs, while the rough or dull ones have many.

Thickness. — Varieties differ also in the thickness of the leaves. McIntosh and Wealthy have relatively thick, stiff, rigid leaves, while those of Rhode Island Greening, Grimes and Fall Pippin seem thinner and less rigid to the touch.

Color. — All apple leaves are, of course, a deep rich green in color. The shade of green depends a good deal on the vigor of the trees, being deeper in vigorous trees, and a paler, more yellowish green in trees making little growth. There are also varietal differences in color. In Rhode Island Greening and in all green-fruited varieties the color is a rich, clear green; in varieties that have much red in the color of the fruit the leaves are a deeper green with a slight bluish or purplish cast. This is seen in McIntosh. Yellow Transparent has leaves of a yellowish green cast. These differences in leaf color are not pronounced, and as stated above vary with the condition of the trees, but they are very helpful in recognizing varieties.

In distinguishing two or more varieties which are mixed in the nursery row, one may often find some peculiarity of a certain variety present at the particular time at which the observation is made, which serves to distinguish that variety with ease and certainty. For example, in separating out Wolf River trees in a mixture with McIntosh it was observed that, at the time the Wolf River leaves were beginning to turn yellow and perhaps one-third of them had fallen, the McIntosh leaves showed very little yellowing and few if any had fallen. By observing this difference it was possible to separate the two varieties with the greatest ease and certainty. Yet at an earlier period this difference would not have been present. In the late summer the Yellow Transparent leaves near the tips of the shoots frequently show a spiral folding that displays plainly the under side of a portion of the leaf. When this peculiarity is shown it is possible to recognize a Yellow Transparent tree as far as it can be seen. It is the usual thing in separating mixed varieties to fix on some one character by which the varieties can, at that particular time and place, be positively distinguished one from the other.

Classification of Varieties.

Twenty-six varieties of more or less importance in Massachusetts have been selected for illustration and description in this bulletin. The following key is arranged to show, as well as possible, the differences by which these varieties may be distinguished. It is not thought that this key will enable one to trace out unknown varieties, but it may help in orchard and nursery studies of the leaves of these varieties. A few tree characters are mentioned with the hope that they may be helpful.

A. Varieties important in Massachusetts.

- 1. Leaves large, broad, flat or only slightly folded.
  - (*a*) Sides not waved or only very slightly so.
    - *Gravenstein.* — Leaves broad oblong; serrations dull, shallow, regular; branches broadly ascending; bark dark yellowish. (Fig. 2.)
    - *McIntosh.* — Leaves broad oval, base often cordate, edges often slightly folded; serrations dull and shallow, especially at base. (Fig. 3.)
    - *Rhode Island Greening.* — Serrations very sharp and distinct. (Fig. 4.)
  - (*b*) Sides more or less waved.
    - *Red Astrachan.* — Leaf waves "crinkly" or wrinkled, not reaching to midrib. (Fig. 5.)
    - *Oldenburg.* — Leaves broad at base and apex; shoots few and stout. (Fig. 6.)
    - *Wealthy.* — Leaf relatively narrow at base and apex; midrib often tending to spiral form or reflexed at tip. (Fig. 7.)

A. Varieties important in Massachusetts — *Concluded.*

2. Leaves more or less distinctly folded.

(*a*) Folding "saucer-shaped" or broad U-shaped.

Baldwin. — Leaves broad, distinctly saucer-shaped; serrations sharp, close set and usually curved. (Fig. 8.)

Roxbury Russet. — Serrations distinct and only moderately sharp; bark olive green. (Fig. 9.)

Winter Banana. — Leaves rather long and narrow; serrations regular and dull; branches long and slender, yellowish. (Fig. 10.)

(*b*) Folding narrow U-shaped.

(1) Serrations dull.

Williams. — Waves large, coarse; serrations uniform; growth open; bark yellowish. (Fig. 11.)

Wolf River. — Leaf only moderately folded, oval, narrowing at base and apex; serrations coarse, dull. (Fig. 12.)

Yellow Transparent. — Leaves broad at base and rather narrow at apex; serrations uniform, shallow. (Fig. 13.)

(2) Serrations at least moderately sharp.

Delicious. — Leaves narrow at apex; serrations coarse and distinct. (Fig. 14.)

Wagener. — Leaves strongly folded; midrib much reflexed; shoots stout with large buds. (Fig. 15.)

Northern Spy. — Leaves sometimes little folded, upright; serrations sharp; shoots upright; bark russet with many small dots. (Fig. 16.)

B. Varieties of minor importance in Massachusetts.

1. Leaves usually only slightly folded, serrations rarely sharp.

(*a*) Leaves small, coarsely and irregularly serrate.

Jonathan. — Leaves very small, narrow at base and apex, sometimes folded; tree slender, of open habit. (Fig. 17.)

King David. — Leaves narrow at base but wider at apex; tree strong and vigorous. (Fig. 18.)

Stayman. — Leaves nearly round, spur leaves and some shoot leaves sharply serrate; tree vigorous. (Fig. 19.)

(*b*) Leaves medium-sized, serrations rather fine and regular.

Opalescent. — Leaves sometimes slightly waved, rather narrow at apex; bark of shoots very smooth. (Fig. 20.)

2. Leaves distinctly folded and waved.

(*a*) Serrations distinct and rather sharp.

Fall Pippin. — Leaves long, sharply and distinctly serrate; tree vigorous. (Fig. 21.)

Hubbardston. — Serrations moderately sharp; midrib reflexed; bark olive green. (Fig. 22.)

Grimes. — Serrations sharp and distinct; midrib reflexed. (Fig. 23.)

Tompkins King. — Tree vigorous with long stout shoots, does not branch freely. (Fig. 24.)

(*b*) Serrations not sharp but rather dull.

Ben Davis. — Leaves rather narrow, grayish and woolly. (Fig. 25.)

Esopus Spitzenburg. — Serrations dull and regular; midrib usually only slightly reflexed. (Fig. 26.)

Tolman. — Leaves narrow at base and strongly waved; serrations only moderately dull. (Fig. 27.)

The varieties in the foregoing classification are illustrated in the following pages. These cuts are approximately two-thirds life size. While, as stated in the text, the size of the leaves may vary with cultural conditions, yet these may be taken as fairly representative, and are comparable one with another.

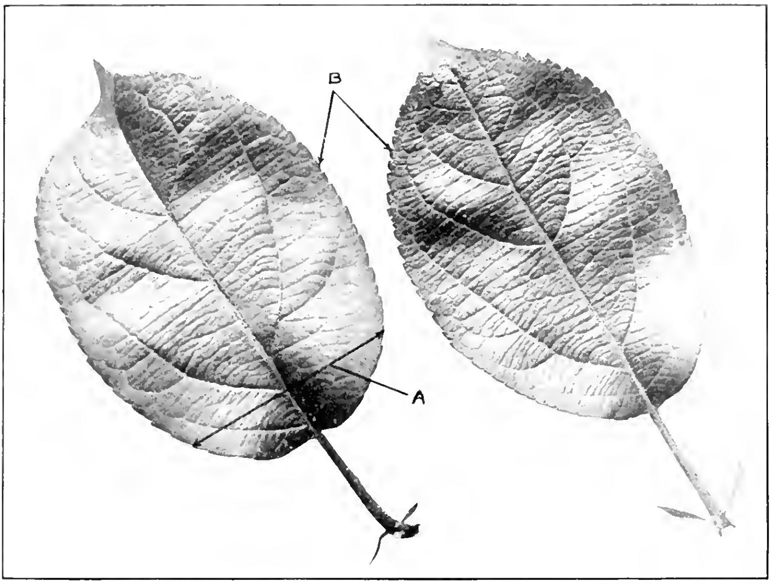

Photo by R. L. Coffin.

FIG. 2. — GRAVENSTEIN. Blade large, flat, rounded or rather narrow at base (A); serrations moderately sharp and shallow (B), fairly regular.

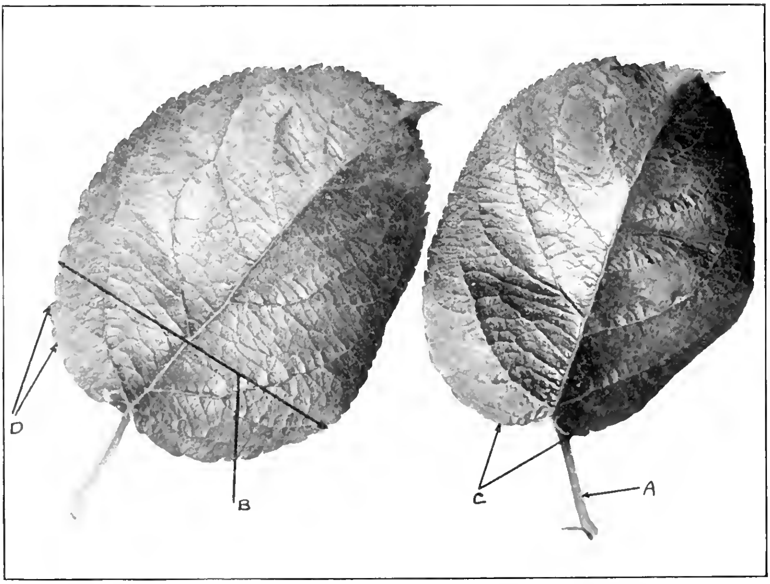

FIG. 3. — MCINTOSH. Petiole short (A); blade large, flat or slightly folded near edge, broad (B) and heart shaped (C) at base, deep bluish green; serrations rather dull and shallow, especially at base (D).

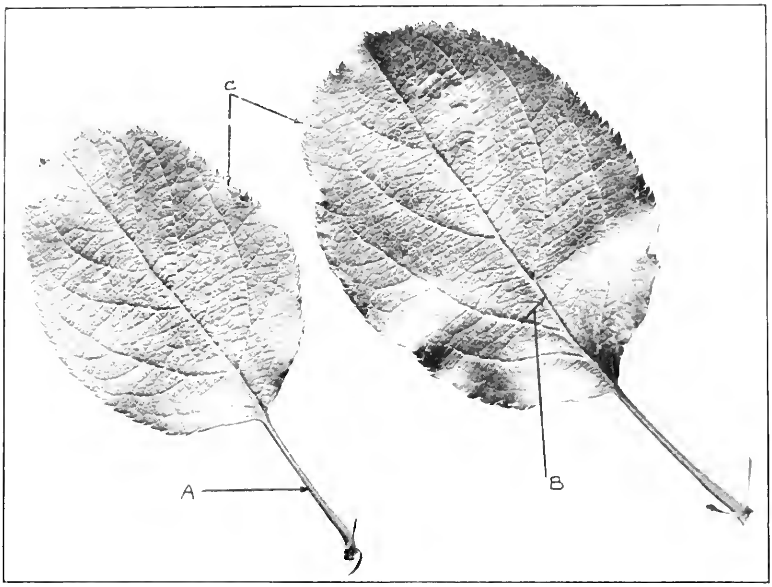

Photo by R. L. Coffin.

FIG. 4. — RHODE ISLAND GREENING. Petiole long (A); blade large, flat, deep clear green; vein angle sharp (B); serrations very sharp, deep and distinct (C).

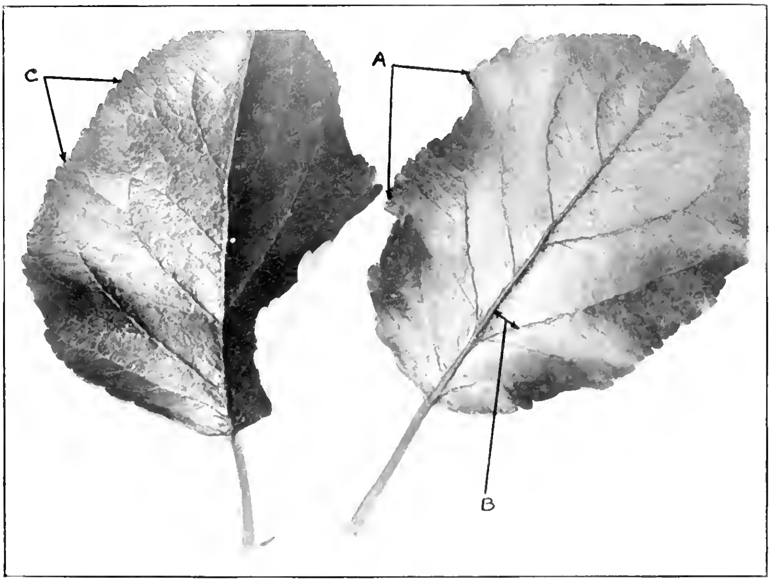

FIG. 5. — RED ASTRACHAN. Blade large, broad, flat, with waved and wrinkled edges (A); vein angle sharp (B); serrations dull and irregular (C).

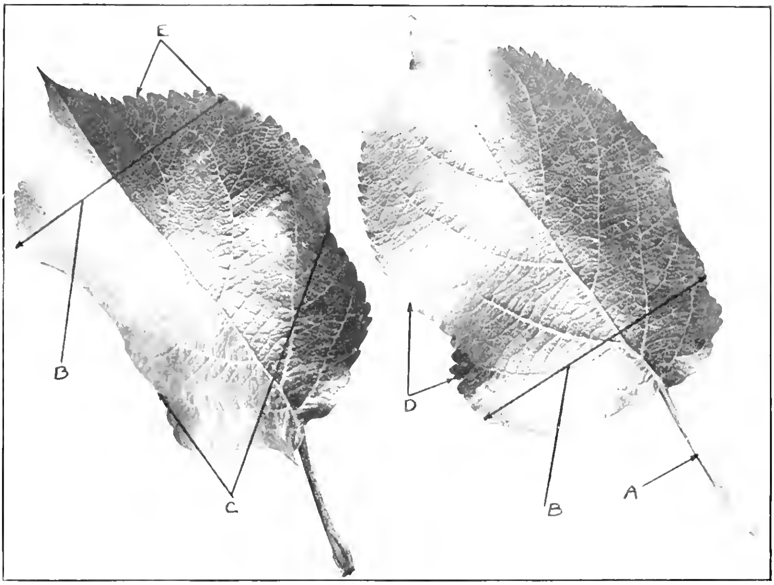

Photo by R. L. Coffin.

FIG. 6. — OLDENBURG. Petiole long (A); blade above medium to large, broad at base and apex (B), somewhat folded (C), and waved (D); serrations moderately sharp and irregular (E).

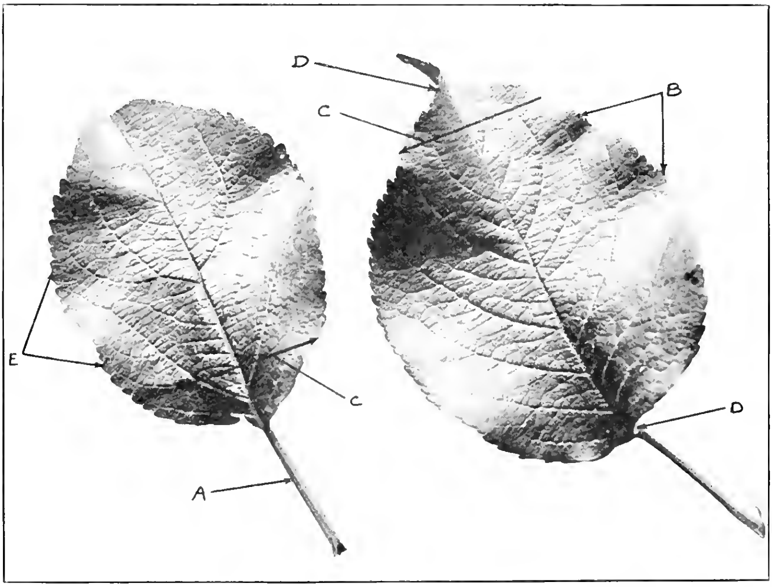

Photo by R. L. Coffin.

FIG. 7. — WEALTHY. Petiole long (A); blade moderately large, flat, with waved edges (B), narrow at base and apex (C); midrib reflexed or spiral (D); serrations rather dull (E).

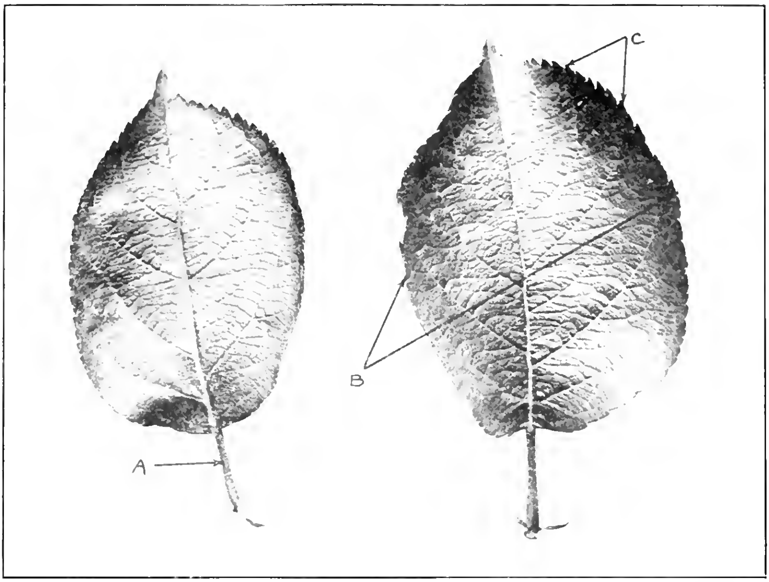

Photo by R. L. Coffin.

Fig. 8. — Baldwin. Petiole short (A); blade large, broad, with "saucer shaped" folding (B); serrations sharp, close set, usually curved (C).

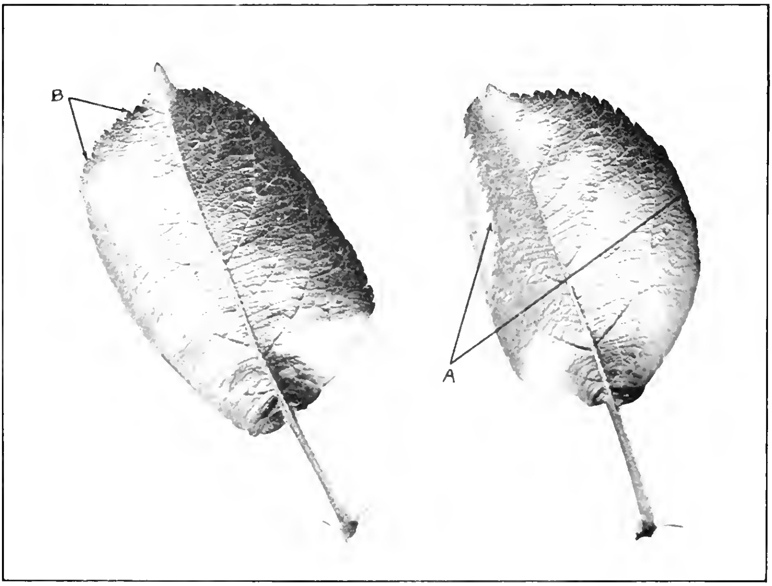

Photo by R. L. Coffin.

Fig. 9. — Roxbury Russet. Blade large, broad, with "saucer shaped" folding (A); serrations not sharp nor curved (B).

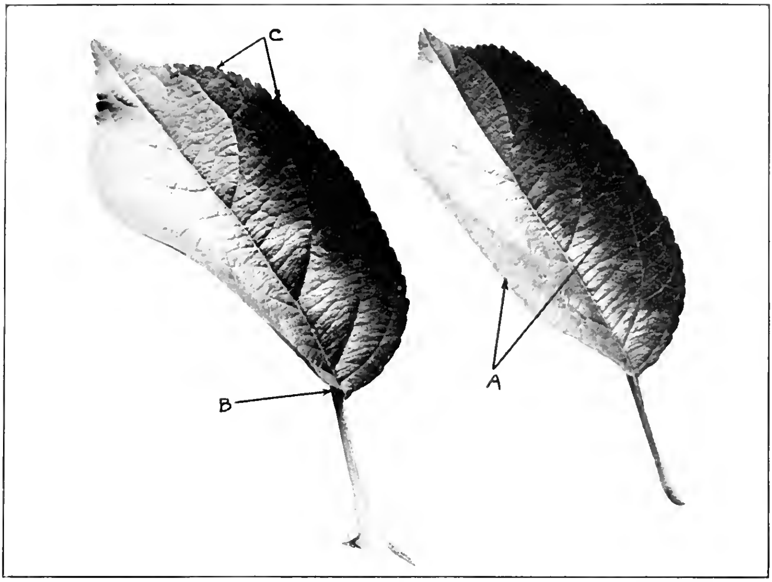

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FIG. 10. — WINTER BANANA. Blade medium size, rather long and narrow, folded (A); midrib bent at base (B); serrations rather dull and shallow (C).

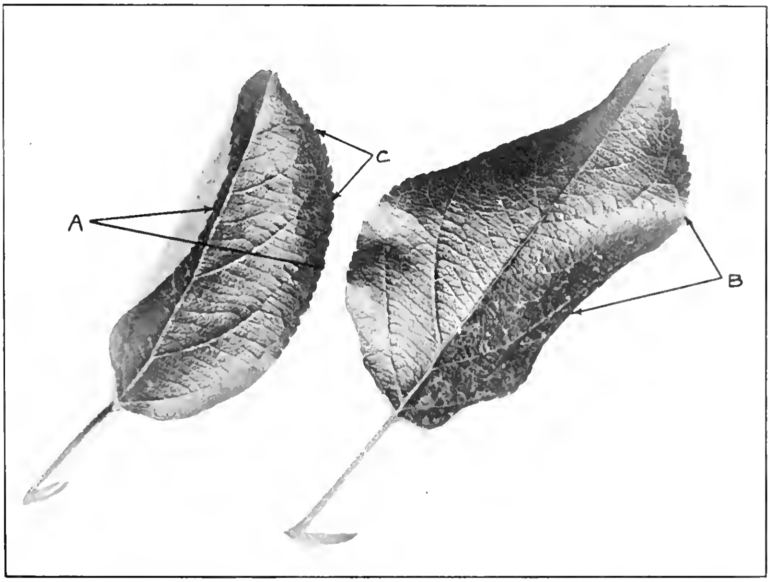

FIG. 11. — WILLIAMS. Blade medium size, folded (A) and often coarsely waved (B); serrations rather dull and quite regular (C).

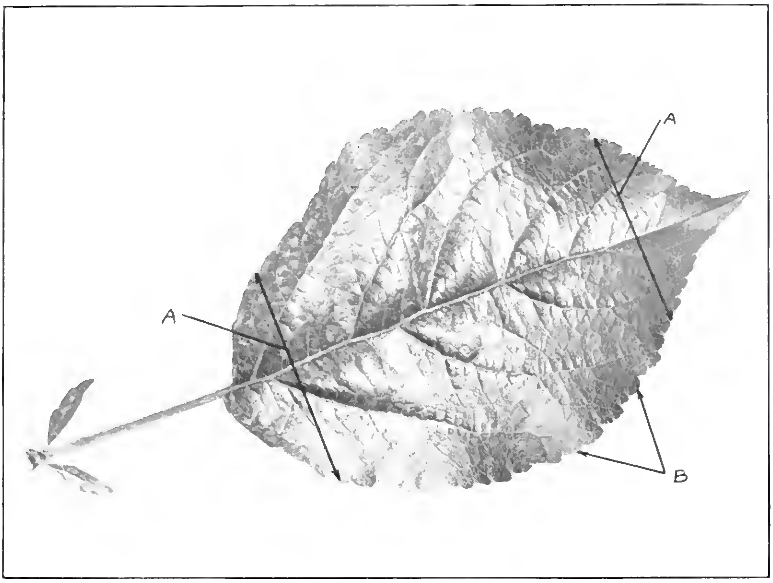

Fig. 12. — Wolf River. Petiole long; blade often only slightly folded, narrow at base and apex (A); serrations coarse and dull, often double (B).

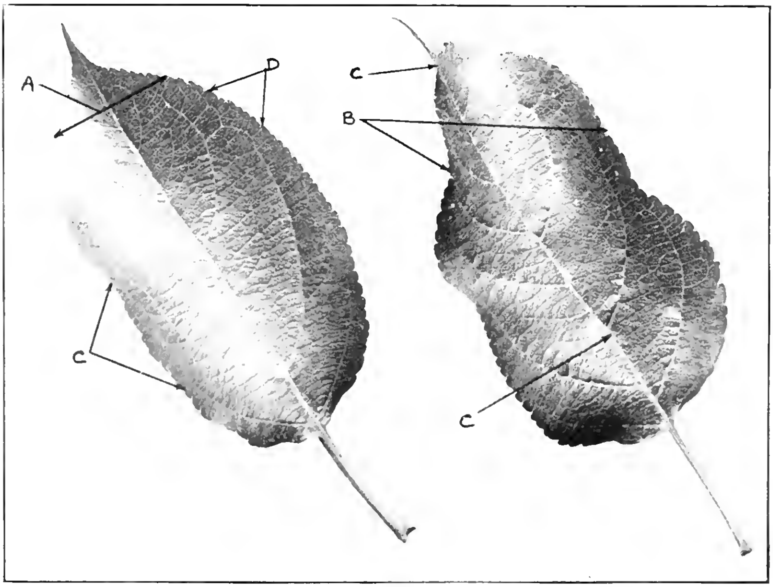

Photo by R. L. Coffin.

Fig. 13. — Yellow Transparent. Blade medium size, rather broad at base and narrow at apex (A), more or less folded (B), more or less waved, and often spiral (C); serrations rather dull, shallow and quite regular (D).

FIG. 14.—DELICIOUS. Blade medium size, apex narrowing to point (A), partly folded (B); serrations moderately sharp, coarse and rather irregular (C).

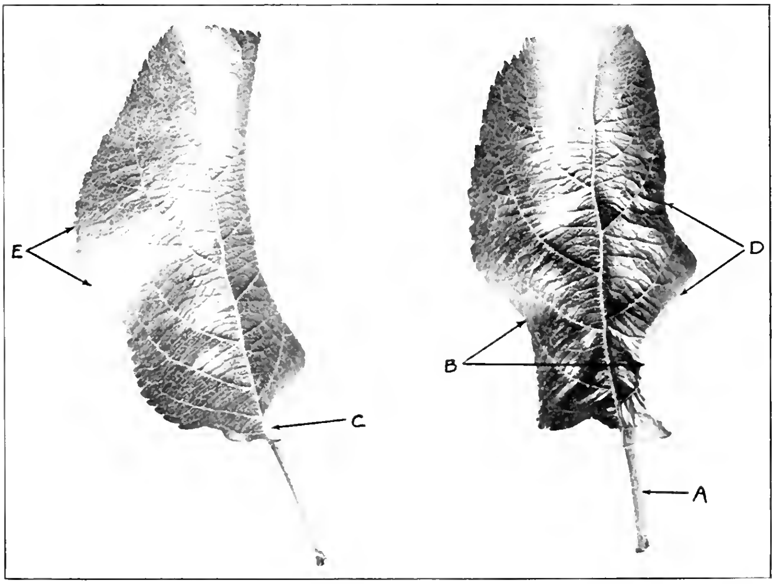

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FIG. 15.—WAGENER. Petiole short and stout (A); blade large, long and rather narrow, strongly folded (B), reflexed (C), and waved (D); serrations rather sharp, coarse and distinct (E).

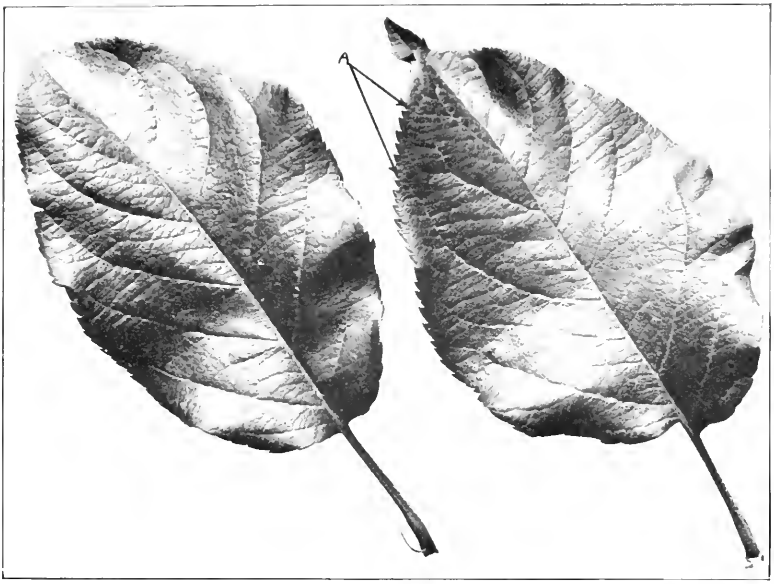

Photo by R. L. Coffin.

FIG. 16. — NORTHERN SPY. Blade large, somewhat folded and waved, upright, often somewhat reflexed; serrations sharp, often curved (A).

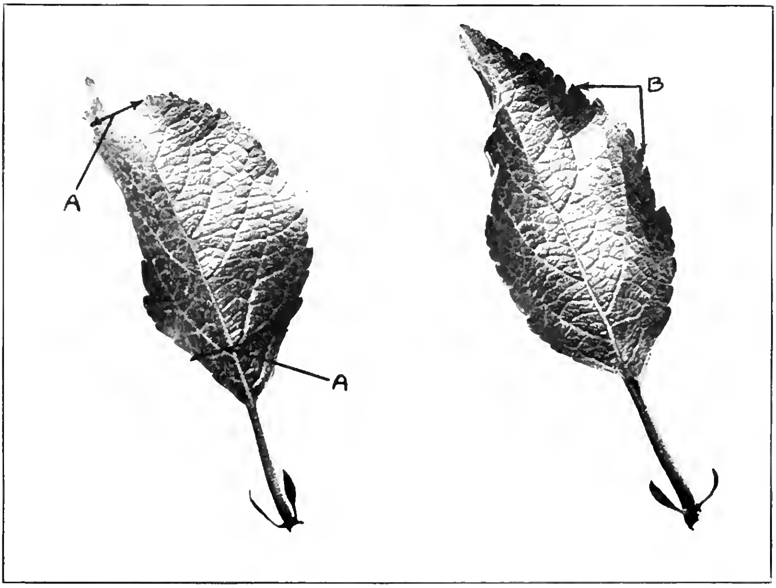

Photo by R. L. Coffin.

FIG. 17. — JONATHAN. Blade very small, more or less folded, sometimes reflexed, narrow at base and apex (A); serrations moderately sharp, coarse and irregular (B).

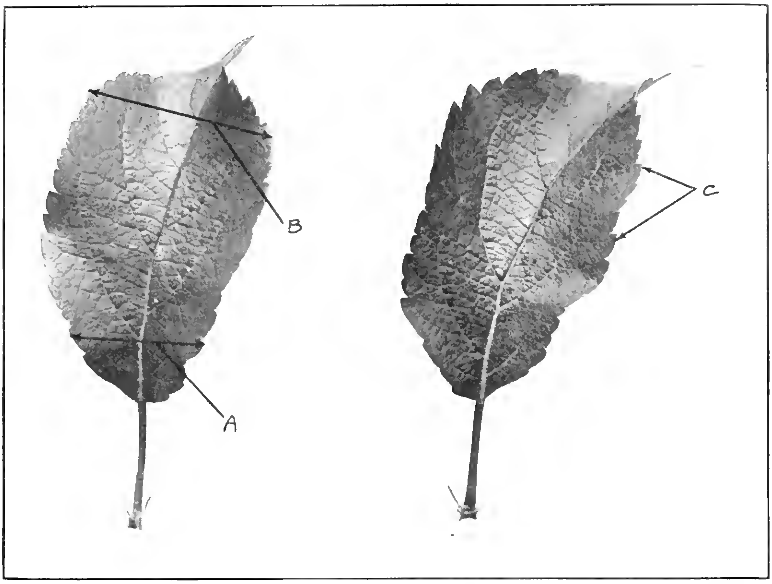

Photo by R. L. Coffin.

Fig. 18. — King David. Blade small, narrow at base (A), but broader at apex (B), more or less folded and reflexed; serrations moderately sharp, coarse and irregular (C).

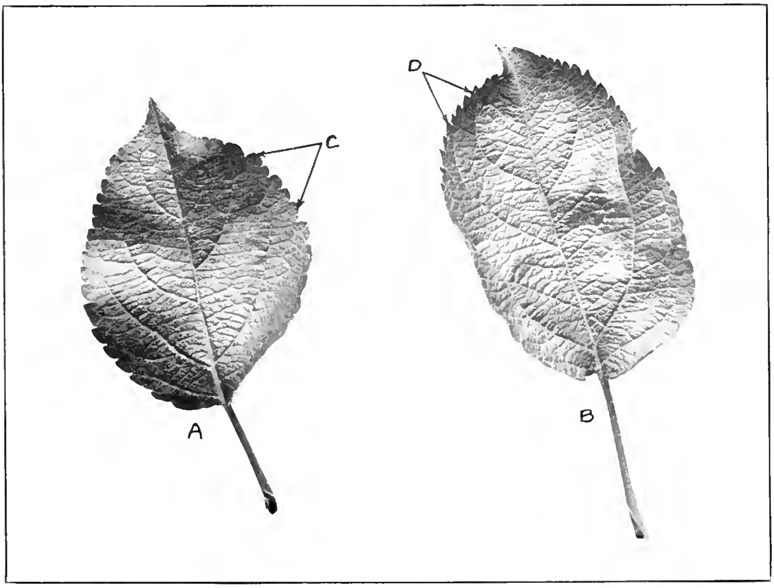

Photo by R. L. Coffin.

Fig. 19. — Stayman. Blade medium or below in size, usually nearly round (A), sometimes oblong (B); serrations usually dull and coarse (C), sometimes sharp (D). An exceptional variety, often having leaves of two distinct types.

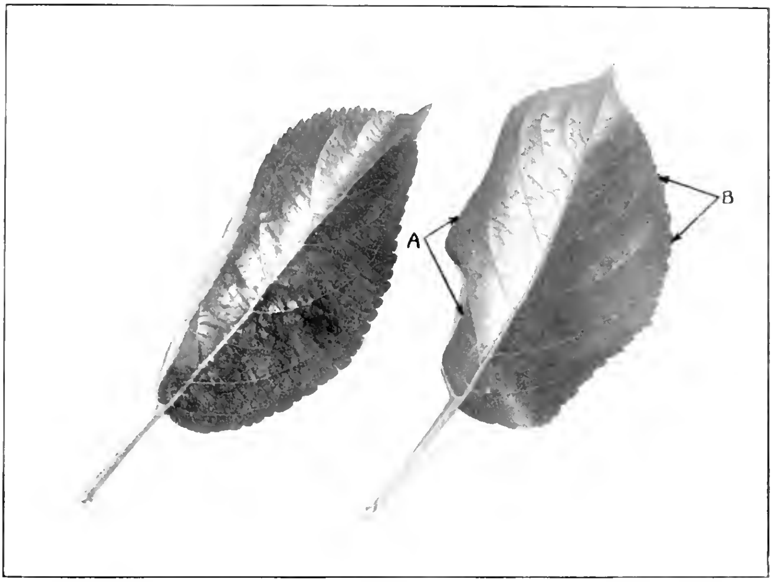

FIG. 20. — OPALESCENT. Blade medium size, somewhat folded, sometimes slightly waved (A); serrations rather dull, fine and regular (B).

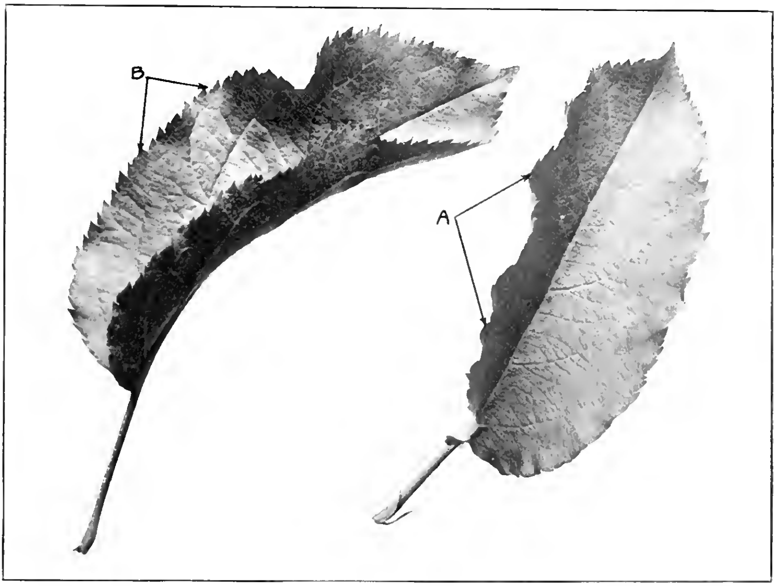

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FIG. 21. — FALL PIPPIN. Blade large, long and rather narrow, folded, reflexed and waved or wrinkled (A); serrations sharp, coarse and distinct (B).

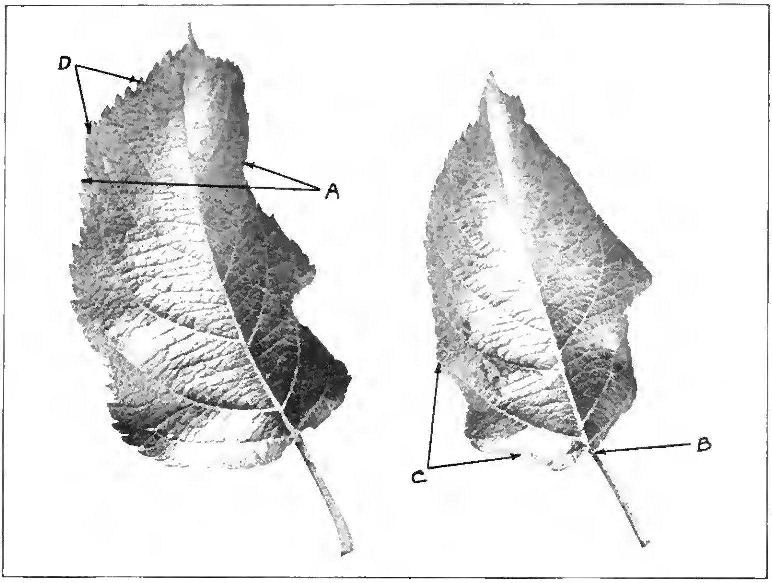

Photo by R. L. Coffin.

FIG. 22. — HUBBARDSTON. Blade medium size, folded (A), reflexed (B), and waved (C); serrations rather sharp and distinct, rather irregular (D).

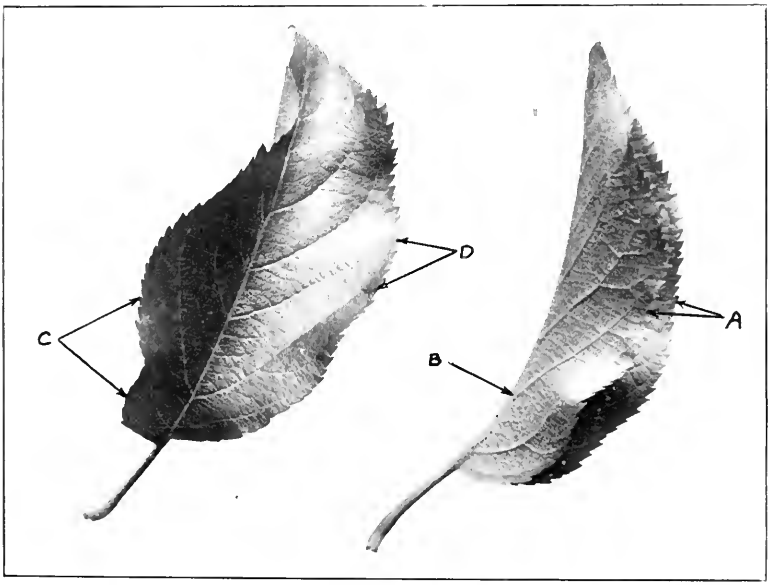

Photo by R. L. Coffin.

FIG. 23. — GRIMES. Blade medium size, folded (A), reflexed (B), and waved (C); serrations sharp, regular and distinct (D).

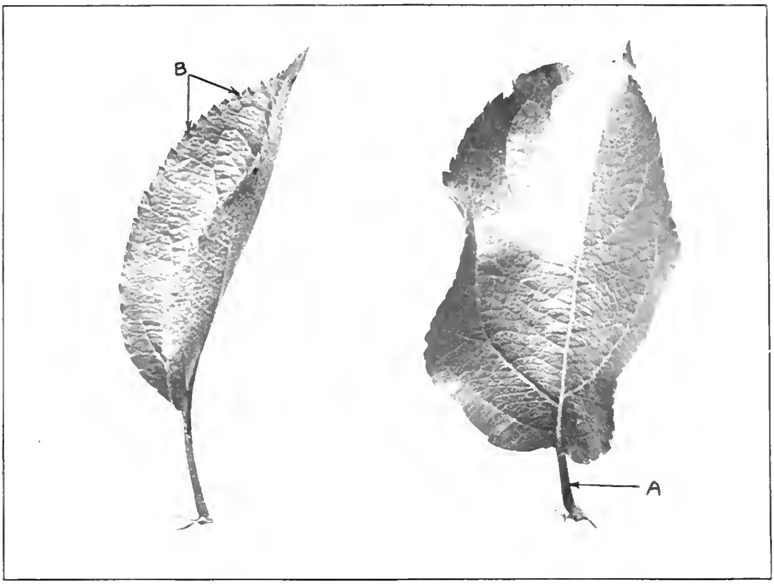

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FIG. 24. — TOMPKINS KING. Petiole short (A); blade large, folded and reflexed, usually waved; serrations sharp, distinct and quite regular (B).

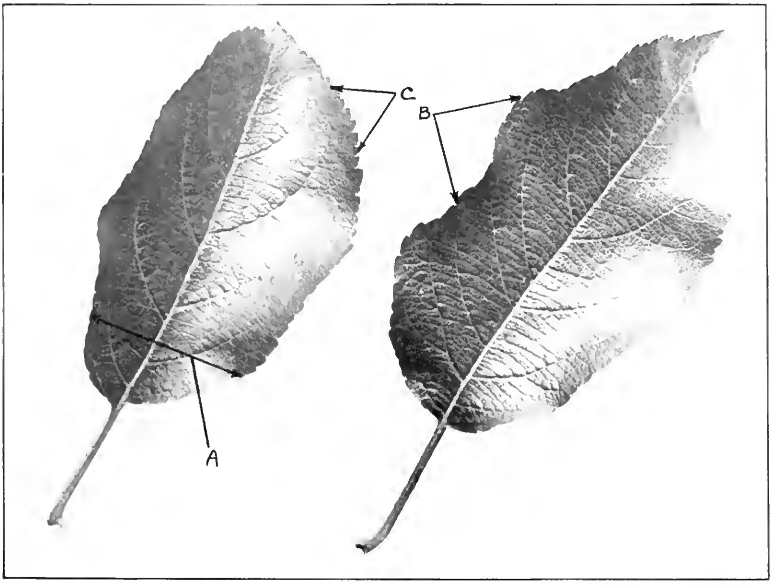

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FIG. 25. — BEN DAVIS. Blade medium size or above, long and narrow especially at base (A), folded, reflexed and waved (B); serrations dull, rather fine and irregular (C).

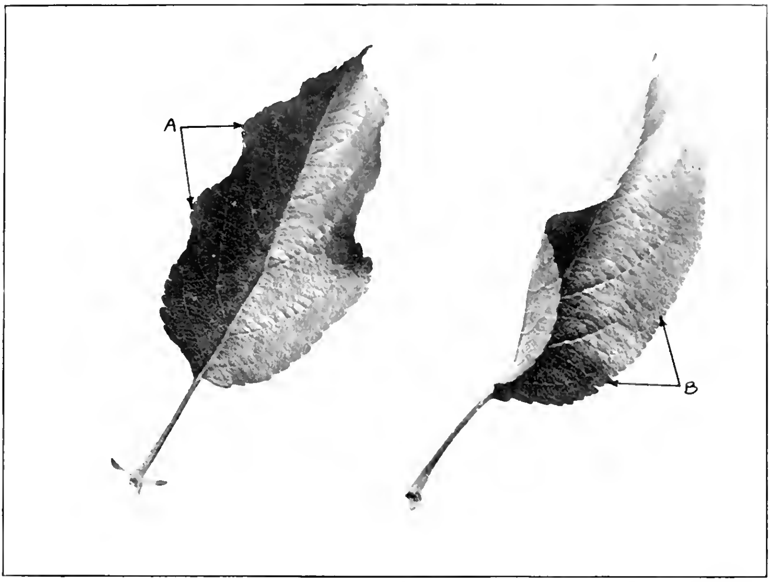

Photo by R. L. Coffin.

FIG. 26. — ESOPUS SPITZENBURG. Blade medium size, folded, reflexed and more or less waved (A); serrations rather dull and quite regular (B).

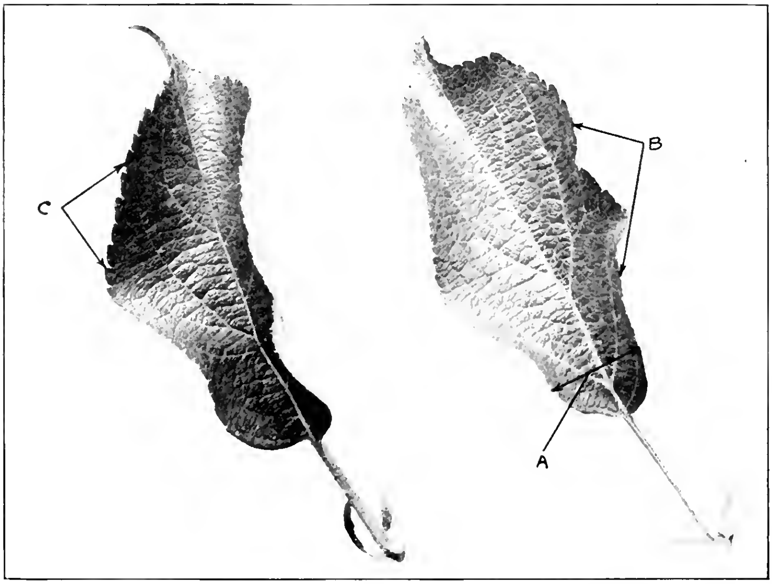

Photo by R. L. Coffin.

FIG. 27. — TOLMAN. Blade medium size, very narrow at base (A), narrow at apex, folded, reflexed and waved (B); serrations rather dull and coarse (C).

Description of Varieties.

There are many leaf characters that are of considerable value in identifying varieties that cannot be well shown in photographs. They have been discussed in the text. In order to present these characters the following technical descriptions of the leaf characters of the varieties illustrated are presented: —

Baldwin. — Petiole medium. Blade above medium size, folded near margin, straight or slightly reflexed, not waved, broad oval, broad at base and very broad at apex, nearly erect, rather thin, smooth, fine texture with little pubescence. Serrations sharp, strongly forward, medium size, fairly regular, usually curved, rather deep and close set. Color medium green. (Fig. 8.)

Ben Davis. — Petiole long, medium size. Blade below medium size, folded, often reflexed, waved, narrow oval, very narrow at base, nearly spreading, rather thin, smooth with considerable pubescence. Serratures dull, moderately forward, rather small and shallow, sometimes slightly curved, quite regular. Color slightly grayish green. (Fig. 25.)

Delicious. — Petiole length, short to medium. Blade below medium size, slightly folded, straight or slightly reflexed, even, ovate, apex narrowing into the point, rather erect, thick, rather coarse texture with little pubescence. Serratures moderately sharp, rather coarse and deep, irregular. Color deep green. (Fig. 14.)

Esopus Spitzenburg. — Petiole medium. Blade below medium in size, more or less folded and waved, slightly reflexed, oval or ovate usually narrowing at apex, medium in texture and pubescence. Serratures rather dull, small and rather shallow, fairly regular. Color medium green. (Fig. 26.)

Fall Pippin. — Petiole medium long, stout. Blade large, folded, reflexed and waved, ovate with apex merging into acute or acuminate point, rather smooth and shining. Serratures sharp, deep and distinct, not curved, rather irregular. Color bright clear green. (Fig. 21.)

Gravenstein. — Petiole medium. Blade large, flat, not waved, oval, smooth and shining. Serratures rather sharp, shallow, fairly regular. Color medium green. (Fig. 2.)

Grimes. — Petiole medium. Blade medium size, strongly folded, waved and reflexed, long and narrow, narrowing at base and apex, rather thin, smooth and shining, with little pubescence. Serrations sharp, distinct and rather deep, rather irregular. Color medium green. Grimes resembles Wagener, but it has less pubescence, is thinner, and has finer and sharper serrations. (Fig. 23.)

Hubbardston. — Petiole rather short, medium size. Blade below medium, folded, more or less waved, reflexed, generally ovate, rounded at base and generally narrow at apex, nearly erect, medium thickness, dull, rather coarse texture with considerable pubescence. Serratures fairly sharp, medium size, moderately deep and distinct, fairly regular. Color deep grayish green. (Fig. 22.)

Jonathan. — Petiole short and rather slender. Blade very small, more or less folded, waved, sometimes reflexed, oval, narrow at base and apex, rather spreading, rather coarse texture with considerable pubescence. Serratures rather dull, rather coarse, shallow and irregular. Color grayish green. (Fig. 17.)

King David. — This is like Jonathan, except that the leaf is somewhat larger, distinctly broader in the apex, less apt to be folded and with somewhat less pubescence. (Fig. 18.)

McIntosh. — Petiole short and rather stout. Blade large, flat or slightly folded near margin, straight, not waved, broad oval, often cordate at base, spreading, rather coarse and thick, with considerable pubescence. Serratures dull, medium size, very shallow at base, fairly regular. Color deep grayish blue green. (Fig. 3.)

Northern Spy. — Petiole generally rather long and slender. Blade medium size, more or less folded and waved, often slightly reflexed, ovate, erect, rather thin, smooth with little fine pubescence. Serratures rather sharp, medium size, rather shallow, fairly regular. Color clear medium green. (Fig. 16.)

Oldenburg. — Petiole long. Blade above medium to large, more or less folded, slightly reflexed, distinctly waved, broad oval, broad at base and apex, spreading, medium thickness, rather dull surface with medium pubescence. Serratures rather dull, medium in size and depth, irregular. Color medium green. (Fig. 6.)

Opalescent. — Petiole medium. Blade medium size, somewhat folded, sometimes waved, oval, rather narrow at base, apex narrowing into the point, spreading, medium thickness, smooth and shining with little pubescence. Serratures dull, rather small, of medium depth, quite regular. Color medium green. (Fig. 20.)

Red Astrachan. — Petiole medium. Blade large, flat or slightly folded, waved or wrinkled, broad oval, broad at apex, spreading, medium thickness, dull surface with a little pubescence. Serratures dull, medium in size and depth, rather irregular. Color dull medium green. (Fig. 5.)

Rhode Island Greening. — Petiole long, medium size. Blade large, flat or reverse curved, not waved, broad oval, rounded or narrow at base, broad at apex, spreading or drooping, smooth with little pubescence. Serratures very sharp and distinct, rather deep, fairly regular. Color deep clear green. (Fig. 4.)

Roxbury Russet. — Petiole medium or short, rather stout. Blade medium in size, folded near edge, not waved nor reflexed, broad oval, broad at base and apex, spreading, rather smooth with medium pubescence. Serratures only moderately sharp, rather small, not deep, rather irregular. Color deep green. Much like Baldwin, but the serratures are not so sharp nor so close set and are not curved. (Fig. 9.)

Stayman. — Petiole short to medium. Blade rather small, roundish or broad oval, partly folded, not waved nor reflexed, spreading, rather thick, coarse texture with medium pubescence. Serratures dull and coarse to sharp and small. Color deep green. Stayman seems to be unique in having distinct types of leaves as shown in Fig. 19.

Tolman. — Petiole medium. Blade medium, folded, reflexed and waved, narrow oval, narrow at base and apex, spreading, medium texture with considerable pubescence. Serratures moderately sharp, medium size, quite distinct, generally quite regular. Color deep bluish or grayish green. (Fig. 27.)

Tompkins King. — Petiole rather short and stout. Blade medium to large, folded, more or less waved and reflexed, rather long oval, rather narrow at base and apex, spreading, medium thickness with little pubescence. Serratures sharp, medium to small, shallow and close set. Color medium green. (Fig. 24.)

Wagener. — Petiole, medium or short, stout. Blade medium or above, strongly folded and reflexed, more or less waved, oval with medium base and apex, erect, rather thin with moderate pubescence. Serratures quite sharp, rather coarse, deep and distinct, not curved. Color medium green or slightly grayish. Wagener resembles Grimes, but the leaf is coarser, the serrations not quite so sharp, and it has more pubescence. (Fig. 15.)

Wealthy. — Petiole medium or rather long, slender. Blade medium or above, nearly flat, often somewhat reflexed, often spiral and waved, oval with narrow base and apex, spreading, thick and with little pubescence. Serrations dull, medium in size and depth, somewhat irregular. Color medium green. Wealthy resembles Oldenburg, but the serrations are duller, the blade less folded and much narrower at the base and apex. (Fig. 7.)

Williams. — Petiole medium, rather slender. Blade medium size, partly folded, somewhat reflexed, sometimes coarsely waved, spreading, rather coarse with little pubescence. Serratures dull, small and shallow, regular. Color medium green. (Fig. 11.)

Winter Banana. — Petiole short and stout. Blade medium size, folded near margin, midrib bent at base, not often waved, narrow oval, spreading, medium thickness with little pubescence. Serrations rather dull and shallow, pointing well forward. Color rather pale green. (Fig. 10.)

Wolf River. — Petiole medium. Blade flat or somewhat folded, often waved and wrinkled, often reflexed, oval, narrow at base and apex, spreading, medium thickness, rather coarse with medium pubescence. Serratures very dull, quite distinct and rather irregular, often double. Color medium green. (Fig. 12.)

Yellow Transparent. — Petiole medium. Blade medium size, more or less folded, often waved and somewhat reflexed, often spiral especially near tips of shoots, rather narrow oval, rather narrow at apex, smooth, rather fine texture with considerable pubescence. Serratures dull, rather small and shallow, quite regular. Color rather paie green. (Fig. 13.)

Glossary.

In the foregoing descriptions there are a number of words that are used in a restricted, technical sense. Definitions of the technical meaning of these words are here given: —

Acute: sharp pointed.
Acuminate: very sharp pointed.
Apex: about one-third of the leaf blade. (See Fig. 1.)
Base: same as apex, but referring to the opposite end.
Blade: the leaf, barring petiole and stipules. (See Fig. 1.)
Cordate: heart-shaped; applied to shape of leaf base. (See McIntosh, Fig. 3.)
Close set: referring to serratures having little space between. (See Baldwin, Fig. 8.)
Curved: applied to "teeth" of serratures. (See Baldwin, Fig. 8.)
Distinct: having spaces between the "teeth" of serratures, the opposite of close set. (See Fall Pippin, Fig. 21.)
Drooping: applied to the angle of leaf and the shoot from which it grows; a very wide angle.
Erect: the opposite of drooping; a sharp angle between leaf and shoot.
Folded: the halves of the leaf curved upward toward each other.
Irregular: serratures of varying sizes.
Midrib: the main vein along the middle of the blade.
Point: the extreme tip of the leaf blade.
Pubescence: the short hairy growth found mainly on the under side of the leaf blade.
Reflexed: having the blade curved backward or downward.
Regular: serratures all of equal size.
Reverse curved: the midrib and blade bent slightly like the letter S.
Serratures, serrations: the notches on the margin of the leaf blade.
Spreading: the usual angle of the leaf and shoot; between erect and drooping.
Spiral: a slight twisting of the leaf blade. (See Wealthy, Fig. 17.)
Texture: applied to the surface of the leaf blade, due mainly to character of the net veins.
Waved: having undulating leaf margins.
Wrinkled: the same as waved, but with smaller undulations.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 209 JULY, 1922

EXPERIMENTS IN SOIL MANAGEMENT

AND

FERTILIZATION OF ORCHARDS

By J. K. SHAW

This bulletin reports the results of the application of four different fertility practices to an orchard containing four varieties of apple trees, and subjected during the course of thirty years to three significantly different cultural practices.

This work is checked by a study of a second orchard on a different soil type, where practically the same plant-food combinations were used on a single variety grown under a single definite cultural treatment.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

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Supervisor of Administration.

CONTENTS.

BULLETIN No. 209.

DEPARTMENT OF POMOLOGY.

EXPERIMENTS IN SOIL MANAGEMENT AND FERTILIZATION OF ORCHARDS.

BY J. K. SHAW.

THE OLD STATION ORCHARD.[1]

The orchard experiment here reported was begun in 1890 and has continued to the present time. It is, so far as the writer's knowledge goes, the oldest orchard fertilizer experiment in America, and perhaps in the world. The arrangement of the orchard is shown on page 34. It lies on a gentle western slope and is bordered on the west and north by grassland. To the east and south the slope is steeper and covered by a heavy growth of forest trees. The orchard and forest are separated by an open space which in the writer's judgment is sufficient to prevent any injurious influence on the orchard trees from root trespass, though there may possibly have been an injurious effect from shading. This, however, is distributed quite evenly over the whole orchard.

The soil is a strong and retentive gravelly loam underlain by a fairly compact subsoil. It is well supplied with moisture. A ditch above the orchard prevents surface wash from the forest slope above. It was originally somewhat overmoist, especially on plot 3, which is slightly lower than plots 4 and 5. This may have influenced in some degree the growth and yield of this plot, but in the writer's judgment any such influence is small even if it exists at all. Before the trees were planted tile drains were laid to care for surplus water.

[1] This experiment was planned and started by the late Dr. C. A. Goessmann as director and chemist of the State Experiment Station. For most of its life it has been under the direction of Dr. Wm. P. Brooks. The details of management and recording of data have been in the hands of several different men, recently of E. F. Gaskill and R. L. Coffin. The writer is responsible for the tabulation and interpretation of the data.

Below is shown the arrangement of the plots and trees. The trees are spaced 40 × 30 feet, with an additional space of 14 feet between plots. Plot 1 is at the north end of the orchard.

PLOT 1. — MANURE, 10 TONS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein (died before 1907).	Gravenstein.	Gravenstein (died in 1919).

PLOT 2. — ASHES, 2,000 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet (died in 1919).
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 3. — NO FERTILIZER.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin (died about 1913).	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 4. — BONE, 600 POUNDS; MURIATE OF POTASH, 200 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet (died in 1907–08).	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 5. — BONE, 600 POUNDS; LOW-GRADE SULFATE OF POTASH, 400 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

Fertilizer Treatment.

Previous to 1889 the soil was in rather poor condition, but had been gradually improved by cultivation in corn and other cereals and grass. The manurial treatment was begun in the spring of 1889, and the following annual applications were continued up to and including 1916. Since 1916 no manure or fertilizer has been applied.

Plot.	Fertilizer.	Pounds per Acre.
1	Barnyard manure	20,000
2	Ashes	2,000
3	Check, no fertilizer	
4	Ground bone	600
	Muriate of potash	200
5	Ground bone	600
	Low-grade sulfate of potash	400

The fertilizer and manure have been applied on various dates, generally between April 1 and May 15, though in 1906 they were not applied until July 2.

Soil Management.

During the period from 1889 to 1893 various crops, such as barley, oats, corn, vetch and soy beans, were grown in the orchard. In the fall of 1893 it was seeded to rye and grass, and the sod then established continued until the fall of 1910. For the first few years small circles around the trees were kept free from grass by hand culture. Until 1902 the grass was cut usually twice each year, made into hay and removed from the orchard. In that year the first crop was made into hay and the second allowed to lie in the orchard. Since 1902 no hay has been removed, but the grass has been cut and allowed to lie where it fell. In November, 1910, four strips, each about 8 to 12 feet wide, were plowed the long way of the orchard. These strips have since been kept in cultivation by harrowing four to eight times during the summer; and usually about August 25 a cover crop of oats or rye has been sown. The grass along the tree rows has been cut and allowed to lie as before.

The history of the soil management, therefore, falls into four periods: —

1. With various intercrops . . . . 1889–1893, 5 years.
2. In sod with grass removed . . . . 1894–1902, 9 years.
3. In sod mulch . . . . 1903–1910, 8 years.
4. In strip cultivation . . . . 1911–1920, 10 years.

The fourth period might be subdivided between 1916 and 1917, marking the cessation of the application of fertilizer and manure.

Orchard Management.

The trees have been pruned in most years, at least since they have been in bearing. Heading back the new growth has been practiced more or less, and all dead wood has been removed.

During the early years apparently no spray treatment was given. Beginning in 1902 annual treatments for San José scale have been given which have kept the pest from doing serious damage to the trees. Generally lime-sulfur has been used for scale control, but in 1912 and 1913 miscible oil was applied in the late fall. This was followed by the dying of branches on some trees, which was attributed in part to the use of the oil, so that it was discontinued. One or two summer sprays have been given except in a very few years when the crop promised to be very light. Curculio injury has been common in most years, and in 1913 the red bug was found to be present. Partial control of these pests has been secured by the use of nicotine preparations in the spray. During the early years copper sulfate preparations and Paris green, and recently lime-sulfur and arsenate of lead, have been used in the summer sprays.

No records of growth were taken previous to 1902. Beginning in that year the circumference of the trunk 6 inches from the ground has been measured annually except in the years 1905, 1906, 1910, 1912 and 1918. Records of the yields of drops and picked fruit for each variety from each plot have been taken each year. The yield of individual trees has not been taken.

Five trees have died since the orchard came into bearing. One Gravenstein in plot 1 died before 1907, and another in 1919. The remaining Gravenstein in this plot was girdled by mice in 1907–08, but was bridge grafted and is now in good condition. One Baldwin in plot 3 died about 1913, one Roxbury Russet in plot 4 died in 1907–08, and one in plot 2 in 1919. (See page 34.) These have all been replaced, but none of the young trees is in bearing. In the tables given for trunk circumference the missing trees are omitted from the averages, but no corrections are made in yields.

Growth Records.

The only record of tree growth is that of trunk circumference which has been taken in most years beginning in 1902. Fig. 1 shows the averages of these measurements by plots. It may fairly be assumed that at the start the trees on the several plots averaged the same size. The differences in 1902 show what happened under the system of sod with removal of the hay. The manure and sulfate plots were alike, averaging about 27 inches. The graph shows that these two plots have steadily diverged up to the present time.

Certain years, such as 1904 and 1908, seem to have been especially favorable to tree growth, while 1917 was unfavorable. The writer has tried to correlate these variations in growth with rainfall, temperature, sunshine and size of crop, but without very much success. It is evident that no one of these factors is entirely responsible.

The relative growth on the different plots is more clearly shown in Fig. 2, where the average trunk circumference of the trees on plot 1 is shown as 100, and that of the other plots as percentages of plot 1. The steady decline of plot 5 from 100 to 89 per cent is clearly shown. Plot 2 (wood ashes) had fallen to about 88 per cent in 1902, and continued to fall off slowly until about 1912, but since that time it has nearly held its own. Plot 4 (bone and muriate) has behaved about the same as plot 2.

The check plot (plot 3) had fallen below 80 per cent at the commencement of our records, and continued to fall off rapidly up to 1911. From 1911 to 1915 it not only kept up with plot 1, but actually gained quite rapidly. Since 1915 it has kept even with plot 1 until the season of 1920, when plot 1 made remarkably strong growth, causing a relative falling off of plot 3 and of the other three plots as well.

The relative gain of plot 3 is beyond doubt due to cultivation of strips between the tree rows begun in the fall of 1910. As shown in Fig. 1, cultivation does not seem to have increased the growth on plot 1, but its effect is seen in all the other plots, though most strikingly in plot 3.

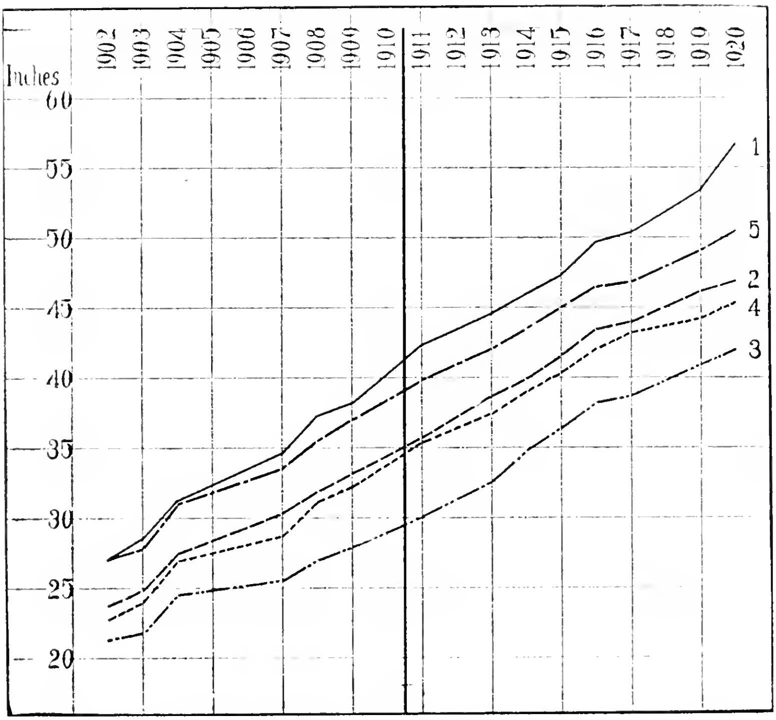

FIG. 1. — Increase in trunk circumferences. The perpendicular line marks the transition from sod mulch to strip cultivation. Plot numbers are shown at the right. See page 35 for treatments given.

No fertilizers of any kind have been applied since 1916, yet the growth on plot 1 has been well maintained as shown in Fig. 1. The other plots show a decrease in rate of growth since 1915, as shown in Fig. 2. It seems doubtful if this can be ascribed wholly to the cessation of fertilizer applications, because the decrease appears first in 1916, when fertilizers were applied, and it is seen in plot 3 which has never had any fertilizer applications. It seems more reasonable to suppose that the relative gain on plots 2, 3, 4 and 5 since 1911 was due mostly to the stimulus of cultivation which lasted through 1915. From 1915 to 1919 the check plot maintained just about the same growth as plot 1, while plots 2, 4 and 5 fell away. This may indicate an effect of the withdrawal of the fertilizer applications, though, as stated above, the fact that it is seen in 1916 indicates that it is not wholly due to that cause.

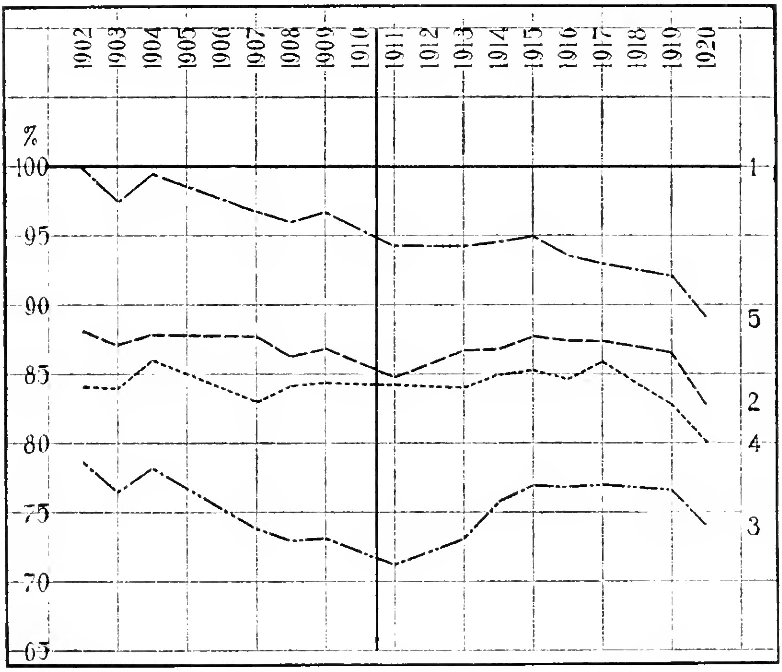

FIG. 2. — Relative trunk circumferences. Circumferences on plot 1 taken as 100 per cent. Plot numbers are shown at the right.

Varietal Response to Treatment.

Turning now to the question of whether all varieties have responded in the same manner to the various fertilizer treatments, we may examine Fig. 3. This shows the average trunk circumferences of the four varieties at three periods: first, in 1902, at the end of the period of hay removal; second, in 1911, at the end of the sod mulch period; third, in 1919, after nine years of partial or strip cultivation.

An examination of these graphs shows that the several varieties have maintained about the same relative positions during the entire period for which growth records have been kept. With increased size of the trees, the absolute differences have naturally increased. Rhode Island Greening has done better on the manure and ashes plots than on the other three

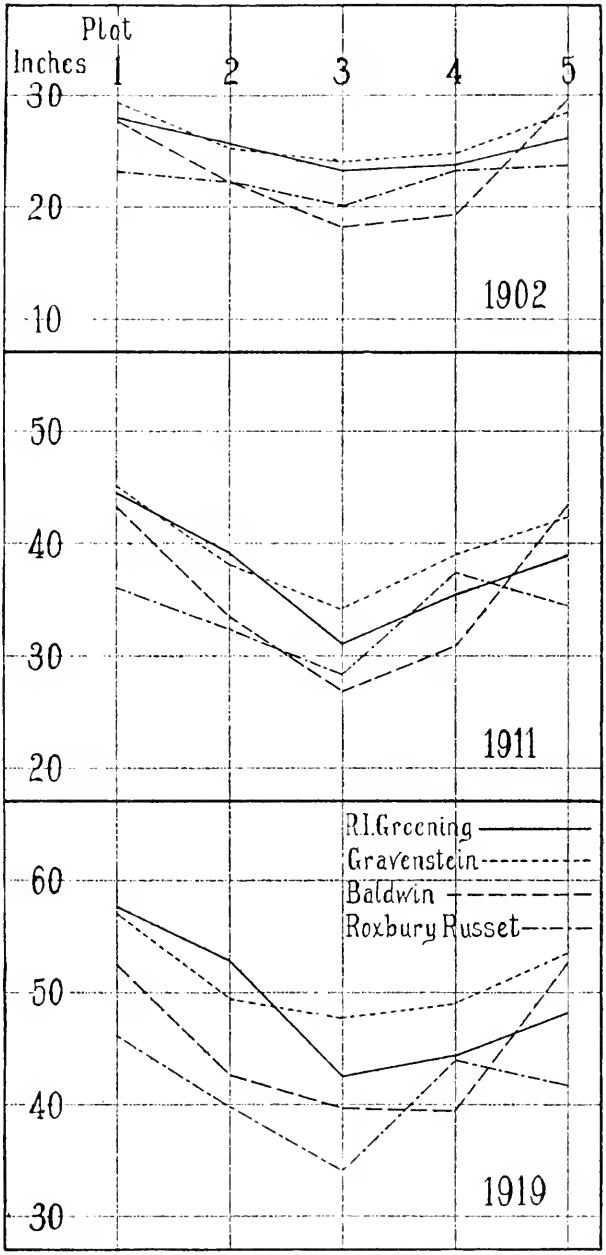

FIG. 3. — Trunk circumferences by varieties. Figures across top are plot numbers.

plots. Roxbury Russet is larger than Baldwin on the muriate plot, and the opposite is true on the sulfate plot, the differences here being quite marked and increasing with the age of the trees.

On the manure plot Rhode Island Greening has gained on the other varieties, which may be due to the fact that it is the outside row with free exposure to the north. On the ashes plot no relative change of the four varieties appears. On the check plot Baldwin has gone ahead of Roxbury Russet during the period of strip cultivation. Gravenstein has increased its lead over the other varieties, especially during strip cultivation. On the sulfate plot Gravenstein has gone ahead of Baldwin during the strip cultivation period, while the other varieties have maintained very much the same relative positions.

While there seem to be some quite marked varietal differences in growth, notably in the Baldwin and Russet on the two potash plots, it would be unsafe to conclude that they are due to the fertilizer treatments. They may be in part, but it is more likely that disease, natural soil differences, or inherent differences in the stocks used may be responsible.

Yield Records.

In Table 1 are given the total yields by plots and by varieties for the periods when no cultivation was practiced, and for the later period of strip cultivation.

TABLE 1. — *Total Yields by Varieties and by Plots (Pounds).*

Varieties.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
R. I. Greening:						
Before 1912	11,043	5,420	1,471	5,062	5,091	28,087
1912-20	16,989	14,310	7,344	10,367	9,881	58,891
Totals	28,032	19,730	8,815	15,429	14,972	86,978
Roxbury Russet:						
Before 1912	7,832	4,930	1,652	6,010	7,375	27,799
1912-20	12,123	7,620 [1]	4,554	6,954 [2]	8,397	39,648
Totals	19,955	12,550	6,206	12,964	15,772	67,447
Baldwin:						
Before 1912	8,168	4,155	735	2,359	10,936	26,353
1912-20	12,853	10,225	3,515 [3]	5,234	12,616	44,443
Totals	21,021	14,380	4,250	7,593	23,552	70,796
Gravenstein:						
Before 1912	4,308	2,697	1,490	4,412	4,035	16,942
1912-20	3,839 [4]	5,855	5,289	7,175	5,175	27,333
Totals	8,147	8,552	6,779	11,587	9,210	44,275
All varieties:						
Before 1912	31,351	17,202	5,348	17,843	27,437	99,181
1912-20	45,804	38,010	20,702	29,730	36,069	170,315
Totals	77,155	55,212	26,050	47,573	63,506	269,496

[1] One tree died in 1919.
[2] One tree died in 1907.
[3] One tree died in 1913.
[4] One tree died before 1907, and one in 1919.

The yields have been light, averaging only about $2\frac{1}{4}$ barrels per year per tree for the period from 1912 to 1920, inclusive, when the trees were practically mature. Rhode Island Greening has been the heaviest producer, deriving its superiority largely from plots 1 and 2. Baldwin is second, due in part to its superiority on plot 5. Roxbury Russet is third, and Gravenstein fourth, this variety being considerably inferior to the others in yield.

In total yields of all varieties by plots, the order is the same as for the size of the trees measured by trunk circumference. Plot 1 is ahead, followed by plots 5, 2, 4 and 3 in order.

All varieties increased their yield strikingly in the second period on nearly all plots, and especially on plot 3, the unfertilized plot. Here the total yield of all varieties was nearly fourfold. Baldwin increased nearly fivefold despite the loss of one of the three trees in 1913. On plot 1 the increase of all varieties was a little less than 50 per cent, though the yield of Gravenstein fell off, owing to the death of one tree before 1907, and the decline and death of another in 1919. If we assume that the normal increase due to growth of the trees is about 50 per cent, then plot 3 has increased its yield about two and one-half times over its normal, while the increase on plot 2 was about 40 per cent more than this assumed normal increase. Plot 4 has increased slightly more than the normal, while plot 5 has failed to make the normal gain.

There are several suggestive things that can be noted concerning the response of the different varieties to strip cultivation, but the small number of trees involved makes it rather doubtful if these differences have real significance.

The total yield of apples from the five plots from 1902 to 1920, inclusive, is shown graphically in Fig. 4. The heavy crops have been in the odd years, and are shown by heavy lines, while the light yields of the even years are shown by the lighter lines. The heavy perpendicular line between 1910 and 1911 marks the transition from sod mulch to strip cultivation.

This chart shows that in the off years there were no very great nor consistent differences between the plots until the 1920 crop. Nor has there been a very great increase in yield with the larger size of the trees in succeeding years. The off-year crop on the unfertilized plot has been the lowest of all in most years until the last two crops, when it has been about the average of the whole orchard. This better showing probably is the result of the increased growth of these trees since strip cultivation has been practiced. The crop of 1920 was heavier than that in any other off year, and, together with the light crop set in 1921 at the time of this writing, may mark a reversal of the off and on years. In 1920 the crops on the several plots were in much the same order as in the on years.

The off-year yields of the muriate and sulfate plots have been closely parallel, and the same is true of the on-year yields, yet the yields of the muriate plot have been distinctly inferior to those of the sulfate plot. This difference is less since 1911 than before, and may be due merely to the smaller size of the trees. The manure plot has been the best producer in most years, and its superiority seems to have increased in the last three on-year crops. The ashes plot has approached the manure plot more closely since 1911 than before. The unfertilized plot has been, up to 1920, far in the rear of all the fertilized plots, though showing material gains in on-year yields since 1911, which brought it slightly above the muriate plot in 1919.

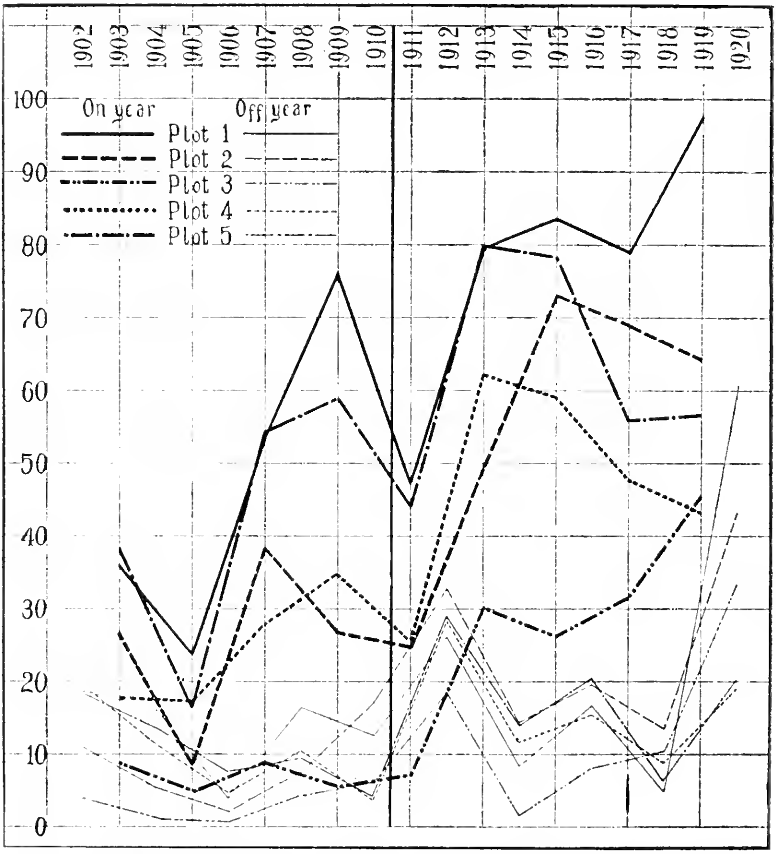

FIG. 4. — Total yields by plots in hundreds of pounds. The odd numbered years are the bearing or "on" years. Figures at left are hundreds of pounds.

It is apparent that the effect of the manurial treatment on yield has been slight in the off years, but in the on years it seems reasonable to conclude that there have been differences in yield due to the different manurial treatments. These differences in the on years follow closely the differences in growth of the trees. It is probable that the fertilized plots have exceeded in yields the unfertilized plot mostly because the trees were larger. The fertilized plots have received greater or less supply of nitrogen.

Many experiments have shown that abundant nitrogen favors the set of fruit. There is also no doubt that on these plots the fruit has been larger than on the unfertilized plot. These additional factors would contribute to the increased yield of the trees on the four fertilized plots. Inasmuch as the trees on the unfertilized plot now approach those of the other plots in size, it is probable that this inferiority would be somewhat less marked in the future were the treatment to be continued as in the past.

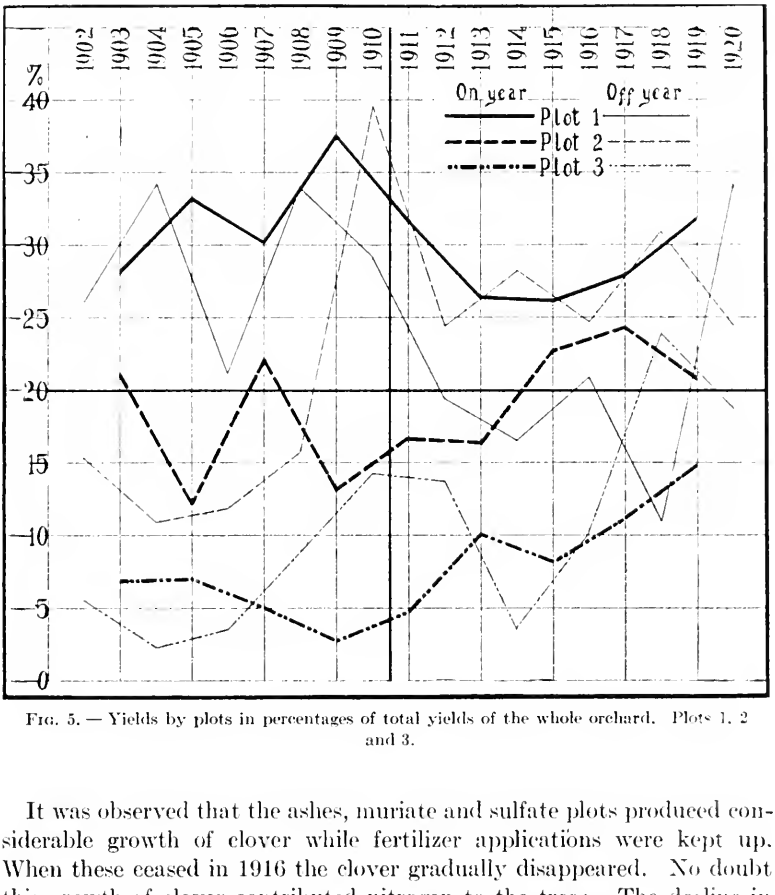

FIG. 5. — Yields by plots in percentages of total yields of the whole orchard. Plots 1, 2 and 3.

It was observed that the ashes, muriate and sulfate plots produced considerable growth of clover while fertilizer applications were kept up. When these ceased in 1916 the clover gradually disappeared. No doubt this growth of clover contributed nitrogen to the trees. The decline in growth and production of these three plots during the last four or five years may have been in some measure due to this lessened nitrogen supply.

The relative yields of the five plots are shown from another viewpoint in Figs. 5 and 6, where the yields are shown in percentages of the total crop of the whole orchard. Fig. 5 shows plots 1, 2 and 3, and Fig. 6 shows plots 4 and 5. Here, again, the heavy lines show the on-year yields and the light lines the off-year yields. Inasmuch as there are five plots, the horizontal line along the abscissa of 20 per cent shows what we may call the normal yield of each plot.

The manure plot produced from 8 to 17 per cent excess over its normal 20 per cent under sod mulch in the on years, and only a little smaller excess in the off years. Under strip cultivation since 1910 it has fallen to an average excess of about 8 per cent in the on years, and in three of the off years it has failed to produce its normal 20 per cent of the crop. Of course this percentage loss of the manure plot is made up by the other plots, and the ashes plot has helped do this. In all but two of the on years under sod mulch it failed to produce its normal 20 per cent, while in three out of five crops under strip cultivation it has exceeded its normal share. In the off years since strip cultivation its excess is much more marked. The unfertilized plot was far behind under the sod mulch system, but shows fairly consistent gains since strip cultivation has been practiced, and in one of the off years has exceeded its normal 20 per cent.

Effect of Form of Potash. — The muriate and sulfate plots have usually been in close accord in the off years, but in the on years there was marked superiority in the sulfate plot up to and including 1911, with the exception of 1905. Since 1911 the yields of these two plots have not differed widely.

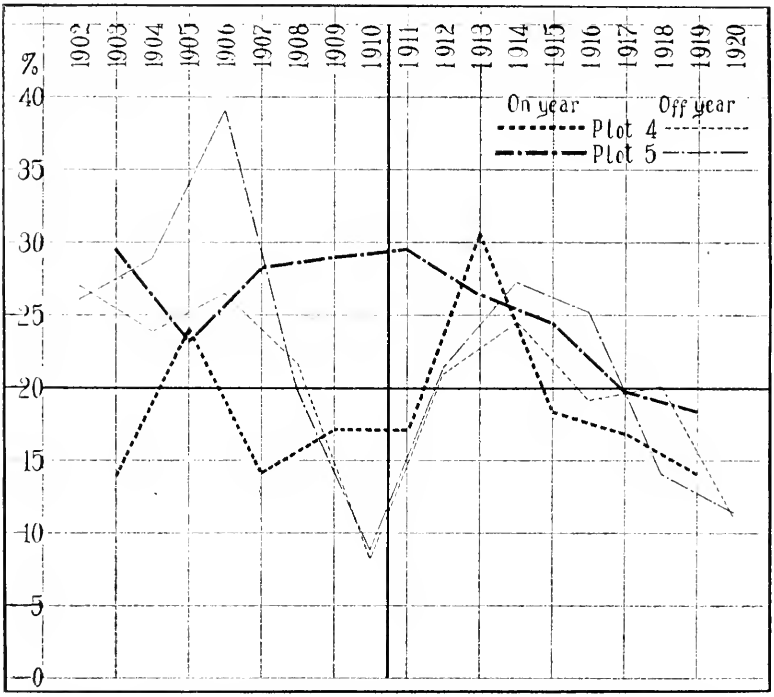

FIG. 6. — Yields by plots in percentages of total yields of the whole orchard. Plots 4 and 5.

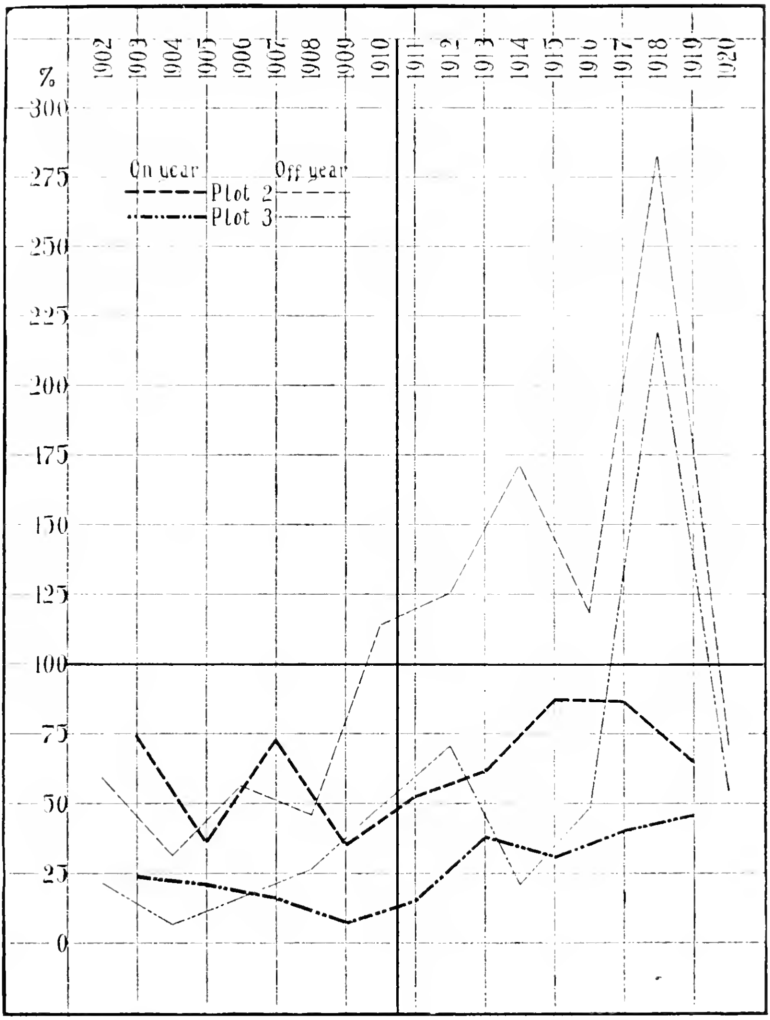

FIG. 7. — Relative yields of plots 1, 2 and 3. Yields on plot 1 taken as 100 per cent.

Whether the wide differences of the crops of 1903, 1907, 1909 and 1911 were accidental, or were due to the different fertilizers used on the sod mulch system then practiced, it is impossible to say. It seems certain that no significant differences have appeared since 1911, and of course the buds for that crop were formed while the plots were handled under the sod mulch system. Both these plots have, since 1913, produced a steadily decreasing proportion of the crop of the orchard.

Still another view of the plot yields is shown in Figs. 7 and 8, which show the yields of plots 2, 3, 4 and 5, with plot 1, the manure plot, taken as 100. These figures show clearly how plot 1 has often been exceeded by the other plots in the off years and scarcely at all in the on years. The increased production of the ashes and unfertilized plots since strip cultivation was begun is shown. The relative decrease of the ashes and unfertilized plots under sod mulch is shown, and also their gain on the manure plot when strip cultivation was begun. The unfertilized plot still continues a relative increase, while the ashes plot shows a falling away in the last few years. Fig. 8 shows clearly the parallel courses of the muriate and sulfate plots, with a relatively wider difference under sod mulch, and a gradual convergence since strip cultivation has been practiced.

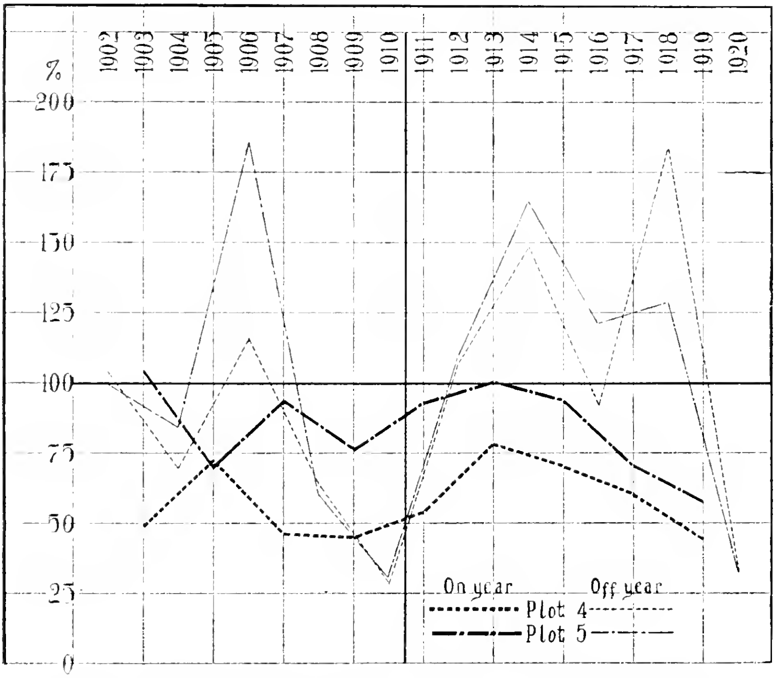

FIG. 8. — Relative yields of plots 1, 4 and 5. Yields on plot 1 taken as 100 per cent.

Correlation between Growth and Yields.

It is interesting to compare these graphs with Fig. 2 showing similar measures of growth as indicated by trunk circumference. Several investigators have shown a close correlation between growth and fruit production. Within limits the two go together, — the more growth the greater fruit production. This conclusion is supported by a comparison of Fig. 2 with Figs. 7 and 8. Especially do the lines representing growth and production on the unfertilized plot show a general resemblance, both falling off under sod mulch and rising when strip cultivation was begun. There is only a little less striking resemblance in the curves for the other three plots.

Quality.

Considerable differences in quality of the product of the several plots have appeared. This is considered to include size, color, keeping quality and dessert quality. No special records of size have been kept, but observation shows that differences in size have been closely correlated with yield; the apples on plot 3 have been small and those on plot 1 generally larger than those of any other plot. Rarely has the crop on any tree been large enough to limit the size of the fruit.

Brooks[1] reports near the end of the sod mulch period: —

In color and general attractiveness of appearance the fruit of the several plots has usually ranked in the following order: plots 2, 5, 4, 1 and 3. In the early years of the experiment the rank of the fruit in size was in the order: plots 5, 4, 1, 2 and 3. At the present time (1909) the apples on plot 1 take a higher relative rank, and in all cases where the quantity of fruit is not excessive the apples on plot 1 are usually larger than on any of the other plots.

A number of tests of keeping quality have been made, and in this respect the fruit has usually ranked in about the following order: plots 5, 4, 1, 2 and 3. The relatively low rank of the fruit from plot 2 in keeping quality appears to be connected with the fact that this fruit comes to maturity earlier than that on the other manured or fertilized plots. It will be noted that the fruit from plot 2 ranks highest in appearance. This is due to its superiority in coloring. This in turn is undoubtedly connected with the fact that the fruit is somewhat more mature. Such fruit might undoubtedly be kept if promptly put into cold storage; but in ordinary storage it is considerably inferior to the somewhat less thoroughly ripened fruit on the other manured plots.

The fruit from plot 5 has almost invariably been much superior in appearance to that produced on plots 1 or 4. Here again there have been individual variations in the product of the different trees of the same variety on all of the different plots. There has, however, been no doubt as to the fact that on the whole the product of plot 5 has been considerably superior in color and general attractiveness as well as in firmness of flesh to the product from plot 4; while the product from plot 1, which receives barnyard manure, ranks below either of the others in the qualities just mentioned. In general, the fruit produced on plot 5 shows a considerably brighter and clearer color than that on either plots 4 or 1. There can be no doubt that it would sell at a higher price in the general market than either of the others, although the difference between plots 4 and 5 is considerably less than between plots 1 and 5. The product of the unmanured plot, 3, shows good color and in some cases is of fair size, but in general is too small to command the best prices.

At the present time, after ten years of strip cultivation, these differences between the several plots are not as marked as during the sod mulch period, yet they continue in considerably reduced degree.

[1] Mass. Agr. Expt. Sta., Ann. Rept. 22, Pt. 2, p. 14 (1910).

The Graves Orchard.[1]

As the experiment above reported progressed, marked differences appeared between plots 4 and 5, the muriate and sulfate plots. Though these differences became less in later years, in 1907 they appeared important enough to justify further investigation. Accordingly a ten-year lease of a young Baldwin orchard, located in the southeastern part of the town of Amherst about six miles distant from the Experiment Station, was secured.

An experiment was planned to show whether differences similar to those which had appeared between plots 4 and 5 would appear here also, and whether, if such differences did appear, they were due to the form of the potash, which was muriate in one case and sulfate in the other, or to the presence of magnesium in the low-grade sulfate of potash.

The site of the orchard was a gentle northeasterly slope, with the steep slope of the easterly end of the Holyoke mountains about 40 rods to the south. The soil was a medium sandy loam rather low in fertility.

The trees, with the exception of four scattered trees, were of the Baldwin variety, and were said to be six years old at the beginning of the experiment. While most of the trees were fairly uniform at the start, there were a number of poor stunted trees which died or were replaced with new trees early in the experiment. None of these young trees bore fruit during the experimental period, and they are omitted in the consideration of the results. A plan of the orchard is shown in Fig. 9.

The orchard was in sod when taken over, but it was plowed in the spring of 1908, and in the following years handled in a system of cultivation and non-leguminous cover crops. As shown in the plan a strip on the north end was left in sod during the whole period.

Fertilizer Treatment.

In the spring of 1908 the orchard was laid out in eight plots of two rows each, and application of fertilizers made as shown in Fig. 9. Application of these materials at the given rates was made annually during the first half of May, beginning in 1908 and continuing for six years. In 1914 the applications to row 2 of each plot were discontinued, and the amounts given to row 1 of each plot reduced to one-half the former amounts. This plan was followed for four seasons until the expiration of the lease ended the experiment.

The circumference of the trunks 1 foot from the soil was taken in the spring of 1908; in April, 1914; in April, 1916; in November, 1917; and in August, 1921.

The first crop of fruit was produced in 1911. This was followed by a very light crop in 1912 and moderate crops in 1914, 1915, 1916 and 1917. Yield records were taken by plots, omitting the four odd trees mentioned

[1] This experiment was planned by Dr. Wm. P. Brooks, then director of the Experiment Station. The data were taken under the direction of Prof. F. C. Sears and E. F. Gaskill. The writer is responsible for the tabulation and interpretation of the data.

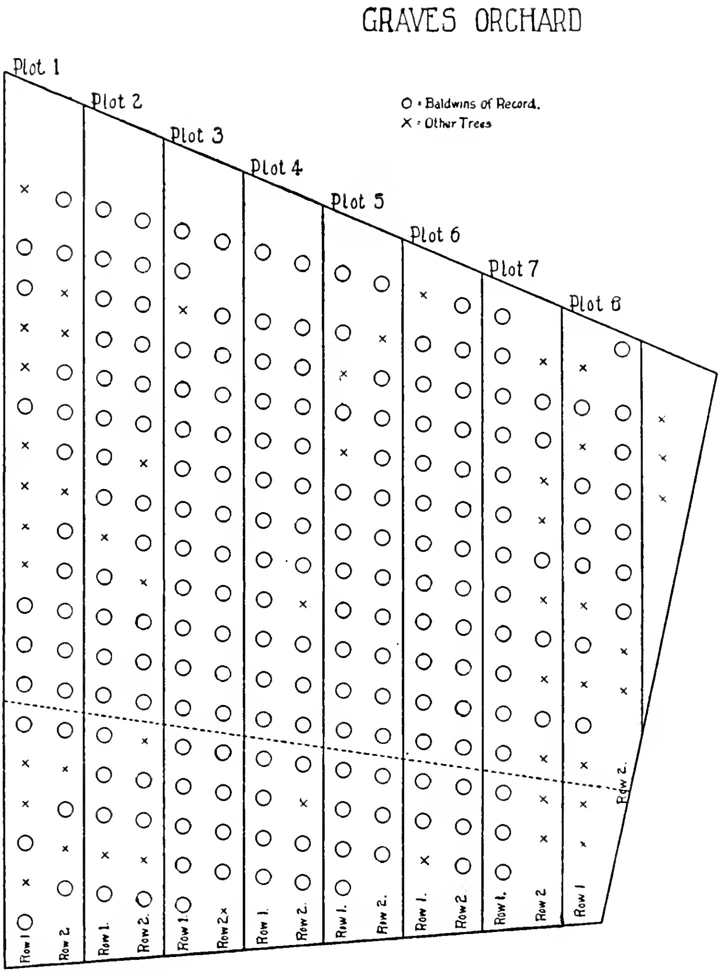

FIG. 9. — Plan of the Graves orchard. The portion below the dotted line was in sod.

Fertilizer Treatment per Acre.

Plot 1.	Manure	8 tons
Plot 2.	Ashes	1,600 pounds
Plot 3.	No fertilizer.	
Plot 4.	Bone	600 pounds
	Muriate of potash	160 pounds
Plot 5.	Bone	600 pounds
	Low-grade sulfate of potash	320 pounds
Plot 6.	Bone	600 pounds
	Muriate of potash	160 pounds
	Sulfate of magnesia	255 pounds
Plot 7.	Bone	600 pounds
	High-grade sulfate of potash	160 pounds
Plot 8.	Basic slag	800 pounds
	Low-grade sulfate of potash	320 pounds

above. Individual tree records of yield were not taken, nor was any separation made of the yields of that portion of the trees remaining in sod. In the early years no separate record of dropped and picked fruit was made, but in the last four years the picked fruit was recorded separately.

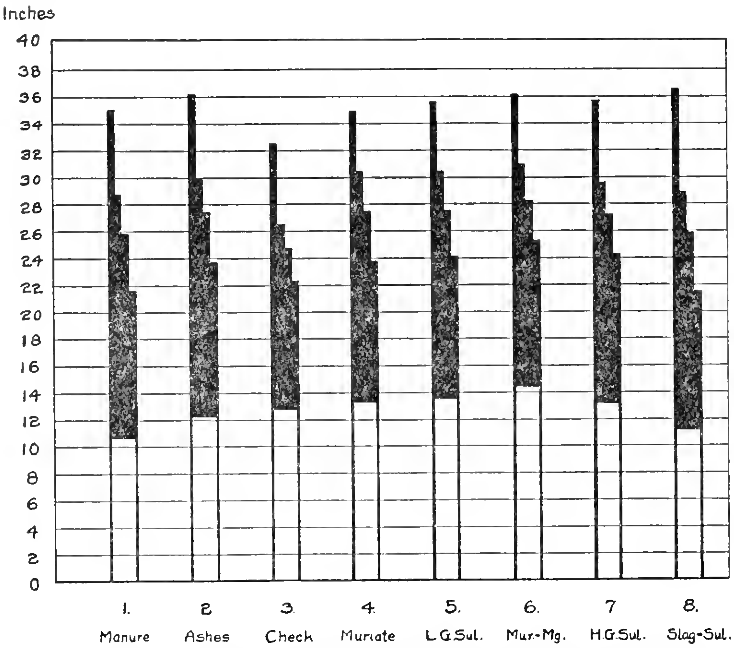

FIG. 10. — Average trunk circumference by plots, cultivated Baldwin trees only (Graves orchard).

Growth Records.

Fig. 10 shows the increase in trunk circumference of the trees in cultivation in the several plots. The growth on plot 3, the check plot, has been less than on the other plots, indicating that the trees responded to the application of all the fertilizers by increased growth. At the beginning of the experiment the trees on plot 3 were exceeded in size by those on plots 4, 5, 6 and 7. In 1917, at the end of the period of fertilization, this difference had increased somewhat, while the trees on plots 1, 2 and 8 had grown so that the check plot then had the smallest trees of any plot. A later measurement of the same trees made in August, 1921, showed that the check trees were still the smallest. It is interesting to note that plots 1, 2 and 8 are the only plots that showed greater growth than the check plot in this four-year post-experimental period.

One seems justified in concluding that on these Baldwin trees under cultivation the fertilizer applications have caused greater growth, and that manure and lime-carrying fertilizers have been more beneficial than those chemical fertilizers which carried no lime.

As has been stated, there was a strip across the north ends of the plots that remained in sod during the entire experimental period. The trees on this strip made considerably less growth than those in cultivation, as shown in Table 2.

TABLE 2. — *Average Increase in Trunk Circumference, 1908–17.*

Plot.	Treatment.	Trees in Sod.		Trees in Cultivation.	
		Number.	Increase in Circumference.	Number.	Increase in Circumference.
1	Manure	6	15.2	16	18.1
2	Ashes	7	14.5	24	17.6
3	No fertilizer	9	11.0	25	13.7
4	Bone and muriate	7	12.6	23	17.2
5	Bone and low-grade sulfate	9	12.1	21	16.9
6	Bone, muriate and magnesia	7	12.8	23	16.4
7	Bone and high-grade sulfate	4	14.5	17	16.4
	Averages and totals	49	13.3	149	16.6

The trees on plot 7 made relatively more growth in sod than those on the other fertilized plots, but owing to the small number of trees involved there is a question if the difference is significant. With this one exception the two series of plots parallel each other very closely. The parallel between plots 4 and 5 is very close. As previously stated, there was some indication that in the station orchard, under sod or sod mulch conditions, low-grade sulfate of potash was superior to muriate. In this orchard, what slight difference there is is reversed in both the sod and cultivated portions of the plots.

It has been stated that in 1914 and following years row 2 of each plot received no fertilizer, while row 1 of each plot received only one-half the amounts previously applied. Table 3 shows the average increase in trunk circumference of the trees in cultivation; no dependable comparison can be made of those in sod because of too few trees.

TABLE 3. — *Average Trunk Circumference of Trees in Cultivation, All Plots except Check (Inches).*

Row.	Treatment.	1913.	1915.	1917.
1	One-half previous amounts	23.50	27.26	30.19
2	No fertilizer	22.94	26.68	29.24
	Difference	.56	.58	.98

These figures indicate a slight response in circumference increase apparently due to the fertilizers, but not enough to be of much significance.

Yield Records.

The yield records of this orchard have been kept by plots only. Inasmuch as the plots are of different sizes and include different numbers of trees, it seems best to divide the total plot yields by the number of bearing trees, thus obtaining the average yield per tree. The average total yield per tree is shown in Table 4.

TABLE 4. — *Average Yields per Tree (Pounds).*

Plot.	Treatment.	1911.	1912.	1914.	1915.	1916.	1917.	Average.
1	Manure	92	15	117	224	328	158	156
2	Wood ashes	217	44	211	221	316	133	191
3	No fertilizer	234	67	101	188	102	223	153
4	Bone and muriate . . .	188	38	66	390	213	268	194
5	Bone and low-grade sulfate . .	114	55	334	212	347	141	201
6	Bone, muriate and magnesia .	251	58	418	195	332	191	241
7	Bone and high-grade sulfate .	279	45	338	260	200	159	214
8	Slag and low-grade sulfate . .	163	11	334	175	387	221	215

The lowest yield is from the unfertilized plot, 3, and the highest yield is from the muriate and magnesium plot, 6. Plots 4 to 8 show rather uniform yields, varying from 194 to 241 pounds per tree, and it is probably unsafe to attribute the differences that do show to the differential fertilizer treatment. The yield from the ashes plot (189 pounds) is only a little below that of these plots, and may or may not indicate that this fertilizer treatment was less effective in producing apples than the treatments given to plots 4 to 8. The yield on the manure plot is low and may indicate an inferiority of manure as fertilizer on this soil, yet it should be noted that these trees were at first the smallest in the orchard, and at the end of the experimental period were exceeded in trunk circumference by all except those on the unfertilized plot. Plots 4 and 5 received practically the same fertilizer treatments as plots 4 and 5 in the station orchard, the results from which this experiment was planned to explain. The difference in yield is here only 7 pounds per tree, a degree of similarity rarely secured from plots receiving identical fertilizer treatments.

Fig. 11 shows the average yield per tree by two-year periods, — 1911 and 1912, 1914 and 1915, and 1916 and 1917, — there being no crop in 1913. The most significant fact brought out here is that the unfertilized plot shows practically the same yield for each period, while the fertilized plots all show substantial gains for the second two periods over the first. The slag-sulfate plot, 8, shows a large gain, and the manure plot, 1, makes a better showing from this viewpoint than from that of average total yields per tree. The ashes plot, 2, made a substantial gain during the second period, but made little further gain in the third period.

It seems reasonable to conclude that under the conditions at this orchard, which is on a sandy soil of inferior fertility, as indicated by the growth of cover crops and other herbaceous plants, the fertilizers applied have been beneficial to the trees, as indicated by increased growth and greater production.

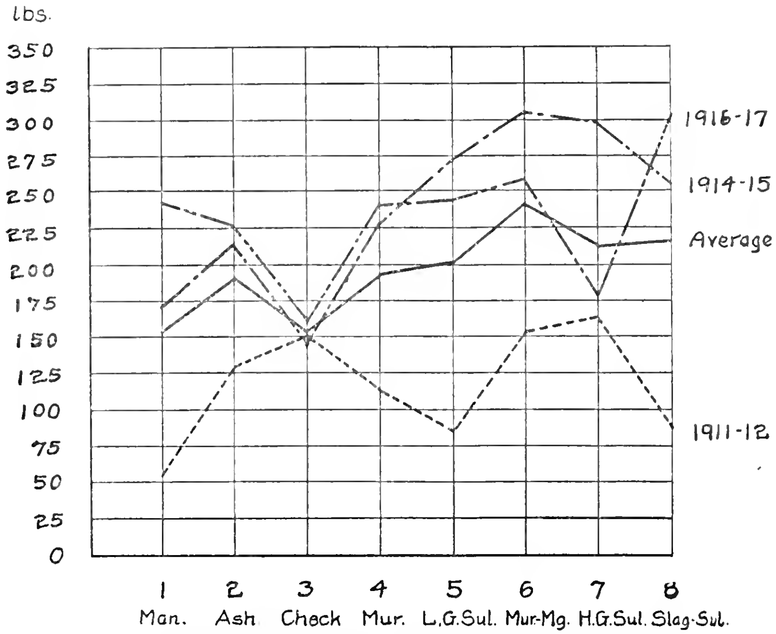

FIG. 11. — Average yield per tree by two-year periods (Graves orchard).

DISCUSSION OF RESULTS.

The results of many orchard fertilizer experiments in this country have shown that, of all the fertilizer elements usually taken into consideration, nitrogen is most likely to produce a response. This response appears in darker colored and more luxuriant foliage, more growth, and often increased production of fruit. It may be worth while to consider how far the observed results, especially those of growth, can be explained on the basis of variation in available nitrogen supply.

The manure plot in the station orchard has plainly responded to the generous supply of nitrogen it has received. Growth, foliage color, and size and color of fruit have all been typical of trees well supplied with nitrogen. Both the potash plots in this orchard have received small supplies of nitrogen in the ground-bone application of 600 pounds per acre. This amount of bone supplies only about one-tenth as much nitrogen as plot 1 has received, and yet it is doubtless enough to account in part, at least, for the greater growth than that observed on the unfertilized plot. The uniformity of the several potash plots in the Graves orchard indicates that this may have been a nitrogen response rather than one to potash. All indications are that the Graves orchard soil is deficient in nitrogen, and a small supply of this element might be expected to produce marked results.

The relatively strong growth of the trees on the ashes plots and on the slag-sulfate plot in the Graves orchard indicates that added nitrogen cannot wholly account for the greater growth of the fertilized trees. Probably the presence of lime has favored greater availability of the nitrogen-carrying humus, even though this may have been present in only small amount in this soil, and so operated to increase the nitrogen available for the trees. The striking response to cultivation of the trees on the unfertilized plot in the station orchard may be fairly taken to indicate that lime is not always necessary to render the humus nitrogen available.

Manure has had a more persistent residual effect in both orchards than the other materials used. Evidently the effect of greater nitrogen supply because of cultivation, on plots not receiving manure, lasted about five years, after which the nitrogen supply was insufficient to maintain the increased growth of the trees.

The fact of inferior growth and production of the muriate plot in the station orchard as compared with the low-grade sulfate plot is interesting, and seems to have been peculiar to sod mulch management. Its inferiority apparently disappeared when the soil was cultivated. There is no evidence of such a difference on the lighter, better-drained soil of the Graves orchard. It is probable that this superiority of the low-grade sulfate was a real one. It has been suggested that the difference was due to the poorer drainage of the muriate plot. But the adjoining unfertilized plot is still more inferior in this respect, and yet this plot gave very good results when strip cultivation was adopted. It has been shown that muriate of potash may exert a depressing effect on nitrification, and this may possibly explain the results obtained. The attempt to explain whether this difference was due to the difference in the form of potash or to the presence of magnesium in the low-grade sulfate was unsuccessful, as no significant differences were obtained in the Graves orchard even with the trees in sod. The Graves orchard received a lighter application of potash and for a shorter period of years. Possibly this may have been a factor in bringing about different responses.

Summary.

1. In the two orchard experiments here reported, growth and fruit production were closely correlated. Increased growth was followed by increased production.

2. In one of the orchards, trees in cultivation gave better growth and higher production than when in sod.

3. In a sod orchard, low-grade sulfate of potash gave better results than muriate of potash, both plots receiving also ground bone. With strip cultivation this difference seemed to disappear. In a cultivated orchard, on lighter, better-drained soil, no significant differences appeared. On the sod portion of this second orchard, furthermore, there were no material differences.

4. The residual effect of manure was greater than that of ashes or the chemical fertilizers used.

APPENDIX.

Here are given the original data on which the discussion in this paper is based.

TABLE I. — *Station Orchard: Tree Circumferences (Inches).*

Rhode Island Greening.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 28.0			Av. 25.5			Av. 23.2			Av. 23.7			Av. 26.2		
1903[1]	Av. 30.3			Av. 27.0			Av. 23.6			Av. 25.9			Av. 27.0		
1904[1]	Av. 33.0			Av. 29.8			Av. 26.1			Av. 28.2			Av. 30.8		
1907	36.5	34.3	38.8	33.5	29.5	37.0	26.5	20.8	34.3	30.0	23.0	35.5	29.0	34.5	34.0
1908	39.0	38.0	41.0	35.0	30.8	39.3	28.0	21.5	35.8	31.5	25.0	37.0	31.5	36.5	37.0
1909	40.5	40.0	42.5	36.5	32.0	40.8	28.5	21.5	36.8	32.5	26.5	38.5	32.5	38.5	37.8
1911	44.0	44.3	45.5	38.5	35.0	43.8	30.5	23.3	39.5	35.5	29.8	41.3	35.0	41.8	40.3
1913	46.0	48.5	48.0	42.5	37.0	47.5	32.0	25.0	43.0	37.5	32.0	43.3	36.0	42.5	44.0
1914	48.0	49.5	49.3	44.5	38.5	49.8	33.8	26.0	44.3	38.8	33.8	44.8	36.8	44.5	46.0
1915	49.3	52.3	51.3	46.8	40.0	51.3	36.0	27.5	46.5	40.0	35.8	46.0	38.3	45.0	47.5
1916	52.3	55.5	54.0	49.5	42.0	54.0	37.5	29.3	49.5	42.0	37.5	48.0	39.8	47.3	50.0
1917	52.5	55.5	54.0	50.0	42.3	55.0	38.3	30.3	49.8	42.3	38.0	48.0	40.0	47.5	50.0
1919	56.0	59.5	57.8	54.3	46.8	57.5	40.5	32.8	53.0	43.0	40.5	49.5	42.0	50.0	53.0
1920	57.5	59.8	58.5	55.5	45.8	58.3	41.3	33.5	53.5	44.0	41.5	50.8	43.0	51.5	54.5

Roxbury Russet.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
1902[1]	Av. 23.2			Av. 22.3			Av. 20.0			Av. 23.3			Av. 23.8		
1903[1]	Av. 24.0			Av. 23.0			Av. 20.4			Av. 24.0			Av. 24.8		
1904[1]	Av. 26.8			Av. 25.0			Av. 22.6			Av. 26.4			Av. 26.9		
1907	30.0	29.5	30.0	27.5	28.5	27.0	21.0	26.0	24.0	28.8	33.5	23.3	30.5	29.5	28.0
1908	32.0	31.5	30.5	28.5	29.5	28.3	22.0	27.5	25.5	30.0	35.0	23.3	32.0	30.8	29.8
1909	32.8	32.8	32.8	29.8	30.5	29.3	22.5	28.5	26.8	31.0	36.3	[2]	33.0	31.8	30.5
1911	35.0	36.0	37.0	32.5	32.8	32.0	24.5	31.3	29.0	34.8	40.0		35.5	34.0	33.5
1913	37.8	38.8	39.5	34.5	34.5	33.0	25.5	33.0	31.0	36.5	41.3		37.0	36.0	35.0
1914	39.3	40.3	40.5	35.8	35.5	34.0	28.8	33.5	31.8	37.8	45.3		38.0	37.3	36.0
1915	40.5	41.3	41.5	37.0	37.0	36.0	28.0	34.5	32.5	39.5	43.8		39.8	38.5	37.5
1916	42.5	43.0	44.0	38.5	38.8	37.5	28.8	36.3	33.3	40.5	45.0		40.5	39.8	39.0
1917	42.5	43.0	45.0	38.5	38.8	37.5	29.0	36.3	33.5	40.5	45.0		40.8	40.0	39.0
1919	45.5	45.3	47.5	40.5	40.3	39.0	30.3	37.3	35.0	42.3	46.0		42.8	42.3	40.5
1920	47.3	46.8	48.5	[2]	41.0	39.8	31.0	37.8	36.0	43.3	47.8		43.8	43.3	41.8

[1] Measurements of individual trees for these years not available. [2] Tree died.

TABLE I. — *Station Orchard: Tree Circumferences (Inches)* — Concluded.

Baldwin.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 27.7			Av. 22.3			Av. 18.2			Av. 19.3			Av. 29.8		
1903[1]	Av. 29.1			Av. 23.3			Av. 19.0			Av. 20.3			Av. 31.2		
1904[1]	Av. 32.5			Av. 25.9			Av. 21.4			Av. 23.1			Av. 34.3		
1907	36.5	36.0	34.0	28.8	25.5	31.3	24.8	23.5	19.8	21.5	30.0	23.5	38.0	33.0	40.3
1908	39.5	39.0	36.0	30.0	27.5	32.8	25.5	25.5	21.0	23.0	32.0	25.3	40.0	31.5	42.8
1909	40.5	40.0	36.5	31.0	28.3	34.0	26.0	26.5	23.0	24.0	33.3	26.3	41.8	35.5	44.0
1911	44.0	41.8	41.0	33.0	31.3	36.0	28.0	29.0	23.8	27.8	36.5	28.5	45.3	38.0	47.5
1913	47.0	47.3	41.0	35.5	31.0	39.0	29.5	34.0	24.0	28.5	39.0	30.8	48.8	39.5	51.0
1914	48.0	48.5	42.3	37.0	35.3	40.0	30.8	35.5	[2]	29.8	40.0	32.0	50.5	41.0	52.0
1915	49.5	50.0	43.3	38.5	37.0	41.5	32.3	38.0		31.0	42.0	33.5	52.0	42.8	53.5
1916	51.5	52.5	45.0	40.0	39.0	43.0	33.5	40.3		32.5	43.5	35.3	53.5	43.3	55.5
1917	52.5	53.3	45.3	40.5	39.5	43.0	33.8	41.0		32.8	44.3	36.0	54.0	43.5	55.8
1919	54.8	56.5	47.0	42.3	41.5	44.5	35.5	44.0		34.8	46.3	37.5	56.0	44.8	58.0
1920	56.8	58.3	48.0	43.3	42.5	45.5	36.5	46.0		35.3	47.5	38.5	56.8	46.0	60.0

Gravenstein.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
1902[1]	Av. 29.5			Av. 25.3			Av. 24.0			Av. 24.8			Av. 28.5		
1903[1]	Av. 31.0			Av. 26.3			Av. 24.5			Av. 25.9			Av. 28.5		
1904[1]	Av. 33.8			Av. 29.4			Av. 28.0			Av. 30.1			Av. 32.6		
1907	36.0	40.0	2.5	30.3	32.5	34.0	26.0	29.0	31.8	31.0	35.0	30.5	33.0	37.8	35.5
1908	39.3	42.0	3.5	32.0	34.0	35.8	27.0	30.8	34.0	32.5	37.5	32.3	35.0	39.5	37.3
1909	40.5	42.0	3.5	33.5	35.8	37.5	28.5	32.0	35.3	34.3	39.5	33.0	36.8	42.0	40.3
1911	43.8	46.3	7.0	36.0	38.5	40.3	30.5	34.5	37.3	37.5	43.5	36.0	40.3	43.8	43.0
1913	47.5	49.5	12.0	39.5	42.5	43.0	31.0	37.8	43.0	39.5	47.0	37.5	41.8	48.5	45.0
1914	48.0	52.5	12.0	41.0	43.8	44.3	35.3	39.3	44.8	41.5	48.0	38.5	43.5	50.3	46.8
1915	49.0	53.5	[2]	43.0	45.5	45.8	37.5	41.5	47.0	43.0	50.0	40.0	44.8	52.0	48.5
1916	50.5	56.5		45.0	47.8	47.5	39.0	43.0	50.0	45.0	52.3	41.3	46.0	54.0	50.5
1917	50.5	60.0		45.8	48.0	47.8	39.3	44.0	51.0	45.3	52.5	41.5	46.0	54.8	51.0
1919	50.0	64.0		48.0	50.3	50.0	42.0	46.8	54.5	47.3	55.5	44.3	48.5	59.0	53.3
1920	[2]	66.5		49.3	51.3	51.0	43.3	48.8	55.5	48.8	57.0	45.3	49.5	61.0	55.5

[1] Measurements of individual trees for these years not available. [2] Tree died.

TABLE II. — *Station Orchard: Total Yields by Plots (Pounds).*

Rhode Island Greening.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	270	45	41	130	85	571
1902	777	272	65	521	260	1,895
1903	970	891	394	435	945	3,635
1904	972	139	34	566	297	2,068
1905	596	168	101	338	79	1,282
1906	274	39	27	419	52	811
1907	1,496	973	226	760	798	4,253
1908	948	232	85	328	270	1,863
1909	2,157	1,165	140	604	1,087	5,153
1910	806	334	84	146	101	1,471
1911	1,777	1,162	274	815	1,117	5,145
1912	864	922	811	1,220	747	4,564
1913	1,546	2,196	718	1,354	2,111	7,925
1914	325	194	93	259	189	1,060
1915	2,859	2,467	1,109	2,271	2,240	10,946
1916	761	338	378	188	210	1,875
1917	3,370	2,820	1,191	1,846	1,813	11,040
1918	123	226	135	124	76	684
1919	3,150	2,389	1,097	1,529	1,055	9,220
1920	3,991	2,758	1,812	1,580	1,440	11,581

TABLE II. — *Station Orchard: Total Yields by Plots (Pounds)* — Concluded.

Roxbury Russet.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	269	119	39	251	291	969
1902	874	631	269	1,235	1,023	4,032
1903	703	567	330	608	1,067	3,275
1904	391	384	5	396	410	1,586
1905	548	206	165	621	769	2,300
1906	128	61	8	26	68	291
1907	1,361	1,295	313	903	1,389	5,261
1908	328	78	71	270	232	979
1909	1,719	547	90	991	1,172	4,519
1910	372	403	331	149	135	1,390
1911	1,139	639	31	560	828	3,197
1912	1,055	703	466	1,043	914	4,181
1913	1,963	1,128	754	1,629	2,390	7,864
1914	161	447	57	329	458	1,452
1915	2,398	1,984	400	1,311	2,066	8,159
1916	566	535	293	821	595	2,810
1917	1,942	1,455	345	802	1,045	5,589
1918	9	39	453	209	25	735
1919	2,839	922	1,057	722	753	6,293
1920	1,190	407	729	98	151	2,575

Baldwin.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	151	43	3	46	475	718
1902	43	207	0	114	548	912
1903	1,043	705	55	228	1,400	3,431
1904	231	18	51	98	577	975
1905	1,024	277	43	165	474	1,983
1906	4	128	33	26	634	825
1907	1,718	1,102	189	561	2,514	6,084
1908	110	106	88	25	280	609
1909	2,590	695	132	682	2,443	6,542
1910	41	469	8	22	121	661
1911	1,213	405	133	392	1,470	3,613
1912	683	1,264	205	537	1,176	3,865
1913	2,546	655	663	514	2,017	6,395
1914	371	820	36	690	765	2,682
1915	2,425	1,381	354	637	2,389	7,186
1916	333	910	99	479	1,178	2,999
1917	2,125	1,145	412	695	1,694	6,071
1918	315	1,046	261	528	480	2,630
1919	3,430	2,040	1,425	1,148	2,835	10,878
1920	625	964	60	6	82	1,737

Gravenstein.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	75	15	27	51	43	211
1902	196	3	65	91	57	412
1903	884	531	110	518	347	2,390
1904	44	10	22	84	103	263
1905	225	231	201	614	365	1,636
1906[1]	–	–	–	–	–	–
1907	775	482	162	572	709	2,700
1908	265	347	189	431	184	1,416
1909	1,180	284	224	1,217	1,192	4,097
1910	50	514	199	41	27	831
1911	612	282	291	793	1,008	2,986
1912	24	402	377	25	50	878
1913	1,922	976	897	2,736	1,474	8,005
1914[1]	–	–	–	–	–	–
1915	694	1,472	778	1,685	1,149	5,778
1916	16	199	79	54	50	398
1917	479	1,475	1,223	1,432	1,036	5,645
1918	37	53	209	26	39	364
1919	370	1,054	979	912	1,012	4,327
1920	297	224	747	305	365	1,938

[1] No crop.

TABLE III. — *Graves Orchard: Trunk Circumferences of Individual Trees (Inches).*

	Plot 1.		Plot 2.		Plot 3.		Plot 4.		Plot 5.		Plot 6.		Plot 7.		Plot 8.	
Row.	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1908		6.3	10.0	8.0	14.5	11.5	9.5	11.0	12.0	17.0		10.0	10.0			
1913		11.0	19.5	16.5	22.3	19.8	17.8	18.8	20.5	29.6		17.3	17.0			
1915		13.8	23.5	20.5	24.5	23.0	22.5	22.0	23.8	33.5		17.8	19.0			
1917		16.8	25.8	24.0	25.5	25.0	26.5	24.0	25.5	36.0		19.5	20.5			
1921			32.0	30.5	31.5	30.8	30.8	28.5	33.0	44.0		24.5	24.8			
1908	6.0	9.0	7.3	14.0	14.0											
1913	14.8	18.0	18.1	27.9	24.9											
1915	19.0	21.5	22.5	31.5	27.5											
1917	23.5	24.5	25.8	34.0	30.0											
1921	29.5	30.0	33.0	38.5	36.0											
1908	10.0		14.0	15.0		12.5	13.5	15.0	2.8		11.5	13.0	14.5			10.0
1913	20.5		28.3	29.1		22.8	30.0	29.4	9.0		22.6	19.8	24.4			17.5
1915	24.8		32.0	33.5		25.8	33.3	33.0	13.5		27.5	21.3	26.5			
1917	28.0		34.0	35.5		28.0	37.5	36.0	18.3		30.0	23.5	29.0			23.0
1921	31.8		39.0	41.3		33.5	42.3	41.8	24.5		37.0	28.3	32.3			29.8
1908			11.5	8.0	12.5	11.5	12.0	11.0		10.0	17.0	10.0	18.0	11.0	17.0	11.0
1913			24.0	18.3	25.9	19.3	21.5	18.8		20.8	27.4	17.8	27.1	19.8	32.5	22.0
1915			28.0	22.0	28.8	21.0	24.8	21.5		24.0	30.8	20.0	30.5	22.8	37.5	26.5
1917			31.0	25.0	31.0	23.0	27.5	23.5		27.0	34.0	22.8	33.0	25.0	40.0	30.5
1921			37.0	29.5	37.5	27.5	31.3	27.8		30.5	40.0	27.0	37.5	31.5	48.8	37.0
1908		13.0	11.5	14.5	14.5	11.5	15.0	13.5	13.0	10.5	15.5	18.0	16.0	17.0		11.0
1913		25.3	26.1	29.0	26.5	16.3	25.1	25.0	22.0	20.9	28.4	31.0	28.8	28.8		23.5
1915		30.0	30.5	31.8	29.5	17.5	29.0	29.8	25.8	25.0	32.0	33.3	31.8	32.0		27.8
1917		32.8	33.3	34.0	31.0	18.3	32.0	32.0	28.3	26.5	34.0	37.5	34.0	34.5		30.5
1921		39.8	38.0	39.8	37.8	20.5	37.8	37.5	32.0	31.5	40.3	42.8	40.5	40.0		38.3
1908	8.8	11.0	9.0	13.0	13.0	10.0	12.0	15.0		17.0	12.5	16.0	16.0		15.5	8.5
1913	18.0	24.0	19.4	23.8	25.5	15.5	20.0	24.6		31.0	21.4	28.5	27.8		27.0	13.5
1915	22.3	28.5	22.0	27.3	28.3	16.0	23.5	28.0		35.8	23.0	31.5	31.3		31.3	16.0
1917	25.5	32.0	24.3	28.3	31.5	17.8	24.8	30.0		38.8	25.0	35.5	33.0		35.5	18.5
1921	31.5	38.8	30.0	32.5	37.5	19.8	29.5	36.5		47.0	30.3	39.5	39.8		40.5	24.3
1908		11.0	12.0		13.5	12.0	15.0	14.5	14.0	17.5	17.0	15.5	13.5		13.5	13.5
1913		23.0	23.1		24.1	21.0	21.9	25.8	21.3	29.8	29.0	23.0	21.5		25.1	22.4
1915		28.3	26.8		29.0	23.5	24.0	29.5	24.5	34.0	31.8	24.8	23.3		30.5	25.0
1917		31.8	29.5		32.0	24.0	25.0	32.3	26.5	37.0	35.0	26.0	25.0		34.5	28.0
1921		37.5	35.0		38.3	30.0	28.8	38.0	31.3	42.0	39.8	31.0	27.8		39.5	34.3
1908			12.5	9.0	17.0	13.0	13.0	14.0	12.5	9.5	17.5	16.0	12.0	6.0	11.0	9.0
1913			22.3	17.8	28.0	23.6	23.5	23.8	21.0	17.3	30.5	26.5	19.5	8.9	24.1	18.6
1915			25.8	20.5	30.3	25.3	26.5	26.5	23.0	19.5	34.8	29.0	21.8	10.0	28.0	22.3
1917			28.0	23.5	31.0	27.0	28.5	29.0	24.5	21.0	37.3	31.8	23.8	10.8	31.0	26.0
1921			33.0	28.0		30.8	31.3	35.5	27.5	27.5	43.0	38.0	27.3		37.0	32.5
1908		13.0		13.5	14.0	13.0	13.0	14.5	15.0	16.0	12.0	17.0	14.5			12.0
1913		25.0		25.0	21.0	19.0	24.5	22.9	27.1	27.6	28.9	28.5	25.0			24.0
1915		29.8		29.5	23.0	20.5	28.8	25.8	32.0	30.5	32.3	32.5	29.0			28.5
1917		31.5		33.0	25.0	22.0	30.5	28.8	35.0	32.0	34.5	35.5	31.0			32.0
1921		37.3		39.8	29.3	24.8	36.5	34.0	41.3	38.0	39.5	41.8	36.0			38.8
1908		13.5	14.0		16.0	15.5	14.5		12.0	15.5	14.0	13.5	14.0	15.0	13.0	
1913		26.0	26.3		24.8	25.8	28.6		22.9	27.5	24.5	24.0	24.1	26.5	26.0	
1915		30.0	30.0		26.3	28.8	32.3		26.3	30.8	27.5	26.3	27.5	30.8	31.0	
1917		33.5	33.5		28.0	31.0	34.5		28.5	33.5	30.0	29.5	29.5	33.5	34.0	
1921		38.5	39.0		33.8	36.5	41.3		35.3	38.5	35.0	34.5	34.8	39.8	39.3	
1908	12.5	12.5	17.0	15.0	10.0	14.0	10.5	16.0	16.0	11.0	15.5	15.0	17.5			
1913	25.5	25.0	30.5	29.0	21.0	24.6	21.0	28.0	28.9	22.5	24.4	27.1	29.8			
1915	30.5	28.5	34.3	33.5	23.5	27.3	24.8	32.3	32.0	25.5	27.0	31.0	33.5			
1917	33.5	28.5	37.0	36.5	25.3	30.0	27.0	36.0	35.0	27.0	29.3	34.5	36.0			
1921	39.3	33.0	42.0	41.5	30.3	35.5	31.3	40.5	41.0	31.5	34.0	38.8	40.8			
1908	10.5	13.0	16.5	14.0	13.5	14.5	13.5	14.0	14.0	16.0	14.0	15.5	17.5	13.0	8.0	
1913	22.8	26.3	30.9	25.0	24.8	24.1	26.0	25.1	23.3	27.0	26.3	26.8	29.5	26.5	19.0	
1915	29.5	31.0	36.0	28.8	28.8	27.0	30.5	28.8	26.5	30.3	29.5	30.5	32.8	31.3	22.8	
1917	30.5	34.8	39.0	31.0	32.0	29.5	33.0	32.0	28.0	31.5	32.0	33.0	35.0	34.0	26.3	
1921	37.0	39.8	44.5	37.0	37.3	35.5	38.0	37.5	32.8	38.0	37.5	39.0	39.8	40.0	32.5	

TABLE III. — *Graves Orchard: Trunk Circumferences of Individual Trees (Inches)* — Concluded.

	PLOT 1.		PLOT 2.		PLOT 3.		PLOT 4.		PLOT 5.		PLOT 6.		PLOT 7.		PLOT 8.	
Row.	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1908	8.5	12.0	14.0	11.5	16.5	11.5	10.0	14.0	15.0	17.5	13.0	15.0	14.5			
1913	21.3	20.8	25.5	23.5	29.8	20.0	21.0	26.5	25.9	29.0	23.0	27.3	27.6			
1915	25.5	23.3	29.5	27.0	33.8	22.8	24.8	30.0	30.0	33.0	25.5	30.8	31.0			
1917	28.0	25.0	31.5	30.0	36.0	23.5	27.8	32.5	33.0	35.3	27.5	34.0	34.5			
1921	31.0	29.5	35.8	36.8	41.3	30.5	32.0	36.0	39.0	40.5	31.8	38.5	39.0			
1908	7.5	12.0	14.0		15.5	12.0	13.0	16.0	15.0	11.0	12.5	14.0	14.0			
1913	19.0	21.8	26.5		25.5	19.0	21.0	24.5	23.5	16.5	20.4	21.8	24.0			
1915	19.5	24.3	29.8		28.8	20.8	23.8	28.8	26.5	17.8	23.0	24.0	25.8			
1917	22.0	26.0	32.5		30.8	23.0	25.5	31.3	28.8	18.5	25.0	26.0	28.5			
1921	28.5	32.0	38.0		37.8	26.5	29.0	35.8	33.5	23.5	30.0	31.5	35.5			
1908			11.0	15.0	15.0	14.0	14.0		14.5	11.0	10.0	15.5	16.0			
1913			16.8	25.5	21.6	20.5	22.9		21.0	20.4	17.0	21.5	24.0			
1915			18.0	27.8	23.3	23.3	25.0		22.5	22.5	20.0	23.0	26.3			
1917			19.5	29.3	24.3	29.0	28.0		24.3	26.0	22.0	23.0	28.0			
1921			25.0	33.3	32.0	32.0	32.0		28.0	31.5	28.3	31.3	35.8			
1908		8.5	10.0	14.0	13.5	14.0	16.0	9.0	11.0	11.5		13.0	11.0			
1913		15.0	19.4	22.5	21.0	19.0	24.6	14.8	17.9	15.6		19.5	16.9			
1915		17.3	22.5	25.0	22.3	20.5	26.0	16.5	19.5	19.8		22.3	20.3			
1917		20.5	25.5	27.0	25.0	21.5	27.8	19.5	21.5	18.0		25.0	22.5			
1921		28.5	32.5	32.5	31.3	28.0	31.5	25.8	27.5			32.0	29.8			
1908	5.0				12.0	15.0	12.5	13.5	12.0							
1913	12.3				18.5	21.6	18.8	22.1	15.0							
1915	15.5				20.3	22.3	19.8	25.5	18.3							
1917	19.3				22.0	24.5	22.0	28.0	20.8							
1921	27.8				29.3	28.3	27.0	35.8	28.8							
1908		11.0	13.5	15.0	14.5											
1913		23.3	23.9	24.0	20.0											
1915		26.3	26.8	27.5	19.5											
1917		30.3	29.5	30.5	20.5											
1921		36.8	38.5	39.0	25.8											
1908	9.0															
1913	17.8															
1915	21.5															
1917	26.0															
1921	32.5															

TABLE IV. — *Graves Orchard: Yield of Baldwin Trees (Pounds).*

PLOT.	ROW.	Number of Trees.	1911.	1912.	1914.	1915.	1916.	1917.
1	1	9			1,215	1,114	3,040	1,056
	2	13			1,357	3,817	4,191	2,433
	Total	22	2,023	326				
2	1	16			4,000	3,866	5,780	2,736
	2	14			2,331	2,773	3,719	1,269
	Total	30	6,519	1,307				
3	1	17			2,380	3,993	2,294	4,549
	2	16			964	2,199	1,069	2,806
	Total	33	7,734	2,216				
4	1	16			801	6,154	3,230	4,569
	2	14			1,175	5,560	3,154	3,484
	Total	30	6,540	1,125				
5	1	14			3,410	2,237	4,796	1,121
	2	14			5,944	3,706	4,922	2,827
	Total	28	3,179	1,642				
6	1	13			6,073	1,974	4,886	2,294
	2	15			5,648	3,475	4,413	3,059
	Total	28	7,040	1,625				
7	1	15			5,697	4,076	3,183	1,624
	2	5			1,070	1,125	827	1,561
	Total	20	5,581	907				
8	1	6			3,213	1,230	3,868	1,114
	2	7			1,130	1,052	1,164	1,766
	Total	13	2,124	146				

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 210 AUGUST, 1922

INJURY TO FOLIAGE BY ARSENICAL SPRAYS

II. CALCIUM ARSENATES AND ARSENITES

III. NOTES ON OTHER ARSENICALS

By H. T. FERNALD and A. I. BOURNE

This bulletin supplements the report on foliage injury from arsenical sprays recently published as Bulletin No. 207. Of the materials here treated, calcium arsenate is the only one which can be used with safety, and this has proved less satisfactory than the lead arsenates.

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CONTENTS.

BULLETIN No. 210.

DEPARTMENT OF ENTOMOLOGY.

INJURY TO FOLIAGE BY ARSENICAL SPRAYS.

II. CALCIUM ARSENATES AND ARSENITES.
III. NOTES ON OTHER ARSENICALS.

BY H. T. FERNALD AND A. I. BOURNE.

In Bulletin No. 207 of this station the effects of lead arsenate sprays on foliage were discussed. In a similar way this bulletin gives the results of studies with calcium arsenates and arsenites, and the factors which appear to cause foliage injury following their use, together with notes on other arsenicals.

As in the case of the lead arsenates, the chemical work was done under the supervision of Dr. E. B. Holland of the Department of Plant and Animal Chemistry of the Experiment Station, and the applications of the materials and studies of the results were made by the Department of Entomology. All the statements made in Bulletin No. 207 with reference to responsibility for the various parts of the work, methods of application, and adequacy of methods, apply also to this part of the investigation.

II. CALCIUM ARSENATES AND ARSENITES.

Materials.

Pure Acid Calcium Arsenate. — To obtain pure calcium arsenate from manufacturers proved impossible, and a quantity of this substance was finally prepared by the Department of Plant and Animal Chemistry of this station. It was the acid arsenate ($CaHAsO_4 . H_2O$) and was a white powder consisting of rhombic crystals varying in size and with about 1 per cent of them broken. Analyzed, it gave the following: —

	Air Dry.	Dried.
Water	.120	–
Calcium oxide, CaO	28.300	28.334
Arsenic pentoxide, As_2O_5	57.955	58.025
Water of combination	13.630	13.646
	100.005	100.005

The powder, therefore, was a practically pure acid calcium arsenate. This substance proved very soluble on standing twenty-four hours, 44.82 per cent of the arsenic pentoxide entering into solution. The addition of milk of lime to the material was therefore tried, and after 1 per cent of this had been added, the amount dissolved was only .17 per cent. As finally used, the spray was accordingly prepared as follows: —

Four pounds of quicklime were slaked in about 40 gallons of water, just enough water being added at a time to maintain a brisk action without "drowning" the lime. After the slaking was completed, enough more water to make 50 gallons in all was added. Eighty-five hundredths of a pound of the arsenate was then mixed in, this being the amount calculated as necessary to give the spray the same strength of arsenic pentoxide as that of the lead arsenate sprays, in order to make the tests comparative. The material was strained into the spray pump and kept well agitated.

Commercial Calcium Arsenate. — This was a bulky, white powder consisting of minute spherical particles. It was purchased in the market, and on analysis proved not to be similar to the pure material considered above, but a combination of calcium and arsenic acid, with a considerable excess of lime. It might, perhaps, be fairly described as a basic lime arsenate. Its analysis gave —

	Per Cent.
Water, H_2O	1.38
Water in combination and occluded	2.92
Ferric and aluminum oxides	1.30
Calcium oxide, CaO	45.47
Magnesium oxide, MgO	.68
Sodium oxide, Na_2O	1.09
Arsenic pentoxide, As_2O_5	46.61
Sulfur trioxide, SO_3	.18
Chlorine, Cl	.02
Soluble silica, SiO_2	.16
Acid insoluble matter	.13
	99.94

This was not a pure material, but the impurities were not of such a nature nor present in such amounts as to be likely to cause injury to foliage.

Tests of the solubility of this material gave only a trace of arsenic pentoxide as dissolving after twenty-four hours' treatment with water. In order to make a direct comparison of this substance with the pure acid salt, milk of lime was added as described above, and 1.14 pounds of the arsenate were used for each 50 gallons of spray, this amount providing enough arsenic pentoxide to equal that used in the other tests.

Calcium Metarsenite. — Two samples of this material (both pastes) were tested, having been received from manufacturing companies. Their analyses follow: —

I.

	Per Cent.
Water, H_2O	67.87
Calcium oxide, CaO	6.78
Arsenic trioxide, As_2O_3	23.87
Arsenic pentoxide, As_2O_5	.09
Magnesium oxide, MgO	.05
Sodium oxide, Na_2O (estimated)	.70
Chlorine, Cl	.80
Insoluble matter	.01
	100.17

The original composition of this material was probably about as follows: —

	Per Cent.
Water, H_2O	67.87
Calcium ortho arsenate, $Ca_3(AsO_4)_2$	.18
Calcium metarsenite, $Ca(AsO_2)_2$	30.31
Magnesium metarsenite, $Mg(AsO_2)_2$	.30
Sodium chloride, $NaCl$	1.32
Insoluble matter	.01
	99.99

This substance gave 11.58 per cent of soluble arsenic trioxide on standing in water for twenty-four hours, showing at once its dangerous nature when applied to foliage. When mixed with milk of lime, however, the amount soluble was greatly reduced, but even then safety could not be obtained with any certainty.

II.

	Per Cent.
Water, H_2O	79.03
Arsenic trioxide, As_2O_3	16.20
Arsenic pentoxide, As_2O_5	.03
Calcium oxide, CaO	4.51
Magnesium oxide, MgO	.05
Sodium oxide, Na_2O (estimated)	.07
Chlorine, Cl	.03
Organic matter, etc.	.08
Insoluble matter	.01
	100.01

The original composition of this material was probably substantially as follows: —

	Per Cent.
Water, H_2O	79.03
Calcium ortho arsenate, $Ca_3(AsO_4)_2$	.06
Calcium metarsenite, $Ca(AsO_2)_2$	20.34
Magnesium metarsenite, $Mg\ (AsO_2)_2$	.30
Sodium arsenite, $NaAsO_2$	.13
Sodium chloride, NaCl	.05
Organic matter, etc.	.08
Insoluble matter	.01
	100.00

The arsenic in this material, also, proved so soluble on standing in water as to make it unsafe for application to foliage. It was tested both in water alone and with the addition of various percentages of milk of lime. With both samples, enough was taken to give the standard amount of arsenic, so that the treatments should be comparable with those made with the lead arsenates and lime arsenates.

Experimental Work.

The materials described above were sprayed upon the apple, cherry, peach, pear, plum and elm, under the same conditions as given in Bulletin No. 207, and the results obtained follow.

Pure Acid Calcium Arsenate with 1 Per Cent Milk of Lime. — The apple, sprayed with this material in clear weather, shows injury above the safety line (Fig. 1, AB), from high temperature with low humidity to low temperature with high humidity. The line for the greater part of its course runs lower than the safety line for lead arsenates, though at the high humidity end the reverse is true to a slight degree. As the general safety line for the apple is much below most of those given in clear weather, the difference is more marked by comparing any of the clear weather lead arsenate safety lines in Bulletin No. 207 with Fig. 1, than when the general one is used. The evidence is that pure acid calcium arsenate with 1 per cent milk of lime cannot be used on the apple at as high temperatures and humidities as the lead arsenates in clear weather. This is true, also, for cloudy weather, though the difference is not so great.

On the pear, clear-weather tests gave six cases of injury above the safety line (Fig. 2, AB), which runs considerably higher than in the case of the apple. In the cloudy weather tests (Fig. 2, CD), as was the case with the lead arsenates, the pear is evidently much more resistant to spray injury than the apple.

In the case of the cherry (Fig. 3), the leaves are more liable to injury than the apple, but less so than the plum. The cloudy weather safety lines for the cherry and plum (Figs. 3 and 4, CD) are very nearly the same, however. With the plum, temperature seems to play an important part, injury beginning in clear weather at quite a low point, while high humidity seems to be less dangerous (Fig. 4, AB).

SAFETY LINES FOR SPRAYING WITH PURE ACID CALCIUM ARSENATE.
AB, clear weather; CD, cloudy weather.

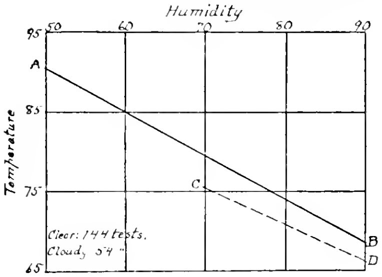

FIG. 1. — Apple.

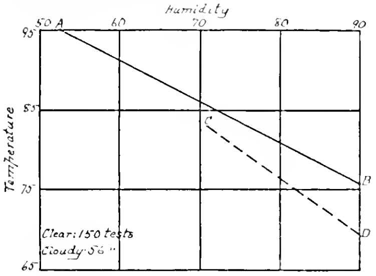

FIG. 2. — Pear.

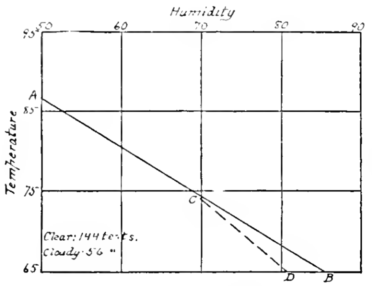

FIG. 3. — Cherry.

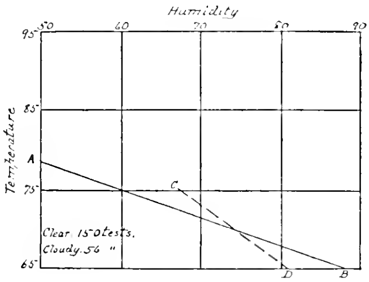

FIG. 4. — Plum.

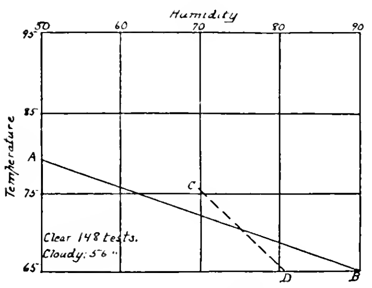

FIG. 5. — Peach.

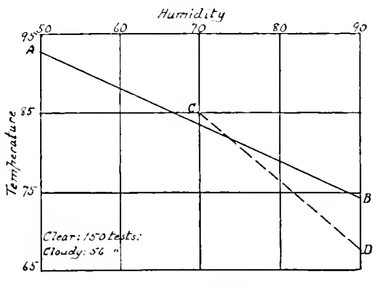

FIG. 6. — Elm.

The peach (Fig. 5) quite closely follows the plum in its resistance to calcium arsenate, and the two figures (4 and 5) show no more difference than might perhaps easily disappear could a greater number of tests have been made.

The elm (Fig. 6) is evidently less resistant to pure acid calcium arsenate than the pear, as eleven cases of injury were obtained above the safety line AB of the figure, in clear-weather tests, and the line itself runs considerably lower than that for the pear. In cloudy weather the elm also appears to be more easily injured at high humidities, even if the temperature is low.

Commercial Calcium Arsenate with 1 Per Cent Milk of Lime. — On the apple (Fig. 7) this material gives results differing little from those obtained with the pure acid calcium arsenate described above. The cloudy weather tests suggest a little greater safety with the commercial material at medium combinations of temperature and humidity, but the rather small number of tests obtained makes this difference less significant than if similar results had been shown by a larger number.

In the case of the pear (Fig. 8) no injury was obtained following any of the tests, and AB is simply placed along the highest tests obtained. Whether higher combinations of temperature and humidity would have shown injury could they have been obtained, is, of course, unknown. The cloudy weather safety line CD is more satisfactorily located, three cases of injury having shown that the line could not be placed higher.

Tests of the cherry (Fig. 9) give in general an agreement between the two materials (compare Figs. 3 and 9), though the commercial substances seem, as in the case of the apple, to be a little safer at medium combinations of temperature and humidity.

With the plum (Fig. 10) it would seem that the commercial material can be used with safety at a considerably higher temperature than the pure when the humidity is low (86° as compared with 79° at 50° humidity). Aside from this, nothing of significance appears on comparing Figs. 4 and 10.

On the peach (Fig. 11) the two materials give almost identical results (compare Figs. 5 and 11). On the elm (Fig. 12) the commercial article appears to be safer in clear weather than the pure substance (compare Figs. 6 and 12), although one doubtful injury at 85° humidity suggests that the point B on Fig. 12 may be too high.

Comparison of the safety lines obtained on the different kinds of foliage tested with commercial calcium arsenate in clear weather brings out several points of interest. The elm (Fig. 13, 2) would at first seem to be more resistant than the pear (1), particularly at high T and low H. It should be remembered, however, that line 1 was located along the highest tests obtained, no injury showing up to that line, and no tests being available above it. It is not improbable that this line could go considerably higher than where it is now located. The cherry (4) is more resistant than the plum (5) at high T, but slightly the reverse holds at high H, and both,

SAFETY LINES FOR SPRAYING WITH COMMERCIAL CALCIUM ARSENATE.

AB, clear weather; CD, cloudy weather.

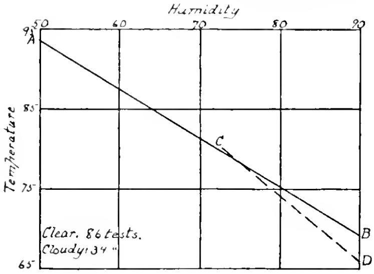

FIG. 7. — Apple.

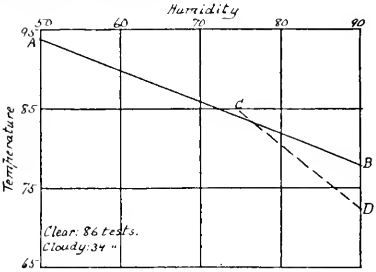

FIG. 8. — Pear.

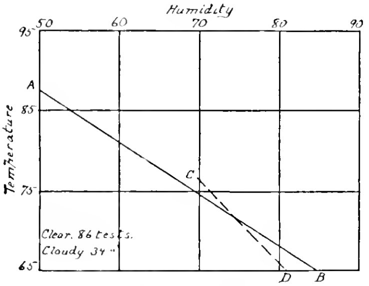

FIG. 9. — Cherry.

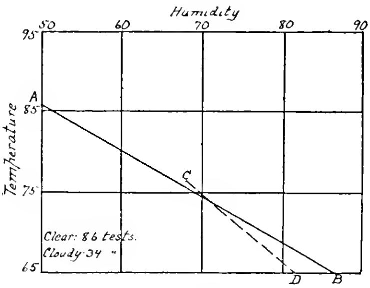

FIG. 10. — Plum.

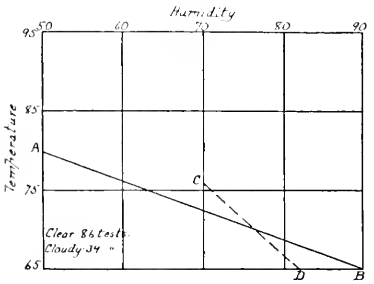

FIG. 11. — Peach.

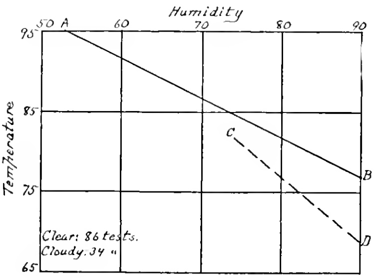

FIG. 12. — Elm.

at this end of the figure, are less resistant than the peach (6), though at high T the latter is considerably less resistant than the other two.

In cloudy weather (Fig. 14) the pear, elm and apple show about the relative relations to each other that would be expected from the studies on lead arsenates, while the cherry, plum and peach are almost identical for the high H limit of safety, and nearly so at the other ends of their safety lines. Such differences as they do show might easily disappear were more tests available, though, on the other hand, such tests might have led to greater differences.

Finally, it is evident that there is a wide difference in the safety lines, and that the spraying of different kinds of trees cannot always be done with safety on the same day. It may be perfectly safe to spray apples on a day when spraying plums, peaches or even cherries might prove disastrous.

Calcium Metarsenite. — The two samples of this substance described above, produced injury on the foliage of all the kinds of trees tested, within two or three days after the application, the injury increasing until the leaves were practically destroyed and dropped off. Though the addition of milk of lime appeared to bring down the solubility of the arsenic within reasonable safety limits in laboratory tests, this did not appear to hold under field conditions, even when the milk of lime was increased to 3 per cent, so further investigation of this material was given up.

III. NOTES ON OTHER ARSENICALS.

Magnesium Arsenate. — This substance, sent in by an insecticide manufacturing company for trial, was tested on the same basis as the other materials. Two hundred and eight clear-weather tests were made at temperatures and humidities ranging from T92 H54 through T86 H70 and T80 H80 to T77 H81, for the high limits, and as low as T78 H55 and T67.5 H 69. In every case, no matter how low T and H were, injury developed on all the trees except the pear and one or two tests on the elm. Apparently, spraying with magnesium arsenate is unsafe at almost any combinations of T and H, except on the pear, where the higher combinations become unsafe, and possibly on the elm, where at low combinations only traces of injury were evident.

In cloudy weather 108 tests were made at combinations of T and H as low as T73 H76 and T67 H72, and as high as T82 H74, T78 H84 and T68 H90. In every test injury, often very serious, followed, except in two instances on the pear.

As a general conclusion from these tests, therefore, magnesium arsenate is not a safe material for spraying under any conditions.

Zinc Arsenite. — Two samples of this material, received from different manufacturers, were tested in 1913. Both were finely divided, bulky powders, light and "fluffy." They were applied, at the rates of 1 pound and $1\frac{1}{2}$ pounds in 50 gallons of water, to the same kinds of trees as were

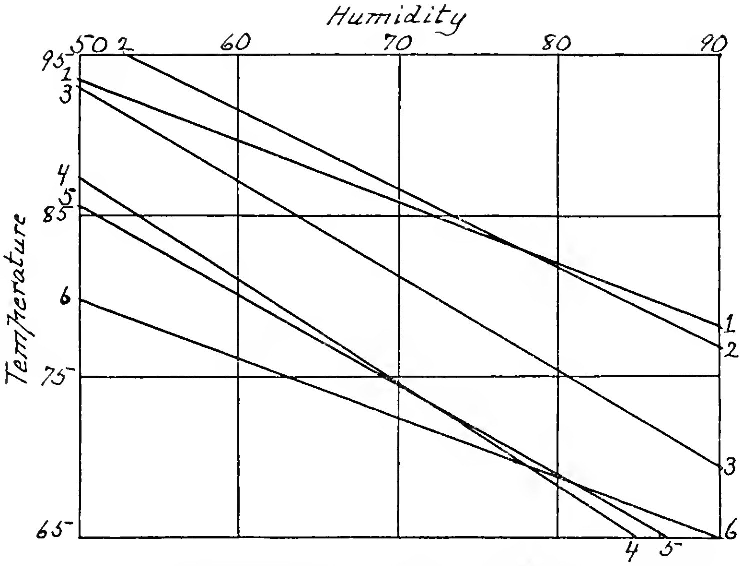

FIG. 13. — Safety lines for spraying with commercial calcium arsenate in clear weather: 1, pear; 2, elm; 3, apple; 4, cherry; 5, plum; 6, peach.

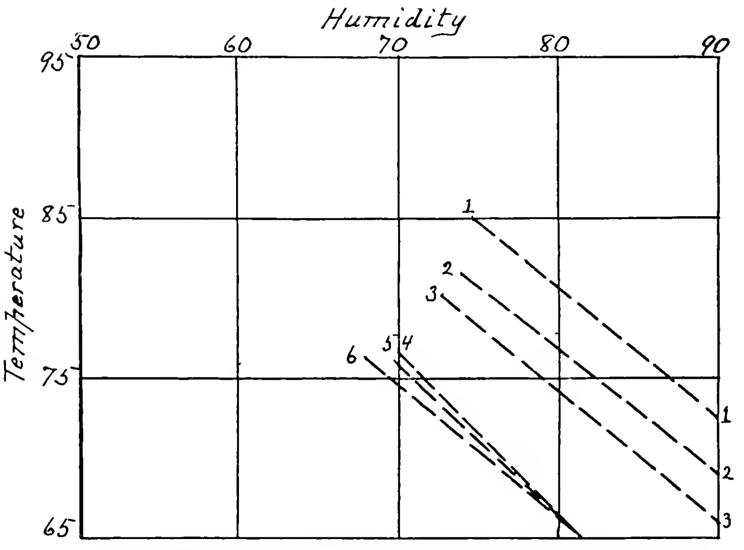

FIG. 14. — Safety lines for spraying with commercial calcium arsenate in cloudy weather: 1, pear; 2, elm; 3, apple; 4, cherry; 5, peach; 6, plum.

used for the other tests, and in every case injury followed, generally severe. Clear or cloudy weather seemed to give little difference in the results, and spraying at low T and H combinations produced injury as certainly as with high combinations of these factors. Extensive tests of zinc arsenite, therefore, were not continued.

SUMMARY.

1. Pure acid calcium arsenate is not on the market. Tests with it indicate in a general way that the same factors determining injury to foliage hold good as with the lead arsenates, but that the safety lines run lower.

2. With commercial calcium arsenate the safety lines run about as high (in some cases a little higher) as with the pure material, but lower than with the lead arsenates. In the case of the peach, however, the safety line does not differ greatly from that obtained with the lead arsenate powder.

3. It is possible that the excess of lime in the commercial calcium arsenate may be sufficient to prevent the arsenic pentoxide from entering into solution. Further tests are needed on this point, as considerable time and bother can be saved if the addition of milk of lime is unnecessary.

4. In general, lime arsenate does not give as satisfactory results as the lead arsenates, the range of T and H combinations at which it is safe being more limited.

5. The spraying of different kinds of trees with commercial calcium arsenate cannot always be done with safety on the same day. The treatment may be safe on some kinds of trees under conditions which make it dangerous to others.

6. Calcium metarsenite is not safe for use on fruit tree foliage.

7. The same is true for magnesium arsenate and zinc arsenite — at least for the samples tested.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 211 OCTOBER, 1922

CHANGES IN EGG PRODUCTION IN THE STATION FLOCK

By H. D. GOODALE AND RUBY SANBORN

The egg production of a flock of Rhode Island Reds was increased from an average of 114 eggs per bird annually in 1912–13 to 200 in the last year of record, 1920–21. This represents an increase of seven dozen eggs per bird resulting from the breeding methods followed. The pullets in the last flock commenced laying much younger than those in the earlier flocks, there being a difference of 55 days in age at first egg between the two extremes of record. The winter production per bird increased from 28 eggs in the earlier flock to 67 eggs in the last flock. This bulletin describes the breeding methods through which these marked changes in the egg-producing efficiency of the Rhode Island Red flock were secured.

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CONTENTS.

BULLETIN No. 211.

DEPARTMENT OF POULTRY HUSBANDRY.

CHANGES IN EGG PRODUCTION IN THE STATION FLOCK.

BY H. D. GOODALE AND RUBY SANBORN.

Introduction.

For the past eight years the work of the Massachusetts Agricultural Experiment Station with poultry has centered about the problem of breeding better layers. A certain measure of success has been reached. The present paper is a descriptive history of the work. The theory that is under test, the plan of procedure, the results secured to date, with such comment as seems to be required to prevent misinterpretation of the data, with such suggestions as can be offered to the breeder, are presented.

The Working Hypothesis.

The studies were begun in December, 1912. It was then supposed that the inheritance of fecundity was a simple two-factor Mendelian matter, but it was not long before it gradually became clear that, with Rhode Island Reds, the egg record made by a bird was the result of the combined action of a number of inheritable characteristics.

Simplifying matters as much as possible, five main characteristics may be recognized, namely: —

1. Maturity.
2. Rate (intensity).
3. Broodiness.
4. Point at which production ceases (persistency).
5. Winter pause.

Each component is very variable. Resulting egg records from combinations of these five variable characteristics are illustrated in Figs. 1 and 2. In Fig. 1 are used the two extremes only of each of the five components, which make 32 possible combinations, each illustrated by an actual

Fig. 1. — Typical Egg Records.

Illustrative of the part played by several factors in determining the number of eggs laid.

BAND NUMBER	FORMULA	DATE HATCHED	AGE AT FIRST EGG	NUMBER EGGS PER MONTH															365	
				SEP	OCT.	NOV.	DEC.	JAN	FEB.	MAR	APR	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DAYS	TOTAL
B 357	ENFCA	MAR 25	187	3	25	25	19	22	18	24	21	27	28	22	28	26	17		286	305
B 8324	ENFCQ	APR 4	192		10	19	23	19	18	24	21	23	23	25	23	10			238	238
B 8566	ENFPA	APR. 11	185		12	23	18	20	1	25	25	27	22	26	23	23	12		254	257
B 8355	ENFPQ	APR 4	177	3	20	22	26	4	16	18	21	26	25	22	25	6			232	232
B 8336	ENSCA	APR. 4	185		11	21	18	16	14	18	16	16	16	19	20	18	8		206	211
B 3033	ENSCQ	MAR. 31	193		15	10	14	15	16	19	17	20	12	9					147	147
B 24	ENSPA	MAR. 18	191	4	22	9	1	13	13	18	20	17	15	18	17	17	10		181	194
B 4440	ENSPQ	MAY 5	187			10	16	12	10	13	13	17	9		15	4			119	119
8490	EBFCA	APR. 30	170		13	26	29	25	20	21B	17	B12	B14	B14	B1	12	8		210	212
B 3245	EBFCQ	APR. 7	182		23	14B	25	B6	19B	18	B16B	14B	12B	13	10B				170	170
B 8008	EBFPA	MAR. 28	194		8	25	22	5	15	25	B15B	15B	15B	B7	B13	B9	B6	7	190	197
B 2885	EBFPQ	MAR. 31	182	1	27	18		17	21	22	25	25	B9	20B					185	185
8751	EBSCA	MAY 7	193			11	10B	17	B11	12B	16B	12B	12B	11	9	1B0	4		135	135
B 2185	EBSCQ	MAY 3	197			2	18	16	16	20	17	9B	10B	8	B3	13B			132	132
B 2907	EBSPA	MAR. 31	190		4		12	18	15	8	14	17B	21	19	B7	11	11		150	150
B 4512	EBSPQ	MAY 5	189			8	19		15	B11	B9	B1	B3	5B					81	81

B8080	LNFCA	MAR. 28	217		1	20	22	19	19	22	22	25	25	24	26	20	17		262	262
B9028	LNFCQ	APR. 25	221				23	22	15	22	22	26	24	23	14				191	191
B8105	LNFPA	MAR. 28	221			20	23	4	21	24	27	28	22	24	22	19	14		248	248
B9027	LNFPQ	APR. 25	217			2	6	25	21	26	27	29	22	24	14				196	196
B587	LNSCA	APR 1	248				17	17	15	15	17	17	1	16	1	18	10		144	144
8087	LNSCQ	APR. 9	217			8	19	15	13	14	10	12		6	2				99	99
B63	LNSPA	MAR. 18	203		14	19	5		7	10	16	19	15	19	20	16	2		162	162
B3089	LNSPQ	APR 7	292					1.	5	10	18	10	3						47	47
119	LBFCA	MAR 23	246			5	26	24	25	27	19^B	15^B	14	$^B13$	$^B14$	$^B14^B$	12		208	208
B4082	LBFCQ	APR. 28	240				5	24	24	24	$^B20$	$^B16$	$^B14$	$^B13$	$^B10$	$^B8$			158	158
7918	LBFPA	APR. 2	226			1	14	25	2	22	28	$^B15^B$	6^B	10^B	9	5	11		148	148
B2818	LBFPQ	MAR 31	234			8	17		11	28	25	25	24	13	20^B				171	171
803	LBSCA	APR. 27	228				14	15	14	15	11^B	9^B	7	$^B4$		6	10		105	105
8602	LBSCQ	APR. 30	227				13	17	17	13	15^B	16^B	13	B	19				123	123
7697	LBSPA	MAR. 19	268				6	19	3	12	16^B	$^B6$	$^B9$	9^B	17	4	8		119	119
8941	LBSPQ	MAY 14	254					4	3	19	12^B	6^B	7^B						51	51
B1209	LNS-Q	APR 22	274					1.	1.		. 1		.2		2	. 2			9	9
B1202		APR 22																	0	0

Legend: E, early (laid before 201 days of age); B, broody; F, fast (usually laid at the rate of more than 21 eggs per month); P, winter pause of ten or more days; A, persistent (continued production later than September 30); L, late (laid after 200 days of age); N, not broody; S, slow (usually laid less than 22 eggs per month); C, continuous (no winter pause); Q, quitter (stopped laying before October 1). Classification of broody birds in respect to rate is based on the non-broody months. For certain combinations it has not been possible to find records that fit the definitions closely in all respects. The horizontal lines indicate periods over which production extended; a pause of ten or more days is shown by a break in the line; B above the break indicates a broody pause. Under the heading Total is given the production for the biological laying year, which sometimes exceeds the 365-day year.

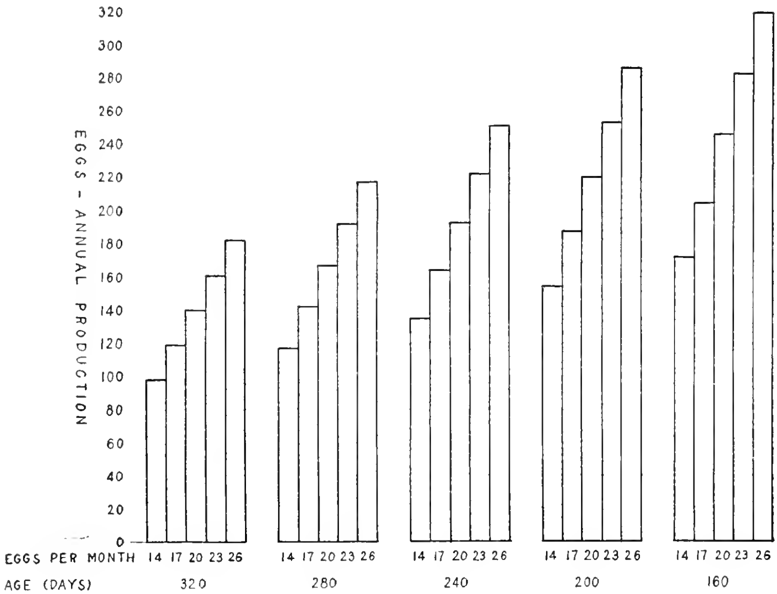

Fig. 2. — The Effect of Variation in Two Factors.

Five points of maturity and rate are chosen, and it is assumed that each bird was hatched April 15, was non-broody, was without winter pause and stopped laying September 30.

record. Fig. 2 was made by choosing five points of the first and second characteristics (maturity and rate), assuming that the other three remain unchanged, and showing by artificial records what would be the resulting yearly production. If all the variations of all the characteristics were combined in all possible ways, the number of different egg records secured would be in the thousands.[1] Environment is also responsible for much variation in production.

If the records of the highest producing hens are examined, it is to be noted that they begin early in life (and also fairly early in the season) and continue at a steady and relatively high rate throughout the twelve months. Examined from the negative standpoint, it is noticed that there are no broody pauses, no winter pause, no delay in beginning production, no early cessation of production, no slow rate while laying. A record at the low end of the series is zero, but one only shortly removed shows late maturity, early cessation and slow rate. The problem of the breeder, then, is to devise a method of eliminating the undesirable characteristics from the flock and of securing fairly uniform high production.

[1] It is a point of considerable importance to recognize that the greatest complexity occurs in those records near the mode of the egg production curve, and that those records near each extreme are less complex, so that studies made on a flock composed of either very high or very low producing birds will be simpler than if made on flocks of average production.

As long as attention is fixed solely on the number of eggs laid, and no recognition given to the fact that the difference between a 150-egg hen and a 200-egg hen is something more than just 50 eggs, progress in getting at the fundamentals of the inheritance of egg production is hindered. The solution of the problem demands that the inheritance of each component be ascertained by specially planned experiments. This would require about fifty years of one man's time, with a flock of 500 pullets trapnested through their first laying year.

The policy which was therefore adopted at this station was, using as a working theory the concept of an egg record as briefly outlined above, to establish a high-producing strain by improving the flock step by step, making it fairly homogeneous for one of the five characteristics and then for another. In this way there would eventually be built up a flock which would meet the standards required for the highest production. At the same time it was planned to make an intensive study of broodiness and to collect data on the other characteristics, with the purpose of gaining as much useful information as possible.

Plan of Procedure.

The Foundation Stocks.

The foundation stock as a whole proved deficient in desirable characteristics. The birds were late maturing and, when hatched in April or May, did not begin laying till midwinter. Many stopped producing by midsummer or soon after. The winter pause was present but not conspicuous because of the late start made. Rate of production while laying was excellent. The birds were deficient in vitality and were poor breeders. It was essential, of course, to remedy these last two defects before further work could be done. Stock of good vitality was added, but unfortunately the general satisfactory rate of production was lost and the winter pause accentuated, so that, as the next paragraph shows, ground was lost for the time being. (See Fig. 5, p. 109.)

The members of the flock hatched in 1915 were, on the whole, late maturing and broody, and exhibited a well-marked winter pause in early layers, a slow rate, and a tendency to stop production early in the summer. There were, however, individuals which matured early, others that were not broody, some that laid at a high rate, some that persisted in production till late fall, and some that lacked a winter pause. Individuals exhibiting various combinations of these characteristics also occurred, but there were none in which all the desired characteristics were combined. This was to be accomplished by breeding, and the present plan of procedure, vaguely formulated the year before, was put into active practice.

Basis of Selection of Breeding Females.

Beginning in 1916, female breeders were selected primarily for early maturity, and late maturing individuals used only when exceptional in other respects. A fair approach to the objective was obtained in the laying flock of 1917–18, partly through a fortunate nick between a single pair.

Meanwhile, the intensive work on broodiness had given a flock comparatively free from broodiness, so that it was known that broodiness could be very much reduced even if not eliminated. The next step was an attempt to fuse the low-broody strain, which were poor producers, with the early maturing line, which were good layers, by choosing non-broodies from the latter and good layers from the former. Of course, it was expected that the fusion would result in a temporary setback. The first year after the fusion, 1919–20, fewer eggs were laid and more broody birds occurred in the combined flocks than in the respective contributing strains, but this difficulty has been overcome. On reviewing the situation, it is clear that the desired objective would have been reached had the non-broody members of the high line alone been used, for these birds are the ones that constitute the major portion of the ancestry of to-day's flock.

While concentrating on maturity and broodiness, some progress has been made in eliminating the winter pause, and in securing larger numbers of birds that lay at a high rate. Data covering these statements are given in later sections of the paper. The proportion of birds in the flock that approach the desired type is much greater. With the increase in the number of birds approaching the desired type, birds with records that would have qualified them for breeders in the early stages of the work are now rejected. The basis of selection has been progressively altered and selection made progressively more stringent, as shown in Fig. 3 and Table I.

Table I. — *Data on the Mothers of the Several Flocks.*

Mothers of Pullets Hatched In —	Mean Age at First Egg.		Mean Winter Production.		Mean Annual Production.	
	Number of Birds.	Days.	Number of Birds.	Eggs.	Number of Birds.	Eggs.
1913	-	-	72	26.72	42	123.52
1914	36	252.89	59	40.17	49	141.02
1915	89	253.45	118	29.07	92	122.62
1916	60	228.60	61	47.38	57	147.72
1917	40	198.93	39	76.18	36	186.36
1918	25	193.08	25	92.76	22	204.41
1919	29	199.79	29	85.69	28	222.68
1920	38	197.71	37	84.78	16	228.06

In each case those mothers only are included having daughters with a corresponding record. Because of the clean-up in June, 1920, an exception is made so that the annual production for 1919 is for birds having daughters that laid up to June 1. For the first four years birds of the original stock whose hatching date is unknown were used in decreasing numbers as breeders, which accounts for the small number of birds whose mean age at first egg is given.

Other qualifications besides those exhibited in the egg records are required. A hen is a good breeder only if she produces such a number of pullets that they constitute a satisfactory index of her capacity (with a given mate) to transmit her own good laying qualities. Small families are undesirable, because they are often an inadequate sample of a bird's real breeding quality. As soon as it appears that a breeder's eggs are not hatching well, she is taken from the breeding pen and her offspring discarded. A few breeders are discarded for other defects, such as low vitality of their progeny.

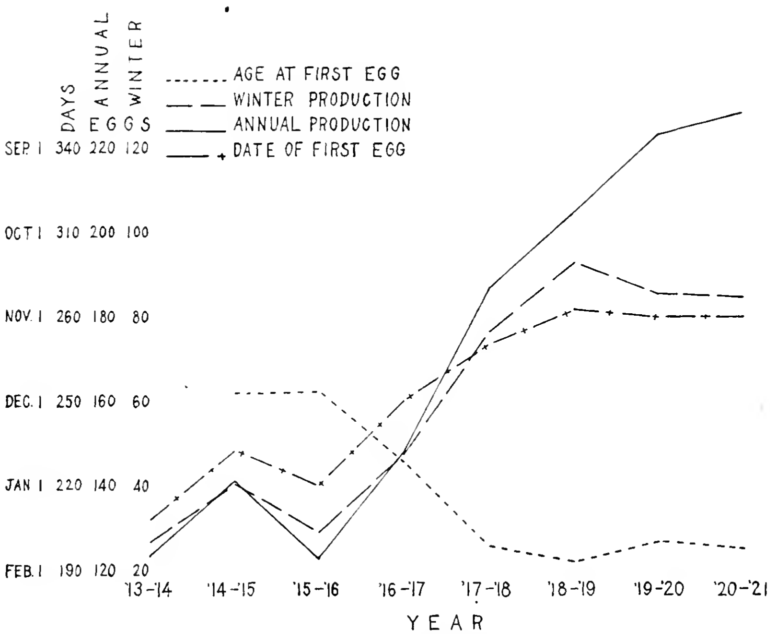

FIG. 3. — Mean Production of Female Breeders.
(From data given in Table I.)

Basis of Selection of Breeding Males.

The selection of suitable males is quite simple. First, each one comes from a large family and is the strongest, the most vigorous and usually the largest member of the group; second, he comes from a good mother; and third, the most important point of all, his sisters must have made good records.[1] The family which produces the largest proportion of females capable of qualifying as breeders is the first choice for one or more males. Naturally, males will be chosen from several families and always such as stand highest in desired characteristics.

[1] This involves keeping one or more representatives of each family till his sisters' records are available.

Continued Use of Breeders on the Basis of the Performance of their Offspring.

Birds used as breeders are kept till the records of their progeny are at hand. Many fail to transmit the desired qualities, either wholly or to a sufficient number of their progeny, and therefore are discarded. Exceptions are sometimes made with females that are otherwise remarkable, in the hope that they may nick better with another mate. Those birds that show pronounced ability in producing offspring that make egg records of the desired type may be bred several years in succession. The importance of a very few birds of this sort cannot be too greatly emphasized, for through these progress is made.

Points in Management that affect the Results.

A few points in the handling of the flocks need especial emphasis, as they bear directly on the interpretation of the results.

Flock Number. — Throughout these experiments the pullets have been kept in relatively large flocks, 100 to 125, while making their records, with the following exceptions: in 1912–13 there were two pens of 72 birds each; in 1913–14 there was one pen of 72 birds and several smaller groups of 25 to 35 each; in 1914–15 the pedigreed pullets were in large flocks, but the new stock was in smaller groups. The latter are excluded from the averages. Some years the high-line birds, or part of them, have been penned by themselves; other years they have been scattered through the flock. They have received exactly the same treatment that was given the rest.

The selection of the pullets that are put into the laying pens is based on the family. The best families having been decided upon, all the daughters in those families are included except those of exceedingly poor vitality, amounting to less than 5 per cent. As far as possible, families (offspring of one mother) containing fewer than seven daughters each are excluded. This has been done in order to enable a fair judgment of the breeding ability of any mother to be made. An exception was made to this rule in 1920–21, when all daughters weighing less than 3 pounds 6 ounces at four months of age were excluded. The effect of such exclusion, if any, on egg production is slight, as shown by correlation tables.

The time of year in which a flock of birds is hatched is one of the most important factors in determining the number of eggs laid. This is illustrated in several figures and tables, of which Fig. 13 (page 117) may be especially cited. Note that the late hatched flock loses about two months' production, — a production that, as far as the records show, is not compensated for, except in slight measure, at other seasons.

It is the practice at this station to hatch weekly. The length of the hatching season has varied from year to year, but, unless otherwise stated, only records made by birds hatched between March 25 and May 14, inclusive, are presented in this paper. The mean hatching date is April 18, from which the several yearly means vary little as shown by Table II.

TABLE II. — *Data on the Flocks of 1912–20.*

PULLET YEAR.	Hatching Date.[1]		Date of First Egg.		Age at First Egg.			Winter Production.			Annual Production.		
	Mean.	Change from 1913 (Days).	Mean.	Change from 1912 (Days).	Number of Birds.	Mean Number of Days.	Change from 1913 (Days).	Number of Birds.	Mean Number of Eggs.	Change from 1912 (Eggs).	Number of Birds.	Mean Number of Eggs.	Change from 1912 (Eggs).
1912–13	–[2]	–	Jan. 19	0	–	–[2]	–	138	28.39[3]	0.00	123	114.38[3]	0.00
1913–14	Apr. 19	0	Dec. 31	—19	168[4]	255.61	0.00	171	36.44	+8.05	171	123.64[5]	+9.26
1914–15	Apr. 19	0	Jan. 26	+7	115	282.80	+27.00	113	13.27	—15.12	80	103.25	—11.13
1915–16	Apr. 18	—1	Jan. 7	—12	224	264.27	+8.66	237	29.44	+1.05	208	121.70	+7.32
1916–17	Apr. 19	0	Dec. 5	—45	329	229.71	—25.90	328	42.46	+14.07	294	133.67	+19.29
1917–18	Apr. 17	—2	Nov. 16	—64	291	212.96	—42.65	280	59.40	+31.01	237	165.85	+51.47
1918–19	Apr. 19	0	Oct. 30	—81	141	194.44	—61.17	109	63.45	+35.06	64	169.19	+54.81
1919–20	Apr. 20	+1	Nov. 18	—62	157	212.04	—43.57	124	58.23	+29.84	–[6]	–[6]	–[6]
1920–21	Apr. 12	—7	Oct. 29	—82	168	199.99	—55.62	160	67.65	+39.26	109	199.73	+85.35

[1] Mean hatching date based on birds that completed the winter.

[2] Mean hatching date and mean age at first egg not known for 1912.

[3] Five eggs arbitrarily added as November's quota, since trapnesting was not begun until December.

[4] Is less than 171 because of birds that never laid; kept through winter but not through year.

[5] Because of limited facilities, only 59 birds in 1913–14, hatched between the limiting dates, were trapped throughout the year. They were a selected group with an average winter production of 41.92 eggs against 36.44 for the entire flock, which, therefore, has a probable mean annual production of 123.64 eggs.

[6] Records stopped June 1. See p. 108.

Successive years do not represent successive generations. The later years include the offspring of selected parents belonging to several generations.

Floor eggs are excluded from all the data used in this paper. Artificial lighting has not been used.

Because of the prevalence of disease, the whole plant, both college and experimental, was given a thorough cleaning during the summer of 1920. All adult birds were disposed of June 1, so there are no annual records for that year.

Seasons at which Increased Production is most Desirable.

The average well-cared-for flock of pullets of American breeds begins production some time in late fall or early winter, reaches its maximum

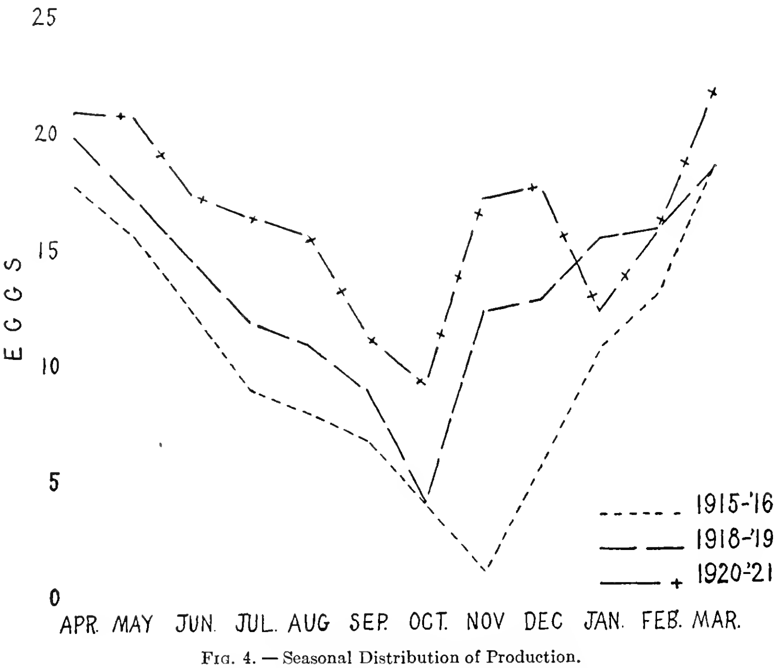

Fig. 4. — Seasonal Distribution of Production.

The right-hand part of the curve beginning with November precedes, chronologically, the left-hand portion. This arrangement emphasizes lack of production in certain months.

in March or April, and then declines more or less rapidly toward zero the following autumn, as represented in Fig. 4. The curve starts at the high point in April and ends at the high point in the preceding March, instead of starting with the beginning of production, as is customary. This arrangement emphasizes the hollow between the two high points. It is clear that if good production can be obtained in October, November and

December it should not be hard to improve production in other months, where necessary. Hence, emphasis is laid on winter production, so called, as at this season eggs bring two to two and one-half times the price paid in April. The producer who can secure a 50 per cent yield in those months will reap the reward due to his ability, at least in the immediate future, while if the methods by which such a yield is obtained become common practice, the consumer will benefit through lower prices and steady supply. While the producer may not continue to reap the harvest due to pioneer methods, his business will be on a firm basis, with the period of all outgo and no income eliminated.

The desirability of increased fall and winter production is made clearer by a comparison of the station flocks with certain farm contest flocks in Missouri as reported by Townsley (1920). The latter's average November production for the last four years ranges from 2.0 to 2.5 per hen, being 2.3 eggs each for nearly 25,000 birds in 1920. The best flock of 124 birds averaged 8.1 eggs each. On the other hand, a flock of high-line birds of similar size at this station averaged 18 eggs each. If all the flocks of the country were as good layers as this particular flock, — and there is no biological reason why they should not be, — it is apparent that both consumer and producer would benefit.

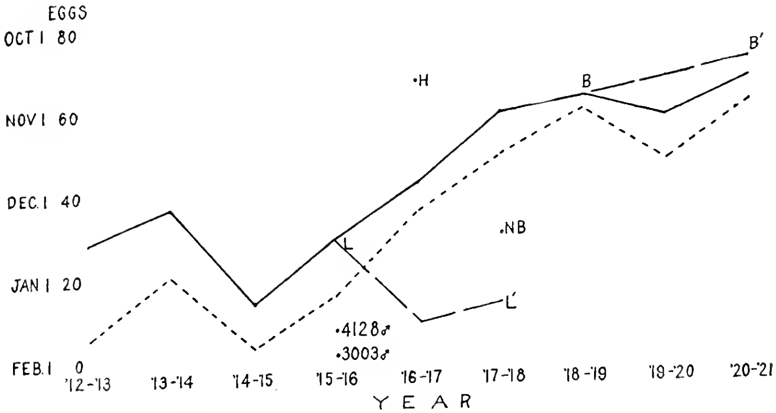

Fig. 5. — Winter Production and Date of First Egg for Flocks of 1912–20.

Solid line represents mean winter production. Up to but not including 1917–18, the mean for the entire flock is given. From 1917–18 on, it is for the high line only. L–L', low line. B–B', original high line. H, mean of several high families in 1916–17. NB, mean of low-broody flock. 4128♂ and 3003♂, mean of daughters of the respective males.

Dotted line represents mean date of first egg for set of birds making winter records shown in continuous line.

Results secured.

Data on mean winter production, mean annual production, and mean age at first egg are presented for each year of the experiment. Data on broodiness have been recently published and need not be repeated here.

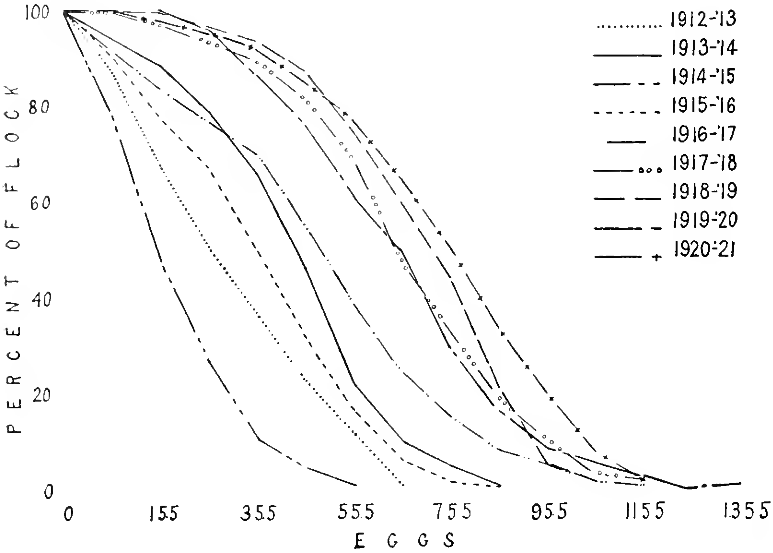

Fig. 6.—Integral Curves showing the Percentage of Each Flock having a Winter Egg Production as Great as that indicated, or Greater.

No allowance made for November in 1912. (See Table II.)

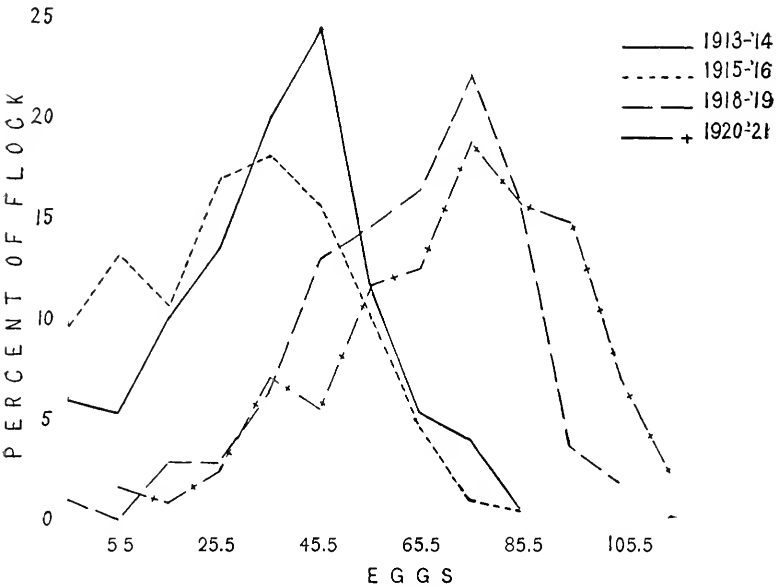

Fig. 7.—Frequency Polygons showing the Percentages of Flocks having Winter Production indicated.

1920–21 curve is for the original high line only.

Data on the initial cycle, winter pause, spring production, summer production, date of last egg and rate of production are restricted to certain years, because breeding for changes in these characteristics has necessarily been secondary. They indicate clearly such changes as have occurred. For purposes of clarity, intermediate years are omitted in certain graphs.

Changes in Mean Winter Egg Production.

Winter egg production is defined as the number of eggs laid prior to March 1 in the first laying (pullet) year. In Table II, represented graphically in Fig. 5, is given the mean winter production of the flocks from 1912 to 1920, inclusive. A high-line strain, as a definite entity, was not propagated until 1917. From 1917 on, the winter production given in the table and graph is that of the high line. A low line, L-L [1], Fig. 5, was propagated in a small way for a time, but finally lost. In 1917 a point is indicated for comparison with the high line which is the weighted production of a flock bred primarily for absence of broodiness, and in whose establishment all non-broodies available, high producers or low, were mated with three males: No. 3003; his son, No. 5470, by his sister; and his grandson, sired by No. 5470 out of an unrelated bird with a good record. The sisters of No. 3003 were noted for very low production in addition to non-broodiness. The average winter egg production of the daughters of No. 3003, as well as of the daughters of No. 4128, another low male of separate origin, is indicated for further comparison.

Graphic representation of the improvement made is shown by integral curves for each year as given in Fig. 6, while frequency polygons for winter egg production for certain years are given in Fig. 7, the statistical constants being given in Table III.

TABLE III. — *Statistical Constants for Certain of the Flocks.*

WINTER EGG PRODUCTION.

YEAR.	Number of Birds.	Mean.[1]	Standard Deviation.	Coefficient of Variation.
1913-14	171	36.70± .88	17.05± .62	46.45±2.03
1915-16	237	29.86± .76	17.40± .54	58.27±2.34
1918-19	109	63.61±1.27	19.62± .90	30.85±1.54
1919-20	124	58.56±1.45	23.93±1.02	40.87±2.02
1920-21	160	67.34±1.33	24.88± .94	36.94±1.57
ANNUAL EGG PRODUCTION.				
1913-14	59	145.41±3.04	34.66±2.15	41.06±2.95
1915-16	211	121.21±1.87	40.20±1.32	33.17±1.20
1918-19	64	170.02±2.52	29.89±1.78	43.31±3.03
1920-21	109	200.98±2.57	39.78±1.82	33.15±1.67

[1] **Means calculated from grouped data instead of ungrouped as in Table II.**

TABLE III. — *Statistical Constants for Certain of the Flocks* — Concluded.

AGE AT FIRST EGG (DAYS).

YEAR.	Number of Birds.	Mean.[1]	Standard Deviation.	Coefficient of Variation.
1913-14	168	255.62±1.13	21.68± .80	48.60±2.17
1915-16	243	263.69±1.50	34.61±1.06	47.61±1.76
1918-19	141	194.58±1.38	24.23± .97	55.60±2.84
1920-21	168	200.44±1.38	26.50± .98	53.61±2.48

[1] Means calculated from grouped data instead of ungrouped as in Table II.

In Fig. 8 certain changes in winter production of selected groups are given, comprising, first, the highest record made in each season by any one individual; second, the best average record made by the daughters of any one mother, provided not less than five daughters comprised the

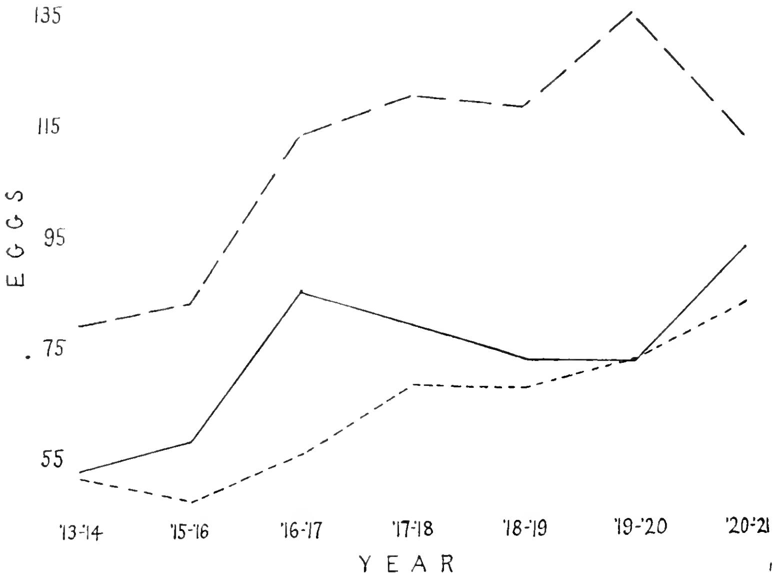

FIG. 8. — Winter Production.

Broken line, best individual; solid line, best average made by daughters of one female; dotted line, best average made by daughters of one male.

group; and third, the best average record made by the daughters of any one male for each season, provided that he had ten or more daughters.

Changes in Mean Annual Production.

Annual production is the number of eggs laid in the first laying year, beginning with the first egg and running 365 days therefrom. Barring longevity, it is probably the best index of a bird's innate laying capacity.

Reasons for this view have been presented elsewhere. In Table II and Fig. 9 are given the data showing the changes that have taken place. The statements regarding the flocks, as given for winter production, apply here also.

The integral curves for each year will be found in Fig. 10; frequency polygons are given in Fig. 11, the constants in Table III.

Changes in Daily Winter Production.

The daily flow of eggs is a matter of some importance to the commercial poultryman, because of market fluctuations in price. Daily production curves illustrating this flow show some points not brought out in curves plotted on larger time units. The labor of compiling such curves is great, however, unless birds are penned in such a way that the pen record can be used. A few such pen records have been studied and are shown in Figs. 12 and 13 (see pages 116 and 117).

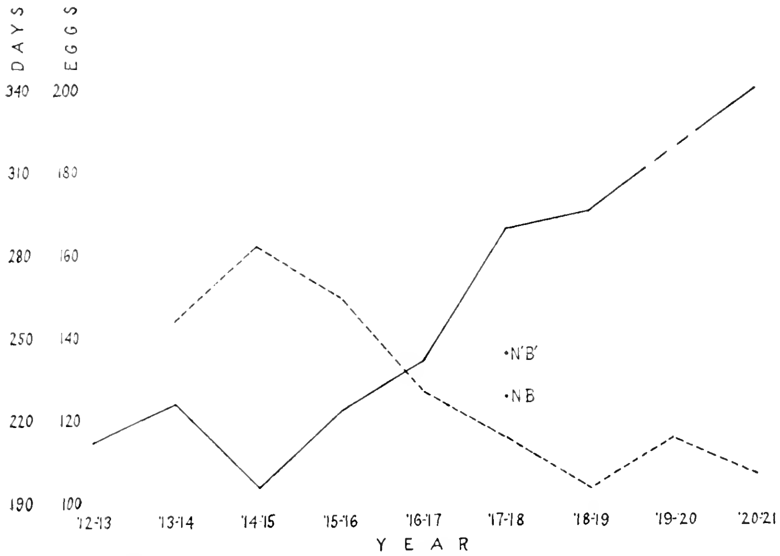

FIG. 9. — Mean Annual Production (Solid Line) and Mean Age at First Egg (Dotted Line).

NB, mean annual production, and N' B', mean age at first egg, for low-broody flock. No annual record for 1919–20. (See page 108.)

The points in all curves calling for particular attention are: the marked irregularity in number of eggs laid on consecutive days; the occurrence of waves of several sorts; the angle of slope of the curve at the beginning of production; the sharp descent from the maximum, due to the winter pause, in the curves of early hatched flocks, and the more gradual rise on recovery, with the marked rise in the curve toward the end of February. The later hatched layers do not exhibit such a sharp decline due to the winter pause. The amount is less and recovery quicker.

Changes in Age at which First Egg is laid.

Early in the history of these experiments it became evident that, on the average, those birds that laid the largest number of eggs before March 1 were those that began laying first. As the average age at which the first egg was laid was eight months, it was evident that either the pullets must be hatched early to get them mature early in the fall, or else they must grow and develop faster. Early maturity, therefore, was made the chief aim of the breeding program, with the results shown in Table II and Fig. 9. Changes in mean date of first egg, Fig. 5, vary directly with changes in mean age at first egg. Integral curves are given in Fig. 14, frequency polygons in Fig. 15 (page 119), and their constants in Table III. Note that

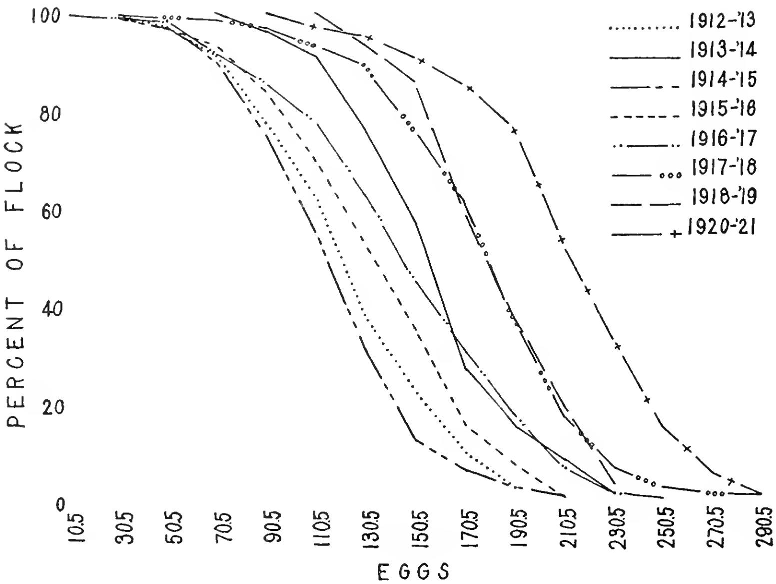

Fig. 10. — Integral Curves showing the Percentage of Each Flock having an Annual Production as Great as that indicated, or Greater.

One zero in 1917-18 is not shown. In 1912-13 no allowance is made for November production as in Table II. The curve for 1913-14 is that of the 59 birds kept through the year. (See Table II.)

apparently something more than a sifting out of an early maturing strain has occurred, as indicated by the mean and range for 1918-19, Fig. 15.

Earlier maturity uncovered, or at least was associated with, more evidence of the winter pause than appeared earlier, so that the gain in production was not as great as was anticipated. As indicated below, progress is being made in reducing the length of the pause, so that, eventually, continuous production throughout the winter is expected.

Since 1917 no attempt has been made to lower the age at first egg. The basis of selection has been the same in each year since 1917. (See

Table I and Fig. 3.) Although there is a fascinating problem involved in attempting further selection for earlier maturity, such an endeavor is not consonant with the main project.

Changes in Length of the Initial Cycle and its Complement, the Winter Pause.

In the station strain of Rhode Island Reds, many individuals produce an initial series of eggs which is followed by a rest period, the winter pause. The trait does not lend itself to ordinary statistical treatment because of its nature, which depends partly on an inherent condition of the strain, and partly on environmental conditions, particularly those

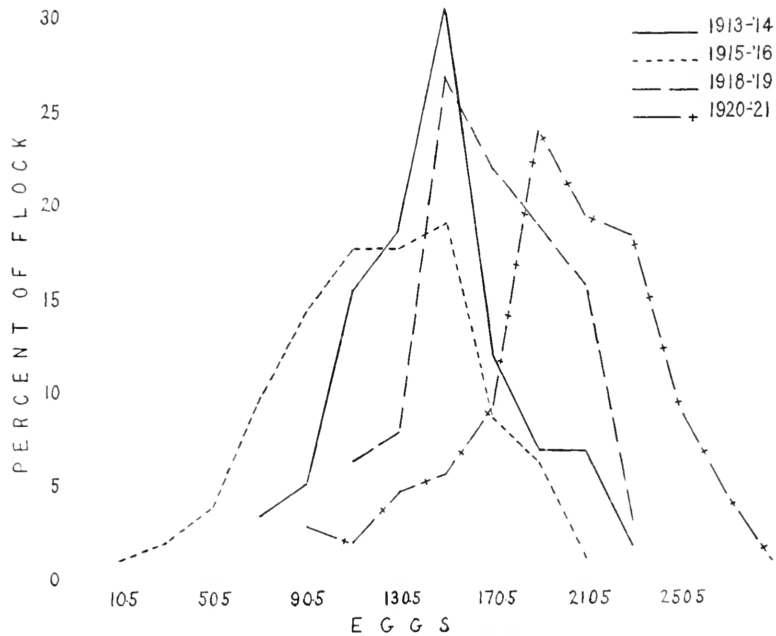

Fig. 11. — Frequency Polygons showing the Percentages of Flocks laying the Given Number of Eggs per Year.

The curve for 1913-14 is that of the 59 birds kept through the year. (See Table II.)

that determine the time of year when the birds begin to lay. Further, it is possible that more than one cycle is involved. The present discussion, therefore, is limited to a general descriptive treatment of the subject, based on experiences with flocks subsequent to those studied in an earlier paper (Goodale, 1918).

It is now clear that the earlier a pullet begins to lay in the autumn, the more likely she is to exhibit the winter pause. A few early layers, however, go through the entire winter without pausing. Roughly speaking, 90 per cent of pullets laying their first egg early in the season (September) exhibit the pause, in contrast to only 30 per cent of those beginning late in the season (December). It is possible that the appearance of the pause is due to some direct effect of the season (length of days, for instance), but since there is no uniformity in the length of the egg-laying period, and since one member of a flock may begin the second laying period at the same moment another is finishing the first, it is clear that whatever influence the environment may exert is secondary, the primary cause being a change in the physiological condition of the layers, expressed in some individuals by an actual pause, in others by a slowing down in production, while in a few individuals no external effect becomes apparent. Note, as shown in Fig. 13, that a flock of late-hatched pullets were laying at a high level at the same time that their early-hatched sisters were in a slump. Clearly it is not the environment alone that is responsible for the pause. Some observations lead to the belief that environmental conditions which

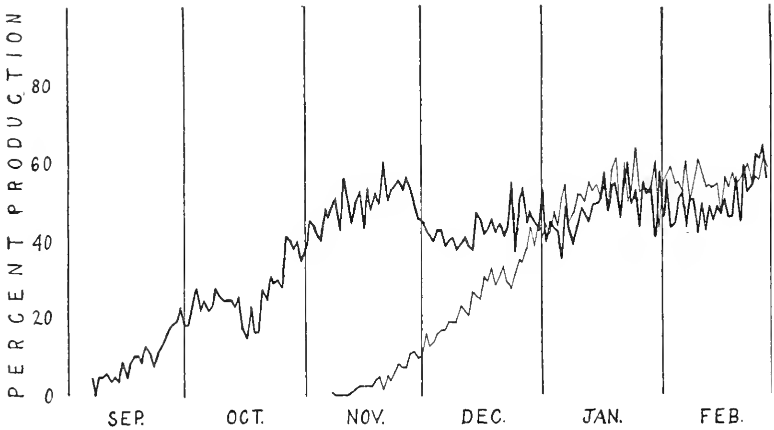

Fig. 12. — Daily Production.
Heavy line 1917-18, Pen III; light line 1913-14. (See text for details.)

at other times would not stop production may do so in this sensitive physiological state. Given an initial (winter) cycle of variable length, it is apparent that in some individuals it may extend into early spring and either overlap the spring cycle and thus fail to become apparent, or perhaps, because of a direct stimulus due to longer days, production may be kept up, and thus the winter pause is suppressed in pullets beginning to lay late in the season.

As far as possible, selection has been directed against the winter pause, and while not eliminated, there is evidence that its length has decreased, and, correspondingly, the length of the initial period increased. This is shown in Fig. 13, where a high production over a period of six weeks was maintained, which is much longer than three years previously, as seen in Fig. 12. The average number of eggs laid, prior to the pause, was 12 more in 1920 than in 1917.

Changes in Amount of Broodiness.

This phase of breeding for increased egg production has been discussed in another place (Goodale, 1920). Here it is sufficient to recall that, while some birds lay continuously throughout spring and summer without any marked slowing in rate of production, others lose much time on account of broodiness, — a loss that very clearly is *not* compensated for.

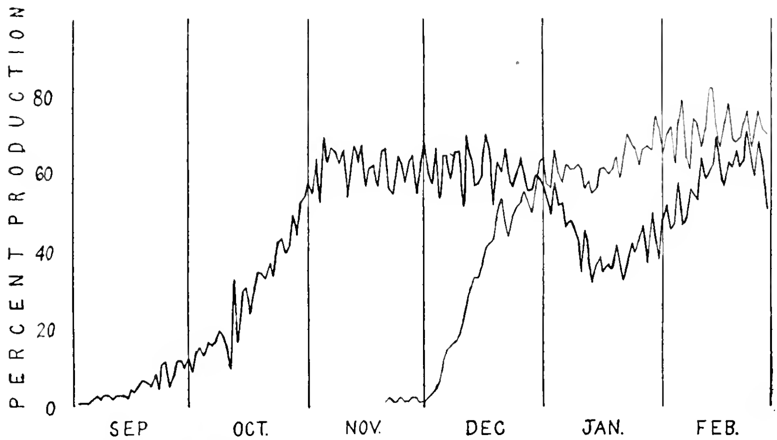

FIG. 13. — Daily Production of Two Pens of the Same Breeding, 1920–21. Heavy line, April hatched; light line, late hatched.

NOTE. — The records of this flock were made under quite different conditions and methods of management from those made by the other flocks. *A priori*, they appeared to be considerably sub-optimal, but the results show that they were at once correct and simple. A brief description of the conditions and methods of management follow. The 50 females and 6 males were in a pen 22 by 11, 6 feet high at the plate and 10 at the ridgepole, made by stretching wire netting across the south side of a second-story barn floor. A windbreak of paper extended 3 feet from the floor. Roosts were at the west. The main opening was a pitch hole about 4 feet square in the south side. Additional light came from a window 2 feet square in the gable, plus some light from two openings in other parts of the loft. A little sand was put on the floor and straw used as a litter. The birds had water and open boxes of dry mash constantly before them. Oyster shell was fed on the floor. No special grit was fed. Three to 4 pounds of cracked corn were fed in the morning, and double that amount at noon. *Green* sprouted oats *ad libitum* (165 square inches) were fed at noon. Droppings accumulated on the floor back of a wire litter stop. Besides gathering the eggs and keeping straw in the nests and the litter distributed (the latter mostly done by feeding the cracked corn where it was thickest), no other attention was given. The caretaker was away during the day.

The loss due to broodiness is shown when the seasonal production of a broody race is compared with that of a non-broody race. The maximum production of a broody flock comes in March. April is nearly as high, but during May and June, corresponding to the period of progressive increase in the number of broody birds, production declines sharply to a level that either remains nearly constant for July, August and September, or in which the descent is much less marked. (See Fig. 4, 1915–16 and

1918–19.) The highline flock of 1916–17 averaged 105 eggs during the six non-broody months, November to April, while for the six broody months following, May to October, the average was only 70 eggs. Leghorns, on the other hand, continue production at a relatively high level all summer, and first decline sharply in early fall. Kirkpatrick and Card (1917) give data showing a parallelism between degrees of non-broodiness and summer production. The several races, viz., Rocks, Wyandottes, Reds and Leghorns, lay nearly the same number of eggs per bird in March and April and do not differ much in production prior to this date. But during May, June, July, August and September the Leghorns, having the smallest amount of broodiness, lay much more heavily than the other breeds, while the Reds, the most broody race, give the poorest summer production. The Rocks and Wyandottes, which are very much alike in amount of broodiness and intermediate between the Leghorns and Reds, are much alike in their summer production which is intermediate between that of the Reds and Leghorns.

A striking illustration of the loss due to broodiness in an individual bird is shown by BS316, whose egg record is given in Fig. 16. If she had not become broody, but had instead continued to lay through June, July and August at the rate of 26.4 eggs (her average for the seven months preceding), her annual production would have been 306 eggs, 27 more than her actual record of 279 eggs. (The pause in September looks much like a broody period, but she did not stick to the nest, and therefore was not put in the broody coop.)

The first experiment in breeding out broodiness was successful, but at the expense of egg production (Goodale, 1920). The experiment in breeding broodiness out of the high line and still maintaining production is not yet complete, but gives promise of success.

Changes in Date of Last Egg.

The dates of last egg and of first egg determine the length of the annual period. The two limiting dates are treated separately, because it seems probable that date of last egg results from the action of some internal mechanism the nature of which is unknown. While practically all birds are laying from the middle of March to the middle of June, after this, one by one, the birds stop laying, not to resume until next season. The majority, however, continue production till the middle of September, the mean date of last egg being near October 1 in 1914 and 1919. Cessation of production has a genetic foundation, as is indicated by the behavior of various families in this respect, some stopping early and others late. Moreover, many of the best layers show a tendency to continue production indefinitely.

The lack of evidence that the average date of cessation of production has been advanced well into the fall may be associated with lack of especial effort to secure by breeding continued production late into the fall, — an effort that did not seem worth while till after broodiness had been bred out.

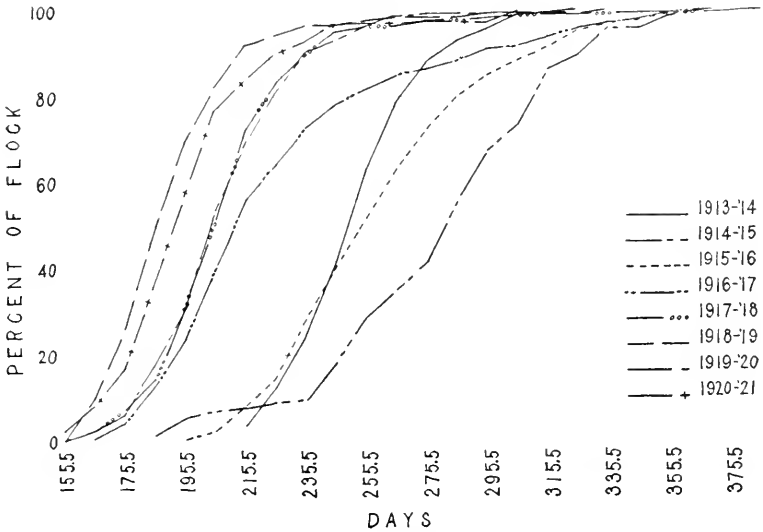

FIG. 14. — Integral Curves showing the Percentage of Each Flock beginning to lay at or before the Ages indicated.

One exceptionally old bird is omitted from 1915-16, and one from 1920-21.

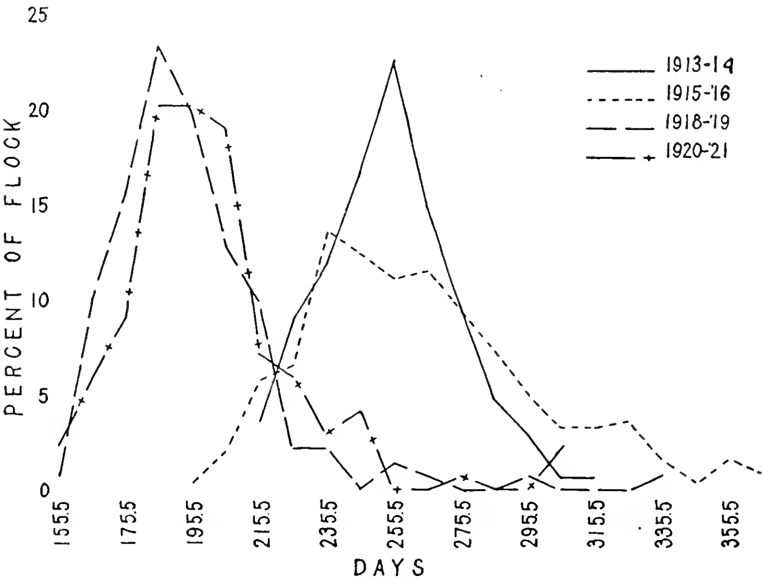

FIG. 15. — Frequency Polygons showing Percentages of Flocks beginning to lay at Ages indicated.

Changes in Rate (Intensity) of Production.

Rate or intensity of production is defined as the number of eggs laid per time unit measured in days. There are several possible time units, such as the month, the initial cycle, the inter-broody periods, the summer period and the spring period. Closely associated with this character is length of clutch, or number of days of continuous (daily) production. Units including well-defined rest periods, such as those due to broodiness or the winter pause, are specifically excluded.

While breeders have been selected, other desiderata permitting, on the basis of high monthly production during the winter, the heterogeneous condition of the flocks in respect to other characters makes comparisons unsatisfactory. The present discussion, therefore, is limited to a comparison of the highest production in any one calendar month before March 1. The use of the calendar month, instead of the highest production for a period of thirty or thirty-one days, although unsuitable in comparing individuals, is sufficiently satisfactory for comparison of flock averages. The average highest monthly production in 1913–14 was 19.28 eggs; in 1920–21 it was 21.10, showing an apparent gain of nearly 2 eggs.

Changes in Seasonal Distribution of Production.

It has been pointed out that the season at which increased production comes may be quite as important as an absolute increase. In addition to winter production, the year may be divided into spring, summer and fall, but differing from the calendar seasons.[1] Spring production includes March, April and May, chiefly because the station statistics show that, regardless of changes at other seasons, the average for these three months (Table IV) has remained nearly constant during these experiments. The period, moreover, is characterized by a sharp decline in mean monthly production from March (sometimes April) to June, due almost wholly to broodiness. A slight increase in mean production for this season has been noted with higher annual production.

[1] Other divisions might be made from the biological standpoint, but such divisions vary from flock to flock and with methods of breeding. The divisions used are approximate and somewhat arbitrary. Further, in studying seasonal distribution, the 365-day limit to a year has been disregarded.

NO. B8316 HATCHED APR. 4, 1920

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
SEP.																																
OCT.																				I	I		I	I	I		I	I		I	I	9
NOV.	I	I	I	I	I	I		I	I	I	I	I		I	I	I	I		I	I	I	I		I	I		I	I		I		24
DEC.	I		I	I		I	I	I		I	I	I	I		I	I	I	I	I		I	I	I	I	I		I	I	I	I		24
JAN.	I	I	I	I		I		I	I	I	I	I	I	I		I	I	I	I	I	I	I	I	I	I	I	I	I		I	I	27
FEB.	I	I	I	I	I	I	I		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I				26
MAR.	I		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I	I	I	29
APR.	I	I		I	I	I	I			I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		27
MAY	I	I	I	I	I	I	I	I	I	I		I	I	I	I		I	I	I	I	I		I	I	I	I	I	I	I	I	I	28
JUN.	I	I	I	I	I	I	I	I	I		B	R	O	O	D	Y	—						I	I	I	I	I	I	I			16
JUL.		I	I	I	I	I	I	I	I	I	I	I	I		B	R	O	O	D	Y					I	I	I	I	I	I	I	19
AUG.	I	I	I	I	I	I	I	I	I	I	I	I			B	R	O	O	D	Y	—	—	—			I	I	I	I		I	17
SEP.	I	I	I	I	I	I	I	I	I	I	I	I													I	I	I	I	I	I		18
OCT.	I			I	I	I	I	I	I	I	I	I	I	I	I	I	I															15
NOV.																																

YEAR'S TOTAL 279

Fig. 16. — Egg Record of a Hen, showing the Effect of Broodiness.

TABLE IV. — *Seasonal Distribution of Production.*

YEAR.	Mean Number of Eggs for —						
	November 1 to March 1.	March 1 to May 1.	March 1 to June 1.	November 1 to May 1.	May 1 to November 1.	June 1 to October 1.	Year, November 1 to November 1.
1912-13	28.73	34.54	50.66	63.27	50.98	34.86	114.25
1913-14	36.34	33.17	47.13	69.51	54.12	40.16	123.63
1915-16	30.40	36.24	51.79	66.64	55.16	39.61	121.80
1916-17	41.39	38.15	53.60	79.54	52.91	37.46	132.45
1917-18	55.95	37.90	52.96	93.85	68.96	53.90	162.81
1918-19	56.07	38.36	55.61	94.43	67.58	50.33	162.01
1919-20	51.07	34.90	50.50	85.97	–[1]	–[1]	–[1]
1920-21	62.34	42.65	63.30	104.99	90.37	60.67	195.36

[1] Records stopped June 1. See p. 108.

Summer production includes June, July, August and September. The sharp decline previously noted is checked, and the mean monthly production declines much more gradually from month to month till October. Some years the decline is less than others (see Table V). The decline during the summer is due to the completion of the annual cycle on the part of some individuals, the first cases occurring in June, and to some slackening in rate (intensity). As shown in Table IV, there has been some increase in

TABLE V. — *Decrease in Mean Monthly Production from Highest Monthly Mean (March or April) to June, and from June to September.*

YEAR.	Mean Production.					
	Greatest Monthly.	June.	Difference.	June.	September.	Difference.
1913-14	M. 17.17	10.75	6.42	10.75	7.74	3.01
1915-16	M. 18.56	12.26	6.30	12.26	6.67	5.59
1916-17	M. 19.41	10.62	8.79	10.62	6.98	3.64
1917-18	M. 20.66	13.28	7.38	13.28	10.69	2.59
1918-19	A. 19.78	14.56	5.22	14.56	8.86	5.70
Average for five years .	19.12	12.29	6.82	12.29	8.19	4.11

summer production in the high line over the earlier years. It is believed that the elimination of broodiness will be the main factor in securing further increase of production during these months.

Fall production includes October, overlapping into the following months and thus the next calendar year. It is the season of completion of the annual cycle on the part of most individuals. There is a considerable tendency for the best layers to keep producing, and, as their numbers have increased, it has been reflected in somewhat higher average production during this period.

Changes in Variability.

As shown by both the standard deviation and the coefficient of variation[1] (Table III), and by the several frequency polygons (Figs. 7, 11 and 15) for winter egg production, annual production and age at first egg, there has been no especially significant lessening of variability as a result of selection. Selection has merely moved the frequency polygon to one side without changing its general character.

Influence of Changes in Sanitary Methods.

The work was commenced on the basis of the best poultry practices available, but the sanitary measures proved wholly inadequate, and suitable methods had to be developed. There are, however, sufficient checks, indicated especially in Fig. 5, which show, with the exceptions noted in the next paragraph, that fundamentally the changes in production are due to breeding.

The low mean production of 1912–13 is due in part to late hatching. Other factors can only be guessed at. The low production of 1914–15 is probably due to improper methods of brooding plus disease and poor help.

RECOMMENDATIONS.

It is difficult, at present, to lay down a series of recommendations that can be followed by breeders, with a guarantee that they will work in every case. The following recommendations, based on experience, are intended only for the man who is prepared to go to the necessary expense, time and trouble.

A. Prerequisites.
1. Proper management, including housing, feed, sanitation.
2. Maintenance of vigor. It is true, hens of poor vigor are sometimes good layers, but good vigor as a rule is essential.
3. (*a*) Careful trapnest egg records.
   (*b*) Careful pedigree records.
4. A good understanding of both desirable and undesirable egg production characteristics in the flock to be improved.
5. Families of at least seven pullets.
6. Pullets hatched between March 25 and May 15.

[1] The coefficient of variation, if calculated according to the usual formula $C. V. = \frac{\sigma}{M} \times 100$, is a poor index of the real variability, since the range of the polygon does not begin at zero. It is obvious that the formula $C. V. = \frac{\sigma}{M-X} \times 100$, where X is the lower end of the range, is a better index of variability. This is the formula used for age at first egg and for annual production in Table III.

B. Method.

The flock is to be improved by degrees, taking one desirable character at a time and making sure that it is well established in the flock as a whole before concentrating on a second.

In order to be as specific as possible, the following detailed outline is given: —

First Step. — Get the flock so that the pullets will mature before 200 days of age, by choosing as breeders those that mature before that age. The males must be from hens of the same qualifications, or brothers to those families of pullets that give the greatest percentage of qualifying females.

Second Step. — Choose as breeders birds that mature right and which are not broody. This step is not necessary for Leghorns.

Third Step. — As soon as a sufficient percentage of the flock — say 50 per cent — qualifies in these two respects, make the breeders qualify in three characters. Require them to mature before 200 days of age; to be free from broodiness; and to lay 22 eggs in either November or December.

Fourth Step. — As soon as enough birds qualify, make the breeders qualify in still another point, so that the qualifications become: first egg before 200 days of age; not broody; 22 eggs in November or December; not less than 80 during the winter, and continuous production for at least twelve months. At this point, if the breeder so desires, egg size, color or other characters may be added to the qualifications required of breeders, or he may aim for still better production.

Only those females should be used a second time, at least with the same male, some of whose progeny make an advance over the parent, unless the family as a whole is better than the average of the preceding generation. On the other hand, any pairing that gives superior results may be repeated year after year, or until something better has been obtained.

It should be pointed out that the larger the flock trapnested, the more rapid should be the progress made, for with a flock of two to three thousand pullets under the trapnest, it should be possible to pick out 30 to 40 birds that when tested will give ten or fifteen breeders of proven ability. These, if properly handled, should make possible very rapid progress.

Summary.

1. A description of changes in various phases of egg production is given.

2. Both mean winter and mean annual egg production have increased.

3. The age at which the first egg is laid has been reduced.

4. Progress in eliminating both the winter pause and broodiness is shown.

5. Provisional recommendations for improving egg production by breeding are given.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 212 NOVEMBER, 1922

A THIRTY-YEAR FERTILIZER TEST

By SIDNEY B. HASKELL

Thirty years ago two soil tests were laid out on the grounds of the Experiment Station, in an attempt to determine the "fertilizer needs" of the soil. After thirty years the original problem is still unsolved. It has been shown, however, that fertilizer needs are determined as much by the farming system followed and the kind of crops grown as they are by the type of soil being farmed. Under a cropping system which removes everything from the soil, severe potash shortage results. Where the crops are fed on the farm, need for fertilizer potash is correspondingly less. Under almost any condition the grass crop responds to fertilizer nitrogen, while the clover crop shows a marked preference for potash and phosphoric acid. Certain fertilizing systems have been shown to be very destructive, while others have been at least moderately efficient in maintaining the crop-producing power of the soil. These facts are among the more important brought out in the experimental work reported in this bulletin.

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AGRICULTURAL EXPERIMENT STATION
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CONTENTS.

BULLETIN No. 212.

DEPARTMENT OF AGRICULTURE.

A THIRTY-YEAR FERTILIZER TEST.

BY SIDNEY B. HASKELL.

History of Plots.

In February of 1889 Dr. W. O. Atwater, then director of the Office of Experiment Stations of the United States Department of Agriculture, issued a call for a conference to consider and adopt if practicable a uniform method of conducting what were then called soil tests. As a result of this call a conference was held in Washington, this Station being represented by Professor Wm. P. Brooks. A method of testing the soil by means of comparative field plots was decided upon, and in Massachusetts a number of such tests were instituted. Two of these were on the Station grounds, — the South Soil Test started in 1889 and the North Soil Test in 1890. Nine similar tests were laid out in other parts of the State. The object was "to find out the particular fertilizer requirements of the soils of different localities;" and in the letter sent out arranging for the co-operative tests, the statement was made that "the best soil for the purpose is one which represents best the average conditions in your county, which is level or of uniform moderate slope, of uniform and low fertility, and now in grass."

Up to and including 1917 these soil tests were under the supervision of Dr. William P. Brooks, formerly agriculturist and later director and agriculturist of the Experiment Station. Progress reports under the authorship of Dr. Brooks were made in Bulletins Nos. 9, 14, 18 and 58 of the Hatch Experiment Station, and likewise in the annual reports of that Station and its successor, the Massachusetts Agricultural Experiment Station. Records from these tests, with analysis and discussion, were also published in "Das Nährstoffbedürfnis Verschiedener in Fruchtfolge auf demselben Felde Angebauter Pflanzen nach Versuchen in Massachusetts, Nordamerika," presented by Dr. Brooks at the University of Halle, Germany, as a doctorate dissertation.

The greatest service of these field tests to date has probably been the establishment of the fact that individual crops vary widely in their plant food requirements, and that fertility practice may be affected more by the kind of crop than by the type of soil on which it is grown. Dr. Brooks presented this idea in his summarization of these experiments published in Bulletin No. 58 above cited, and was one of the first, if not the first, of the fertility workers of the country to observe this fact. Results secured during the score of years which has elapsed since the observation was first made have confirmed the conclusion in abundant measure.

The South Soil Test.

This test is on a soil classified in the soil survey of the Connecticut Valley as a Merrimac coarse sandy loam. The field is practically level, and had been in grass without manure for five years previous to the laying out of the test. Earlier still, for an unknown number of years, it had been in pasture.

Cropping System.

The original plan was apparently that of a five-year rotation, consisting of two years of corn, then a grain crop, followed by two years of grass and clover. This plan, however, was not followed consistently, although, in the thirty years of which we have full record, thirteen corn crops were grown. A complete list of crops as grown year by year is contained in Table I of the Appendix.

Fertilizer Treatment.

The fertilizer treatment is shown in the following schedule: —

Plot.	Fertilizer.	Pounds per Acre.
1	Nitrate of soda	160
2	Dissolved boneblack	320
3	Nothing.	
4	Muriate of potash	160
5	Lime	800
6	Nothing.	
7	Manure	30,000
8	Nitrate of soda Dissolved boneblack	160 320
9	Nothing.	
10	Nitrate of soda Muriate of potash	160 160
11	Dissolved boneblack Muriate of potash	320 160
12	Nothing.	
13	Plaster	800
14	Nitrate of soda Dissolved boneblack Muriate of potash	160 320 160

The plots were 18 by 121 feet in size, or exactly one-twentieth of an acre. A strip 3 feet wide between plots was cultivated as though a part of the adjacent plots, but yields on these strips were never recorded.

Lime History.

Lime was applied in the following amounts: —

Year.		Pounds per Acre.
1899.	Slaked lime	2,000
1904.	Slaked lime, about	3,000
1907.	Agricultural lime, about	1,000
1909.	Agricultural lime	2,000
1916.	Ground limestone	4,000

Precipitation and Frost Records.

Tables II and III in the Appendix show the observations on temperature, frost and precipitation as taken by the Department of Meteorology of the Experiment Station for the years from 1889 to 1921, inclusive.

During this thirty-three-year period there have occurred certain fairly definite weather cycles. For a period of eight years, 1897 to 1904, inclusive, the annual rainfall was consecutively above the mean for the period. From 1907 to 1914, inclusive, with the exception of a single year, the annual precipitation was below the mean of the period, and averaged 10 inches annually below that of the preceding period. From 1907 to 1913 the rainfall of the growing season, April to August, inclusive, averaged 14.7 inches; while for the succeeding seven years the average for the same period was 20.3 inches. There were also in the whole period wide extremes in total precipitation, the least being 10.82 inches for the growing period in 1894, and the highest 32.25 inches in 1892. The growing season, or the time between the last killing frost of the spring and the first killing frost of autumn, varied from 99 days in 1894 to 164 days in 1920. With such wide variations in weather conditions, especially as regards the dominant influence of precipitation, temperature and length of season, it is not to be expected that results from fertilizer use would in all cases be as expected, or show records always consistent one with the other.

Yields.

A complete statement of yields is given in Table I of the Appendix. Corn was grown more often than any other single crop, there having been a total of thirteen corn crops. For two years preceding the eleventh crop, however, the land was practically fallow; while the twelfth and thirteenth crops followed partial or total crop failures. The best picture of results, therefore, may be obtained by considering the corn crop as the common denominator of all the crops, and dividing the corn yields into three periods, including the first five crops in the first, the second five in the second, and the last three somewhat abnormal crops in the third, as shown in Table 1: —

TABLE 1. — *The Corn Crops.*

Grain (Average Yields per Acre, Bushels).

Plot.	Treatment.	First Period.	Second Period.	Third Period.
1	Nitrate of soda	26.73	6.05	26.55
2	Dissolved boneblack	23.96	4.52	13.03
3	Nothing	20.74	4.31	10.97
4	Muriate of potash	44.61	31.83	44.79
5	Lime	23.71	2.81	9.26
6	Nothing	20.79	5.27	11.08
7	Manure	63.11	57.20	56.13
8	Nitrate of soda Dissolved boneblack	32.33	9.84	–[1]
9	Nothing	25.37	5.53	–[1]
10	Nitrate of soda Muriate of potash	42.07	35.38	43.85
11	Dissolved boneblack Muriate of potash	54.90	39.33	44.53
12	Nothing	23.10	7.50	20.43
13	Plaster	27.09	9.14	14.54
14	Nitrate of soda Dissolved boneblack Muriate of potash	62.46	41.89	38.52

[1] These plots were discontinued in 1911.

These results are presented in graphic form in Fig. 1, arranged to show the total yields of grain and stover, and likewise the comparative yields in the two five-year periods. It will be noted that the yield of grain decreased very materially and significantly in the second five-year period. In all of those plots to which potash treatment was applied, the yield of stover did not decrease in like measure. On the other hand, where potash was not applied, the decrease in the yield of stover was somewhat similar in its significance to the decrease in grain. In all cases, the number of pounds of stover produced per bushel of grain was larger in the second period than in the first, and very materially so in the no-potash treatments.

The First Ten Corn Crops.

The Check Plots. — The significance of the results and their interpretations may best be judged on the basis of the yields on the check plots. There were four such plots, numbered respectively, 3, 6, 9 and 12. The following table shows the yields of corn divided into two five-year periods. Under the system of farming followed, the yielding power of the untreated soil was very low. The acre yields in the second period were practically zero. The check plots were, however, fairly uniform in production.

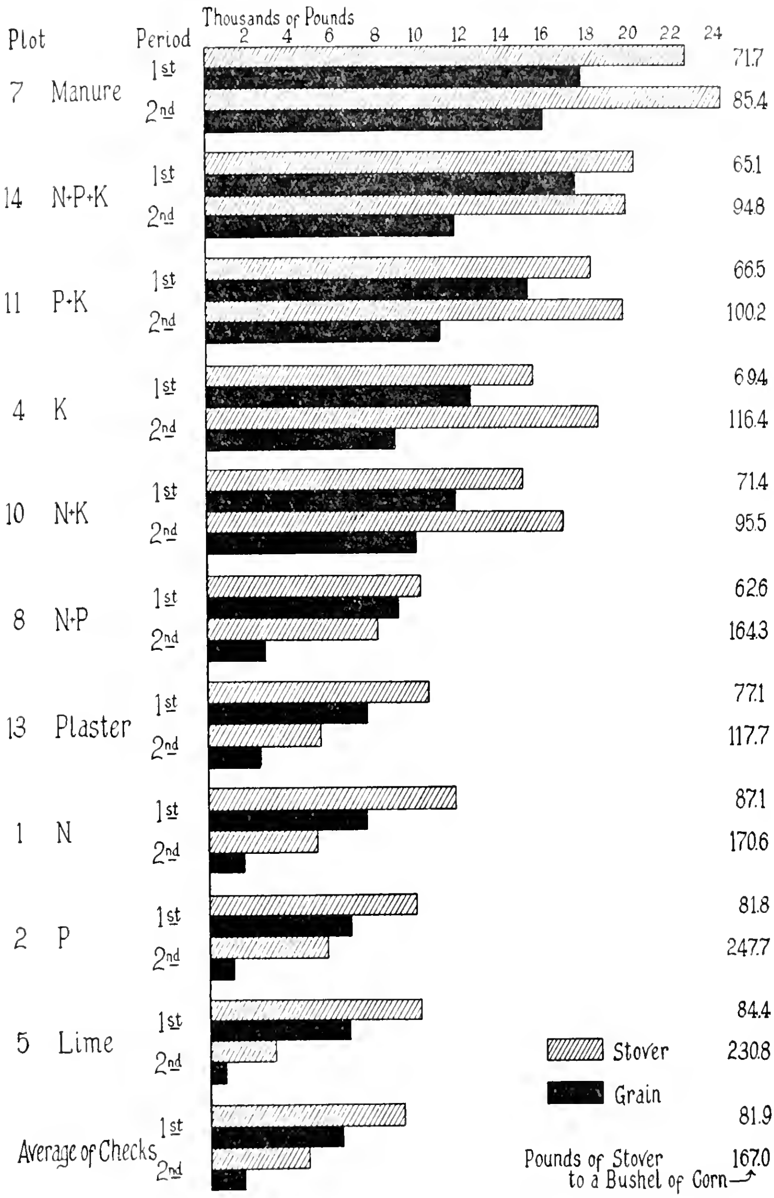


FIG. 51. — South Soil Test. Total yields per acre. Ten corn crops.

Table 2. — *The Check Plots.*

Plot.	Corn (Bushels per Acre).		
	First Period.	Second Period.	Decrease.
3	20.74	4.31	16.43
6	20.79	5.27	15.52
9	25.37	5.53	19.84
12	23.10	7.50	15.60

The Effect of Potash. — The most marked and most striking result of the test, especially as indicated by the corn crop, was the great response to potash. The following table shows the average yields of corn for the two periods under discussion for those treatments which include this plant food: —

Table 3. — *The Treatments containing Potash.*

Plot.	Treatment.	Corn (Bushels per Acre).		
		First Period.	Second Period.	Decrease.
4	Muriate of potash	44.61	31.83	12.78
7	Manure	63.11	57.20	5.91
10	Nitrate of soda Muriate of potash	42.07	35.38	6.69
11	Dissolved boneblack Muriate of potash	54.90	39.33	15.57
14	Nitrate of soda Dissolved boneblack Muriate of potash	62.46	41.89	20.57

Potash alone was effective, although the difference between the first period and the second period is very large. This treatment outyielded the potash and nitrogen treatment in the first period, but results were reversed in the second.

The use of a mineral plant-food ration consisting of phosphoric acid and potash gave marked results. Here again, however, the decrease in yield between the two periods was fully as great as, in fact somewhat larger than, the decrease on either the potash or potash and nitrogen plots. On the complete fertilizer, however, the decrease was even greater; for whereas this treatment was definitely superior in yield during the first period, it was very little better than the phosphoric acid and potash treatment in the second.

There are two explanations for this apparent decrease in yielding power in the two periods under discussion. The weather conditions may not have been the same for the two series of corn years; and the destructive system of farming followed may have seriously affected the ability of the soil to produce crops on fertilizers alone, as compared to its ability to produce crops on barnyard manure.

With reference to the first possibility, Table 6, page 136, presents data for moisture and temperature during all of the years in question. An attempt is made to epitomize these records in a single sentence descriptive of the growing conditions for the years in question. Bringing these together, the following picture is obtained of the comparative growing conditions in the two periods: —

First Period.		*Second Period.*	
1889.	Warm and moist in the early season.	1902.	Cool with abundant moisture.
1890.	Normal.	1903.	Drought in May; very cold and wet in June; very cold in August.
1894.	Warm and generally dry following a dry winter.	1904.	Wet spring; cool.
1898.	Good growing season.	1907.	Cold and dry following a dry winter.
1899.	Slight moisture deficiency.	1910.	Drought.

It is evident that the weather conditions in the last period were less favorable than in the first period.

In interpreting the significance of the above facts, thought must be given to the farming system followed. At the very beginning the stage was apparently set, although unconsciously, for a crop increase from the use of fertilizer potash. Grass, a heavy potash feeder, had been occupying the land for a number of years, but without return to the soil of either manure or fertilizer. As the years passed, this initial condition was accentuated through the removal from the soil of successive crops of corn and of grass and clover. Had these crops been fed on the farm, as in practical agriculture they must have been, there would have been potash return to the soil by natural means and less need for the use of commercial potash.

The Destructive Treatments. — A number of treatments were definitely destructive, *i.e.*, yields decreased definitely and significantly from one period to another, and reached a point at which profitable farming would have been absolutely impossible. Nitrate of soda alone, acid phosphate alone, lime alone, nitrate of soda and acid phosphate, and land plaster come in this list. The average yields for the first and second periods for plots treated with these materials were as follows: —

TABLE 4. — *The Destructive Treatments.*

Plot.	Treatment.	Corn (Bushels per Acre).		
		First Period.	Second Period.	Decrease.
1	Nitrate of soda	26.73	6.05	20.68
2	Dissolved boneblack	23.96	4.52	19.44
5	Lime	23.71	2.81	20.90
8	Nitrate of soda Dissolved boneblack	32.33	9.84	22.49
13	Plaster	27.09	9.14	17.95

Since the farming system followed was one which logically and on many soils inevitably results in need of complete fertilizer applied in large quantities, it is not astonishing that the one-sided treatments should give such poor results.

It will be noted that the above-mentioned destructive treatments are those which contain no potash, which fact is of importance in connection with the lime history of the field. Commencing in 1899, lime was applied at frequent intervals, and in generous quantity. It has sometimes been claimed that such use of lime makes soil potash available. Did it have such an effect, it would be expected that the yields on the nitrate of soda, the dissolved boneblack (acid phosphate) and the nitrate and boneblack plots would approximate those secured on equivalent treatments with potash added. This expectation has not been realized. There is no indication in the data at hand that lime has had any measurable or significant effect in increasing the availability of soil potash.

Manure versus Fertilizer. — Table 5 shows the comparative corn yields year by year, with averages for the two periods in question, of Plot 7, receiving manure, and Plot 14, receiving complete fertilizer.

TABLE 5. — *Comparison of Manure and Complete Fertilizer.*

First Period.			Second Period.		
Year.	Corn (bushels per acre).		Year.	Corn (bushels per acre).	
	Plot 7, Manure.	Plot 14, Complete Fertilizer.		Plot 7, Manure.	Plot 14, Complete Fertilizer.
1889	57.50	61.50	1902	68.70	56.20
1890	59.75	71.00	1903	37.39	25.56
1894	54.70	51.00	1904	50.00	47.78
1898	67.70	55.90	1907	72.50	38.31
1899	75.90	72.90	1910	57.43	41.57
Average	63.11	62.46	Average	57.20	41.89

For the first five crops the two treatments gave practically the same results. For the last five crops, yields were maintained fairly well by the manure treatment, and not at all well on the fertilizer treatment. This difference in plot behavior may be explained, in part, either by the fact that manure contained organic matter while the fertilizer used did not, or by the difference in plant food. The amounts of plant food applied per acre in the two contrasted treatments are as follows: —

	Pounds per Acre (Average per Year).	
	Applied in Manure.	Applied in Fertilizer.
Nitrogen	108	24
Phosphoric acid	118	51
Potash	169	80

The amount of manure used is larger than could have been produced had all crops grown been fed to animals and all of the manure produced carefully saved and returned to the land. For this reason the fact brought out in the foregoing table has no great significance in its bearing on actual practice.

Response of Corn to Fertilizer Nitrogen. — There was wide variation in the degree of response of the crop to the use of fertilizer nitrogen. In two cases there was apparently a significant decrease in crop produced by such use, — a result which, while unusual, is by no means impossible. Owing to its favorable effect on nitrification, corn seldom shows marked response to the use of this plant food except under those conditions where the soil supply of organic nitrogen is very limited. Less response would therefore be expected on the corn crops following legumes or grown on sod than on the corn crops following non-legumes or grown on stubble, while the greatest increase would be expected from those corn crops which are three years from a legume.

The following tabulation was made to see if this expectancy be supported by facts. Owing to the comparatively small variation in checks, the yields on the phosphoric acid and potash plot are compared directly with those on the complete fertilizer plots. The yields on the manure plots are included, as significant of results secured where there was a sufficiency of plant food and organic matter in the soil. Since moisture and temperature conditions influence nitrification, the departure from normal of both precipitation and mean hourly temperature is tabulated alongside the yield records.

TABLE 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation and Weather Conditions.*

CORN, YIELDS PER ACRE, SOUTH SOIL TEST.

I. *Following Legume or "Old Sod."*

[The first row of figures under the date line is bushels of corn per acre; the second row, pounds of stover per acre.]

Precipitation (Inches). Above Normal.		Precipitation (Inches). Below Normal.	Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit). Above Normal.		Mean Hourly Temperature (Degrees Fahrenheit). Below Normal.
			1889.					
	April	—0.84	57.50	58.00	61.50	+3.2	April	
+1.03	May		4,200	3,960	4,180	+4.0	May	
+1.63	June		Warm and moist in early season.			+2.0	June	
+6.11	July						July	—1.1
	August	—1.53					August	—2.5
			1894.					
	April	—1.42	54.7	49.5	51.0	+1.8	April	
+0.32	May		3,760	3,820	3,780	+1.3	May	
	June	—0 25	Warm and generally dry following a dry winter.			+3.7	June	
	July	—2.86				+2.9	July	
	August	—3.94				+1.3	August	
			1902.					
+0.05	April		68.7	55.9	56.2	+1.2	April	
	May	—1.36	6,220	4,640	4,540		May	—0.4
+1.16	June		Cool and abundant moisture.				June	—2.2
+0.25	July						July	—2.8
+0.40	August						August	—1.9
			1907.					
	April	—1.28	72.50	30 13	38.31		April	—4.6
+0.34	May		6,900	6,500	5,500		May	—5.6
	June	—1.02	Cold and dry following a dry winter.				June	—1.8
	July	—0.54					July	—0.6
	August	—2.81					August	—1.9
			1913.					
+0.04	April		66.8	49.7	44.4	+1.5	April	
+1.26	May		5,140	4,040	3,840		May	—1.8
	June	—2.48	Dry from June on.			+0.7	June	
	July	—2.82				+0.8	July	
	August	—1.99				+1.5	August	
			1915.					
+0.73	April		60.79	37.58	35 15	+3.8	April	
	May	—2 48	3,520	3,250	3,400		May	—3 3
	June	—0.38	Cool, with flood conditions in late season.				June	—1.5
+4.72	July						July	—1.7
+4.03	August						August	—2.0
			1917.					
	April	—1.43	40.8	46.3	36.0		April	—3.2
+0.45	May		5,200	3,300	5,400		May	—8.1
+1.89	June		Very cool in early season.				June	—0.4
	July	—1.05				+1.1	July	
+2.81	August					+2.9	August	

Table 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation, and Weather Conditions* — Continued.

Corn, Yields per Acre, South Soil Test — *Concluded.*

II. *Second Year after Legume or Sod.*

Precipitation (Inches). Above Normal.		Precipitation (Inches). Below Normal.	Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit). Above Normal.		Mean Hourly Temperature (Degrees Fahrenheit). Below Normal.
			1890.					
	April	—1.53	59.75	65.90	71.00	+0.4	April	
+1.71	May		5,520	4,880	5,320		May	—0 3
	June	—1.85	"Normal."				June	—0.4
+1.22	July						July	—0.8
+0.63	August						August	—0.8
			1898.					
+0.47	April		67.7	41.2	55.9		April	—3 1
+1.93	May		3,800	2,440	2,600		May	—1.8
+0.31	June		Good growing conditions.			+0 3	June	
+0.32	July					+0.3	July	
+2.60	August					+1.7	August	
			1903.					
	April	—0.96	37.39	20.39	25.56	+0.8	April	
	May	—3.20	3,600	2,320	3,040	+1.8	May	
+4.41	June		*Drought in May;* very cold and wet in June; very cold in August.				June	—6.1
+0.23	July						July	—1.7
+0.67	August						August	—6.0
			1910.					
	April	—0.19	57.43	37.14	41.57	+4.5	April	
	May	—1 01	3,700	2,300	3,080		May	—1.3
	June	—0.73	Drought.				June	—1.9
	July	—2.51				+1.5	July	
	August	—0.22					August	—0.9

III. *Third Year after Legume or Sod.*

			1899.					
	April	—1.47	75.9	59.9	72.9		April	0
	May	—2.40	5,350	3,160	4,450		May	—1.7
+0.75	June		Slight moisture deficiency.			+1.7	June	
+0.48	July						July	—0.5
	August	—2.25					August	0
			1904.					
+2 47	April		50 00	53 11	47.78		April	—3.6
+0 87	May		4,000	3,940	3,700	+2.7	May	
+1.97	June		Wet spring; cool.				June	—0 7
	July	—1.79					July	—0.8
	August	—0.16					August	—1.6

TABLE 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation, and Weather Conditions* — Concluded.

CORN, YIELDS PER ACRE, NORTH SOIL TEST.

I. *Following Legume or Sod.*

Precipitation (Inches). Above Normal.		Precipitation (Inches). Below Normal.	Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit). Above Normal.		Mean Hourly Temperature (Degrees Fahrenheit). Below Normal.
			1890.					
			Whole Plot.					
	April	−1.53		74.0	74.9	+0.4	April	
+1.71	May			5,740	5,820		May	−0.3
	June	−1.85	"Normal."				June	−0.4
+1.22	July						July	−0.8
+0.63	August						August	−0.8
			1905.					
			Limed.					
	April	−0.70		34.24	43.06		April	−0.5
	May	−2.40		3,400	4,840		May	−0.5
	June	−0.52	Cool and very dry.				June	−1.3
	July	−1.78				+0.5	July	
+2.22	August						August	−2.2
			Unlimed.					
				11.29	36.24			
				4,520	5,840			
			1916.					
			Limed.					
+0.43	April			48.1	41.2		April	−2.2
	May	−0.47		4,000	4,200		May	−1.5
+1.96	June						June	−4.6
+2.44	July					+1.0	July	
	August	−1.76				+1.5	August	
			Unlimed.					
				30.3	38.3			
				2,500	4,200			

In the year following a legume there has been no consistent response of the crop to the use of fertilizer nitrogen, and this almost without regard to the condition of the weather. The second year after a legume, however, there has been such response, — in one case in a marked degree. In the two cases where corn was planted three years after the legume, one showed an apparent increase rather significant in size, the other an apparent decrease.

For comparison, the results of the three corn crops grown on the North Soil Test are presented. All of these were grown after sod or legume. On the limed section or on the undivided plot, nitrogen brought a crop increase in one case out of three. On the unlimed section, in the two years of record, there was a definite increase. This result may trace back to the poor growth of the clover on the unlimed land.

The Last Three Corn Crops.

Cultural methods from 1909 on departed widely from the normal. In 1908 a catch crop of crimson clover was turned under as a green manure. In 1909 a partial crop of buckwheat was turned under. In 1911 there was a cultivated fallow, and in 1912 something which in its effect was practically a fallow. The 1913 corn crop therefore had the benefit of two years of soil idleness. In 1914 a crop of soy beans failed to mature, and hence presumably left more of value in the stubble than would have been the case had the crop ripened its seed. In 1916 sweet clover was sown, but the crop appeared to be mostly weeds. This was cut and removed from the soil but not weighed. The corn crops of 1913, 1915 and 1917 therefore are not comparable with the earlier crops, although they may indicate the fertility tendencies as brought about by this abnormal treatment.

The Hay Crops.

There were six crops of grass and clover. One of the most marked results in the whole history of the experiment was the character of the vegetation produced by differential fertilizer treatment on uniform seeding. Clovers failed to grow where potash was not applied. The effect of this is shown primarily in the rowen crop, which consisted largely of clover. The number of hay crops was, however, too small and the crop too responsive to varying weather conditions to admit of any very satisfactory interpretation of the data. The graphic presentation (Fig. 2) represents the total yields for the six crops.

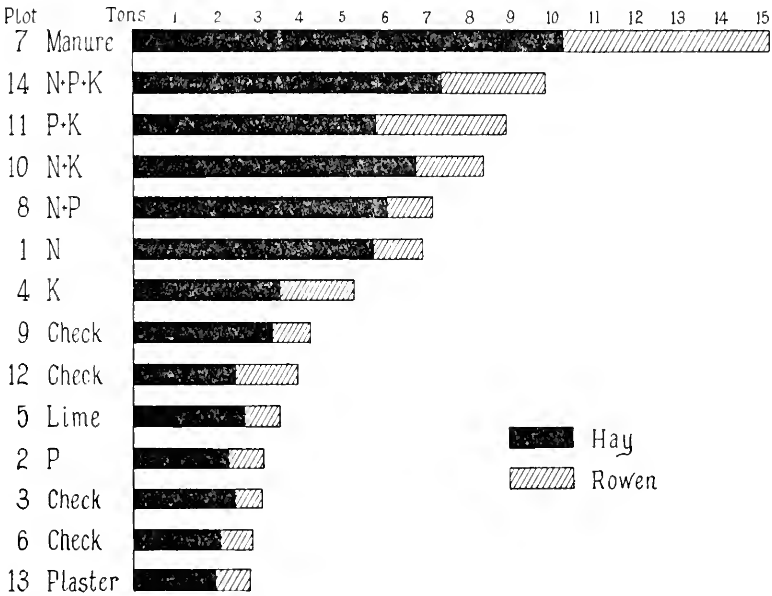


FIG. 2. — South Soil Test. Total yields per acre. Six hay crops.

Financial Interpretation.

No satisfactory financial interpretation of the results of the experiment is possible. Fertilizers were applied according to a set schedule, without reference to the value of the crop or to its ability to make payment through increased acre value for the plant food applied. Neither was there any attempt to estimate the necessity of one plant food or another as indicated by the previous history of the plots, and response of the crops grown to varying fertility treatments.

The North Soil Test.

History.

This field was started in 1890. Previously it had been pasture, without definite manure application, for a number of years. The plots are located about 150 yards from the South Soil Test, and are on soil of the same formation, although with a more definite slope toward the west. Fig. 3 shows the shape and arrangement of plots as compared with the South Soil Test.

Fertilizer Treatment.

The fertilizer treatment was the same in principle as that on the South Soil Test, except that the plots were differently laid out and hence bore different numbers. The schedule follows: —

Plot.	Treatment.	Pounds per Acre.
1	No fertilizer.	
2	Nitrate of soda	160
3	Dissolved boneblack	320
4	No fertilizer.	
5	Muriate of potash	160
6	Nitrate of soda Dissolved boneblack	160 320
7	Nitrate of soda Muriate of potash	160 160
8	No fertilizer.	
9	Dissolved boneblack Muriate of potash	320 160
10	Nitrate of soda Dissolved boneblack Muriate of potash	160 320 160
11	Plaster	800[1]
12	No fertilizer.	

[1] 1892–95, 160 pounds per acre; 1896, increased to 400 pounds per acre; 1902, increased to 800 pounds per acre.

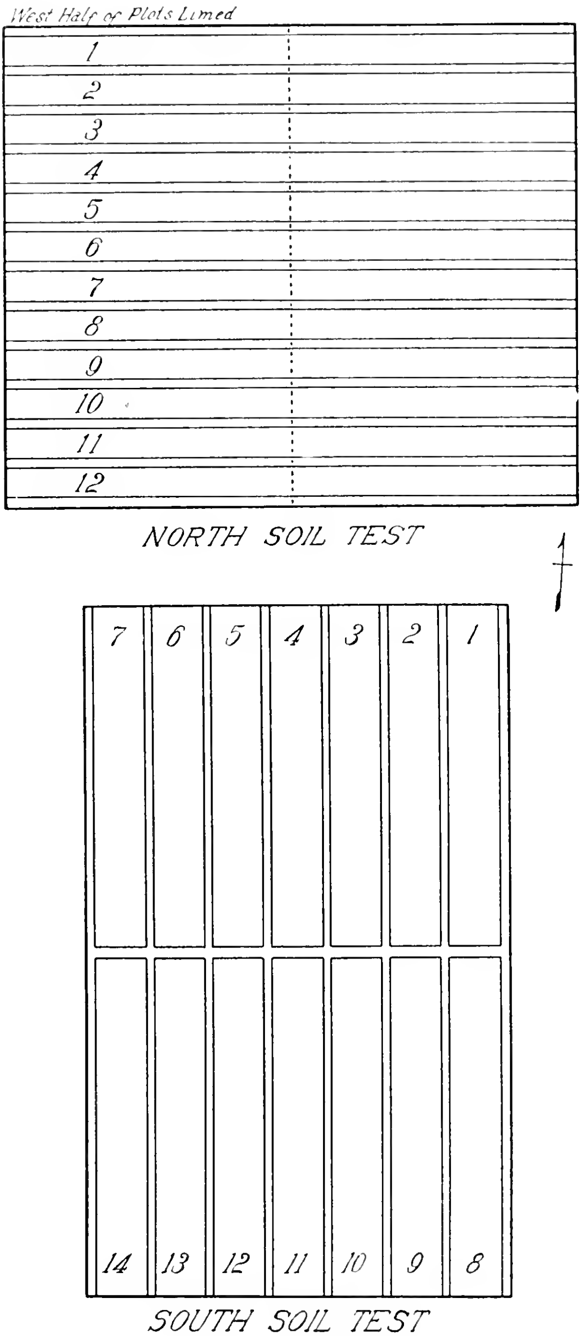


Fig. 3. — Plan of the plots.

In 1897 and 1902 for potatoes, in 1898, 1899, 1900 and 1901 for onions, and in 1903 and 1904 for grass and clover, the fertilizer applications were doubled. In 1899 lime was applied to the west half of the field, and was repeated in 1904, 1907 and 1916, a total of 4½ tons per acre of lime in one form or another being applied over a period of eighteen years.

Table IV of the Appendix gives the record of yields over the period of the experiment.

Variation in Checks.

The check plots were very variable. The yields of grass and clover on the limed and unlimed halves of the field illustrate this fact.

TABLE 7. — *Grass and Clover Yields on Check Plots (Yields per Acre, Pounds).*

YEAR.	UNLIMED.				LIMED.			
	Plot 1.	Plot 4.	Plot 8.	Plot 12.	Plot 1.	Plot 4.	Plot 8.	Plot 12.
1903	360	**550**	450	420	**1,150**	1,010	570	1,140
1904	**1,200**	590	600	650	880	690	1,440	**1,520**
1908	**1,340**	780	480	440	2,160	1,560	1,640	**2,220**
1909	**1,280**	1,180	1,150	720	**1,570**	1,520	1,560	1,520
1914	**1,600**	1,240	820	600	1,840	2,030	2,920	**3,060**
1915	920	**1,020**	520	480	1,480	2,220	2,320	**2,940**

The highest yielding plots in each year are bold-faced type.

Plot 1 on the limed and unlimed portions of the field is seemingly superior, at least in its ability to grow grass and clover, to Plots 4 and 8. Plot 12, unlimed, is the poorest of the checks, while on the limed portion of the field it is superior to Plot 1. Owing to this variation in different parts of the field, the data presented in Table IV of the Appendix do not permit of clear-cut numerical discussion. They serve to indicate tendencies rather than to furnish statistical proof. It is probable, also, that the natural variation in the checks has been exaggerated somewhat by the fact that there has been cross washing on this field, the soil working in a more or less diagonal direction from the unlimed portion of Plot 12 to the limed half of Plot 1.

Effect of Lime and of Fertilizer Applications.

Even though the uniformity of conditions is not as great as could be desired, the results from the use of many of the plant food and lime combinations are so striking as to be beyond the range of probable experimental error. Table 8 has accordingly been prepared, showing the comparisons for a number of the more important crops grown. From this table the following facts are developed: —

1. The effect of lime is very marked, but crop increase from its use is less when it is added to phosphoric acid alone, or to phosphoric acid and nitrogen, than when added to any other treatment. In general, the phosphoric acid and nitrogen treatment on the unlimed portion of the field leads all except the complete fertilizer. On the limed portion, however, complete fertilizer, phosphoric acid and potash, nitrogen and potash, and, occasionally, potash alone are superior.

2. The gain from applying lime in addition to a ration of potash alone is very much greater than from applying it in addition to phosphoric acid.

3. Potash has not given as marked results as on the South Soil Test.

4. The use of potash, phosphoric acid and lime has maintained yields at a comparatively high level, despite the infrequency with which clovers have been grown.

5. Nitrogen, used in addition to phosphoric acid and potash, has given fairly large increases in crop.

Effect of Lime on the Availability of Soil Potash.

On the limed half of this field there are three comparisons — namely, nitrogen with and without potash, phosphoric acid with and without potash, nitrogen and phosphoric acid with and without potash — where the effect of lime in increasing the availability of soil potash should be apparent. Table 9 shows the crop yields secured and presents the estimated gain from the use of potash in each case.

TABLE 8. — *The Interrelation of Lime and Fertilizer (Yields per Acre).*

Crop.	Average of Checks (Plots 1, 4, 8, 12).			Nitrogen (Plot 2).			Phosphoric Acid (Plot 3).			Potash (Plot 5).		
	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.
Grass and clover:												
1903	968	445	-	3,140	1,520	-	1,560	950	-	950	660	-
1904	1,133	760	-	1,690	2,020	-	800	1,060	-	2,700	670	-
1908	1,895	760	-	3,880	3,280	-	1,600	940	-	2,380	860	-
1909	1,543	1,083	-	1,780	1,980	-	1,420	1,260	-	3,640	1,050	-
1914	2,463	1,065	-	2,870	2,020	-	1,680	1,490	-	5,540	1,280	-
1915	2,240	735	-	1,580	1,440	-	1,380	1,180	-	6,750	1,580	-
Average	1,707	808	+899	2,490	2,043	+447	1,407	1,147	+260	3,660	1,017	+2,643
Beans (green weight), 1918	1,005	1,680	—675	960	1,240	—280	800	960	—160	3,840	2,320	+1,520
Cabbage, 1917	18,410	1,365	+17,045	23,240	3,080	+20,160	9,220	9,800	—580	22,680	1,580	+21,100
Corn, grain (bushels):												
1905	13.7	8.7	-	9.1	13.9	-	5.9	7.8	-	18.4	5.7	-
1916	27.1	20.2	-	19.7	34.5	-	21.7	35.1	-	36.9	25.9	-
Average	20.4	14.5	+5.9	14.4	24.2	—9.8	13.8	21.4	—7.6	27.8	15.8	+12.0
Corn, stover:												
1905	2,810	2,800	-	3,960	480	-	2,640	3,400	-	4,400	4,040	-
1916	1,800	1,700	-	1,600	2,200	-	1,600	3,000	-	2,600	3,000	-
Average	2,305	2,250	+55	2,780	1,340	+1,440	2,120	3,200	—1,080	3,500	3,520	—20
Soy beans (bushels):												
1906	7.6	10.5	-	3.5	4.5	-	4.0	5.5	-	12.4	8.3	-
1910	17.7	12.1	-	19.3	14.8	-	13.8	11.4	-	24.8	9.0	-
1911	6.3	10.6	-	2.1	4.7	-	.9	4.7	-	20.3	14.5	-
Average	10.5	11.1	—.6	8.3	8.0	+.3	6.2	7.2	—1.0	19.2	10.6	+8.6

Soy beans, straw:												
1906	503	660	–	490	440	–	400	380	–	720	520	–
1910	3,235	1,625	–	3,480	3,140	–	2,800	2,680	–	1,560	1,680	–
1911	2,033	1,848	–	1,480	1,450	–	950	1,530	–	2,820	2,160	–
Average	1,924	1,378	+546	1,817	1,677	+140	1,383	1,530	—147	1,700	1,453	+247
Onions (bushels):												
1899	19.5[1]	3.7[1]	–	91.4	18.7	–	12.3	6.5	–	161.7[1]	3.1	–
1900	95.9	35.2	–	155.0	50.0	–	37.7	17.3	–	383.5	37.7	–
Average	57.7	19.5	+38.2	123.2	34.4	+88.8	25.0	11.9	+13.1	272.6	20.4	+252.2
Potatoes (bushels), 1902	48.7	54.1	—5.4	47.6	50.7	—3.1	48.0	59.3	—11.3	81.7	73.3	+8.4
Rye, grain (bushels):												
1913	33.9	24.1	–	36.4	30.7	–	28.9	29.6	–	35.3	28.9	–
1921	13.1	8.6	–	11.8	10.0	–	12.1	11.8	–	15.5	10.4	–
Average	23.5	16.4	+7.1	24.1	20.4	+3.7	20.5	20.7	—.2	25.4	19.7	+5.7
Rye, straw:												
1913	5,075	3,725	–	6,220	4,060	–	5,180	3,860	–	5,220	4,380	–
1921	1,515	1,010	–	1,340	1,240	–	1,340	1,490	–	1,820	1,320	–
Average	3,295	2,368	+927	3,780	2,650	+1,130	3,260	2,675	+585	3,520	2,850	+670

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

TABLE 8. — *The Interrelation of Lime and Fertilizer (Yields per Acre)* — Concluded.

Crop.	Phosphoric Acid and Nitrogen (Plot 6).			Potash and Nitrogen (Plot 7).			Phosphoric Acid and Potash (Plot 9).			Complete Fertilizer (Plot 10).		
	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.
Grass and clover:												
1903	3,180	1,830	-	2,190	1,820	-	920	620	-	2,830	2,330	-
1904	3,130	2,330	-	2,380	1,970	-	6,160	940	-	7,240	2,820	-
1908	4,600	3,720	-	3,800	3,240	-	3,240	800	-	4,730	4,240	-
1909	2,760	2,010	-	2,980	1,240	-	3,840	920	-	2,520	1,790	-
1914	3,840	2,540	-	4,080	2,000	-	4,420	1,030	-	6,110	2,600	-
1915	4,190	1,280	-	5,560	960	-	5,220	580	-	5,800	900	-
Average	3,617	2,285	+1,332	3,498	1,872	+1,626	3,967	815	+3,152	4,872	2,447	+2,425
Beans (green weight), 1918	2,200	1,980	+220	4,360	2,380	+1,980	3,040	1,680	+1,360	3,740	2,500	+1,240
Cabbage, 1917	27,440	23,160	+4,280	28,000	1,000	+27,000	32,720	13,880	+18,840	45,400	33,360	+12,040
Corn, grain (bushels):												
1905	29.2	20.2	-	29.5	12.5	-	34.2	11.3	-	43.1	36.2	-
1916	41.3	43.3	-	45.7	25.1	-	48.1	30.3	-	51.2	38.3	-
Average	35.3	31.8	+3.5	37.6	18.8	+18.8	41.2	20.8	+20.4	47.2	37.8	+9.4
Grain, stover:												
1905	3,680	3,600	-	3,720	2,960	-	3,400	4,520	-	4,810	5,840	-
1916	2,800	3,600	-	3,800	2,900	-	4,000	2,500	-	4,200	4,200	-
Average	3,240	3,600	—360	3,760	2,930	+830	3,700	3,510	+190	4,520	5,020	—500
Soy beans (bushels):												
1906	9.5	6.9	-	14.1	9.7	-	10.3	6.9	-	14.1	7.9	-
1910	18.6	14.5	-	19.0	8.3	-	19.7	4.8	-	16.6	8.3	-
1911	6.9	10.9	-	20.7	14.5	-	15.9	14.3	-	20.2	17.1	-
Average	11.7	10.8	+.9	17.9	10.8	+7.1	15.3	8.7	+6.6	17.0	11.1	+5.9

Soy beans, straw:												
1906	760	520	-	780	740	-	600	420	-	920	400	-
1910	4,120	2,160	-	1,820	1,520	-	1,460	1,040	-	3,240	2,200	-
1911	2,600	2,290	-	3,000	2,360	-	2,880	3,370	-	3,830	3,610	-
Average	2,493	1,657	+836	1,867	1,540	+327	1,647	1,610	+37	2,663	2,070	+593
Onions (bushels):												
1899	145.4	143.1	-	200.0[1]	3.1	-	183.8	40.4[1]	-	224.6	46.2[1]	-
1900	202.3	225.8	-	310.8	9.2	-	380.0	159.6	-	488.5	136.9	-
Average	173.9	184.5	—10.6	255.4	6.2	+249.2	281.9	100.0	+181.9	356.5	91.5	+265.0
Potatoes (bushels), 1902	100.3	98.0	+2.3	75.6	77.3	—1.7	113.7	91.7	+22.0	132.6	127.3	+5.3
Rye, grain (bushels):												
1913	35.3	27.9	-	35.3	22.9	-	31.1	17.1	-	35.7	21.8	-
1921	15.7	16.4	-	13.9	10.0	-	6.1	9.6	-	7.1	7.5	-
Average	25.5	22.2	+3.3	24.6	16.5	+8.1	18.6	13.4	+5.2	21.4	14.7	+6.7
Rye, straw:												
1913	5,020	4,240	-	5,620	4,720	-	5,260	3,640	-	5,600	3,780	-
1921	1,760	960	-	1,440	1,240	-	2,360	1,300	-	1,280	800	-
Average	3,390	2,600	+790	3,530	2,980	+550	3,810	2,470	+1,340	3,440	2,290	+1,150

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

Table 9. — *Yields per Acre, Limed Portion of Field.*

Treatment.	Corn (2 Crops) (Bushels).		Grass and Clover (6 Crops) (Pounds).		Soy Beans (3 Crops) (Bushels).	
	Yield.	Gain from Use of Potash.[1]	Yield.	Gain from Use of Potash.[1]	Yield.	Gain from Use of Potash.[1]
Nitrogen alone	14.4		2,490		8.3	
Nitrogen and potash	37.6	23.2	3,498	1,008	17.9	9.6
Phosphoric acid alone	21.7		1,407		6.2	
Phosphoric acid and potash	41.2	19.5	3,967	2,560	15.3	9.1
Nitrogen and phosphoric acid	35.3		3,617		11.7	
Complete fertilizer	47.2	11.9	4,872	1,255	17.0	5.3

[1] By difference.

The large and consistent differences secured through the use of potash indicate that whatever effect the lime may have had on the availability of soil potash was relatively insignificant. This checks the results secured on the South Soil Test, as already discussed.

Miscellaneous Effects of Fertilizers on Crops.

Even though the fertilizer applications were in some cases doubled, as indicated on page 142, either the soil conditions were unfavorable or the amount of plant food applied was too small to give satisfactory crops of onions or potatoes. The yield of 488 bushels of onions on the limed complete fertilizer plot in 1900 is indeed well above the average, but still is not a large yield. In 1898 and likewise in 1901, the crop was a failure. The yield records do, however, indicate two things very strongly: first, the great importance to the onion crop of maintaining a suitable reaction of the soil; and second, the need by the crop of large quantities of all three of the essential plant foods. The potato crops of 1897 and 1902 were virtual failures.

The cabbage crop of 1917 was remarkably satisfactory and furnishes several illustrations of the fact that crops of the same size may be secured through radically different plant food treatments. As an illustration, the crop on the limed half of Plot 9, which in 1917 had been receiving phosphoric acid and potash annually for twenty-seven years, was the same as the crop on complete fertilizer without lime. Neither one of these, however, approached the crop produced with complete fertilizer and lime. Again, the crop on the limed portion of Plot 6, which had received no potash for twenty-seven years, was almost identical with that on the limed portion of Plot 7, which had received no phosphoric acid for the

PLATE I.

CROP RESPONSE TO NITROGEN AND LIME.

CABBAGES, CROP OF 1917.

Potash and phosphoric acid with lime. Yield per acre: good, 25,000 pounds; poor, 7,720 pounds.

Potash, phosphoric acid and nitrogen without lime. Yield per acre: good, 26,040 pounds; poor, 7,320 pounds.

A. Lime versus *Nitrogen.*

A very fair crop was produced with potash and phosphoric acid plus lime, or with complete fertilizer without lime.

Potash and phosphoric acid without lime. Yield per acre: good, 6,320 pounds; poor, 7,560 pounds.

Potash, phosphoric acid and nitrogen with lime. Yield per acre: good, 42,480 pounds; poor, 2,920 pounds.

B. Nitrogen with and without Lime.

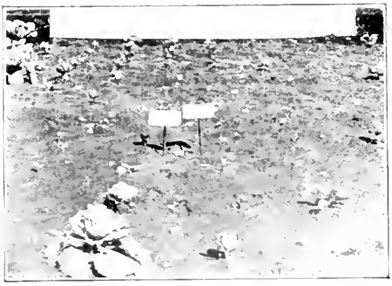
The lower left compared with upper right indicates the effect of nitrogen without lime: upper left compared with lower right the effect of nitrogen with lime.

PLATE II.

EFFECT OF ACIDULATED PHOSPHATE IN NEUTRALIZING THE EFFECT OF "SOIL ACIDITY."

CABBAGES, CROP OF 1917.

Nitrogen and phosphoric acid without lime. Yield per acre: good, 13,560 pounds; poor, 9,600 pounds.



Nitrogen and potash without lime. Yield per acre: good, 160 pounds; poor, 840 pounds. (An absolute crop failure.)

A. Without Lime.

The omission of phosphoric acid under acid soil conditions was fatal.

Nitrogen and phosphoric acid with lime. Yield per acre: good, 21,560 pounds; poor, 5,880 pounds.

Nitrogen and potash with lime. Yield per acre: good, 20,000 pounds; poor, 7,600 pounds.

B. With Lime.

A fair crop was produced without phosphoric acid, although, as shown on the opposite page, complete treatment gave much the larger crop.

same length of time. In both cases the crop was fairly satisfactory. On the other hand, nitrogen and phosphoric acid without lime gave an immensely larger crop than did nitrogen and potash without lime, — once again indicating that under certain conditions phosphorus functions in reducing need for lime, or in neutralizing the effects of soil acidity. It is also of interest to note that the yield of cabbages classified as "poor" is less absolutely, and very much less relatively, on the high-yielding plots than on the low-yielding plots.

General Summary.

The more important conclusions which may be drawn from this work, in their application to the fertility practice of Massachusetts farmers, are as follows: —

1. The kind of crop being grown and the cropping system followed determine the fertilizer needs of crops fully as much as does the soil type.

2. Where the soil is farmed without live stock, and no manure returned to the land, a complete fertilizer is more certain to bring satisfactory results than is any other fertilizer treatment.

3. The nitrogen response of crops is affected by nearness in the rotation to a legume crop, and likewise by the kind of crop. The tests indicate that where corn is grown either the first or second year following a legume, the use of fertilizer nitrogen does not bring anything more than a moderate return. The character of the season does not seem to have a dominant influence on the functioning of this plant food when applied in artificial form.

4. Where the whole crop is removed and manure not returned to the soil, large returns from the use of potash may be expected. As a corollary, the greater the extent to which crops are removed, the greater relatively will be the need for fertilizer potash; and on the other hand, the greater the extent to which crops produced are fed on the farm and manure returned, the lower will be the need for this plant food. The lesson therefore applies most particularly to farms where the supply of manure is deficient, and particularly to those where hay is cut for market, or where tobacco, onions or other money crops are raised continuously on the same land.

5. The use of lime in the cropping system followed has increased very significantly the size of crops. Apparently, however, it has had no effect on the availability of soil potash.

6. The tests show the great dependence of clover on a generous supply of lime, potash and phosphoric acid. They demonstrate a principle which is believed to be of almost universal application.

7. Soluble phosphates function in reducing, although not in eliminating, the crop damage caused by "acidity" or lack of lime.

8. Crops vary enormously in their response to the different plant foods. Except for corn and for grass and clover, however, the number of tests on individual crops is too small to permit of safe generalization.

APPENDIX.

TABLE I. — *South Soil Test (Yields per Acre).*

Year.	Crop.		Plot 1, Nitrate of Soda.	Plot 2, Dissolved Boneblack.	Plot 3, Check.	Plot 4, Muriate of Potash.	Plot 5, Lime.	Plot 6, Check.	Plot 7, Manure.	Plot 8, Nitrate and Boneblack.	Plot 9, Check.	Plot 10, Nitrate and Muriate.	Plot 11, Boneblack and Muriate.	Plot 12, Check.	Plot 13, Plaster.	Plot 14, Nitrate, Boneblack and Muriate.
1889	Corn	Grain (bushels)	31.25	30.00	24.75	49.25	30.75	23.50	57.50	37.00	36.75	53.00	58.00	32.50	31.25	61.50
		Stover (pounds)	1,660	1,940	1,440	2,980	1,740	1,400	4,200	2,100	2,080	3,020	3,960	2,100	1,880	4,180
1890	Corn	Grain (bushels)	45.60	49.50	43.75	62.60	51.80	45.56	59.75	50.37	42.50	53.94	65.90	52.20	52.00	71.00
		Stover (pounds)	3,750	3,590	4,850	4,590	3,660	3,500	5,520	3,260	3,130	4,235	4,880	3,525	3,540	5,320
1891	Oats	Grain (bushels)	33.13	18.13	18.13	24.07	24.69	20.31	38.44	29.07	16.56	29.69	25.94	17.50	15.94	33.13
		Straw (pounds)	2,500	1,490	1,490	1,750	1,300	1,400	4,620	2,210	1,260	2,270	1,630	1,350	1,240	3,010
1892	Grass and clover	Hay (pounds)	1,920	960	1,160	1,160	1,020	780	2,960	2,060	2,460	2,060	2,560	1,200	960	2,860
		Rowen (pounds)	720	800	640	1,400	720	600	2,240	640	660	1,040	1,900	840	680	1,340
1893	Grass and clover	Hay (pounds)	2,260	1,070	1,000	1,380	1,020	920	3,640	2,080	720	2,440	1,440	780	520	2,600
		Rowen pounds)	520	360	330	950	400	380	2,240	520	460	840	1,680	480	480	1,340
1894	Corn	Grain (bushels)	22.5	18.3	21.5	41.7	18.4	13.0	54.7	20.9	29.2	44.6	49.5	16.7	23.7	51.0
		Stover (pounds)	2,860	2,300	2,280	3,600	2,500	1,780	3,760	1,840	2,460	4,100	3,820	1,620	2,740	3,780
1895	Rye	Grain (bushels)	15.36	11.79	11.43	16.06	13.21	13.21	34.28	12.68	12.50	11.78	15.00	11.07	13.21	26.45
		Straw (pounds)	2,000	1,900	1,700	2,160	1,900	1,880	5,080	2,040	1,740	1,920	2,420	1,480	1,820	3,960
1896	Soy beans	Beans (bushels)	2.4	4.8	5.5	13.1	2.4	4.1	30.4	5.2	7.6	14.1	15.5	6.9	5.5	22.1
		Straw (pounds)	680	800	890	1,000	540	720	4,600	790	780	940	1,040	640	900	1,480
1897	Mustard (pounds)		–	–	–	–	20	–	8,500	900	–	–	500	–	–	5,100
1898	Corn	Grain (bushels)	20.6	18.5	9.8	19.8	10.4	16.9	67.7	32.0	12.5	10.9	41.2	10.5	21.9	55.9
		Stover (pounds)	2,210	1,400	1,050	1,540	1,000	1,100	3,800	1,700	800	1,300	2,440	650	1,300	2,600
1899	Corn	Grain (bushels)	13.7	3.5	3.9	49.7	7.2	5.0	75.9	21.4	5.9	47.9	59.9	3.6	6.6	72.9
		Stover (pounds)	1,160	620	730	2,760	1,100	820	5,350	1,220	840	2,360	3,160	680	990	4,450

1900	Grass and clover	Hay (pounds)	2,460	1,000	800	1,140	880	720	4,160	2,540	1,100	3,000	1,600	1,100	900	2,300
1901	Grass and clover	Hay (pounds)	900	300	400	600	500	300	3,600	1,200	400	2,100	1,900	400	200	3,300
		Rowen (pounds)	550	370	240	700	360	270	2,700	530	360	900	1,500	380	200	1,100
1902	Corn	Grain (bushels)	7.3	11.4	10.4	47.7	4.9	10.4	68.7	11.2	9.2	53.4	55.9	8.8	11.6	56.2
		Stover (pounds)	1,180	1,780	1,480	4,760	860	800	6,220	1,380	1,360	3,540	4,640	1,300	1,880	4,540
1903	Corn	Grain (bushels)	.56	.94	.94	16.61	.15	1.06	37.39	3.89	1.28	18.00	20.39	1.78	2.06	25.56
		Stover (pounds)	360	360	300	1,880	160	1,200	3,600	800	340	2,200	2,320	490	400	3,040
1904	Corn	Grain (bushels)	7.11	3.89	4.33	46.89	2.67	3.41	50.00	15.11	8.78	47.67	53.11	6.33	7.41	47.78
		Stover (pounds)	1,200	960	870	3,760	820	740	4,000	1,500	1,180	3,560	3,940	1,000	1,100	3,700
1905	Grass and clover	Hay (pounds)	2,600	400	600	2,100	1,000	700	3,200	2,000	1,200	1,500	2,300	1,400	700	1,700
1906	Grass and clover	Hay (pounds)	1,400	760	910	690	890	660	2,940	2,200	820	2,400	1,790	950	640	3,000
		Rowen (pounds)	520	295	300	440	260	325	2,670	520	390	470	1,220	410	320	1,100
1907	Corn	Grain (bushels)	1.00	.81	2.00	23.31	1.25	2.25	72.50	10.06	3.81	31.13	30.13	3.38	7.75	38.31
		Stover (pounds)	720	700	1,000	6,000	900	1,100	6,900	2,500	1,100	5,400	6,500	800	1,200	5,500
1908	Oats and crimson clover	Oat hay (pounds)	2,430	1,600	850	3,300	610	720	7,600	3,510	780	4,420	4,680	675	1,090	6,600
1909	Buckwheat (weight as cut, pounds)		5,808	2,299	3,388	6,897	3,872	4,054	16,214	7,744	4,235	10,043	9,922	3,993	4,840	14,036
1910	Corn	Grain (bushels)	14.28	5.57	3.86	24.65	5.07	9.21	57.43	8.93	4.57	26.72	37.11	17.21	13.86	41.57
		Stover (pounds)	1,700	1,800	400	2,120	500	1,100	3,700	1,900	700	2,200	2,300	1,700	800	3,080
1911	No crop		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1912	Crimson clover[1]		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1913	Corn	Grain (bushels)	22.6	11.0	11.7	52.6	8.7	8.4	66.8	–	–	51.2	19.7	29.1	11.0	44.1
		Stover (pounds)	2,420	2,180	2,240	4,360	2,460	1,700	5,140	–	–	3,500	4,040	2,710	1,880	3,840
1914	Soy beans (total weight, pounds)		3,500	900	1,000	6,000	1,200	1,800	11,500	–	–	9,100	7,700	1,700	1,700	9,800
1915	Corn	Grain (bushels)	22.86	10.00	8.50	40.86	5.29	10.93	60.79	–	–	34.25	37.58	16.5	10.92	35.15
		Stover (pounds)	1,490	760	615	1,980	635	720	3,520	–	–	3,365	3,250	960	805	3,400
1916	Sweet clover[1]		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1917	Corn	Grain (bushels)	34.2	18.1	12.7	40.9	13.8	13.9	40.8	–	–	46.1	16.3	15.7	21.7	36.0
		Stover (pounds)	1,900	1,600	2,400	3,300	1,700	1,500	5,200	–	–	3,500	3,300	2,100	1,400	5,100
1918	Alfalfa	First cutting (pounds)	1,020	180	140	1,710	120	0	4,050	–	–	1,600	1,920	640	150	1,960
		Second cutting (pounds)	1,480	1,590	1,005	1,815	1,170	735	3,035	–	–	2,160	2,415	1,180	1,090	1,555

[1] No weights taken.

South Soil Test.

1889. An 8-rowed flint corn. 80 pounds per bushel.
1890. An early dent corn. 80 pounds per bushel.
1891. Variety, Early Race Horse. There was sown with the oats the following mixture of grass and clover: timothy, 12 pounds; redtop, 8 pounds; red clover, 6 pounds; white clover, 2 pounds; alsike clover, 3 pounds.
1894. Pride of the North. 80 pounds per bushel.
1895. After rye, the land was plowed and sown to white mustard, without additional fertilizer (July 31). Germination was quick and even, but except on the plots where manure or phosphate, lime and plaster have been applied, there was almost absolutely no growth.
1896. Medium Green. A wet fall. Beans not ripened well. Plots 1, 2, 5, 6 and 8 molded a little in stack.
1897. Unfavorable weather conditions destroyed the onions and cabbages. Sowed mustard August 14. Only four plots furnished sufficient growth to cut and weigh. Double application of manure and fertilizer made.
1898. Pride of the North. 80 pounds per bushel. On July 29 mustard was sown, covering plots and division strips. The mustard came up on all plots, but made no growth except on Plots 7 and 14, and even here was very spindling and light.
1899. Pride of the North. 80 pounds per bushel. Ears and leaves eaten by cows for 1 rod on the north end of Plot 7. Weights of stover on the best plots low because the corn, making a normal growth, was ripe long before it was cut and the stover became dry. Except on Plots 4, 7, 10, 11 and 14, the ears were very poor, immature and small.
1900. Spring sowing: awnless brome, 20 pounds; tall oat, 5 pounds; Italian rye, 8 pounds; meadow fescue, 8 pounds; orchard, 8 pounds; yellow oat, 5 pounds; medium red clover, 16 pounds.
1901. Hay; no clover except where potash has been applied. Brome grass most abundant on lime plots.
1902. From 1902 on the application of lime and plaster is at the rate of 40 pounds per plot instead of 20 pounds as heretofore.
1902. Pride of the North. 90 pounds per bushel. Corn weighed two weeks after husking. Stover varies greatly as to moisture.
1903. Pride of the North. 90 pounds per bushel. Stover well dried out.
1904. Pride of the North. 90 pounds per bushel.
1905. Spring sowing: timothy, 18 pounds; redtop, 8 pounds; meadow oat, 6 pounds; Italian rye, 8 pounds; awnless brome, 6 pounds; orchard, 15 pounds; mammoth red clover, 5 pounds; alsike, 4 pounds.
1907. Rustler white dent. 80 pounds per bushel. Weighed after drying out in glasshouse.
1908. Lincoln oats. A part of the oats on Plot 8, measuring 602 square feet, has been destroyed by Mr. Fitts' hens. Correction for same is made in the record of the yield.
Crimson clover, poor, plowed under.
1909. Product of a strip 10 feet wide across plots. The rest plowed under. Weighed as cut. Winter vetch and rye sown on September 30.
1910. 70 pounds per bushel. Fertilizer for Plot 11 probably applied to Plot 12 by mistake. Sowed alsike clover in corn, August 2.
1911. No crop. Flint Laboratory takes Plots 8 and 9. Fertilizer applied as usual, field plowed and kept cultivated and free from weeds.
1912. Crimson clover, poor, no crop.
1913. Rustler white dent. 70 pounds per bushel. Weighed after being dried in glasshouse.
1914. Medium Green. Did not mature.
1915. Longfellow. 70 pounds per bushel.
1916. Sweet clover. Mostly weeds; cut and removed without weighing.
1917. Sweet clover plowed under.
Corn, Early Canada Flint. Plot 12 received about one-half the fertilizer for Plot 11. This amount was made up on Plot 11. 70 pounds per bushel.
1918. Alfalfa, sown Aug. 20, 1917, in corn. Second cutting, Plots 2, 3, 5, 12 and 13 mostly grass and weeds; Plot 6 all grass and weeds.

TABLE II. — *Precipitation in Inches.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1889 . .	3.29	1.45	1.46	2.42	4.71	5.01	10.52	2.72	3.17	4.58	6.04	3.57	48.94
1890 . .	2.61	4.20	5.37	1.73	5.39	1.53	5.63	4.88	5.85	7.13	1.32	2.86	48.50
1891 . .	6.75	4.23	2.99	2.66	1.97	4.75	5.28	4.18	2.66	2.94	2.99	5.40	46.80
1892 . .	5.85	1.90	2.40	0.76	6.28	3.46	4.41	6.47	2.16	0.66	4.98	1.01	40.34
1893 . .	3.33	5.75	3.66	4.41	5.02	3.32	2.59	3.49	2.82	4.88	2.81	4.86	46.94
1894 . .	2.16	1.74	1.77	1.83	4.00	3.13	1.55	0.31	4.63	4.85	3.14	3.53	32.64
1895 . .	3.87	1.05	2.71	5.56	2.07	2.76	3.87	3.46	5.04	4.77	5.36	3.94	44.46
1896 . .	1.07	4.67	6.11	1.32	2.58	2.57	4.96	3.84	5.41	3.23	3.03	0.87	39.66
1897 . .	3.00	2.52	3.53	2.42	4.38	6.65	14.51	4.29	1.94	0.73	5.85	7.23	57.05
1898 . .	7.15	3.80	1.63	3.73	5.61	3.69	4.09	6.85	3.65	6.27	5.48	2.30	54.25
1899 . .	2.80	3.56	7.13	1.79	1.28	4.13	4.89	2.00	7.90	1.84	2.17	2.00	41.49
1900 . .	4.08	8.12	5.76	1.85	3.78	3.65	4.67	4.11	3.67	3.72	5.87	2.40	51.68
1901 . .	1.81	0.62	5.66	5.95	6.91	0.87	3.86	6.14	4.17	3.88	2.08	7.77	49.72
1902 . .	1.72	3.54	5.29	3.31	2.32	4.54	4.66	4.65	5.83	5.59	1.27	4.27	46.99
1903 . .	3.28	4.27	6.40	2.30	0.48	7.79	4.64	4.92	1.66	2.72	2.04	3.95	44.45
1904 . .	4.74	2.45	4.48	5.73	4.55	5.35	2.62	4.09	5.45	1.74	1.35	2.75	45.30
1905 . .	3.90	1.70	3.66	2.56	1.28	2.86	2.63	6.47	6.26	2.27	2.06	3.15	38.80
1906 . .	2.18	2.73	4.90	3.25	4.95	2.82	3.45	6.42	2.59	5.69	1.98	4.49	45.45
1907 . .	2.73	1.92	1.82	1.98	4.02	2.36	3.87	1.44	8.74	5.00	4.50	3.89	42.27
1908 . .	2.25	3.53	2.86	1.97	4.35	0.76	3.28	4.27	1.73	1.57	1.06	3.05	30.68
1909 . .	3.56	5.16	3.01	5.53	3.36	2.24	2.24	3.79	4.99	1.23	1.06	2.95	39.12
1910 . .	6.14	5.08	1.37	3.07	2.67	2.65	1.90	4.03	2.86	0.93	3.69	1.72	36.11
1911 . .	2.36	2.18	3.80	1.87	1.37	2.02	4.21	5.92	3.41	8.81	3.84	4.42	44.21
1912 . .	2.18	3.16	5.70	3.92	4.34	0.77	2.61	3.22	2.52	2.07	4.03	4.04	38.56
1913 . .	3.98	2.94	6.38	3.30	4.94	0.90	1.59	2.26	2.56	5.16	2.11	3.38	39.50
1914 . .	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	0.52	2.09	2.62	2.89	41.83
1915 . .	6.52	7.02	0.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916 . .	2.56	5.27	3.97	3.69	3.21	5.34	6.85	2.49	5.08	1.01	3.29	2.85	45.61
1917 . .	3.64	1.98	4.08	1.83	4.13	5.27	3.36	7.06	2.42	6.60	0.63	2.56	43.56
1918 . .	4.11	2.99	2.91	2.78	2.47	4.01	1.84	2.22	7.00	1.32	2.87	2.95	37.47
1919 . .	2.02	2.80	4.22	2.37	6.20	1.09	4.17	4.81	4.25	1.81	6.20	1.48	41.42
1920 . .	2.74	4.45	3.63	4.71	3.65	6.26	2.06	3.62	6.74	1.54	5.62	6.02	51.04
1921 . .	2.00	2.38	3.57	6.47	4.56	3.87	6.00	2.35	1.84	1.08	6.20	1.90	42.22

TABLE III. — *Temperature and Frost Records.*

Year.	Mean Hourly Temperature (Degrees Fahrenheit).						Last Spring Frost.	First Fall Frost.
	April.	May.	June.	July.	August.	September		
1889	49.3	61.4	67.7	69.5	65.5	61.9	May 26	Sept. 21
1890	46.5	57.1	65.3	69.8	67.2	59.7	May 12	Sept. 25
1891	49.4	57.3	66.6	68.2	70.2	65.3	May 19	Oct. 12
1892	48.7	56.1	70.3	72.2	70.0	60.6	May 10	Sept. 30
1893	44.7	58.7	69.0	71.4	71.0	58.1	May 8	Sept. 3
1894	47.9	58.7	69.4	73.5	69.3	64.8	May 22	Aug. 22
1895	46.9	61.3	70.5	69.3	70.4	63.8	May 17	Aug. 22
1896	49.2	62.4	65.0	70.7	68.2	59.2	May 1	Sept. 24
1897	46.5	57.1	61.8	70.5	66.0	59.8	May 8	Sept. 22
1898	43.0	55.6	66.0	70.9	69.7	63.0	April 27	Sept. 21
1899	46.1	55.7	67.4	70.1	68.0	59.7	May 4	Sept. 14
1900	46.9	55.4	67.1	70.6	70.1	63.8	May 29	Sept. 15
1901	46.8	56.2	68.0	72.5	69.9	62.1	May 6	Sept. 26
1902	47.3	57.0	63.5	67.8	66.1	60.3	May 14	Sept. 6
1903	46.9	59.2	59.6	68.9	62.0	61.3	May 2	Sept. 25
1904	42.5	60.1	65.0	69.8	66.4	59.8	April 23	Sept. 22
1905	45.6	56.9	64.4	71.1	65.8	59.1	May 24	Sept. 12
1906	45.1	56.7	66.1	70.1	70.5	64.0	May 20	Sept. 25
1907	41.5	51.8	63.9	70.0	66.1	61.3	May 22	Sept. 27
1908	45.1	59.2	67.6	72.5	66.6	62.9	June 3	Sept. 16
1909	44.4	55.5	66.4	68.7	66.5	60.5	May 12	Oct. 13
1910	50.6	56.1	63.8	72.1	67.1	61.1	May 6	Sept. 23
1911	43.7	61.9	64.5	73.7	67.8	60.2	May 5	Sept. 14
1912	45.2	58.1	65.0	71.6	66.4	61.2	May 1	Aug. 31
1913	47.6	55.6	66.4	71.4	69.5	59.7	May 15	Sept. 10
1914	42.1	59.0	64.4	67.7	68.9	60.2	May 16	Sept. 28
1915	49.9	54.1	64.2	68.9	66.0	64.2	May 20	Sept. 23
1916	43.9	55.9	61.1	71.6	69.5	60.8	May 19	Sept. 17
1917	42.9	49.3	65.3	71.7	70.9	57.0	May 18	Sept. 11
1918	45.7	62.1	62.9	70.1	70.5	57.6	April 26	Sept. 11
1919	45.4	57.6	68.4	71.8	65.8	61.7	May 1	Sept. 18
1920	43.2	54.6	64.5	68.3	70.2	62.8	April 26	Oct. 7
1921	51.5	58.9	66.9	73.4	66.9	65.6	May 12	Oct. 9

TABLE IV. — *North Soil Test (Yields per Acre).*

Year.	Crop.		Plot 1, Check.	Plot 2, Nitrate of Soda.	Plot 3, Dissolved Boneblack.	Plot 4, Check.	Plot 5, Muriate.	Plot 6, Nitrate and Boneblack.	Plot 7, Nitrate and Muriate.	Plot 8, Check.	Plot 9, Boneblack and Muriate.	Plot 10, Nitrate, Boneblack and Muriate.	Plot 11, Plaster.	Plot 12, Check.
1890	Corn	Grain (bushels)	51.2	53.3	57.5	51.3	69.3	59.4	67.6	48.1	74.0	74.9	51.5	47.5
		Stover (pounds)	5,620	5,700	4,340	4,190	5,740	4,330	5,430	3,890	5,740	5,820	4,240	4,180
1891	Potatoes	Large (bushels)	25.67	26.33	35.67	17.33	63.33	32.33	61.33	16.67	49.33	58.33	15.67	11.67
		Small (bushels)	4.33	4.67	5.67	5.67	4.00	6.33	5.00	2.67	3.33	6.33	6.67	6.00
1892	Soy beans	Beans (bushels)	12.83	13.67	10.33	11.75	15.42	13.00	16.08	13.08	12.92	13.67	13.17	12.67
		Straw (pounds)	1,000	920	940	1,040	1,140	1,200	1,100	960	900	960	960	1,190
1893	Oats	Grain (bushels)	48.13	42.19	41.56	43.75	52.19	45.94	49.69	42.81	47.59	46.56	41.25	42.81
		Straw (pounds)	1,920	1,880	1,760	1,700	2,220	2,660	2,680	1,900	2,760	2,920	1,720	1,940
1894	Grass and clover	Hay (pounds)	640	1,320	680	280	240	1,500	680	200	410	1,620	360	220
1895	Grass and clover	Hay (pounds)	1,000	1,000	640	660	1,200	1,340	1,680	640	920	1,860	620	820
		Rowen (pounds)	–	–	–	–	340	–	–	–	220	200	–	–
1896	Cabbage	Hard (pounds)	1,200	3,240	2,080	2,640	10,520	12,000	5,800	3,800	21,200	26,200	3,320	2,240
		Soft (pounds)	9,680	8,680	8,600	8,000	7,480	9,080	4,200	6,880	7,400	6,680	6,600	4,200
1896	Turnips (pounds)		14,400	12,400	9,800	9,800	10,200	14,000	14,000	9,800	21,200	23,000	8,000	7,000
1897	Potatoes	Large (bushels)	15.50	8.87	22.00	30.00	42.00	88.33	29.67	20.67	54.00	55.33	35.83	38.00
		Small (bushels)	52.00	35.67	32.00	28.17	35.50	33.00	38.83	38.67	30.67	38.50	23.00	26.50
1898	Onions	Tops and bulbs (pounds)	940	830	1,640	1,310	1,540	9,640	650	920	2,100	4,360	680	1,510
		Merchantable (bushels)	.8	2.5	5.2	1.2	.8	116.8	.2	.8	1.9	16.3	.5	1.1
1899	Onions	Sound (bushels), unlimed	2.69	18.65	6.53	5.19	3.07	143.10	3.07	2.88[1]	40.38[1]	46.15[1]	4.01[1]	4.01
		Sound (bushels), limed	4.42	91.43	12.31	26.15	161.75[1]	145.40	200.00[1]	16.93[1]	183.80	224.60	6.35[1]	30.39[1]
1900	Onions	Sound (bushels), unlimed	6.15	50.00	17.31	72.69	37.69	225.77	9.23	38.46	159.62	136.92	4.62	23.46
		Sound (bushels), limed	41.54	155.00	37.69	132.31	383.46	202.31	310.77	107.69	380.00	488.46	23.08	102.31
1901	Onions	Tops and bulbs (pounds), unlimed	1,680	2,400	1,880	1,400	3,000	8,800	2,400	800	10,000	18,600	1,400	1,400
		Tops and bulbs (pounds), limed	3,200	4,200	2,600	2,200	11,200	8,000	13,800	2,480	13,200	22,600	2,960	2,720

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

TABLE IV. — *North Soil Test (Yields per Acre)* — Concluded.

Year.	Crop.		Plot 1, Check.	Plot 2, Nitrate of Soda.	Plot 3, Dissolved Boneblack.	Plot 4, Check.	Plot 5, Muriate.	Plot 6, Nitrate and Boneblack.	Plot 7, Nitrate and Muriate.	Plot 8, Check.	Plot 9, Boneblack and Muriate.	Plot 10, Nitrate, Boneblack and Muriate.	Plot 11, Plaster.	Plot 12, Check.
1902	Potatoes	Large (bushels), unlimed	27.7	30.0	39.3	31.3	58.0	69.3	51.3	35.3	73.7	110.3	24.7	24.5
		Small (bushels)	24.0	20.7	20.0	22.7	15.3	28.7	26.0	29.3	18.0	17.0	16.0	21.7
		Large (bushels), limed	21.3	27.3	26.0	22.7	69.0	71.3	58.3	32.7	93.7	115.3	24.3	30.3
		Small (bushels)	27.7	20.3	22.0	21.3	12.7	29.0	17.3	21.3	20.0	17.3	13.7	17.3
1903	Grass and clover	Hay (pounds), unlimed	360	1,520	950	550	660	1,830	1,820	450	620	2,330	430	420
		Hay (pounds), limed	1,150	3,140	1,560	1,010	950	3,180	2,190	570	920	2,830	480	1,140
1904	Grass and clover	Hay (pounds), unlimed	1,060	1,960	1,000	560	600	2,120	1,920	560	860	2,200	560	640
		Rowen (pounds)	140	60	60	30	70	210	50	40	80	620	20	10
		Hay (pounds), limed	800	1,600	680	560	1,920	2,320	1,860	940	3,600	4,400	600	1,280
		Rowen (pounds)	80	90	120	130	780	810	520	500	2,560	2,840	80	240
1905	Corn	Grain (bushels), unlimed	8.71	13.88	7.76	5.41	5.65	20.24	12.47	4.47	11.29	36.24	10.59	16.00
		Stover (pounds)	3,100	480	3,400	3,160	4,040	3,600	2,960	1,800	4,520	5,840	2,240	3,140
		Grain (bushels), limed	7.88	9.06	5.88	8.94	18.35	29.18	29.53	18.12	34.24	43.06	19.53	20.00
		Stover (pounds)	2,520	3,960	2,640	2,920	4,400	3,680	3,720	3,520	3,400	4,840	2,320	2,280
1906	Soy beans	Beans (bushels), unlimed	10.86	4.48	5.52	13.1	8.28	6.90	9.66	7.76	6.90	7.93	5.34	10.34
		Straw (pounds)	690	440	380	630	520	520	740	600	420	400	400	720
		Beans (bushels), limed	5.17	3.45	3.97	6.72	12.41	9.48	14.14	8.79	10.34	14.14	6.03	9.83
		Straw (pounds)	430	490	400	500	720	760	780	520	600	920	400	560
1907	Grass and clover[1]		–	–	–	–	–	–	–	–	–	–	–	–
1908	Grass and clover	Hay (pounds), unlimed	1,340	3,280	940	780	860	3,720	3,240	480	800	4,240	320	440
		Hay (pounds), limed	2,160	3,880	1,600	1,560	2,380	4,600	3,800	1,640	3,240	4,730	1,580	2,220
1909	Grass and clover	Hay (pounds), unlimed	1,280	1,980	1,260	1,180	1,050	2,010	1,240	1,150	920	1,790	380	720
		Hay (pounds), limed	1,570	1,780	1,420	1,520	3,640	2,760	2,980	1,560	3,840	2,520	1,180	1,520
1910	Soy beans	Beans (bushels), unlimed	15.86	14.83	11.38	12.41	8.97	14.48	8.28	9.66	4.83	8.28	10.00	10.34
		Straw (pounds)	1,680	3,140	2,680	1,580	1,680	2,160	1,520	1,840	1,040	2,200	1,300	1,400
		Beans (bushels), limed	20.00	19.31	13.79	17.59	24.83	18.62	18.97	19.31	19.66	16.55	14.48	13.79
		Straw (pounds)	2,920	3,480	2,800	3,180	1,560	4,120	1,820	3,360	1,460	3,240	2,480	3,480

1911	Soy beans	Beans (bushels), unlimed	10.00	4.66	4.66	10.34	14.48	10.86	14.48	10.86	14.31	17.07	8.28	11.05
		Straw (pounds)	1,820	1,450	1,530	1,920	2,160	2,290	2,360	1,890	3,370	3,610	1,320	1,760
		Beans (bushels), limed	1.03	2.07	.86	2.59	20.34	6.90	20.69	15.52	15.86	20.17	1.38	6.21
		Straw (pounds)	940	1,480	950	1,450	2,820	2,600	3,000	3,100	2,880	3,830	1,920	2,640
1912	Soy beans[2]		–	–	–	–	–	–	–	–	–	–	–	–
1913	Rye	Grain (bushels), unlimed	33.6	30.7	29.6	30.4	28.9	27.9	22.9	16.0	17.1	21.8	15.4	16.4
		Straw (pounds)	5,040	4,060	3,860	4,080	4,380	4,240	4,720	2,900	3,640	3,780	3,140	2,880
		Grain (bushels), limed	33.9	36.4	28.9	33.2	35.3	35.3	35.3	30.7	31.1	35.7	35.7	37.9
		Straw (pounds)	5,200	6,220	5,180	3,940	5,220	5,020	5,620	5,080	5,260	5,600	6,000	6,080
1914	Grass and clover	Hay (pounds), unlimed	1,600	2,020	1,490	1,240	1,280	2,540	2,000	820	1,030	2,600	860	600
		Rowen (pounds)	–	–	–	–	–	–	–	–	–	–	–	–
		Hay (pounds), limed	1,840	2,870	1,680	1,830	4,140	3,800	3,080	2,320	3,620	5,310	2,400	2,980
		Rowen (pounds)	–	–	–	200	1,400	40	1,000	600	800	800	200	80
1915	Grass and clover	Hay (pounds), unlimed	920	1,440	1,180	1,020	1,580	1,280	960	520	580	900	460	480
		Rowen (pounds)	–	–	–	–	–	–	–	–	–	–	–	–
		Hay (pounds), limed	1,260	1,400	1,200	1,400	3,700	3,500	3,800	1,600	3,600	4,200	1,100	2,300
		Rowen (pounds)	220	180	180	820	3,050	690	1,760	720	1,620	1,600	280	640
1916	Corn	Grain (bushels), unlimed	21.3	34.5	35.1	28.8	25.9	43.3	25.1	16.3	30.3	38.3	19.9	14.5
		Stover (pounds)	1,600	2,200	3,000	2,600	3,000	3,600	2,900	1,400	2,500	4,200	2,000	1,200
		Grain (bushels), limed	18.7	19.7	21.7	31.5	36.9	41.3	45.7	31.9	48.1	51.2	27.9	26.4
		Stover (pounds)	1,200	1,600	1,600	2,000	2,600	2,800	3,800	2,400	4,000	4,200	2,000	1,600
1917	Cabbage	Good (pounds), unlimed	240	880	2,560	100	180	13,560	160	160	6,320	26,040	720	–
		Poor (pounds)	1,760	2,200	7,240	920	1,400	9,600	840	1,240	7,560	7,320	6,240	1,040
		Good (pounds), limed	10,120	13,640	2,980	7,240	15,360	21,560	20,400	9,320	25,000	42,480	3,980	7,520
		Poor (pounds)	10,160	9,600	6,240	9,240	7,320	5,880	7,600	10,560	7,720	2,920	9,320	9,480
1918	Beans	Total weight (pounds), unlimed	1,460	1,240	960	1,780	2,320	1,980	2,380	1,960	1,680	2,500	1,000	1,520
		Total weight (pounds), limed	960	960	800	1,180	3,840	2,200	4,360	1,180	3,040	3,740	200	700
1919	Hungarian[3]		–	–	–	–	–	–	–	–	–	–	–	–
1920	Rye[4]		–	–	–	–	–	–	–	–	–	–	–	–
1921	Rye	Grain (bushels), unlimed	10.4	10.0	11.8	7.5	10.4	16.4	10.0	9.3	9.6	7.5	4.6	7.3
		Straw (pounds)	1,280	1,240	1,490	960	1,320	960	1,240	940	1,300	800	520	860
		Grain (bushels), limed	15.2	11.8	12.1	14.3	15.5	15.7	13.9	12.1	6.1	7.1	11.1	10.7
		Straw (pounds)	1,680	1,340	1,340	1,480	1,820	1,760	1,440	1,600	2,360	1,280	1,480	1,300

[1] No weights.
[2] Plowed under.
[3] Not harvested.
[4] Spring seeded; not harvested.

NORTH SOIL TEST.

Plot 11.—Plaster, 160 pounds per acre until 1896. In 1896 increased to 400 pounds per acre. In 1902 increased to 800 pounds per acre.

Lime. — The west half of the field has been limed four times as follows: —

1899, 1 ton per acre air-slaked lime.
1904, about 1 ton per acre air-slaked lime.
1907, ½ ton per acre lime.
1916, about 2 tons per acre limestone.

1890. Variety an early dent. Sown in drills, thinned to 6 inches in the row. Cut, stooked and husked instead of being put into the silo as planned. 75 pounds per bushel.
1891. Variety, Beauty of Hebron, seed from Aroostook County, Me. Sprouted unevenly, leaving many vacant places about equally divided among the plots. Somewhat injured by frost.
1892. 60 pounds per bushel.
1893. Plots 3, 6 and 10 lodged badly; 1, 4, 5, 7, 8 and 12 stand fairly well; 5, 7 and 12 quite green; 6, 9, 10 well matured. Fall seeded: timothy, 20 pounds; redtop, 10 pounds; red clover, 6 pounds; alsike, 4 pounds.
1894. Seeded Nov. 29, 1893. Few flower stalks showing when cut. No clover. As weighed from the field the difference in the degree of dryness was quite noticeable.
1895. Hay, mostly redtop except little clover on Plots 10, 9, 7 and 5.
1896. Cabbage on west half and turnips on east half. Turnips rather poor stand, probably weighed tops and roots together.
1897. Fertilizer doubled. Potatoes under 2 ounces called "small."
1898. Fertilizer doubled.
1899. Fertilizer doubled. First liming of west half.
1900. Fertilizer doubled. Field has washed quite badly diagonally. Plot 1 washed some this summer while crop was in. Fall seeded to oats.
1901. Fertilizer doubled. Fall seeded to rye.
1902. Fertilizer doubled. Potatoes, variety, Delaware. Fall seeded: timothy, 18 pounds; redtop, 8 pounds; red clover, 5 pounds; alsike, 4 pounds.
1903. April 4: sow 15 pounds red clover. July 20: the only clover is on limed halves of Plots 9 and 10. Fertilizer doubled
1904. Fertilizer doubled. Second liming of west half. Limed half: hay, very little timothy except on Plot 10; very little redtop on Plots 9 and 10; mostly clover on Plots 5, 9 and 10. Unlimed half: hay, almost no timothy; 50 per cent or over redtop; very little clover on Plots 1, 2, 3, 4, 7, 8 and 12.
1905. Fertilizer back to normal. Sibley's Pride of the North. Total yield at 85 pounds per bushel.
1906. Medium Green. Rather a poor stand.
1907. Spring seeded, 4½ pounds mixed timothy, redtop and clover per plot. Crop mostly weeds; no weights. Third liming of west half.
1908. Mostly redtop. Small amount of clover on Plots 5 and 9, both limed and unlimed. Very little timothy on any plots.
1910. Medium Early Yellow.
1911. Medium Early Yellow.
1912. Medium Yellow soy beans; very poor stand. Plowed under and seeded to rye.
1913. Fall seeded: timothy, 20 pounds; redtop, 10 pounds; red clover, 5 pounds; alsike, 5 pounds.
1914. Rowen practically all clover.
1915. Hay. Unlimed: 1, 2, 3, 4, 11 and 12 mostly all grass; 10 half grass and half clover; 5 mostly all clover; 6, 7, 8 and 9 some clover. Limed: 2, 3 and 6 mostly all grass; 2 and 3 mostly all redtop; 1, 4, 8, 11 and 12 half grass and half clover; 5, 7, 9 and 10 mostly clover.
1916. Longfellow Corn. Fourth liming.
1917. Danish Ballhead.
1918. Yellow Eye Bean. Very unsatisfactory growth. Total weights taken as harvested. Fall seeded to rye.
1919. Plot 1 used for barium-phosphate test. Hungarian on rest of field, not harvested.
1920. Spring seeded to rye. Plowed and fall seeded to rye. No fertilizer applied.
1921. No fertilizer applied.

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AGRICULTURAL EXPERIMENT STATION

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TOBACCO WILDFIRE IN 1922

By P. J. ANDERSON and G. H. CHAPMAN

Wildfire continues to be the most destructive disease of tobacco in the Connecticut Valley. Experiments for the purpose of perfecting the old methods or finding new methods of checking the disease are in progress.

Results of the 1922 experiments and observations on control are summarized in this bulletin. The value of sterilization of seed, soil, sash and sideboards, spraying and dusting of plants in the bed and in the field, destruction of diseased areas in the beds, roguing of plants and removal of diseased leaves from the field are discussed and directions given for the application of these measures. This bulletin also discusses the overwintering of the wildfire bacteria and their dissemination during the summer.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
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BULLETIN No. 213.

DEPARTMENT OF BOTANY.

TOBACCO WILDFIRE IN 1922.[1]

BY P. J. ANDERSON AND G. H. CHAPMAN.

INTRODUCTION.

Wildfire in the Connecticut Valley.

Wildfire continues to be the most serious menace to the tobacco-growing industry of the Connecticut Valley. The season of 1922 was not less disastrous than that of 1921.

Beginning with the first recorded infection on May 7, fresh reports of infected seed-beds came in from every side with increasing frequency until it was estimated that 30 per cent of the beds of the valley contained some wildfire. No tobacco-growing town in Connecticut or Massachusetts escaped. Continuous rains and cloudy weather during the seed-bed period furnished ideal conditions for the spread of the disease and at the same time made it difficult to apply remedial measures. The same weather conditions continued throughout the setting period of June, and it was not surprising that the disease appeared in the fields almost as soon as the plants were established. It continued to spread there until, by the 4th of July, wildfire was raging in half the fields of the valley. The Broadleaf section was much more seriously affected than in 1921, while, on the other hand, many of the growers of other varieties escaped with less trouble than during the previous year. Growers were discouraged both by the wildfire and by the poor growth of the tobacco during this unfavorable weather, and some of them even plowed up their fields. But after the first week in July the weather cleared, there were no more long-continued rains, and such rains as occurred were followed by hot, clear weather. During the next three or four weeks wildfire spread hardly at all and the tobacco grew rapidly, covering the diseased leaves with healthy ones until many growers felt that the disease had passed. Rainstorms, however, became more frequent during the last few days of July and were accompanied by increased spread of disease throughout the topping period and, with but

[1] A report of co-operative work carried on by the Massachusetts Agricultural Experiment Station and the Tobacco Experiment Station of the Connecticut Agricultural Experiment Station. Published, with a different introduction, as Bulletin 2 of the latter station.

slight interruptions, until the crop was harvested. Many of the growers who had a slight foot-leaf infection profited by their experience of 1921 and did not wait for the tobacco to ripen, but cut it "on the green side" and in this way reduced the damage somewhat. It is probably no exaggeration to say that 90 per cent of the tobacco fields of the valley were more or less affected. Some fields were so badly "fired" that not a clean plant could be found, and the price received for the crop will be but a fraction of the cost of growing.

Wildfire in Other Sections.

During the summer one of the writers had occasion to visit the tobacco regions of New Hampshire and Vermont, where conditions were found to be very similar to those which prevailed in Massachusetts.

A serious outbreak occurred in Wisconsin (Pl. Dis. Bul. 6: 40, 139), from which State the disease had not been reported previously from farms. It was also reported for the first time from New York and Georgia (Pl. Dis. Bul. 6: 62, 63). It occurred with more or less severity in Pennsylvania, Maryland, Kentucky (Pl. Dis. Bul. 6: 21) and Ohio. It is rather surprising to find that in North Carolina and Virginia, in which States the disease was first found and where it was very destructive five years ago, there has been no damage from wildfire during 1922. Under date of August 19, Dr. F. D. Fromme, plant pathologist of the Virginia Agricultural Experiment Station, wrote: "We have yet to see a case of wildfire in the 1922 crop in Virginia. We have inspected well over 100 fields in counties where it has occurred in the past year. Plant beds were equally free from it this year." Under date of August 21, Dr. F. A. Wolf, plant pathologist of the North Carolina Agricultural Experiment Station, wrote: "I have not received this season a single authentic specimen of tobacco wildfire from this State."

Previous to this year wildfire was not known to occur outside the United States. It has now been reported from South Africa (2: 366–368).[1]

Progress in Investigations.

Investigations with the object of developing some method or methods of preventing loss from wildfire, begun in 1921, were continued by the writers in 1922.[2] Although such methods have not been perfected as yet, nevertheless some improvements have been made on the methods previously recommended, and by another season of work we have been able to confirm more fully some measures which were recommended, while others have been found to be of less importance. Some further studies have

[1] The first number in the parenthesis refers to the bibliography on page 27 of this bulletin, and the numbers after the colon refer to pages of these publications.

[2] Results of the investigations of 1921 are recorded in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin, Chapman has been located at the Connecticut Tobacco Substation in Windsor, but the work has been continued in co-operation between that station and the Massachusetts Agricultural Experiment Station. Valuable contributions to our knowledge of wildfire have been made by Clinton and McCormick in Connecticut, and published during the last year as Bulletin 239 of the Connecticut Agricultural Experiment Station. This bulletin and a number of other important publications on wildfire which have appeared during the last year are freely quoted and referred to here in order that the grower who reads the present bulletin may have the advantage of all that has been learned concerning this problem.

been made in regard to the life history of the causal organism, especially with reference to overwintering and dissemination. The results of the life history and control work of 1922 are briefly presented in the present bulletin.

Valuable assistance in the work has been rendered by Prof. A. V. Osmun of the Massachusetts Experiment Station and Mr. C. M. Slagg of the United States Department of Agriculture. Tobacco growers in both States, too numerous to mention here by name, have co-operated heartily with the writers in the work described in the following pages.

LIFE HISTORY STUDIES.

Overwintering of the Bacteria.

As a basis for control measures, probably no problem in regard to life history of the causal organism[1] is more important than determination of the method or methods by which the bacteria survive the winter and thus serve as starting points for wildfire of the next year. Certain experiments with the object of solving this problem were conducted during the winter of 1921–22, and though some of the results are not conclusive progress to date is reported at this time. Other experiments with the same object are now in progress, and it is hoped that they will be more satisfactory.

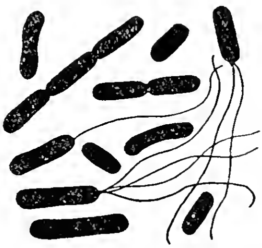

Fig. 1. — A group of the bacteria which cause wildfire. Magnified 5,000 times.

Effect of Freezing the Bacteria.

In studying the problem of overwintering, the first point to be determined is the effect which freezing has on the organisms. If they are not able to withstand the exposure of a New England winter, then the measures of control will be quite different from those which should be tried if they are resistant to cold. Pure cultures of *Bacterium tabacum* on agar were placed out of doors at various times during the winter of 1921–22, some of them being frozen solid for months; but in every case when they were brought back

[1] Wildfire is produced by the parasitic growth of enormous numbers of bacteria (*Bacterium tabacum* Wolf and Foster) in the leaves. Since various investigators who have published concerning the organism do not agree as to some of the morphological characters, Anderson during the past season has made and studied permanent slides on which the bacteria have been stained by (1) the Duckwell modification of the Pitfield method, (2) the Shunk method (Journ. Bact. 5: 181, 1920), and (3) to a less extent by other methods. The organisms are short, cylindrical rods with rounded ends and usually straight sides, but not infrequently individuals are found which are slightly curved or somewhat dumb-bell shaped. Frequently two or three of them remain end to end in a chain on the slide. Those in chains are shorter, indicating immaturity. Only those which were free from each other were used in measuring. The average size of fifty taken from five slides stained in different ways was 2.3x.8 μ. The longest one measured was 3.8 μ and the shortest 1.4 μ. Attached to one end there are one to four flagella several times as long as the body of the bacterium. The bacteria in text, Fig. 1, were drawn from a slide stained by the modified Pitfield method.

into the laboratory and transferred to other media they grew normally. The result was about what one would expect when it is remembered that few species of bacteria are killed by freezing. It is certain from data presented below that freezing does not kill them while in the leaf in the tobacco barn.

On the Seed.

It has been suspected by most workers who have investigated this disease that the bacteria may survive the winter on or with the seed, and that early infections in sterilized beds originate in this way. Although this would seem possible, there is as yet no experimental evidence to prove that such is the case in the Connecticut Valley. In Virginia, Fromme and Wingard (3) find conclusive evidence that the organism of blackfire of tobacco (*Bacterium angulatum*) overwinters in this way. Their evidence for the wildfire organism, however, is not so convincing. A number of experiments were undertaken by the writers for the purpose of determining the possibility of overwintering in this way. In the interest of brevity these experiments need not be given in detail, but the results may be summarized: —

1. All attempts to isolate the organism directly from suspected seed have failed.
2. Suspected seed has been planted and no wildfire has appeared on the seedlings where other sources of infection have been eliminated.
3. Seed inoculated by soaking in a pure culture of the bacteria and kept in a dry room all winter produced only clean plants in the spring.
4. In another experiment seed was artificially inoculated after it had been sterilized and the bacteria killed by heat. The seed remained wet from the culture for two weeks. In the spring it was sprinkled on healthy leaves and wildfire resulted, but the conditions are not the same as where seed is kept in a dry room.

All the evidence in these experiments was negative and has only the weight of such. The possibility is not precluded that there may be conditions under which the bacteria may winter directly on the seed coat.

There is no evidence that in nature a lesion may come in direct contact with the seed. No one has ever reported seeing a lesion on the seed. It is a well-known fact, however, that lesions do occur on the calyx of the flower and on the seed pod. During 1921 in Connecticut and during the late summer of 1922 in Massachusetts, pod lesions were found on plants being kept for seed. Similar lesions were also produced by artificial inoculation. In threshing out the seed small broken bits of the pods remain with the seed as chaff, and no amount of sifting and cleaning will remove every particle of chaff. If the bacteria overwinter in the seed, it is probably not directly on the seed but in these fragments of pods, etc., which are with the seed. Since it is known that they survive the winter in leaf lesions, there could hardly be any doubt that they could live over in similar lesions on the pods. Fromme and Wingard (3:20) present experimental evidence showing that the percentage of wildfire is increased by top-dressing the seed-bed with chaff from infected pods of the previous year. It seems improbable, however, that any considerable proportion of the spring infection in the Connecticut Valley beds starts from the seed, because (1) growers now know the disease well enough so that few of them would save seed from infected plants; (2) many of the growers during the last season used old seed (grown previous to 1920) and yet they did not escape infection; (3) those who sterilized the seed were apparently no more successful in eliminating the disease from the beds than those who did not;[1] (4) even those who advocate most strongly the sterilization of seed do not present convincing data to prove that the disease organism is carried on the seed.

In the Soil.

From the plant the bacteria may get into the soil in two ways: (1) they may be washed from the plant by the rain during the growing season; and (2) when the leaves or other infected parts are turned into the soil or left to rot on the soil, the bacteria probably remain alive for a long time. It is important that we should know how long they remain alive there and capable of infection and whether they may survive the winter in this habitat.

Experiment 1. — In order to see whether the organisms could be carried from one crop to the next through the medium of naturally infested soil, such soil was taken from three beds of diseased plants at different times during the summer of 1921 and seeded with sterilized seed. The plants grown in this soil did not become infected. On the other hand, in one of the greenhouse beds which had grown a number of diseased crops, sterile seed was planted in the spring of 1922 and the seedlings became diseased before the plants were an inch high.

Experiment 2. — In this experiment one pot of soil was inoculated by spraying a suspension of bacteria over it, while another pot had an equal amount of water sprayed on it. Both were seeded shortly after sprinkling, and wildfire developed in the inoculated pot but not in the check.

During some control experiments in Whately, it was observed that even when all diseased leaves were removed from the plants, others became infected after rains and almost always on the tips which were beaten down into the soil. It appeared as though the bacteria had been washed from the diseased leaves into the soil and then splashed from the soil to other leaves.

In two fields in Hadley and North Hadley which were under constant observation by one of the writers during 1922, the plants became so badly diseased during June that all were pulled and carted from the fields. Both fields were set later with healthy plants, but in both cases there was a very heavy reinfection before the new plants were half grown. The second infection must have come by way of the soil.

Clinton and McCormick (2:404) buried wildfire leaves under healthy plants, and by this means the infection was increased to 63 per cent as compared with 13 per cent on adjacent plants not so treated.

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[1] Records were kept on the beds of 11 growers in Massachusetts who treated their seed with mercuric chloride. Wildfire afterward appeared in 5, while the other 6 had no wildfire in the beds.

The above data furnish very strong evidence that the pathogen may be carried from one plant to another or from one crop to another by means of the soil. The failure to get infection in some of the experiments by planting in infested soil shows, however, that infection will not always result necessarily because the soil was infested.

None of the experiments just quoted furnishes evidence of the length of time during which the bacteria may remain alive in the soil or indicates whether they will live through the winter in this habitat. The following experiments and observations throw some light on the latter point: —

Experiment 3. — On July 1, 1921, Erlenmeyer flasks of soil were sterilized and later inoculated with the bacteria. Part were plugged only with cotton, others were paraffined to prevent drying out. At various times during the winter, soil was taken from these flasks and plated out. Then, when bacteria developed about the particles of earth, they were shaken in a suspension of water and atomized on healthy plants. In the flasks which did not have paraffined plugs, the soil became very dry, while in the others it remained muddy. Heavy infection resulted when inoculations were made March 10 and others on March 20, 1922, from the dry flasks, but none from the tightly closed wet flasks. These flasks were kept in the laboratory and were not frozen. In this case the bacteria were still able to produce infection after eight months.

In two instances in Connecticut, wildfire was found starting in the edge of the beds in soil which had been outside the pans when the remainder of the beds were steamed. In both cases wildfire was present in the beds in 1921. The fact that the planks were new and the sash had been sterilized with formaldehyde eliminated these as the source of infection.

In a number of cases, in both States, it was found that those parts of the field which were diseased in 1921 showed the heaviest infection in 1922.

On the other hand, fields have been observed which were badly diseased in 1921 and on which tobacco was free from wildfire in 1922.

On one of the fields at the Connecticut Experiment Station the 1921 crop which was badly infected with wildfire was cut late in September and left lying on the ground over winter with a view to getting data on the overwintering under natural conditions. In this case both leaves and stalks were left to weather. In 1922 this field was planted with Havana and Broadleaf wildfire-free seedlings, the stalks and leaves of the 1921 crop having been disked and plowed under two weeks prior to setting. Throughout the season close examinations were made by Slagg and Chapman for wildfire in this field. Wildfire was not found on this particular field during the growing season, but at harvest an occasional wildfire spot was found, yet nothing to what should have developed if any considerable amount of direct infection occurred as a result of the refuse being left on the field. A careful estimate of the wildfire plants on this plot, made at harvesting, showed that infected plants were not more than one-half of 1 per cent of the total number, and on all of these the infection was light. This slight infection may have come from plants in the wildfire experimental field, since all the station plots — except for the experimental field — showed about this same percentage of infection late in the season.

Clinton and McCormick (2: 376, 419) succeeded in one experiment in infecting tobacco plants in the greenhouse by direct application of overwintered soil which had been exposed to infection the previous year. Wolf and Moss (4: 30) in North Carolina and Fromme and Wingard (3: 24) in Virginia present considerable evidence that in the South the organism winters in the soil, but we cannot accept this as conclusive proof of the same condition in New England.

Altogether the weight of laboratory data and field observations indicates that *Bacterium tabacum* is able in some cases to survive the winter in the soil and start new infection from this source in the spring. On the other hand, it is apparently possible under some conditions to raise a clean crop of tobacco on a field that has borne diseased crops during preceding years. The evidence as to soil wintering is, however, not so convincing as it should be, and further experiments are now under way which it is hoped will remedy the deficiency.

In Cured Leaves.

That the bacteria do not die when the diseased leaves are cured in the tobacco barn has been demonstrated in a number of our experiments.

Experiment 4. — On March 5, 1922, diseased cured leaves were taken from the Hampshire County warehouse just before they were ready to go into the case. They had been in the tobacco barn under normal conditions all winter. They were ground to a powder in a mortar and the powder was sprinkled on wet plants in the greenhouse. After two weeks the plants developed typical lesions of wildfire. Other leaves were ground and the experiment was repeated with the same result on March 28. On March 8 some diseased leaves were received from Mr. H. C. Wells of Deerfield. Some of them were ground and used for inoculation just as the above. Dilution plates were made from the others and the organism thus isolated used for making inoculations. Wildfire developed on the plants inoculated in both ways.

Experiment 5. — At Windsor, several times during the winter, wildfire spots from leaves kept in the station shed were brought to the laboratory and the wildfire organism isolated in pure culture. Cultures of wildfire bacteria were obtained from these leaves until the middle of March in this way, and no doubt living bacteria could have been found later than this.

These experiments were conclusive and there can now be no doubt that the wildfire organism can overwinter in cured leaves. It might get back from the cured leaves to the next year's crop in any one of a number of ways: (1) Refuse containing lesions from the shed may be thrown back to the land. (2) Sash and plank are sometimes stored in the tobacco sheds. Bits of broken diseased leaves could easily be carried out on such sash and plank and serve to start infection in the seed-bed. (3) While drawing the tobacco to the warehouse across or near the fields, parts of the diseased leaves might be scattered on the land.

Clinton and McCormick (2: 417) isolated *Bacterium tabacum* from tobacco leaves which had been dried and kept in the herbarium for periods ranging from one hundred and ninety-eight to two hundred and ninety-eight days. They were unable, however, to secure the bacteria from other leaves which had been kept for two years.

In Leaves which have been left in the Field.

Sometimes leaves when too badly diseased are picked off and thrown on the ground. At other times the whole diseased plant may be left. The suckers which grow from the old stubs after a diseased crop has been cut are usually infected. These are left on the field all winter. If the bacteria live over in these parts, they might easily start infection the following year. Being subjected to more frequent freezing and thawing and other changes of weather, it is possible that they might not survive in these leaves as they do in cured leaves in the tobacco sheds. We have very little data bearing on this point.

Experiment 6. — On April 24, 1922, diseased leaves, which had been cut down in the fall and left in the field all winter, were collected from plants at Windsor. These leaves were ground to a powder in a mortar, some of the powder was immediately applied to punctured leaves in the greenhouse at Amherst, and some of it soaked in water and the wet material applied after twenty-four hours to other plants. No infection resulted.

Similar tests were made with the same material by Chapman and Slagg, but with negative results. This negative evidence should not be considered conclusive. Further experiments are in progress.

Clinton and McCormick (2: 376, 419) succeeded in one case in infecting tobacco plants in the greenhouse with tobacco refuse which was wintered out of doors.

Occurrence of Lesions on Stalks.

Wildfire lesions have been reported previously as occurring only on the leaves and occasionally on the pods. During the inspection of a field of tobacco at South Amherst, some lesions which were suspected of being wildfire were found on the stalks. On further examination it was found that the lesions were not uncommon, but that they were present on a large part of the stalks in this field. Probably they had escaped previous notice because they are inconspicuous and somewhat different in appearance from the lesions on the leaves. They are commonly one-eighth to one-fourth inch in diameter, white, or, at most, light brown and sunken. The halo is not distinct on most of them, but can be seen about some. A number of them were brought to the laboratory and the typical bacteria isolated from them. Inoculation on leaves with these bacteria produced wildfire spots. In this same field and in various others examined through the summer, it was also observed that lesions were common on the "ears" or clasping bases of the leaves. When tobacco is stripped, these bases remain mostly on the stalk. Clinton and McCormick (2: 416) inoculated stalks and produced elongated blackened lesions. The occurrence of lesions on stalks and attached leaf bases may be important in answering the question as to whether land may become infested by throwing tobacco stalks on it. Since the organism overwinters in the leaves, there is no reason why it should not also remain alive in the stalk.

Occurrence of Lesions on Midribs.

In the process of "stemming" tobacco, the midribs are stripped from the leaf and are sold as fertilizer (incorrectly called tobacco stems). The question has frequently been raised as to whether the land may become infested by the use of "stems" from diseased tobacco. Observations as to the occurence of lesions on midribs were made at various times in fields during the summer. Frequently lesions were found running along both sides and encroaching on the midrib and often extending directly across the midrib. When the leaf was stripped from the midrib, parts of the lesion remained with the "stem." *Bacterium tabacum* was isolated directly from such denuded stems. This does not prove that the disease may be carried back to the land by using stems, since it has still to be demonstrated that the bacteria can survive the sweating process, but there can be no doubt that they occur in the midribs and may survive the winter thus in the tobacco shed. Clinton and McCormick (2: 416) produced lesions similar to those described above by inoculating the midribs with pure cultures of the bacteria.

Relation of the Condition of the Plant to Infection.

No set of experiments has been planned to determine the relation of the growth and vigor of the plant to susceptibility, but incidental to other experiments a number of observations have been made which indicate that a rapidly growing plant is much more susceptible than one which is growing slowly. During the fall of 1921 two beds were planted in the greenhouse at Amherst, — one on very poor soil and one on soil rich in rotted compost. Both were inoculated at various times and the rapidly growing plants of the fertile bed became infected, but all inoculations failed in the other bed until late in the spring, when the plants suddenly began to grow rapidly. In the course of some experiments at the Massachusetts Station during the summer of 1922 numerous unsuccessful attempts were made to inoculate a bed of very slow-growing plants which had received no fertilizer. During the same time other rapidly growing beds in the greenhouse were very readily infected. These experiments are not accurate, but certainly give some strong indications. Also the fact that infection is difficult to secure during the winter months points to the same conclusion. The relation of fertilizers to infection can probably be interpreted by their influence in producing a rapid, succulent growth or the reverse. Other investigators of the disease have made similar observations. Clinton and McCormick (2: 390) state that "the use of any fertilizer that favors rapid growth is more likely to help infection . . . than where the fertilization is such that slower or less satisfactory growth takes place." Fromme and Wingard (3: 27) express essentially the same opinion.

Dissemination.

No experiments directly dealing with dissemination were undertaken during the season of 1922, but observations throughout the year confirm the conclusions of 1921 in most respects. There is one notable exception, — the experiments and observations in 1921 led us to believe that all field infection originated from plants which were diseased when taken from the beds. The majority of the field infections, and the worst ones which we have seen in 1922, did come from that source and could be traced without any question to the seed-bed. On the other hand, a number of cases have come to the writers' attention where the beds were free from disease (if it is possible at all to tell when they are free), but disease developed in the fields set from these same beds. A few cases may be mentioned: —

1. Anderson inspected the beds of a certain Sunderland grower at intervals of three or four days throughout the season and is positive that they were free from disease. Yet parts of the fields set from these beds were very badly diseased.
2. Tobacco fields owned by a grower in South Deerfield, but located near Brattleboro, Vt., became badly diseased, and were visited by A. V. Osmun and Anderson in June. Most of these fields were set from beds near the fields, but some plants were brought from the beds in South Deerfield. A most searching examination of the beds at both places failed to reveal a single diseased plant.
3. A field of tobacco on a farm in Whately was isolated from all other tobacco fields and surrounded on all sides by woods. Plants were taken from the beds on the same farm. During the spring these beds were repeatedly inspected by C. M. Slagg, a wildfire expert, but he failed to find any infection. Yet wildfire became fairly prevalent in the isolated field.
4. The seed-beds of a grower in North Hadley were frequently inspected by Anderson during the spring, and not a trace of wildfire could be found at any time. During August some diseased plants were found in the middle of the grower's field.
5. Wildfire occurred in a field of the Massachusetts Experiment Station farm which was not being used for wildfire work, but not a trace of it had been seen in the beds at the experiment station where the plants were raised.
6. A certain Windsor grower kept his seed-beds covered at all times with copper lime dust, and frequent inspections by Chapman and Slagg showed no infection. He planted two fields, about 3 miles apart, from these beds. One of the fields developed a heavy infection during the growing season; on the other, only a trace of wildfire was found.

Many similar cases were reported by growers, but were not checked by the personal observations of the writers. The evidence is conclusive that not all field infection comes from the seed-bed. We are now confronted with the problem of determining how such infections did start. Rain could not have brought them from other fields because they were too far removed. There is some probability that in the Sunderland field the bacteria were in the soil over winter, since the worst infection occurred in the same place as last year. In the other cases, however, either no tobacco had been planted during the previous year on these fields or no wildfire had been observed there during 1921. Apparently there is some long distance disseminator which we have not yet found. Those that suggest themselves are (1) workmen, (2) insects, and (3) wind. Since many isolated infections were discovered within a week or two after the exceptional windstorm of June 12–13, it is possible that the organisms may have been spread with the dust and sand which were blown in great clouds over the valley at that time. It has been shown above in this report that dry, infested soil dusted over healthy plants may produce infection.

All observations of the summer confirm our previous conclusion that the most important short distance disseminator of the disease in the field is the rain, especially when accompanied by wind. It should be noted here, however, that not every rainstorm is followed by a new outbreak of wildfire. It was frequently remarked, especially during July, that heavy short rains quickly followed by drying weather resulted in very little spread of the disease. The ideal conditions for spread are (1) long-continued rains, (2) rains followed by cloudy weather during which the leaves do not become dry, or (3) periods during which the rains follow each other closely. During June of 1922 we had a long-continued combination of all three of the above conditions, which resulted in the worst spread of wildfire which we have ever seen.

CONTROL MEASURES.

Sterilization of Seed.

Seed sterilization has been recommended by the writers because it was thought possible that the bacteria might be carried on or with the seed. Fromme and Wingard (3: 20) of the Virginia Experiment Station, in fact, are of the opinion that a large part of the infection is started from the seed. Although there is no conclusive evidence in the Connecticut Valley or elsewhere that such is the case, nevertheless the practice was recommended as a precautionary measure. In 1921 formaldehyde was recommended as the disinfectant (1: 75), but this year mercuric chloride was recommended because it was found to be just as efficient and was less likely to cause injury to the seed; therefore the following directions for treating tobacco seed were sent out to tobacco growers before planting time.

> Purchase corrosive sublimate tablets at any drug store. Dissolve one tablet in a pint of water to make a 1/1000 solution. Use a glass jar. Place seed in a cheesecloth bag and soak in the solution for exactly fifteen minutes. Poke or stir occasionally with a stick to insure thorough wetting of all the seed. Remove bag of seed and wash thoroughly in water. Spread out seed in a warm room to dry. Store seed where it will not become contaminated. Germination of the seed will not be affected if directions are followed carefully.

Many of the growers in 1922 used the corrosive sublimate treatment for sterilizing their tobacco seed; and at the Windsor laboratory one hundred and twenty lots of seed were sterilized by this method, and the germination before and after sterilization was tested. In no instance in the laboratory tests was there any injury from such seed treatment.

Some of the growers, however, reported that they injured the seed by the corrosive sublimate treatment. Some said that germination was retarded, others that the percentage of germination was lowered; and others that the seed would not germinate at all. It was at first thought that the failure was due to faulty technique, but laboratory tests showed that even a treatment of thirty minutes was not harmful, and some of the growers omitted the washing of the seed after sterilizing without any bad effect. Some reported lack of germination in seed which was sterilized at the tobacco substation by Chapman. It was certain, then, that the injury could not be attributed to faulty technique in all cases. Inquiry among the growers as to the method by which they sprout the seed revealed one difference between their method and that used at the stations, viz., the custom which many growers have of cracking or sprouting the seed in moist cocoanut fiber or apple punk or between sods for a few days before planting. The seed is kept in a warm room of 70 to 90° F. and from time to time sufficient water is added to keep the fiber or other material slightly moist. It was thought that possibly the fiber might have something to do with the lack of germination and some of the seed was taken to the laboratory for test, using both unsterilized and sterilized seed of different lots. It was found that the unsterilized seed sprouted in the fiber and that the sterilized seed did not show any signs of sprouting even after ten days. Other growers brought in samples of seed which they themselves had sterilized and which had failed to sprout in fiber, and these lots were tested also. Chapman tried varying the conditions under which the seed was kept during the sprouting period and found that under the conditions ordinarily used it was almost impossible to sprout the sterilized seed, although the same seed in Petri dishes would germinate satisfactorily. It was found finally that in order to germinate sterilized seed, whether in punk or fiber, the pans should be kept at a lower temperature and also that the moisture content of fiber or punk must be considerably higher than usual. By close attention to these factors it was possible to sprout the different lots of sterilized seed in either punk or fiber almost as well as before sterilization.

Lack of germination of sterilized seed under usual conditions in punk or fiber appears to be due to the fact that the seed coat is hardened by the washing and drying and there is a much slower softening of the seed coat than is the case with the unsterilized seed. This was tested in the following way: —

Experiment 7. — Of two lots of seed, one was sterilized for fifteen minutes with a solution of 1/1000 corrosive sublimate, and the other treated for fifteen minutes in pure water without any chemical added. Both lots were taken from the jars and washed and dried in the usual manner. It was found to our surprise that both lots reacted the same; i.e., when placed in punk or fiber under normal conditions, the germination was greatly delayed or lacking. This experiment showed that lack of germination was not due to the corrosive sublimate treatment, but to another cause, probably the hardening of the seed coat by the washing process or possibly by the rapid drying.

The age of the seed or storage conditions may possibly play a rôle also, as in many cases growers had no difficulty with their seed. A few cases were brought to our attention where the injury was undoubtedly due to incorrect procedure in the corrosive sublimate method.

Data collected from growers who sterilized their seed during 1922 are not conclusive as to the value of the treatment for preventing wildfire.

As a result of our experience this past year, we are of the opinion that in the Connecticut Valley, seed is, at most, a minor source of infection. Nevertheless, this is a possibility which should not be lightly overlooked, and growers should not save seed from plants which show wildfire infection. If this is found necessary, however, we believe the seed should be treated with the corrosive sublimate. To avoid the difficulties discussed above, the beds should be sown with the dry seed. We do not know how long the bacteria will remain on the seed, but it is unlikely that there would be any alive on seed two or three years old. By the use of old seed the chance of infection from this source would be eliminated.

Sterilization of Soil in the Seed-bed.

Sterilization of the seed-bed soil with either steam or formaldehyde was recommended by the writers (1: 75) because it was thought possible that the organism could live from one season to the next in the soil. Considerable additional evidence that this is one of the ways in which it may pass the winter has been obtained during 1922 and presented in a previous part of this report. It is a common practice for growers to sterilize their beds to kill weed seeds, prevent root rot and for other reasons; and many beds were sterilized before the 1922 seed was sowed, a few in the fall and more in the spring. Careful records were taken on fourteen beds in Massachusetts which had been sterilized this year. Wildfire occurred in seven of them and the others remained free. No conclusion can be drawn from these data except that soil sterilization alone cannot be depended on to give a clean seed-bed. It is unquestionable that sterilization of soil by either steam or formaldehyde if properly done will kill all the wildfire bacteria in the soil treated, but it may not be so easy to eliminate the possibility of getting it contaminated again from infested soil in the walks, surrounding areas, tools, etc. These chances are perhaps greater where soil is sterilized in the autumn. Most growers use steam and consider it cheaper. If steam is used, it should be applied for thirty minutes at 100 pounds pressure. Those who do not have boilers which will produce so high a pressure may determine the proper length of exposure by burying a small potato 4 or 5 inches below the surface of the soil under the pan and applying the steam until it is cooked through. Only one of the fourteen mentioned above used formaldehyde. Formaldehyde at a dilution of $1/50$ in water is applied at the rate of one-half to three-quarters gallon to the square foot of surface. Some preferred to change the location of the beds rather than sterilize the soil. In Massachusetts accurate records were kept on eight beds, the location of which had been changed to places where no tobacco was planted last year. Four of them had wildfire this year and four did not. The practice of sterilizing the beds should be continued not only to destroy wildfire bacteria but also to kill other disease organisms and weed seeds.

Sterilization of Sash and Plank.

The writers (1: 76) in 1921 recommended that old sash and plank be drenched with a 1/50 formaldehyde solution, and this was practiced by a number of growers. Some painted the sash and used new plank.

Data as to the benefits from this practice during 1922 are not very conclusive because in most cases other sources of introduction were not eliminated, but in a few cases under the writers' constant observation clean plants were raised in 1922 under the same sash and with the same sideboards (after sterilizing both) which had been used for badly diseased beds in 1921. Danger of infection from contaminated sash is well illustrated by the following experience of a Connecticut grower: His seed-beds in 1921 were so heavily infected in June with wildfire that the plants were destroyed. The sideboards were destroyed, the beds plowed up, and the sash stored over winter in a tobacco barn. The grower in 1922 decided to take no chances of a wildfire infection and contracted with a farmer who did not raise tobacco to grow sufficient plants for his use. The farm on which the plants were grown was remote from any tobacco fields or beds, new land was plowed and fitted, and old seed in which there was no possibility of contamination was used. It might be supposed that these precautions would insure freedom from the trouble; but as the farmer growing the plants had no sash, the sash used on the beds in 1921 were taken from the first farm and used on the beds. They were not sterilized, and shortly after the plants were up a very heavy infection occurred on all the beds on which the sash were used. While the proof is not absolutely conclusive, the inference is justified that the sash carried the bacteria. Unfortunately no beds without sash were grown in this particular instance, but it might be said that the possibility of contamination from other sources was slight indeed.

The following laboratory experiment was made with the object of determining how long the bacteria would remain alive on a piece of dry wood such as a side plank or sash: —

Experiment 8. — Small blocks of pine wood were sterilized and then soaked for eight days in a pure culture of *Bacterium tabacum* in bouillon. Then they were removed to dry, sterile tubes, where they quickly became dry and were kept so for further tests. The experiment was begun July 1, 1921, and the blocks were kept in the laboratory. At various intervals the blocks were tested for live bacteria by dropping one in sterile bouillon. They were still alive on September 10, but were dead on December 3. Sometime between these dates the last of them died. Apparently, then, they are able to live three months or more on dry wood.

In this laboratory experiment, however, the conditions are not the same as they would be in nature: (1) The wood is dried out more rapidly by the laboratory air than by the out-of-door air where they are stored. Sash are usually stored in a tobacco shed or barn, while the planks may even be left out in the weather. The conditions in the shed are more favorable than the laboratory for the survival of the pathogen. (2) If sash are kept in the tobacco shed, it is possible for diseased parts of the hanging crop to become lodged on them. (3) If the plank are kept out of doors, the moisture conditions would be about the same as for soil. In fact, the bacteria might be alive in soil which remains attached to the plank. Since we know that the bacteria can remain alive in the leaves and in the soil over winter, there would seem to be no reason why the sash or plank would not be a source of danger. Wolf and Moss (4: 32) and Fromme and Wingard (3: 22) have presented evidence to show that the germs may be introduced into new beds by the use of old cloth covers which were previously used on infested beds. If such cloth covers or the tent covers used in previous years over wildfire crops are used, they should either be boiled thoroughly in water or soaked in formaldehyde like the sash and planks.

Spraying and Dusting Seed-beds.

Results of the first experiment on the control of tobacco wildfire by spraying or dusting the seed-bed have been published in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin the experiment has been repeated at Amherst four times, using a greenhouse bed 4 x 16 feet for each experiment. The plants were pulled and counted when they were large enough for setting in the field, and then the bed was seeded immediately for the next experiment. The soil was not sterilized between experiments. The greenhouse bed was used in preference to an out-of-door bed because in this way a longer season could be secured and the experiment repeated more times.

Some of the fungicides used in the first experiment were omitted in later experiments because they were found to cause injury to the plants, viz., sulfur dust, lime-sulfur and the Pickering Bordeaux. NuRexo was used in the second experiment but omitted in the later ones, not because it failed to give control, but because it was thought best to confine the tests to one commercial copper spray. The copper-lime dust for the first experiment was furnished by the Riches, Piver & Co.; the dust for the later experiments by the Niagara Sprayer Company; the Pyrox was furnished for all experiments by the Bowker Insecticide Company. In order that all the data may be compared at a glance, the tables of results are first assembled and presented here all together and then followed by the general discussion.

Tests of Fungicides for the Control of Wildfire.

Description of Test.	Fungicides.	Total Number of Plants.	Diseased Plants.		Number of Lesions per 100 Plants.
			Number.	Per Cent.	
Experiment 9: June 6 to July 26, 1921. Cloth bed, out of doors. Two applications at intervals of one week. (Bulletin 203.)	Bordeaux 4-4-50 (2 plots)	473	6	1.25	2.5
	Copper-lime dust 20-80 (2 plots)	534	3	.55	.5
	NuRexo (2 plots)	600	3	.48	.5
	Pyrox 10-50 (2 plots)	570	23	4.1	6.5
	No fungicide (4 plots)	1,079	527	48.25	178.2
Experiment 10: Oct. 10 to Dec. 10, 1921. Greenhouse. Three applications at intervals of about a week.	Bordeaux 4-4-50	848	0	0	0
	Copper-lime dust 20-80	771	3	.38	1.2
	NuRexo	747	6	.8	1.2
	Pyrox 12-40	863	5	.58	1.1
	No fungicide	1,092	221	20.2	37.5
Experiment 11: March 17 to May 10, 1922. Greenhouse. Three applications at intervals of over a week. Some infection started before first application.	Bordeaux 4-4-50	1,637	3	.2	.3
	Copper-lime dust 20-80	1,449	152[1]	10.2	30.1
	Pyrox 12-50	1,375	140[1]	10.0	25.8
	No fungicide	1,714	1,322	77.0	484.0
Experiment 12: May 17 to June 28, 1922. Greenhouse. Five applications at intervals of three or four days.	Bordeaux 4-4-50	1,176	2	.1	.1
	Copper-lime dust 20-80	821	0	0	0
	Pyrox 12-50	1,005	3	.3	.5
	No fungicide	883	499	57.0	208.0
Experiment 13: July 14 to Aug. 26, 1922. Greenhouse. Five applications at intervals of three to five days.	Bordeaux 4-4-50	1,205	12	1.0	1.2
	Copper-lime dust 20-80	1,056	3	.3	.4
	Pyrox 12-50	1,276	12	1.0	1.2
	No fungicide	938	860	92.0	487.0

[1] The high percentage of infection in this experiment is explained by the long intervals between applications and the fact that the bed was watered every day and inoculated twice a week.

Experiment 14. — In similar experiments at Windsor the beds were on soil which had grown a heavily infected crop of tobacco in 1921. The beds were not artificially inoculated as in the preceding experiments. The fungicides used were Sanders Dust No. 1, Niagara 20-80 copper-lime dust, Dosch 15-85 copper-lime dust, orchard brand Bordeaux lead and Bordeaux zinc. Seven applications were made at intervals of three to five days. A natural infection developed on the untreated plot and in one corner of a plot next to it. No other wildfire developed on the treated plots.

Conclusions from the Experiments and Practical Applications.

Frequency of Application. — The writers recommended in 1921 (1: 81) that the fungicide be applied once a week. Later experiments indicate, however, that this is not sufficient under the following conditions: —

1. When the plants are watered very frequently. On some soils it is necessary to water the beds heavily every day. Most of the fungicide is washed off before the end of a week. This factor was tested in Experi-

ment 11, where the plants were watered and inoculated every day or two. The percentage of infection was fairly high on the Pyrox plot and the dust plot. (The plants in the Bordeaux plot of this experiment were very small and in poor condition on account of accidental burning by cyanide gas which was used to fumigate the house. The low percentage of infection on this plot is not significant.) In the next experiment (Experiment 12) the plants were watered and inoculated less frequently and the fungicide was applied oftener. The infection was thus reduced again to less than 1 per cent.

2. When the beds are exposed to frequent rains. The first rains wash off the fungicide and later rains spread the bacteria. Even when the beds are covered during rains there is usually considerable drip through the sash between the glass.

3. When the plants are growing very rapidly, as they usually are just before setting begins. New leaves are produced so rapidly that many of them will be left unprotected for several days if the application is made only once a week.

No definite interval of time between applications can be regarded as safe. There are too many influencing factors. The only safe rule is to *keep all leaves covered at all times with the germicide.* During the very rainy season of 1922 no less than eight or ten applications would have been necessary. Growers have also found it a good practice to dust or spray the beds each time they are pulled over for setting.

Amount of Material to be applied. — In applying the dust or spray the only safe rule for judging whether enough has been applied is to note whether all leaves are covered. The amount of material required to produce a thorough covering will vary somewhat with the type of machine used and the stage of growth of the plant. In the experiments recorded above, in which a small rotary hand duster was used, it was found that no less than a pound of dust for each application was required to cover a square rod of plants when they were of a size suitable for setting. With the compressed air sprayer which was used, $1\frac{1}{2}$ to 2 gallons of spray material were found to be sufficient to cover the same area.

Relative Cost of Spraying and Dusting. — At the local stores in Amherst and Windsor lime cost $4.90 per barrel of 280 pounds, or, since a little more if in smaller quantities, about 2 cents a pound, copper sulfate 11 cents a pound, Pyrox 20 cents a pound and copper-lime dust 10 cents a pound. Using the amounts per square rod which are indicated above, the cost of materials for eight applications would be as follows: —

Bordeaux 4–4–50	12 cents per square rod.
Pyrox 12–50	58 cents per square rod.
Copper-lime dust	80 cents per square rod.

Thus the cost of materials of a commercial fungicide such as Pyrox is nearly five times as great as that of the home-made Bordeaux, while the cost of the dust is nearly seven times as much. A good compressed air sprayer can be secured on the local market for $7 to $10.50, while a suitable dust blower costs $12.50 to $18.50. The advantage which the Bordeaux mixture has in cheapness, however, is counterbalanced by the increased time and labor involved in its preparation. The copper-lime dust is immediately ready for application when received, and the Pyrox or NuRexo has only to be dissolved in water.

Dust v. Liquid Sprays. — The results of the six series of tests detailed above indicate that the percentage of control is about the same for the liquid spray as for the dust. In beds where very frequent watering is necessary, there might be some advantage in the liquid sprays, because when once dried on the leaves they adhere much better than the dust. The dust, however, has the advantage that it comes up and covers the lower side of the leaves better than the liquid. The dust can be applied more quickly, but thorough dusting with a rotary hand duster is very hard work if continued for any length of time. The dust is also irritating to the nose, eyes and throat. Cheapness of materials and machines is in favor of the liquid sprays. Altogether, the choice between liquid and dust seems to be a matter of personal taste.

Home-made v. Commercial Copper Sprays. — In the control obtained there seems to be very little difference between the results secured by the home-made preparation and the commercial sprays such as Pyrox or NuRexo. Home-made Bordeaux has the advantage of cheapness, while the commercial sprays have the advantage of more rapid preparation for application. If a grower has large beds which require frequent application, certainly it would be more satisfactory to prepare his own fungicide. For small beds the commercial sprays might be more satisfactory. Clinton and McCormick (2: 386), after experimenting with Bordeaux mixture and a number of commercial copper sprays, recommend home-made Bordeaux mixture as being cheaper and more effective than other copper fungicides. They tried dust on only one bed and had no wildfire there on either the treated or untreated plot.

Best Time of Day for Application. — Dust should be applied preferably in the early morning when the plants are wet, or after watering. When the copper sulfate and lime in the dust come in contact with water, they unite to form Bordeaux mixture, which dries on the leaf and adheres with at least a part of the tenacity of the liquid Bordeaux. If, however, the dust is applied to the dry plant and water then applied, even when the Bordeaux is formed it is mostly washed from the leaf before it dries. Liquid sprays should be applied when the plants are dry, because the spray is thus not diluted with water already on there and because less of it drips from the leaves at that time.

Absolute v. Partial Elimination of Wildfire. — It will be noted in the tables given above that in almost all of the sprayed and dusted plots a certain amount of wildfire appeared. Only in a few tests has it been possible to eliminate all infection. In the first five series of tests, however, it should be remembered that sprinkling cans full of water teeming with the parasitic bacteria were sprinkled over all the plants every three or four days. Such a method of inoculation is much more drastic than would occur under natural conditions in the beds of the average tobacco grower. If the treatment here recommended is faithfully carried out by the grower, we believe that in the large majority of cases no wildfire will be found in his beds. Even if there are occasional infected plants in the bed, the treatment is not a failure. The removal of diseased plants from the field will be much easier if there are only a few of them. Even if they are not all removed, the amount of final infection may be expected to be less if there are only a few centers from which it can spread.

Will Clean Beds give Clean Fields? — Clean beds are not an absolute guarantee that no wildfire will appear in the fields planted from such beds. During the season of 1922 in at least six instances the writers had convinced themselves by thorough and frequent inspection that the seed-beds of certain growers were entirely free from wildfire, but the disease developed later in the fields planted from these same beds. (Read the paragraph above on "Dissemination" for more details.) Such cases, however, should not encourage any one to believe that no benefit is derived from keeping the seed-bed clean. The worst and the most wide-spread field infections have usually come from the bed. Starting with clean plants in the field is not the whole measure of success, but it is a long start toward it.

Success by Practical Growers. — During the season of 1922 the writers made frequent inspections and kept careful records on the seed-beds of a number of growers. Untreated checks were not left in any case, and for this reason the results are not entirely convincing. They were unable to find wildfire in any of these beds where the plants were kept constantly covered with the fungicide. On the other hand, it did appear in the beds of many who dusted or sprayed a few times, or started to treat only after the disease became evident, or used only a scant amount of material.

Value of an Arsenical in the Fungicide. — In the first test some of the fungicides, both the dry and the liquid, contained an arsenical. This arsenical not only was found to be of no value for the control of wildfire, but frequently caused injury to the plants. There seems to be no reason for adding an insecticide.

Dust Burn and Spray Injury. — Heavy application of dust or copper spray frequently causes some injury to the plants. It has been commonly noted in the experimental beds at Amherst that the plants in the check plots appear healthier (except for the wildfire) and larger than in the treated plots. Growers have frequently called the writers' attention to this condition in their beds. Sometimes it is much more marked than at other times. Frequently it cannot be observed at all. Certain conditions of the plant or its environment must be responsible for this variation, but it is not as yet known just which conditions favor and which prevent such injury.

Dust burn is evidenced on the leaves by small dead spots of one-eighth inch diameter or less, colored white, brown or darker to black, irregular in outline, commonly bordered by indefinite blanching of the immediately surrounding tissue. This border, however, is narrow and inconspicuous and fades away indefinitely into the normal green leaf. It is quite different and easily distinguished from the halo about the wildfire spot. The leaf area about the spot is also commonly distorted or puckered into radiating wrinkles. Where excessive amounts of dust are used, whole leaves or entire plants may exhibit this wrinkled, distorted appearance without central dead spots. This results in dwarfing.

Spray injury resulting from the liquid fungicides is indicated by larger dead areas in the leaves on the margins, tips or other places where the liquid stands in drops.

Injury from either dust or liquid spray has never been serious and at most has resulted only in slightly slower growth of the plants in the beds. The plants immediately recover after being set in the field. The injury is never of sufficient importance to discourage the application of dust or liquid spray.

Secondary Benefits. — Practical growers have frequently called attention to the absence of flea beetle in the treated beds. One prominent grower has stated that he would spray whether he had wildfire or not because the beds were free from these insects. Copper-lime fungicides are known to repel flea beetles.

Frequently when the plants are thick in the bed and kept damp, they rot off at the base of the stem. It has been commonly noticed that this condition does not occur when the beds are properly treated with a fungicide.

Conclusion. — *Any grower who will start when the plants are no larger than a dime and keep the leaves covered at all times with copper-lime dust or any other good copper fungicide can control wildfire in the seed-bed.* We agree with Clinton and McCormick (2: 386) in the following quotation except that we would include dusting as well as spraying: —

> We are convinced that spraying of tobacco beds should be made one of the routine practices of tobacco growing as long as there is danger from wildfire. . . . We have evidence that plants thoroughly coated with the spray do not become infected anything like unsprayed plants in the same bed. Spraying to be most effective, however, must start before the appearance of wildfire and be continued until the end of the transplanting season. We would start with the young plants that have just taken root and whose largest leaves are about the size of a thumb nail. . . . *Spraying, we believe, is the only remedy that prevents spread of the wildfire in a seed-bed no matter what the source of its introduction.*

Destroying Diseased Areas in the Bed.

It is characteristic of the disease that when it is first found in the beds it does not occur uniformly over the bed, but is usually found in round spots which may be from a few inches to several feet in diameter, depending on the length of time during which the spot has been spreading. If only one or a few spots are found in a bed, it is sometimes possible by prompt action to keep the rest of the bed clean. This may be done by immediately destroying the diseased spots by drenching them with a 1/10 formaldehyde solution. Not only the spot but all the plants within a foot or two beyond it must be killed. This treatment was successful in preventing further spread in one bed in Sunderland, in one in Hatfield and two in Windsor, all of which were under the writers' constant observation during the summer. Glass should be removed from all plants of the bed which it is desired to save, because if they are left on, the fumes of the formaldehyde will spread through the bed and burn the leaves with which they come in contact. Plants should not be hoed out or pulled out before treatment, since this only serves to spread the trouble. Plants around the burned-out areas should be watched carefully for further spread. Spraying or dusting should also be started at once if it has not been practiced previously.

Removing All Plants from a Diseased Field and resetting with Healthy Plants.

Two fields have been under the careful observation of the writers during 1922 in which this practice was adopted, but in both cases it resulted in failure. In one field in Hadley and one in North Hadley, when the plants were about a foot high, they were found to be practically all infected. All were removed from the field and after it had been harrowed the field was reset with healthy plants. In both cases before the new plants were ready to harvest, they became almost as badly infected as the old ones. Apparently the pathogen remains in the soil and under favorable conditions will infect the new crop. The grower can gain by this practice only when the weather changes for the better during the growth of the second crop. The same principle would apply also to the restocking of a field where only a part of the plants were diseased. This was tried on a large scale by a grower of shade tobacco at North Hadley, who removed only the diseased plants (about 10 per cent) and restocked with healthy plants, but failed to control the disease. The following experiment bearing on this point was tried at the Windsor station: —

Experiment 15. — In one plot nineteen diseased plants were found ten days after setting. They were all removed and replaced by healthy plants. Eleven out of the nineteen resets developed wildfire later.

During 1921 a number of growers practiced either partial or complete restocking with healthy plants after diseased ones were removed, and little or no wildfire appeared later in the field. The same was true of some Connecticut fields in 1922. This apparent control may have been due to weather conditions which were not favorable for infection of the plants of the second setting. At any rate the results were contrary to most of our experience of 1922. In view of the latter it seems questionable whether restocking should be recommended.

Roguing without Resetting.

When only a few plants in a field are diseased, it is probably best to remove them from the field and leave empty the places from which they were taken. This was tried with success by three growers in North Hadley whose fields were under the writers' observation during the present season. Other growers have told the writers that they kept wildfire in check by this method.

Experiment 16. — In a plot at the Windsor Station, where five plants were found to be diseased ten days after setting, they were all removed and the places not filled. The surrounding plants were inspected regularly and in two cases they became infected later.

In a later experiment, where the plants were about $1\frac{1}{2}$ feet high, the diseased ones were removed and not replaced. Before harvesting, however, wildfire had appeared on the adjacent plants and had spread through four to six plants to the windward and along the row.

It is reasonable to believe that bacteria which came into the soil from the original diseased plant would have less opportunity for further infection if no plant replaced the diseased one which was removed. Certainly the danger of surrounding plants becoming infected is diminished by removal of infected ones from the field. On the whole, there is no question but that this practice of roguing will help to a great extent where there is only a light infection in the field, especially if the plants are pulled when small. After plants are half-grown, however, under favorable conditions the disease may spread in its customary manner, and it may be necessary to remove plants or infected leaves from plants for some distance around the original point of infection.

Picking off Diseased Leaves.

If the plants are large and infection is light, a certain amount of benefit may be derived from removing all diseased leaves and carrying them from the field. The principle of this measure is the elimination of as many as possible of the centers of spread. Then when the rains come the number of bacteria splashed to the healthy leaves will be greatly reduced. This method was tried by Anderson on a 4-acre field in Whately.

Experiment 17. — Infection in this field started from about six to eight rows near the east side, which had been planted from a diseased bed. At the time when the experiment was started a majority of the plants in these rows were diseased, and it had spread more or less to plants on adjacent rows. There was practically no infection on the west half. On June 30 all diseased leaves were picked from the east half (forty-eight rows). No attention was paid to the west half. On the badly infected rows mentioned above a large basketful of leaves was taken from each row, some of the plants being left almost without leaves. It was picked again four days later, the weather having been very rainy during the last month. Probably as many leaves were removed the second time as during the first picking. It was picked over at short intervals five times afterward, and with each picking the number of diseased leaves decreased, until on July 26 hardly a diseased leaf could be found. After the heavy rains of the last few days of July and the first of August, however, wildfire began to appear again on the picked side of the field, but to a greater extent beyond the forty-eighth row, where no picking had been done. The field was harvested on August 8. On that date the picked and unpicked sides of the field were inspected by Mr. Arthur Hubbard, W. H. Davis, D. Potter, C. M. Slagg, Dr. James Johnson and the writer, and it was the opinion of all that the unpicked side showed much more wildfire than the picked side. Mr. Hubbard was of the opinion that the east half would not have been worth harvesting if the disease had been left to take its natural course. The loss in weight from removal of the diseased leaves was not serious. As previously mentioned in this report there was good evidence that when infection began again during the first few days of August it came from bacteria which were in the soil. This source of infection cannot be eliminated and will probably prevent this method of control from ever being entirely successful. In view of the fact, however, that the season of 1922 was usually favorable to the spread of wildfire, the results of the experiment are encouraging.

A similar experiment was conducted on a Round Tip plot at the Windsor Station and with similar results. Growers who tried picking off affected leaves are divided as to their opinion of the practical value of the method. The degree of success varied according to the kind of tobacco and method of harvesting. Chances of success are better in primed tobacco because after harvesting starts the leaves are picked so rapidly that the disease does not have an opportunity to get a good start, and it also becomes increasingly difficult for the germ-laden soil to splash to the first leaves. Field observations on the picking of leaves during 1922 lead to the following conclusion: —

On the Shade Cuban, favorable results were almost uniformly obtained and the disease was practically eliminated. On Havana and Round Tip, where diseased leaves were removed, there was a considerable variation in the results, with a majority of fields showing decided benefit. On Broadleaf there did not seem to be anything gained by picking off the leaves.

For any one who contemplates this method of control it is recommended that (1) the first inspection be made as soon as the plants are established in the field; (2) the leaves be picked off twice a week as long as any diseased ones can be found; (3) sand leaves of diseased plants be picked also.

Clinton and McCormick (2: 396) also experimented with removal of diseased leaves and as a result were somewhat doubtful as to the benefits.

Dusting the Plants in the Field.

The value of dusting the plants in the field with copper-lime dust was tried by two Massachusetts growers under the writers' supervision during the season.

Experiment 18. — Twenty-four acres in Hadley were first dusted with a four-row traction duster, which was furnished by the Niagara Sprayer Company, on July 6, when the plants were 12 to 18 inches high. The infection was bad in parts of the field when the experiment was started. Four rows were left without dust. There were very heavy rains on the 8th and the second application was made on the 13th and 18th. During July there was very little spread of wildfire in any fields and the plants grew enormously. By the first of August the plants had grown until the machine could not be drawn through the field without serious damage to the plants, and therefore no more applications were made. There was considerable spread of the disease during August, until the crop was harvested about the middle of the month. A comparison of the treated and untreated rows at that time showed no difference in the amount of disease. No accurate counts were made, but a cursory examination while walking between the rows did not indicate any benefit from the two applications of dust. It was also noticed that there were dust-burn spots on the treated leaves similar to those which have been previously described as occurring in the beds. The owner feared that if the dusting were continued, the spots might affect the market of the crop.

Experiment 19. — Another grower in North Hadley dusted two fields with the machine used in Experiment 18, but more frequent applications were made. Wildfire was not controlled, the results being similar to those of Experiment 18.

Experiment 20. — On one of the Windsor Station plots Round Tip tobacco, which showed a heavy mixed infection of wildfire and angular leaf spot on the bottom two or three leaves when the plants were from 1 to 1½ feet in height, a copper-lime dust was twice applied to four rows, with a five-day interval between the first and second treatments, no rain falling in the interim. Six rows were left untreated for comparison. For about two weeks after treatment, the spread of the disease in the dusted rows was practically nil, while in the undusted rows it spread steadily and very rapidly. After this time three rainy days ensued, but purposely no more dusting was done. At harvest time it was found that the amount of wildfire on the dusted rows was only 15 per cent (estimated from partial count on cured tobacco) less than on the rows which had not been dusted.

No doubt, if the leaves in the field could be kept covered with dust all the time, the disease could be controlled, but this would require more frequent applications, and when the plants become large it cannot be done without considerable breaking of the leaves. Control by this method is probably possible, but not economically so. Further experiments, however, are planned. It was found that the dust adhered much better if applied early in the morning while the plants were still wet with dew.

Spraying with Bordeaux Mixture in the Field.

Bordeaux mixture was tried with the idea that it would adhere to the leaves more tenaciously and hence so many applications would not be necessary as when dust was used.

Experiment 21. — A field of 12 acres in North Sunderland was sprayed on July 11 with 4–4–50 Bordeaux. No further applications were made because the owner feared that the material would remain permanently on the leaves and affect the sale of the crop. An examination on August 14, when the crop was being harvested, showed that it was present in large enough quantity on many of the leaves to give them a decidedly blue cast. A comparison of the sprayed and unsprayed rows showed no difference in the amount of the disease.

Clinton and McCormick (2: 395) experimented with Bordeaux mixture in a preliminary way and found that it retarded spread of the disease, but they did not consider it practical because of cost and unknown effect of the spray on the quality of the mature leaf.

A few Connecticut growers tried spraying in the field in 1921 and reported good control. This year several growers of sun as well as shade grown tobacco sprayed plants in the field from one to six times, until the plants were too large to permit of further treatment, but the results have not been encouraging in the case of sun-grown tobacco. While the treatment seemed to check the disease for a time, later in the season after the plants had grown too large to continue the treatment, wildfire spread rather rapidly, and at harvesting little difference could be observed between the sprayed and unsprayed areas in the same field. In the case of one grower who had a rather bad field infection when the plants were small, the use of a Bordeaux mixture applied twice on part of the field when the plants were small checked for a long time any further spread of the disease, and at harvesting time the part of the field sprayed twice showed much less wildfire than the unsprayed part of the field.

Bordeaux mixtures are cheaper and under field conditions remain on the leaves a longer time, which is of course desirable from the infection protection standpoint, but a disadvantage when the plants are more than half-grown, as it remains on the leaves and the blue color is undesirable after the cure.

Another factor operating against the efficiency of dusts or sprays in the field is that after the plants are about half-grown it is a practical impossibility to operate a duster or sprayer to advantage, and one is obliged to stop the treatment at what might be termed the critical period, as it is well known that there is often a heavy wildfire infection just prior to maturity.

It is believed, however, that some benefit might be obtained from dusting or spraying when the plants are small and until they are about a foot high, particularly if spraying or dusting were combined with picking off diseased leaves, and the spraying or dusting repeated at very close intervals, say two or three times a week for a period of two weeks or so.

It is believed that the application of dusts or sprays to tobacco in the field is worthy of further consideration both by the growers and the station, and next season more detailed experiments along this line will be carried on.

At present, however, the evidence at hand is not very favorable for this method of control.

THE OUTLOOK FOR 1923.

The question now most frequently asked by the grower is: What can we expect from wildfire in 1923 and in the following years? Will it continue as prevalent and troublesome as it has been in 1922? Will it become worse after our land is thoroughly infested with the germ? Or will it gradually disappear? Frequently tobacco growers have told the writers that they would stop raising tobacco if they thought the disease would continue to be as serious as it has been during 1922. No man can predict its future behavior with certainty or anything which approaches certainty, but we can base some judgment on (1) what we know about its relation to weather conditions and (2) its behavior in States where it has been present longest.

We know that the disease can spread only when the rains are long continued or follow each other in close succession, i.e., when the water remains for long periods on the leaves. The summers of 1921 and 1922 were for the most part ideal in this respect for the spread of the disease. They have not been average summers for the Connecticut Valley. The disease will not be as destructive during an average growing season. We do not believe that wildfire will soon disappear from the valley, but during a dry summer it might not cause any damage. After a succession of unfavorable seasons the sources of infection might be so reduced that it would cause little trouble even with the return of a summer favorable for its spread. The above opinion is supported by the course which the disease has taken in the South. Five years ago it was destructive there. In 1921 the season was very dry and the injury from wildfire was slight. The season of 1922 is said to have been not unusually dry, but the disease has not returned to any extent. Our advice to the Connecticut Valley grower is to plant as usual, take a chance on the weather, but to omit no precaution recommended against wildfire.

CONDENSED RECOMMENDATIONS FOR CONTROL.

There is no one measure by the use of which a tobacco grower may be assured of raising a clean crop. As long as wildfire is in the valley, he must start before the seed is planted, be ever on the alert and ready to put into practice any part or all of the season's program which may now be briefly summarized: —

1. Select seed only from plants known to be free from the disease. If possible, go a step farther and take only from fields known to be disease-free. Protecting the flower heads with bags may be useful. Old seed is less likely to be contaminated.

2. If there is doubt about the seed being sterile, soak it in a cheesecloth bag for fifteen minutes in $\frac{1}{1000}$ corrosive sublimate, wash and spread out to dry.

3. If possible, locate seed-beds only on land where there was no wildfire during the previous year and where there has been no opportunity for contamination.

4. Sterilize soil with steam at 100 pounds pressure for thirty minutes, or with formaldehyde $\frac{1}{50}$ at the rate of one-half gallon to the square foot. It is safer to sterilize walks also. Spring sterilization is safer than fall sterilization.

5. Drench boards and sash with formaldehyde $\frac{1}{50}$. If cloth is used, it should either be new or should be boiled in water or treated like the boards and sash. If sash and plank are new or have never been used for tobacco beds, they need not be sterilized.

6. Keep the plants covered with copper-lime dust or a copper spray such

as Bordeaux mixture at all times, from the stage when they are as large as the finger nail until setting is completed.

7. Remember that the germs can be carried from one bed to another on the hands, tools, sash, etc., and avoid such chances.

8. Adopt a system of bed management which will keep the leaves moist during the shortest length of time compatible with the production of good plants.

9. If the disease appears in certain spots in the bed, these spots, along with a broad margin of plants which appear healthy, should be killed by drenching with 1/10 formaldehyde.

10. Pull plants for setting only from disease-free beds.

11. Starting as soon as the plants have recovered and begun to grow in the field, make frequent inspections and remove every diseased plant from the field.

12. Do not work in a field where there is any wildfire while the leaves are wet.

13. Removal of diseased leaves at intervals of three or four days, where the infection when first found is light, will reduce the number of centers of spread and may materially reduce the percentage of wildfire in the crop when harvested.

14. Rotate tobacco with other crops if practicable.

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COMBATING APPLE SCAB

SPRAYING AND DUSTING EXPERIMENTS IN 1922

By WEBSTER S. KROUT

The scab fungus of the apple affects seriously the McIntosh Red, particularly as it is grown in the eastern apple region of the State. Nowhere in the State has scab yielded completely to the protective spraying and dusting methods commonly followed by apple growers. The Experiment Station started work on disease control in the fall of 1920. The outstanding fact to date is that of a high degree of control even in spite of adverse weather conditions. This bulletin gives the record of the 1922 operations, together with concise recommendations for protective treatment against the disease.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

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BULLETIN No. 214.

DEPARTMENT OF BOTANY.

COMBATING APPLE SCAB.

SPRAYING AND DUSTING EXPERIMENTS IN 1922.[1]

BY WEBSTER S. KROUT.

Introduction.

The fact of control by both spraying and dusting is outstanding at the end of the second year's field study of this fungous disease. Weather conditions in both 1921 and 1922 were most adverse to successful spraying and dusting, and most favorable to scab infection, yet despite these handicaps almost perfect control was obtained.

These investigations were started in the fall of 1920. In the fall of 1921 a report of the results of the first year's work was published through the Extension Service of the College in a pamphlet entitled "Apple Scab and its Control." This bulletin presents to the practical orchardist a similar report for 1922.

The field work has been conducted in three orchards under the direct supervision of the writer. In three other orchards he was present whenever possible. The spraying experiments were in the orchards of Stephen Sabine of Groton and Harry L. Knights and H. L. Frost of Littleton. The dusting experiments were conducted in the orchards of Harry L. Knights and H. L. Frost of Littleton, A. N. Stowe of Hudson, George A. Marshall of Fitchburg and R. J. Fiske of Lunenburg. Especially helpful was the co-operation of J. W. Ames, superintendent of the Knights farm, Roy C. Wilbur, superintendent of the Frost farm, John J. Collins, superintendent of the Stowe farm, and the officers of the Nashoba Fruit Producers Association.

[1] The writer is indebted to Prof. A. Vincent Osmun, head of the Department of Botany of the Massachusetts Agricultural Experiment Station, for many helpful suggestions during the progress of this study.

Apple Scab.

Apple scab presents one of the most serious problems of the commercial apple grower of Massachusetts. The disease is caused by a fungus which attacks the leaves, flowers, fruit, pedicels and twigs. It may attack any variety of apples, but is exceptionally severe on the McIntosh.

Every orchardist should endeavor to familiarize himself with the first symptoms of apple scab as they appear on the leaves, so that the disease may not reach the epidemic stage before he realizes the danger. Scab usually appears first on the lower side of the leaves as grayish or olive webby spots or blotches, darker than the normal surface of the leaf. The color deepens with age to dark brown or black. The spots on the upper surface of the leaves are first noticed as yellowish green discolorations, gradually deepening with age through olive brown to black. They are velvety, somewhat definite in outline, smaller than spots on the lower side, and have a tendency to become raised or convex.

The Causal Fungus.

The scab fungus passes the winter on the dead leaves, under the trees. In the autumn after the leaves fall the fungus continues growing, penetrating the interior of the leaf. Sometimes, in November, it begins to form the flask-shaped bodies (peritheeia) in which mature winter spores (ascospores) are developed by the following spring. During the rainy periods of spring these spores are discharged, and, being extremely light, are carried upward by the air to the under surface of the leaves. The scab spots produced by this infection appear from eight to fifteen days later. These spots, almost as soon as they are noticeable, produce the summer spores in great quantities. These spores cause rapid spread of the disease.

Table I. — *Dates of Discharge of Winter Spores and of the First Appearance of Scab in 1921 and 1922.*

	1921.	1922.
First discharge of winter spores	April 26	May 2
First appearance of scab	May 12	May 18
Last discharge of winter spores	June 10	June 15

During both years the first spots were discovered on the lower side of the leaves at the time of the calyx spray. In other words, the first spots appeared as the petals were dropping.

Spraying Program for 1922.

A series of plots in triplicate were laid off in the three orchards previously mentioned. The sprays used were home-made Bordeaux mixture alone, home-made Bordeaux mixture and liquid lime-sulfur, home-made Bordeaux mixture and dry lime-sulfur, a 4–50 and a 3–50 dry lime-sulfur, liquid lime-sulfur, and liquid lime-sulfur plus lime.

Powdered arsenate of lead, at the rate of 2 pounds to 50 gallons of spray, and 40 per cent nicotine sulfate, at the rate of three-eighths pint to 50 gallons of spray, were used with all the different spray materials in the delayed-dormant, pink and calyx. In the fourth summer spray arsenate of lead was used but the nicotine was omitted.

In the Sabine and Knights orchards the plots were rectangular, 4 rows of 6 trees each, except the check at Sabine's which had 16 trees, and the Bordeaux–dry lime-sulfur plot at Knights' which had 20 trees. In the Frost orchard the plots consisted of single rows of 8 to 11 trees. The data were taken from 5 typical trees of the two middle rows of each plot in the Sabine and Knights orchards; and in the Frost orchard, from 5 typical trees of each row. The trees of each of the three sprayed orchards were approximately twelve years old.

Treatment of Plots.

All plots, except the checks, were given the delayed-dormant application. The plots in the Sabine and Knights orchards were sprayed with a 1–10 liquid lime-sulfur plus arsenate and nicotine. The plots in the Frost orchard were sprayed with a 15–50 dry lime-sulfur plus arsenate and nicotine. Plots 1 to 8 were conducted in each of the three orchards. Plots 9 to 11 were conducted only in the Frost orchard. The plots in the Sabine orchard were the only ones given the fifth summer spray. The detailed treatment of plots follows: —

Plot 1. — Check, unsprayed with fungicides. The same insecticides were used as on the other plots. A single check plot was used in each of the Sabine and Frost orchards. In the Knights orchard two check plots were necessary, because the Bordeaux plot was located in a separate block of trees.

Plot 2. — A 3–10–50 home-made Bordeaux mixture[1] for the pink spray, and a 1–50 liquid lime-sulfur for the calyx and following sprays.

Plot 3. — The same as plot 2, except that dry lime-sulfur was substituted for the liquid.

Plot 4. — 1–50 liquid lime-sulfur.

Plot 5. — 4–50 dry lime-sulfur.

Plot 6. — 1–50 liquid lime-sulfur plus 6 pounds of lump lime to 50 gallons of spray.

Plot 7. — A 3–10–50 home-made Bordeaux mixture for the pre-pink and pink, and liquid lime-sulfur for the calyx and succeeding sprays.

Plot 8. — A 3–10–50 home-made Bordeaux mixture only.

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[1] Directions for making Bordeaux mixture may be obtained by applying to the Extension Service, Massachusetts Agricultural College. Ask for Extension Leaflet No. 33.

Plot 9. — A 4–50 dry lime-sulfur for the pre-pink, pink and following sprays.

Plot 10. — A 3–50 dry lime-sulfur plus arsenate and nicotine.

Plot 11. — A 3–50 dry lime-sulfur plus nicotine sprayed on the trees, allowed to dry, and then the arsenate applied.

Time and Manner of Spray Applications.

TABLE II. — *Time of Application of Sprays for 1921 and 1922.*

Application.	1921.	1922.
Delayed-dormant	April 4– 6	April 13–19
Pre-pink	– –	April 28–May 3
Pink	April 25–27	May 3– 8
Calyx	May 10–12	May 16–20
Fourth summer	June 6– 8	June 9–22
Fifth summer	– –	June 25–31

As previously explained, two additional applications, the pre-pink and fifth summer, were made on some of the plots in 1922. Power sprayers which maintained approximately 200 pounds pressure were used, with spray rods equipped with the regular 45° Friend angle nozzles. By holding the rod close to the ground and in such a position as to shoot the sprays upward, the under surface of the lowest leaves was thoroughly covered. As these are the first leaves attacked by the scab fungus, it is exceedingly important that they be well covered at the pre-pink and pink applications.

DISCUSSION OF RESULTS OF SPRAYING.

Throughout most of the season weather conditions were exceedingly favorable for scab infection.

It will be noted in Tables IV, V and VI (pages 40 and 41) that all of the sprays gave exceptionally good control. In fact, many of the sprayed plots produced 100 per cent marketable fruit, whereas some of the checks produced fruit 100 per cent scabbed. There was not a single scab-free apple on the 16 check trees in the Sabine orchard, and 95 per cent were so badly scabbed that they were unmarketable. In the Knights orchard the situation was nearly as bad, 96 per cent of the fruit being scabbed and 69 per cent unmarketable. In the Frost orchard infection was not quite as severe, only 41 per cent of the fruit being scabbed.

Only small and probably insignificant differences were found in the results obtained from the different fungicides in so far as control of the scab fungus is concerned.

Importance of the First Spray Applications.

The dissemination of scab spores is most rapid about the time of the *pink* application. This is, therefore, the most important spray and should be so timed that it will be on the foliage, blossoms and pedicels of the blossoms before the winter spores are discharged. Observations of the writer *indicate that most growers who fail to control scab apply the pink spray too late in the season.*

In some places a *pre-pink* spray is used in order to make certain that the fungicide is on the leaves before the scab spores are discharged. Explained in the most simple terms, this means setting the pink spray ahead from seven to ten days. It is a spray applied approximately midway between the delayed-dormant and the pink. At that time most of the cluster buds are still closed, and a few only of the most advanced blossom buds show slight amounts of pink. Tables IV, V and VI, plots 7 and 9, show that the series of plots on which the pre-pink spray was applied yielded exceptionally high percentages of both clean and marketable fruit.

If the orchardist were positive that the pink application could be made before the discharge of the winter spores, it would be unnecessary to use a pre-pink spray. The pre-pink application is intended primarily to eliminate this uncertainty connected with the pink treatment. The cost of the spray material at this application is a small item, as the arsenate and nicotine are omitted. As this application has been tested one year only in this State, the writer hesitates to recommend it to the small orchardist. To any orchardist who has three or more days of spraying at the pink application, it is to be recommended without hesitation.

Home-made Bordeaux and Lime-Sulfur.

A 3–10–50 home-made Bordeaux mixture used alone for all applications russeted the fruit and burned the foliage so badly that its use in this way will be discontinued. Foliage burn due to the Bordeaux was not evident until the latter part of the season.

For two years, a 3–10–50 home-made Bordeaux mixture for the pink spray, followed by a 1–50 liquid lime-sulfur for the calyx and succeeding sprays, has given the most satisfactory results. From Tables IV, V and VI it will be seen that this combination in Sabine's orchard produced 98 per cent marketable fruit, but fell slightly lower than some of the other plots in clean fruit. In the Knights and Frost orchards it produced 100 per cent marketable fruit.

Some of the fruit sprayed with the Bordeaux–liquid lime-sulfur combination described above was russeted slightly. The writer questions whether this was caused by the Bordeaux at the pink spray or by natural conditions, as about the same amount of russeting occurred on some of the unsprayed trees. Also, no russeting occurred on similarly treated plots in 1921. The russeting was slight and did not injure the sale of the fruit except where the apples were sold to a fancy trade. In 1921 lime-sulfur burned the blossom buds badly.

A test was made to determine if dry lime-sulfur used with home-made Bordeaux mixture was as effective for the control of scab as the liquid form. Tables IV, V and VI, plots 2 and 3, show that the dry form was practically as good as the liquid, except in the Sabine orchard, where for some unexplained reason the Bordeaux–dry lime-sulfur plot yielded only 49 per cent clean fruit and 90 per cent marketable fruit. The fact that the total yield of this plot was exceptionally low may justify leaving it out of consideration.

Liquid Lime-Sulfur versus Dry Lime-Sulfur.

For two years dry lime-sulfur has given as good control of scab as the liquid form (Tables IV, V and VI). Four pounds of the dry form in 50 gallons of water have been used for all sprays except the delayed-dormant in most of the work, but judging from this year's results 3 pounds will give as good results. Some growers use only 2 pounds in 50 gallons, but in the opinion of the writer this is too dilute.

Dry lime-sulfur has the advantage of less bulk, and it is claimed that the fungicidal value is not injured by freezing. Both the dry and liquid forms of lime-sulfur used with lead will burn the foliage under certain conditions, but judging from the data at hand the liquid form seems to burn slightly more than the dry.

The Cost of Spraying.

In figuring the cost of spraying the writer has used the data from the experimental plots of 1922. It is assumed that there are 30 twelve-year-old McIntosh trees to the acre. Dry lime-sulfur and insecticides are used as indicated in the suggested spraying schedule for 1923: dry lime-sulfur, 15 pounds to 50 gallons of water for the delayed-dormant, and 4 pounds to 50 gallons of water for the four later applications; powdered lead arsenate, 2 pounds to 50 gallons of spray; and nicotine sulfate, three-eighths pint to 50 gallons of spray. Four gallons of spray are allowed for each tree. The cost of lime-sulfur is placed at 10½ cents per pound; powdered arsenate of lead at 14 cents per pound; and nicotine sulfate at $14 per gallon. Spraying with either liquid lime-sulfur or Bordeaux mixture costs slightly less than with dry lime-sulfur.

Table III. — *Cost of Spraying One Acre of Apple Trees.*

Applications.	Material.			Labor.		Total.
	Dry Lime-Sulfur.	Lead Arsenate.	Nicotine Sulfate.	Man.	Team.	
Delayed-dormant	$3 78	$0 67	$1 57	$0 70	$0 30	$7 02
Pre-pink	1 00	–	–	70	30	2 00
Pink	1 00	67	1 57	70	30	4 24
Calyx	1 00	67	1 57	70	30	4 24
Fourth summer	1 00	67	1 57	70	30	4 24
Total for five applications	$7 78	$2 68	$6 28	$3 50	$1 50	$21 74

Dusting Program for 1922.

The use of dusts for the control of apple scab is new in this State. Prior to 1921 the writer knew of only one dusting machine in the eastern part of the State, and that was used for dusting peaches. In 1921 dusting experiments were begun by the station in three orchards. The writer and growers who co-operated were inexperienced in the art of dusting, and consequently the dusts were not applied as well as they might have been. As a result, dusting compared very unfavorably with spraying.

In 1922 a number of growers bought dusting machines. With the experience of the previous year, and willingness on the part of growers to co-operate, extensive plans were made to test the efficacy of dusting materials for the control of apple scab. Accordingly, five orchards, previously mentioned, were chosen in which to locate the experiments. Two dusts, sulfur and a copper-lime-arsenate dust, were used in each orchard. Checks were used in all cases. The plots were all large, one of them containing 179 trees. Only McIntosh trees were used.

It will be noticed that there was no nicotine in any of our dusts. Nicotine makes a dust expensive, and the manufacturers state that it is difficult to manufacture a satisfactory sulfur dust high in sulfur with sufficient nicotine in it. As it happened, no nicotine was needed on any of the plots, but it was planned to spray with a nicotine solution or dust with a nicotine dust should infestation with sucking insects become serious.

Five representative trees of each dusted plot in the Marshall and Stowe orchards, 7 in the Knights orchard and 6 in the Frost orchard were chosen from which to take data. Also 3 representative trees of each undusted check in the Marshall and Knights orchards, 2 of one check in the Stowe orchard and 3 of the other (Table VII, plot 12) and 2 in the Frost orchard were chosen from which to take the data (Tables V, VI and VII, pages 40 and 41). The data of the Fiske orchard are not given as the trees were young and the yield exceptionally low.

Treatment of Plots.

Plots 13 and 14 in all the orchards were given the regular delayed-dormant spray with lime-sulfur. The plots in the Stowe orchard were given three dust applications, — the pre-pink, pink and fourth summer. The plots in the Frost and Fiske orchards had four applications, — the pre-pink, pink, calyx and fourth summer. The plots in the Knights orchard had five applications, — the pre-pink, pink, calyx, fourth and fifth summer. The plots in the Marshall orchard had nine applications, — the pre-pink, pink, calyx and six subsequent applications. The detailed treatment of plots follows: —

Plot 12. — Check untreated with fungicides, but sprayed with the usual insecticides.

Plot 13. — Sulfur dusts. The ordinary commercial dusting sulfur without insecticides was used for the pre-pink, fifth, sixth and seventh summer applications.

A sulfur dust, composed of 85 parts sulfur and 15 parts arsenate of lead, was used for the pink, calyx and fourth summer dusts.

Plot 14. — Copper-lime-arsenate dust for the pre-pink, pink and fourth summer applications only. An 85–15 sulfur dust was used at the calyx application, and dusting sulfur for treatments after the fourth summer application.

Time and Manner of Application.

The dusts were applied at approximately the same time as the sprays (Table II). Two different makes of power dusting machines were used. *The dusts were applied from two sides of the trees while the leaves were wet.* Dusting was started at 5 A.M. and continued until about 8 A.M. The best distribution of dust through the tree was accomplished by giving the hose a circular or a quick upward and downward movement. Care was taken to hit the lower leaves, especially at the pre-pink and the pink applications. The engine and duster should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dusts upward through the tree. Where rows of trees are too close together, this will hinder the operation of the duster.

Discussion of Results of Dusting.

In evaluating the results from dusting in 1922 it must be borne in mind that only a single year's work is represented, and that it is, therefore, decidedly unsafe and unsound to draw any conclusions whatever.

The data in Tables V, VI and VII show that the dusts gave excellent control of scab in a year most favorable for the development of the scab fungus. For example, in the Knights orchard the check for the dusts produced only 1 per cent marketable fruit, while the sulfur and copper-lime-arsenate dust plots produced 97 and 99 per cent marketable fruit. In the Frost orchard the check for the dusts produced 68 per cent marketable fruit; the sulfur dust plot, 96 per cent; and the copper-lime-arsenate plot, 97 per cent.

In the Stowe orchard the checks produced from 46 to 48 per cent marketable fruit; the dusted plots, 92 to 97 per cent. Table VII shows that in the Stowe orchard slightly better results were obtained on the younger trees than on the older. This, with the fact that practically all the scabby apples of the dusted plots were found in the tops of the trees, would indicate that the higher the tree the more difficult it is to apply the dust thoroughly. Although the results on the dusted plots were extremely good, it is evident that even better results might have been obtained had the dusts been more thoroughly applied to the topmost parts of the trees.

In several cases where late summer applications of lime-sulfur and dusts were made side by side in the same orchard, the lime-sulfur burned the foliage, while the sulfur dust caused no injury. Later observations showed that where the foliage was burned by the lime-sulfur, from 8 to 20 per cent of the fruit dropped prematurely; while where the sulfur dust was used, practically the entire crop remained on the trees.

It is quite evident that copper-lime-arsenate dust controlled scab more effectively than the sulfur dusts, as in three of four orchards it gave a higher percentage of clean and marketable fruit. *However, it cannot be recommended for apples on account of the russeting of the fruit and the burning of the foliage.* On the other hand, sulfur dusts neither injured the foliage nor russeted the fruit. If kept covered with the sulfur dust, the leaves grow normally and develop a dark green color. *Sulfur dust is cheap and is the only dust that has shown itself worthy of further trial.* It is possible that the copper-lime-arsenate dust may prove useful for the pre-pink and pink applications, to be followed with sulfur dust for the later applications. This combination will be tested another year.

In the Stowe and Marshall orchards there were no experimentally sprayed plots to compare with the dusted plots, but if we may judge from the results which these orchardists obtained on sprayed trees adjacent to the dusted plots, the sulfur dust was equal to the sprays.

The Effect of Apple Scab on the Vitality of the Tree.

The most striking example of what may be expected of an unsprayed McIntosh orchard may be seen on the check plot in Knights orchard (Table V, plot 1). The trees of this plot have not been sprayed with a fungicide since 1920, and in 1921 and 1922 they showed approximately 100 per cent infection of fruit and foliage. The heavy loss of foliage in 1921, in spite of the fact that the trees were fed heavily, caused a very light set of leaves and blossoms in the spring of 1922, and consequently a greatly reduced yield of fruit. Plots 1 and 2, Table V, are located side by side in the orchard. It is planned to shift the check plot in this orchard from its present location to some other part of the orchard in 1923, as permanent injury to the trees is feared.

The Relation of Weather to Spraying.

Spraying should always be done in advance of rain periods, since the fungicide must be on the leaves in advance of the germination of the spores. If allowed to dry thoroughly, efficient sprays do not wash off sufficiently to destroy their fungicidal value. By studying the low barometric areas of the daily weather reports, the grower should be able to predict, with some degree of accuracy, weather conditions two to three days in advance.[1]

Burning of Apple Foliage by Sprays and Dusts.

The foliage of some of the apple trees in the plots was badly burned with lime-sulfur during 1921, while in 1922 very little injury from this material was noticed. The writer believes that weather conditions were

[1] These daily reports may be obtained by addressing the United States Weather Bureau, Boston, Mass.

largely responsible for this difference. Temperature and humidity were quite high when many of the applications were made in 1921, while to a certain extent the opposite was true in 1922. *Apples should never be sprayed when temperature and humidity are both high, as burning of foliage is almost certain to result.*

The amount of spray applied does not seem to be as important a factor in burning the foliage as was formerly thought. In 1922 the writer selected trees in several plots in the Sabine and Knights orchards and thoroughly drenched them with the spray at the pink and calyx applications. At the end of the season the trees showed only slight injury.

Sulfur dusts have never burned the foliage, while burning from copper-lime dust is frequent.

Recommendations for 1923.

Spraying Program.

It should be borne in mind that the spray schedule which follows is based on only two years of experimental work, and therefore is subject to change. Where two or more spray materials are given, the first is preferable and should be used whenever possible.

Delayed-dormant. — Fifteen pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 9 gallons of water.

Pre-pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Calyx. — Three to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Fourth and Fifth Summer. — Same as the calyx. Unless the rainfall of June, July and August is above normal, the fifth summer spray may not be necessary for the control of scab. On the other hand, if these months are rainy and scab is bad, the fifth summer application will be found very profitable.

Three-eighths of a pint of 40 per cent nicotine sulfate to each 50 gallons of spray is used at the delayed-dormant, pink and calyx applications. Also, 2 pounds of powdered lead arsenate to each 50 gallons of spray are used at the delayed-dormant, pink, calyx and fourth summer applications.

Dusting Program.

If a dusting program is to be followed, the delayed-dormant spray should be applied. *Dusting sulfur* should be used for the *pre-pink* and for all applications after the fourth summer dust. A dust composed of 90 parts sulfur and 10 parts arsenate of lead should be used for the pink; an 85–15 dust for the calyx and fourth summer applications. In case sucking insects are bad, it will be necessary to spray the trees with three-eighths pint of 40 per cent nicotine sulfate in 50 gallons of water, or dust the trees with a commercial nicotine dust.

Miscellaneous.

Dry lime-sulfur passes through the spraying outfit better if it be allowed to stand in water about forty minutes before it is poured into the spray tank. Before going to the orchard with each tank of spray material, it is a good plan to weigh out the desired amount for the next tank in a 5 or 6 gallon pail, pour water over it and agitate with a wooden paddle for a few minutes. On returning, the spray tank is filled about two-thirds full of water, the agitator set in motion, the lime-sulfur from the pail poured into the tank, and the tank filled with water. Some growers consider soaking of the material unnecessary before putting it into the tank.

Lime-sulfur should be well agitated before it is applied to the trees as a too concentrated solution will burn the foliage.

Twelve-year-old trees with a height and spread of approximately 20 feet should receive about 4 gallons of spray material with each application.

Follow the spraying system outlined for 1921.[1] It is better to spray against the wind than with it, as less spray materials are wasted and a better covering is obtained.

The engine and duster of the dusting outfit should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dust upward through the tree. Special effort should be made to hit the extreme tops of the trees. Best results are obtained by giving the hose of the duster a quick circular or an up-and-down movement so as to hit all parts of the tree. Dusting should be done only when the surfaces of the leaves are moist. At least two sides of the trees should be dusted. On trees twelve to fifteen years old, approximately $1\frac{1}{2}$ pounds of dust should be used on each tree at each application.

[1] Extension Circular, "Apple Scab and its Control." This may be obtained by applying to Extension Service, Massachusetts Agricultural College.

Tabulated Results.

Tables IV to VII give briefly the results on the sprayed and dusted plots in each of the orchards during 1922.

Table IV. — *Results on the Sprayed Plots in Sabine Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check, arsenate and nicotine only	0	100	5	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	84	16	98	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	49	51	90	0
4	Liquid lime-sulfur	86	14	97	0
5	Dry lime-sulfur, 4-50	86	14	95	6
6	Liquid lime-sulfur plus lime	76	24	91	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	81	19	96	0
8	Home-made Bordeaux	87	13	97	52

Table V. — *Results on the Sprayed and Dusted Plots in Knights Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 7, arsenate only	4	96	31	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	98	2	100	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	97	3	99	0
4	Liquid lime-sulfur	96	4	99	0
5	Dry lime-sulfur, 4-50	92	8	97	0
6	Liquid lime-sulfur plus lime	93	7	99	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux	87	13	95	47
12	Check for Bordeaux and dusts only	0	100	1	0
13	Sulfur dust	84	16	97	0
14	Copper-lime-arsenate dust	93	7	99	22

Table VI. — *Results on the Sprayed and Dusted Plots in Frost Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 11, arsenate and nicotine only.	59	41	90	Negligible.
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	100	0	100	Negligible.
3	Home-made Bordeaux (pink) and dry lime-sulfur.	99	1	100	Negligible.
4	Liquid lime-sulfur	98	2	99	Negligible.
5	Dry lime-sulfur, 4-50	98	2	100	Negligible.
6	Liquid lime-sulfur plus lime . .	90	10	98	Negligible.
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux	100	0	100	13
9	Dry lime-sulfur, 4-50, on pre-pink, pink, etc.	100	0	100	Negligible.
10	Dry lime-sulfur, 3-50	96	4	98	Negligible.
11	Dry lime-sulfur, 3-50 (lead and lime-sulfur put on separately).	96	4	100	Negligible.
12	Check for plots 13 and 14 . . .	34	66	68	Negligible.
13	Sulfur dust	89	11	96	0
14	Copper-lime-arsenate dust . .	86	14	97	13

Table VII. — *Results on the Dusted Plots in Stowe and Marshall Orchards.*

Stowe Orchard.

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check for 25-year-old trees, sprayed with lead and nicotine only.	15	85	48	0
13	Sulfur dust, 25-year-old trees . .	74	26	92	0
14	Copper-lime-arsenate dust, 25-year-old trees.	87	13	97	21
12	Check for 12-year-old trees, sprayed with lead and nicotine only.	16	84	46	0
13	Sulfur dust, 12-year-old trees . .	83	17	96	0

Marshall Orchard.

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check, sprayed with lead and nicotine only.	56	44	96	0
13	Sulfur dust	84	16	99	0
14	Copper-lime-arsenate dust . . .	93	7	100	26

MASSACHUSETTS

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PEDIGREE

THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

In this bulletin the records of ten years' poultry breeding investigations at the Massachusetts Agricultural Experiment Station are analyzed, specifically from the standpoint of the effect of the female ancestry on the transmitting power of the male. It is shown that the pedigree record basis of selection of the male has given marked results. On the other hand, there is nothing in the work done to date which in any way indicates superiority of this method over that of measuring transmitting power by means of the progeny test.

Available records, however, do indicate that the selection of females on the basis of those specific characters which together are believed to make up the group character of fecundity may be even more important in its results than the particular basis on which the male is selected.

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BULLETIN No. 215.

DEPARTMENT OF POULTRY HUSBANDRY.

PEDIGREE, THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION.[1]

BY F. A. HAYS AND RUBY SANBORN.

INTRODUCTION.

The practical importance of the selection of breeding males in flocks bred for egg production is much appreciated by poultrymen. Some believe that the ability of hens to make good egg records is more largely traceable to their male ancestors than to their female ancestors. At any rate, the fact is well recognized that the male breeders must be carefully considered in developing a flock uniform for high production. Since actual egg production can be measured only by the females of the flock, other criteria must be employed in choosing the males. Some breeders prefer to use cockerels, while others make use of yearling or older cocks for breeding; but the merits or demerits of these practices will not be discussed in this paper. The following discussion of data available at the Massachusetts Experiment Station has a bearing on methods of selection that may be applied to both cockerels and cocks (Inherited Production), and other methods that apply only to cocks (Potential Production). Experimental evidence on the transmission of egg-producing ability through the male is in a confused state at present.

Pearl, '12, concludes, after studying the inheritance of egg production with several thousand Barred Plymouth Rocks representing thirteen generations: (p. 284) "That the record of egg production or fecundity of a hen is not of itself a criterion of any value whatsoever from which to predict the probable egg production of her female progeny. An analysis of the records of production of large numbers of birds shows beyond any possibility of doubt that, in general, there is no correlation between the egg production of individuals and either their ancestors or their progeny." Pearl draws the above conclusions because he found no significant biometric correlation between mothers and daughters or between daughters and their female ancestry in egg production. Pearl states, on the other hand, (p. 379), "High fecundity may be inherited by daughters from their sire, independent of the dam."

Goodale, '19, believes that egg production is transmitted equally through males and females in Rhode Island Reds. He further crossed Cornish males on Rhode Island Red females and secured winter egg production corresponding with that of his Rhode Island Red flock.

Lippincott, '20, in discussing the grading up of mongrel flocks by the use of standard-bred cockerels of three breeds, (p. 45), states that a pullet's egg produc-

[1] The data included in this bulletin were collected by Dr. H. D. Goodale, until recently in charge of poultry investigations at this Station. All Rhode Island Red fowls bred by the Experiment Station from 1912 to 1921 are included, with the following exceptions: a small number of birds in an experiment in studying the behavior of broodiness, and a small number of birds in an inbreeding experiment during the year 1921. The flock included in this report differs from that reported on in Bulletin No. 211 of this Station in that only fowls in the experiment entitled *Breeding for Egg Production* are reported in Bulletin No. 211.

tion seems to bear a closer relation to the breeding of her sire than to the production of her dam.

Dryden, '21, reporting on eight generations of Barred Rocks, eight generations of Leghorns and eight generations of Cross-breds, states that some hens and some males have the power of transmitting high fecundity; others have not this power. He advises the progeny test as the most reliable method of selecting breeders.

Hurst, '21, in his work in breeding White Leghorns and Wyandottes, found no sex linkage in the inheritance of factors for egg production. In other words, he agrees with Goodale and Dryden in his assumption that both parents contribute equally in factors for egg production.

Other authorities rather generally agree with one or the other of the above schools, so that it seems safe to assume that egg production is transmitted in Mendelian fashion from parent to offspring. A discussion of the several proposed genetic theories is not within the province of this report. Whether or not factors for egg production are transmitted in the same fashion in all breeds requires further study. This report is intended to throw some light on the expected progress in mass breeding without considering definite Mendelian factors as operating to control the egg production of the flock.

Review of Progress in the Flock.

The data upon which this report is based cover ten years' work at the Massachusetts Agricultural Experiment Station in breeding Rhode Island Red fowls primarily for egg production. The foundation flock of 100 pullets and eggs from which 50 more were hatched were purchased in the fall of 1912 from a Massachusetts breeder. These were good representatives of the breed, judged by the breed standards of that time. This foundation female stock was placed in the laying houses December, 1912, and all females in the experiment have since been trap-nested at all times unless physically incapacitated. All annual records cover 365 days and were made during the pullet year. Complete pedigrees of all breeding stock have been maintained throughout the period. The foundation males used consisted of twelve birds brought in in the spring of 1913, four from different breeders brought in in 1914, and ten from other outside sources brought in in 1915. Since 1915 no outside stock has been used in the flock.

Dr. Goodale has already given the question of egg production much study and made several reports on the egg-laying flock up to the end of the laying year 1921. His reports include a rather complete study on early maturity, rate and winter pause (Goodale, '18, '19). He has also carefully investigated the question of broodiness (Goodale, '20). This paper deals only with the application of methods for selecting breeding males, from data secured up to the end of 1922.

The average production of the flock by years is presented graphically in Chart I. All pullets that had an opportunity to lay for 364 days after their first egg are included. The birds are divided into six classes for study, and the percentage in each class is presented by years to show the general trend of the flock.

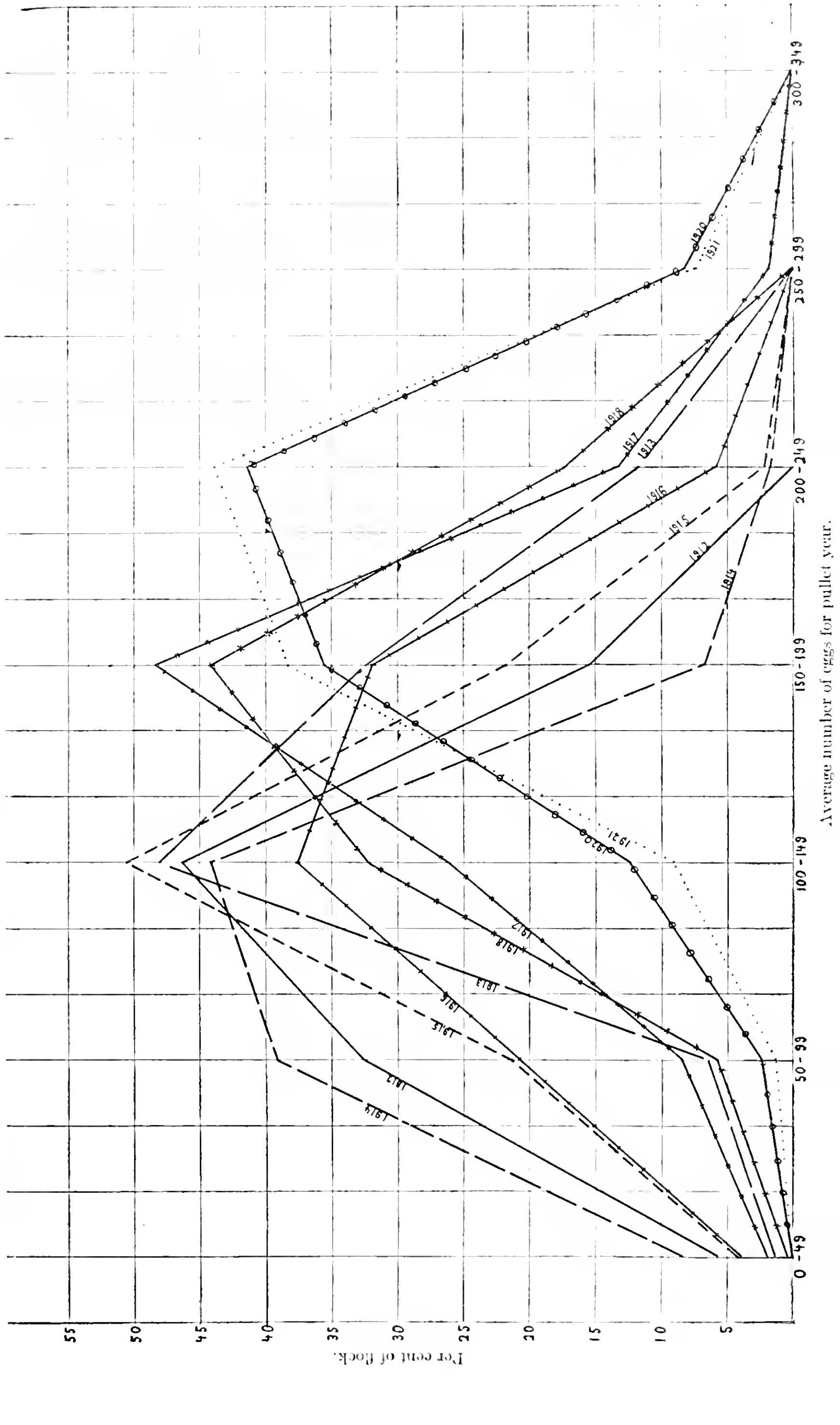
The total number of annual records at the close of 1922 was 1,945. The observation may be made that the mode (most common class) of the foundation stock lies between 100 and 149. Chart I further shows that the mode of the flock remained between 100 and 149 eggs until the 1917 pullets finished their year in the fall of 1918. This fact does not signify a lack of progress in increasing the egg production of the flock between 1913 and 1918. There was a total increase during this period up to the end of the laying year ending in 1918 amounting to an average of 12.97 eggs per hen. The graph for the hatching year 1913 would seem to indicate a higher degree of production in the flock as a whole than could be maintained in the flocks hatched in 1914 and 1915. This is only an apparent discrepancy, however, as explained by the fact that only about half the available flock hatched in 1913 could be trap-nested to the end of their laying year. The half selected represented those having the highest record for the first half of their year and consequently are a select group.

The distribution of the flock will be seen to remain almost the same for the birds

CHART I.

Frequency Distribution in Egg Production.

Flock denoted by the year in which its annual egg-laying record commenced.

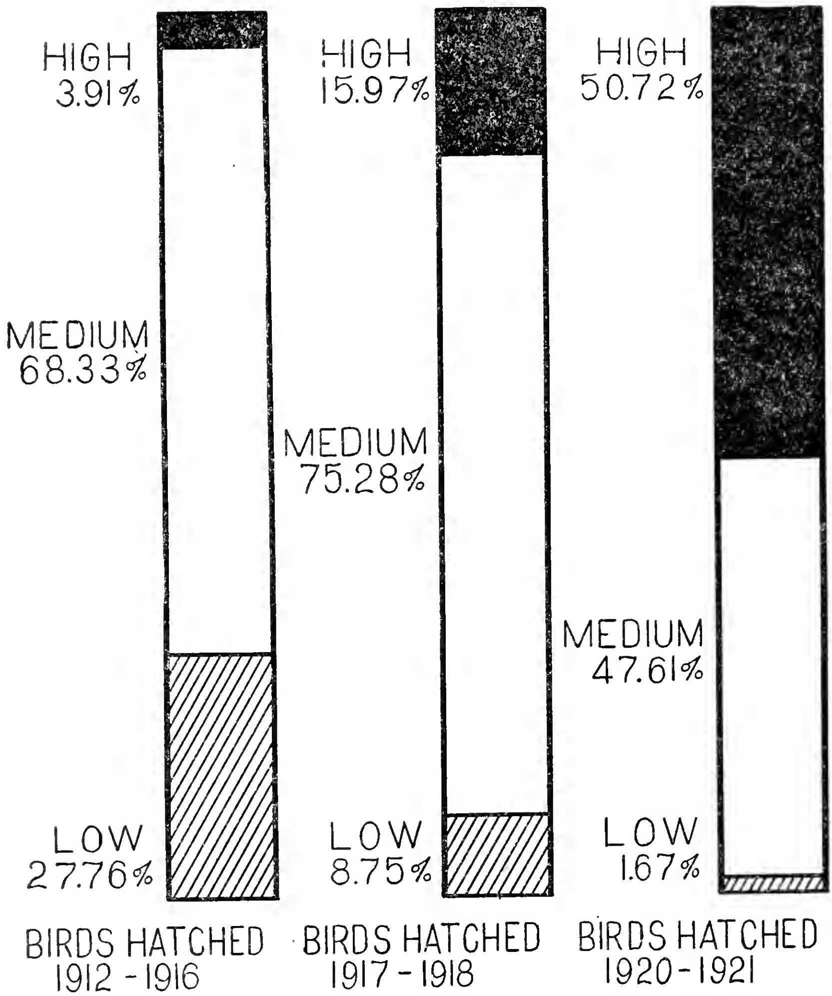


hatched in 1917 and 1918. Records for the flock hatched in 1919 were cut short by disease outbreaks. It was found necessary to dispose of most of the stock and exercise rigid quarantine measures. This prevented the completion of any annual records during 1920.

Referring again to Chart I, the mode of the flock will be observed to have advanced in 1920 to the 200 to 249 egg class, with a skewness indicating that the mode of the flock lies considerably above the average. In other words, a bimodal condition begins to present itself.

CHART II.

General Classification of Birds on the Basis of Production.



The results of the season ending in 1922 indicate that the general distribution of the 1921 flock conforms closely with that of 1920. The graph for 1921 also shows a bimodal condition of the flock, lying in the 150 to 199 class and in the 200 to 249 class.

Chart II is presented as supplementary to Chart I. Chart I shows that the most common group of producers falls in the 100 to 149 egg class in the years 1912 to

1916 inclusive; in the 150 to 199 egg class in the years 1917 and 1918; and in the 200 to 249 egg class in the years 1920 and 1921. Hence in the preparation of Chart II the birds hatched during the first five years have been grouped into one polygon, those hatched in the next two years into a second polygon, and those hatched in the last two years into a third polygon. Low producers laid from 0 to 99 eggs in their pullet year; medium producers laid from 100 to 199 eggs in their pullet year high producers laid over 200 eggs in their pullet year.

Chart II shows that in the first five years there were 27.76 per cent low producers, 68.33 per cent medium producers and 3.91 per cent high producers. During the two-year period following, the percentage of low producers fell to 8.75, the medium class increased to 75.28 per cent, and the high producers increased to 15.97 per cent. During the last two years, the low class fell to 1.67 per cent, the medium class fell to 47.61 per cent, and the high class increased to 50.72 per cent.

Table 1, presented below, gives the number of sires used, the number of dams used, the number of pullets completing yearly records, and the average of all annual records by breeding years. The last column includes pullets hatched in the respective mating years.

TABLE 1.

MATING YEAR.	Number of Sires used.	Number of Dams used.	Number of Pullets with Yearly Records from Mating.	Average Annual Production of Pullets.
1913	12	42	77	146.22
1914	20	55	120	102.33
1915	21	99	378	122.93
1916	18	59	426	131.87
1917	14	52	318	159.19
1918	14	71	208	160.24
1919	12	29	None	None
1920	16	36	121	196.95
1921	9	43	297	197.89

Referring to the first column of the table, it will be observed that during the first four years of the experiment the average number of males was about 18, while during the past five years the number was cut down to an average of about 13. This policy has given a greater opportunity to determine the breeding ability of the sires and to regulate future mating with a greater degree of certainty, because the breeding ability of the sires can be ascertained with a higher degree of accuracy when their progeny are trap-nested in large numbers. This fact made it possible to regulate matings more carefully along specific blood lines.

The number of dams used was greater during the first four years of the experiment than during the last five. The range in number of dams for the nine-year period is from 29 to 99. The use of fewer dams makes possible more rigid selection standards and probably is of value in reducing variability in the flock.

The average number of completed records per year is 243. In general, the mean annual production of the flock shows progress from year to year. The first results of breeding at the Station are shown opposite the mating year 1913. Seventy-seven pullets averaged 146 eggs. These 77 pullets represent a selected group from a larger number, and consequently show a higher average than the 120 pullets hatched in 1914. The offspring of 1915 brings the average of the flock up to 123 eggs, and from that time to the present there has been uninterrupted progress, except for the disease outbreak of 1920. The 121 pullets hatched in 1920 averaged 197 eggs. The 297 hatched in 1921 averaged approximately 198 eggs. There is no noticeable tendency in the flock to produce a few phenomenal records, but rather a general homogeneity in production. This tendency to uniformity is probably traceable to the methods of mating for specific characteristics, and to a certain degree of relationship within the flock.

Selecting Breeding Males on Production Pedigree.

Before proceeding further with this question, it is necessary to define a few terms that are used in this report. *Sire's inherited production* is calculated from the average annual egg records of the 31 dams in five ancestral generations of each sire. *Dam's inherited production* is calculated from the average annual egg production of the 31 dams in five ancestral generations of each dam. *Sire's potential production* is the average of the annual records of all his daughters made during their first laying year. It is the same as daughter's annual production, save in those cases where a sire was used for more than one year.

It is a common practice to select males for breeding that come from dams with high annual egg records. In some flocks the practice is to emphasize the egg records of as many of the dams back of the sire as possible. In such cases the annual egg record is used as the guide for selection in a large measure, rather than any specific characters that the individual and his relatives may possess.

Table 2.

Mating Year.	Sires' Inherited Production.	Sires' Potential Production.	Dams' Inherited Production.	Daughters' Average Production.
1913	Unknown	136.55	Unknown	146.22
1914	138.00	107.29	117.07	162.33
1915	152 35	123 05	125.49	122.93
1916	149.93	133 23	144.63	131.87
1917	156.49	169.31	153 16	159.19
1918	156.77	161.23	151.78	160.24
1919	167.13	Not recorded	158.02	Not recorded
1920	168.79	196.95	163.02	196.95
1921	174 47	197.89	173.67	197.89

The inherited production of the sires used for the mating years included in this report is given in Table 2. This inherited production amounted to an average of 138 eggs in 1914, 152.35 in 1915, 149.93 in 1916, and so on up to an average of 174.47 in 1921, showing that although untested males from the progeny standpoint were used, those in charge were able to select a superior class of males each year, based on average annual records and pedigree. The progress that has been made in the flock as a whole would seem to indicate that this is a commendable practice. Such a method can be followed by breeders who keep complete pedigree and trap-nest records of their flock. Breeding sires from such flocks should command a high figure and should be very much appreciated by all smaller breeders who are seeking to improve their flocks without the use of the trap-nest or pedigree system. This method would be especially useful for selecting the more desirable cockerels to be retained. Mature sires can be selected with a greater degree of certainty from their progeny test.

Relative Importance of Sire's and Dam's Pedigree.

A great deal of discussion and difference of opinion exists as to the relative importance of the sire and the dam in breeding for egg production. Poultry investigators differ in their opinion on this point, some holding that sex linkage makes the sire of greater importance than the dam, while others hold that sire and dam are of equal importance. In Chart III the average inherited production of the dams for each year is given as a dash line. A similar figure for the sire is given as a solid line. The actual annual production of the daughters coming from the mating of these sires and dams on their respective years is given as a dotted line. It should be understood that the egg record of the daughters was finished the year following the hatching year. These graphs are fitted to a straight line by the ordinary method of least squares.

Chart III very clearly indicates that selection on a mass basis from egg records alone will not be an insurance as to what the daughters will do during their first egg-laying year. Reference to the chart shows that the annual production of the daughters crossed the path of the inherited annual production of the dams during the year 1916, and the path of the inherited production of the sires during 1917. *The average annual record of the daughters has far outstripped their inherited production from sires and dams.* These facts are unmistakable evidence of the operation of many factors to influence annual egg production. From the year 1916 this flock was bred for specific characteristics, such as early maturity, lack of broodiness and lack of winter pause. Those hens which showed later maturity, broodiness, and a tendency to stop laying during the winter season were discriminated against as breeders, even though they had made good annual records. Another characteristic which was sought was intensity of production. Those females that showed intense winter production were favored as breeders over others in which the degree of intensity was less marked.

CHART III.

Relation between Parents' Inherited and Daughters' Average Production.

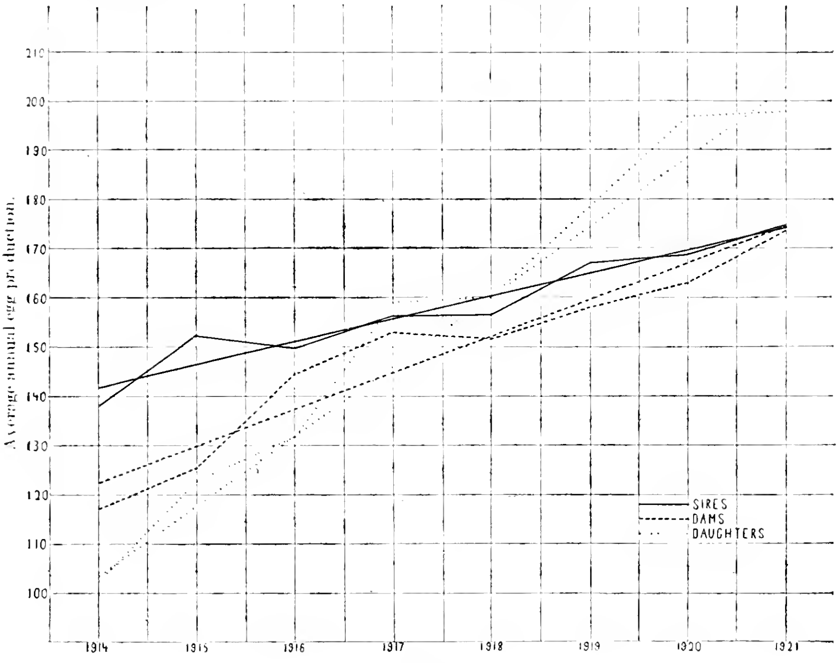


Chart III does not furnish any conclusive indication of the relative importance of sire and dam in transmitting annual egg production. This may be due to the fact that the chart is based on mass data. A similar chart based on specific families or blood lines would be more enlightening on this point. Data are available and will be published later. The one outstanding item to be emphasized on the chart is the advisability of selecting for specific characteristics as affecting annual egg yield.

The Sire's Potential Production as a Guide in Selecting Males.

The average annual egg production of the daughters of a sire we have called his potential production. In other words, in order to know the potential breeding ability of a sire, there must be a trap-nest record of his daughters. This fact greatly reduces the usefulness of the method with many poultrymen. Records at this Station indicate very clearly, however, that males vary widely in their ability to sire daughters that make high annual records. If it were possible to recognize such sires in advance, their usefulness in the flock could be made many fold greater. Referring back to Table 2: the column giving the sires' potential production is very similar to the average egg yield of the daughters for the respective years. It differs only in those cases where some of the sires were used for more than one breeding year. A comparison of this column with the one headed *Sires' Inherited Production* shows that in the early years the inherited production was higher than the potential production, but beginning in 1917 the reverse is the case; clearly indicating that the flock had been developed by the method of breeding to a higher degree of prepotency. This greater prepotency in the last four or five years is due to the fact that the flock has increased in the percentage of early maturing birds, in the percentage of birds that do not show the winter pause, in the percentage that are free from broodiness, and in the annual rate of production. As evidence of this fact, there are now families (all the daughters of a hen) that are non-broody. Other families show no winter pause, others show a uniformly higher rate, etc. There is still a wide range in the annual egg production of the females in the flock. This range may be explained on the Mendelian basis as we have shown elsewhere. The statement still holds good that there is no guide in selecting the sire that is as certain and reliable as the progeny test or the potential production.

How to Select Cockerels.

A great many poultrymen use cockerels to a considerable extent in their breeding operations; and even where cockerels are used only to a minor degree for breeding purposes the first year, it is necessary to select and reserve considerable numbers for future sires. Any guide in the selection of cockerels, then, has a double value to poultrymen.

We have previously shown that the average annual records of the hens in the dam's pedigree is of about the same value as the average annual record of the hens in the sire's pedigree, so far as determining what the daughters from such matings will produce is concerned. Selection of cockerels on their mothers' annual records alone is a very inefficient and inaccurate method, compared with the five-generation pedigree method we have used here. In our opinion, therefore, there is no other method of choosing the cockerels to be used in breeding for egg production that is as satisfactory as the combined sires' inherited production and dams' inherited production behind such cockerels.

How to Select Cocks.

Too much stress cannot be laid upon the importance of making full use of breeding males that have a demonstrated ability to sire heavy egg layers. The history of a good many flocks shows that the great producing hens from the flock trace directly to a very few outstanding males. The same principle holds here as in breeding the higher domestic animals. Sires of proven ability are invaluable.

The cock may be selected both on the pedigree basis and on the progeny test. The yearling cock will have daughters that have a winter record rather well along by his second mating season, if he has been used as a cockerel. Winter records are known to be of great value as guides to annual records. Therefore, the yearling cock can be selected with a good deal of certainty as to what contribution he will make to the flock. As a two-year-old, he will be a strictly tested individual; and if possessing the proper amount of vigor, and if properly handled, can be used very successfully for two or more mating seasons. The items which are the guides to follow in selecting the cock may be summed up as follows:

1. Select those with a high inherited production, both on the sire and the dam side, for as many generations as possible.
2. Select those that have the best progeny performance.
3. Select those whose family are early maturers, free from broodiness, free from a tendency to winter pause, and show a high rate of production.

Summary.

1. In the space of nine years selection of breeding males, largely on an inherited production basis, has assisted in raising the average annual egg production during the pullet year from 146 eggs to 198 eggs per hen.
2. Evidence as presented in this report has no bearing on the value of the progeny test as a guide in the selection of breeding males.
3. Selection of males for production of daughters possessing specific characteristics, such as early maturity, lack of winter pause, high rate of production and freedom from broodiness, is necessary to attain high egg yields.

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DIGESTION EXPERIMENTS WITH CATTLE FEEDS

By J. B. LINDSEY, C. L. BEALS, P. H. SMITH, and J. G. ARCHIBALD

This bulletin reports results of digestibility studies on fourteen different materials, of real or claimed value as cattle feeds. The work of which this is a part was commenced thirty years ago. Results have been published in a number of reports and bulletins, and most of them summarized very briefly in a "Compilation of Analyses" published in November, 1919. Nearly all of the feed products available to Massachusetts dairymen have now been studied, and the digestibility of the nutrients contained measured. The publication of this bulletin, therefore, completes this phase of the service of the Massachusetts Experiment Station.

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BULLETIN No. 216.

DEPARTMENT OF CHEMISTRY.

DIGESTION EXPERIMENTS WITH CATTLE FEEDS.

BY J. B. LINDSEY, C. L. BEALS, P. H. SMITH AND J. G. ARCHIBALD.[1]

Introduction.

The digestion experiments here reported cover a period of four years, the work commencing annually about November 1 and extending through to mid-April or thereabouts. Methods followed in conducting the tests are given elsewhere.[2]

Each digestion period extended over sixteen days, nine of which were preliminary (five in ordinary pens and four in the digestion stall), the last seven constituting the actual trial during which the feces were collected. The animals were grade sheep, as nearly as possible of the same age and weight. The basal ration was either English hay, or English hay and gluten feed. Ten grams of salt were fed daily and water *ad libitum.*

Discussion of Results.

A summary of the coefficients of digestibility is here presented, together with a brief discussion of the same.

English Hay.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
1[3]	XXIII	1	9	57.90	45.16	47.35	61.90	59.67	43.90
1	XXIII	1	11	58.89	45.57	48.27	63.43	60.29	46.98
Average				58.40	45.37	47.81	62.67	59.98	45.44
2	XXIII	10	9	57.83	35.84	47.56	66.16	56.61	36.45
2	XXIII	10	11	60.59	41.43	53.47	67.73	59.40	40.35
2	XXIII	11	15	57.22	47.88	46.89	64.05	55.78	30.54
2	XXIII	11	17	56.76	46.81	45.44	64.38	55.15	24.83
2	XXIII	13	12	58.78	43.20	46.66	64.42	59.77	20.28
2	XXIII	13	13	60.68	28.11	49.25	67.97	61.43	23.22
2	XXIV	10	15	50.71	32.05	43.48	59.24	48.08	33.91
2	XXIV	10	16	53.30	20.57	39.43	63.65	51.12	38.53
Average				56.98	36.99	46.52	64.70	55.92	31.01

[1] Mr. Beals had immediate supervision of the experiments and did some of the analytical work. Mr. Smith, assisted by Miss E. M. Bradley, did the larger part of the analytical work. The tabulations were made by Mr. Archibald. The work at the feeding barn was done by Mr. J. R. Alcock.

[2] Mass. Agr. Expt. Sta., 11th Ann. Rpt., pp. 146–149, 1893.

[3] This lot of hay is the same as was fed in Series XXII, periods 8–17, coefficients of which are published in Mass. Agr. Expt. Sta. Bul. 181, p. 307.

English Hay — Concluded.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitro-gen-free Extract.	Fat.
3	XXV	2	12	59.20	24.26	55.74	64.33	61.22	46.83
3	XXV	2	13	56.77	20.53	49.81	64.67	57.75	43.65
3	XXV	3	9	64.07	39.80	57.06	69.98	65.04	44.97
3	XXV	3	11	61.42	34.17	57.13	67.29	62.48	38.96
3	XXV	9	15	59.41	39.01	58.85	63.21	59.97	50.67
3	XXV	9	16	60.03	37.19	55.28	65.37	60.83	47.57
3	XXVI	1	17	59.95	29.40	54.92	65.68	61.19	46.97
3	XXVI	1	18	64.17	40.54	61.14	68.41	65.29	50.83
3	XXVI	1	19	59.89	34.96	55.22	63.78	61.73	45.76
Average				60.55	33.32	56.13	65.86	61.72	46.25
General average of above				58.82	36.13	51.21	65.03	59.09	39.75
General average, 5 earlier lots				59.47	36.31	49.78	64.10	62.35	46.34
Timothy hay, for comparison				55.00	39.00	47.00	51.00	62.00	50.00

Note. — Each series represents one winter's work, commencing about November 1 of each year and extending through to mid-April or thereabouts.

Three separate lots of hay were used in these experiments. It was of quite uniform quality and composition and consisted of mixed grasses, largely Kentucky blue grass, sweet vernal grass and some clover. It averaged in percentage of dry matter, 6.07 ash, 7.95 protein, 33.81 fiber, 49.52 nitrogen-free extract, and 2.65 fat. Such hay is rather richer in protein and has a higher degree of digestibility than has average timothy hay. The digestion results are on the whole quite uniform. It is interesting in this connection to compare the general average of the present results with the average of five earlier lots here cited and originally reported in Bulletin 181 of this Station. The close agreement of the two sets of coefficients in all items except fat emphasizes the fact that, when any considerable number of results are averaged, the resultant average is a pretty close approximation to accuracy and an accepted standard, even though there be considerable variation among the individual data.

English Hay and Gluten Feed — Basal.

Lot.		Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Hay.	Gluten Feed.									
2	1	XXIV	1	9	63.70	32.02	62.98	65.43	66.74	48.22
2	1	XXIV	1	11	67.31	40.75	69.24	68.37	69.51	54.82
2	1	XXIV	14	12	65.09	46.22	66.29	66.95	66.58	41.34
2	1	XXIV	14	13	65.56	45.61	67.57	66.77	67.28	43.39
3	2	XXV	1	9	64.81	29.53	69.27	66.40	67.34	54.79
3	2	XXV	1	11	67.89	30.57	71.20	70.67	70.42	56.32
3	2	XXV	4	12	66.72	27.44	71.59	67.20	69.63	55.02
3	2	XXV	4	13	66.62	20.55	73.19	67.66	69.48	54.30
3	2	XXV	6	15	67.68	27.40	72.71	67.58	70.88	55.92
3	2	XXV	6	16	65.92	20.94	70.34	66.14	69.44	55.55
3	2	XXVI	3	17	64.88	23.73	68.85	66.81	68.21	44.94
3	2	XXVI	3	18	65.46	23.16	65.11	72.39	67.01	46.96
3	2	XXVI	3	19	64.79	28.18	70.91	66.69	66.92	48.48

Note. — In all of these trials with the exception of period 3, Series XXVI, the ration fed was *500* grams of hay and 150 grams of gluten feed. In the exception noted, the ration was *550* grams of hay and 150 grams of gluten feed. Because of this difference in the ration fed, these results are not averaged.

Experience has proved that gluten feed is a satisfactory supplement to hay for use in basal rations. The necessity for such a supplement is greatest when the material under test is deficient in protein or is of a coarse, fibrous, unpalatable nature.

Gluten Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	1	9[1]	79.37	negative	73.56	37.80	89.76	70.95
XXIV	1	11	94.97	54.09	85.35	92.46	99.83	92.21
XXIV	14	12	82.09	123.50	82.51	83.85	83.86	77.25
XXIV	14	13	84.12	118.34	84.93	80.66	86.40	83.11
XXV	1	9[1]	70.86	negative	81.24	26.30	77.02	87.85
XXV	1	11	84.26	negative	85.05	96.50	89.06	93.31
XXV	4	12	95.72	56.84	89.86	102.10	100.55	84.34
XXV	4	13	95.28	12.76	93.03	109.94	99.95	81.53
XXV	6	15[1]	93.23	negative	88.09	125.06	101.97	76.91
XXV	6	16	85.60	negative	83.41	100.55	96.40	75.42
XXVI	3	17	79.23	negative	81.70	82.49	84.62	29.55
XXVI	3	18[1]	93.37	negative	79.99	281.89	88.37	38.32
XXVI	3	19	78.83	negative	86.21	80.19	79.27	50.86
Average			86.68	-	85.78	92.08	91.10	74.18
Average all previous trials			91.08	-	86.11	124.21	93.56	72.38

[1] Not included in the average.

The average composition and limits of variation of the two lots of gluten feed used in these experiments were as follows: dry matter 90 per cent (87.80–91.22), made up of ash 3.35 (2.52–4.74), protein 27.56 (24.53–29.50), fiber 6.83 (6.31–7.31), nitrogen-free extract 59.16 (56.44–62.52), fat 3.11 (2.08–4.31). The digestion coefficients for gluten feed were secured by applying the coefficients obtained for hay to the amount of hay fed, and deducting the product from the total digestible matter of the basal ration.

The negative results for ash in a majority of the trials are almost always noticed in work with gluten feed. No satisfactory explanation for such results can be given although they may be attributed in part to experimental error due to the small amount of ash present, and in part to the excretion of digested mineral matter from the intestines. In the case of fiber, it will be noticed that occasionally the coefficients were above 100 per cent, due probably to improvement in digestibility of the fiber in the hay as the result of adding a protein concentrate.

Incidentally it may be remarked that as a result of five separate trials with corn bran, the fiber was found to have an average digestibility of 75.12 per cent. This, together with the results secured for the fiber in gluten feed, shows that the fiber in corn is quite well utilized.

The present data, as well as those obtained as a result of many previous trials, show gluten feed to be a highly digestible protein concentrate.

Dried Apple Pomace.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	4	9	63.48	negative	negative	71.41	73.88	28.35
XXVI	4	11	68.11	56.25	negative	72.93	75.78	40.33
XXVI	5	17	71.41	2.53	negative	87.08	79.01	43.85
XXVI	5	19	59.45	14.01	negative	60.98	71.03	36.10
Average			65.61	-	-	73.10	74.93	37.16
XXVI	6	9	77.02	94.03	negative	80.21	83.87	37.14
XXVI	6	11	65.49	53.84	negative	58.61	75.45	25.22
XXVI	8	19	71.82	107.14	negative	52.13	73.39	41.38
Average			71.44	84.67	-	63.65	77.57	34.58
Average present trials			68.11	-	-	69.05	76.06	36.05
Average previous trials (6)			71.50	48.70	-	64.40	84.40	45.30
Dried beet pulp, for comparison			75.00	26.00	52.00	83.00	83.00	-

Note. — In periods 4 and 5 the pomace was fed unground. In periods 6 and 8 it was fed in the finely ground state. Two sheep were started in period 8, but one became sick and had to be rejected. The previous trials, averages of which are reported here for comparison, were with wet pomace.

This material was studied quite extensively during the winter of 1920–21, with respect to chemical composition, digestibility and value for milk production, and the results published in Bulletin 205. It is a carbohydrate feed, having a negligible amount of ash and relatively little protein. An average of the analyses of six samples shows a dry matter content of 94.70 per cent, composed of ash 1.55, protein 5.88, fiber 19.22, nitrogen-free extract 68.64, and fat 4.71.

The results of seven single digestion trials show a fairly high degree of digestibility as regards total dry matter, ash, fiber and nitrogen-free extract. The fat is rather poorly digested, due doubtless to the fact that it is not true fat but waxy material; and the protein is apparently not digested at all, or because of the small amount present the coefficients are of uncertain value. Dried beet pulp, a somewhat similar type of feed, has a slightly higher digestibility.

Barley Screenings.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	12	9	54.31	15.22	65.12	34.25	60.29	9.96
XXIII	12	11	60.59	29.79	82.72	42.65	63.99	8.99
Average			57.45	22.51	73.92	38.45	62.14	9.48
Oat feed, for comparison			52.00	47.00	86.00	49.00	47.00	58.00

Barley screenings is the residue from barley flour, which was prepared in considerable amounts during the war period. It contained dry matter 89.73 per cent, which was composed of ash 6.30, protein 9.98, fiber 19.51, nitrogen-free extract 61.08, fat 3.13.

Except for its lower fiber content, it resembled both oat feed and hay in chemical composition. Its total dry matter is a little better digested than oat feed because of a less complete separation of the starchy matter, and it has approximately 5 per cent greater feeding value.

Carrots.

(*a*) *Carrots fed with Hay.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	4	12[1]	97.56	28.42	80.22	165.87	103.91	106.48
XXIII	4	13	74.34	10.15	65.19	54.28	89.23	75.14
XXIII	5	12	76.95	6.21	67.84	72.24	92.86	60.91
XXIII	5	13	80.65	18.88	83.16	67.97	94.38	66.82
Average present trials			77.31	11.75	72.06	64.83	92.16	67.62
Average 5 previous trials			85.90	47.75	75.90	102.14	93.51	41.33

(*b*) *Carrots fed with Hay and Gluten Feed.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	9	9	78.50	49.64	56.78	80.27	87.82	6.06
XXIV	9	11	82.27	41.27	62.18	91.95	91.94	18.79
XXIV	11	9	85.88	50.17	55.80	140.63	93.31	36.58
XXIV	11	11	74.59	30.68	50.85	108.23	85.31	5.69
Average present trials			80.31	42.94	56.40	105.27	89.60	16.78
Average all trials (7 present, 5 previous)			81.89	37.15	68.44	93.86	91.87	39.72

[1] Not included in the average.

The digestion work with carrots is a continuation of earlier work reported in Bulletin 181. In the present trials, two lots of carrots were fed, averaging 88.02 per cent water, with dry matter composed of ash 9.91, protein 8.92, fiber 8.33, nitrogen-free extract 71.61, fat 1.23. In common with most other roots, they are relatively low in protein, fiber and fat, and high in ash and nitrogen-free extract.

The first lot (periods 4 and 5, Series XXIII) was fed with hay only; the second lot (periods 9 and 11, Series XXIV) was fed with hay and gluten feed; and in both cases constituted about 20 per cent of the dry matter of the ration.

The digestibility of the dry matter of the carrots in the present hay-carrot ration was 77 per cent as against 86 per cent in five previous trials. In both experiments quite wide variations are observed for which a satisfactory explanation cannot be given. It is quite possible that bacterial activity in the intestinal tract was more pronounced in some cases than in others.

When the carrots were fed in combination with hay and gluten feed, their digestibility appeared to be slightly more — 80 per cent as against 77 per cent when fed with hay only.

The fiber in carrots as well as in most roots appears to be quite completely digested, former experiments with mangels and turnips showing a dry matter digestibility of 87 to 89 per cent. The carrots seem to fall slightly below these figures.

Coffee Refuse.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	14	15	26.95	97.18	11.48	12.76	32.03	75.36

This material was the residue from the coffee bean, and was being used as a component of a low-grade feed mixture. It contained 93.77 per cent of dry matter, which was composed of ash 5.29, protein 13.29, fiber 33.86, nitrogen-free extract 40.98 and fat 6.58. It was fed in combination with hay and gluten feed to the extent of about 16 per cent of the dry matter of the ration. One sheep refused the mixture, while the other ate it but digested only a small portion. It evidently had very little nutritive value.

Cottonseed Meal.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	15	12	75.03	95.44	82.57	33.43	82.67	102.75
XXV	15	13	69.54	72.45	81.80	13.35	78.75	93.31
Average			72.29	83.95	82.19	23.39	80.71	98.03
Average all previous trials (14)			79.00	65.00	84.00	32.00	77.00	95.00

The sample contained 92.90 per cent of dry matter, which had 7.40 per cent of ash, 39.35 per cent of protein, and 20.05 per cent of fiber, the latter ingredient being some 8 per cent above the average. It is evident that considerable ground hulls had been added, and the above coefficients show that such an admixture caused the digestibility to be below that for the better grades. As is well known, cottonseed meal is sold on a basis of from 43 to 36 per cent protein; the latter grade results from the addition of ground hulls, which naturally reduces both its feeding and fertilizing value.

Feterita.

Series.	Period.	Sheep.	Dry. Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	10	17	86.71	188.88	86.77	negative	89.73	90.57
XXVI	10	19	86.59	123.08	98.55	negative	89.63	88.61
Average			86.65	155.98	92.66	–	89.68	89.59
Average previous trials (2)			74.65	–	46.55	–	87.94	56.69
Texas Station results[1]			88.99	–	90.03	50.00	96.60	74.52
Corn, for comparison			90.00	–	74.00	57.00	94.00	93.00

[1] Texas Agr. Expt. Sta. Bul. No. 203, p. 32.

Feterita or sudan durra is one of the grain sorghums which include also milo, durra and kaoliang. Two digestion trials were made on another sample a number of years since and reported in Bulletin 181. The present sample analyzed 89.22 per cent of dry matter, which contained ash 1.75, protein 14.46, fiber 1.63, nitrogen-free extract 78.37, and fat 3.8 per cent. In chemical composition it resembles Indian corn, except for its higher protein and lower fat percentage. The present digestion coefficients are quite uniform, and conform fairly well to those secured at the Texas Station. It is evident that feterita is about equal to corn in digestibility. The results secured by us in the former trial, showing 75 per cent of dry matter, 51 per cent of protein and 61 per cent of fat digested, were evidently too low, although they were obtained under satisfactory experimental conditions.

Oat Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	12	12	51.30	92.67	81.48	39.03	44.88	118.62
XXIV	12	13[1]	18.94	52.47	4.85	0.83	19.47	101.80
XXV	11	9[1]	28.71	negative	18.28	22.57	30.74	184.69
XXV	11	11[1]	26.88	negative	22.23	20.93	32.20	99.69
XXV	13	9	54.89	25.70	85.57	55.59	49.38	43.28
XXV	13	11	51.46	25.70	89.90	42.79	49.04	46.23
XXV	18	12	56.68	68.79	89.63	57.12	52.37	15.96
XXV	18	13	46.51	23.07	85.95	52.55	39.61	66.57
Average			52.17	47.19	86.51	49.42	47.06	58.13
Timothy hay, for comparison			55.00	39.00	47.00	51.00	62.00	50.00

[1] Not included in the average.

Note. — The average coefficients for ash, fiber, nitrogen-free extract and fat in oat feed, published in Table II (e), p. 120 of Bulletin No. 200, are incorrect. The correct figures are given here.

The value of this material as a food for farm stock was studied by us some two years ago, and the results of the work have been published as Bulletin 200 of this Station. Oat feed, as the term is generally understood by the trade, is a by-product of oatmeal manufacture, and consists of the reground hulls plus the middlings and dust from the first milling of the grain. At some mills the residue from the second milling is also incorporated, but this is not the usual practice.

An average of the analyses of four samples shows the following percentage composition in dry matter: ash 6.48, protein 6.20, fiber 29.18, nitrogen-free extract 55.82, and fat 2.31. It resembles ordinary English hay in composition, except that it contains rather less fiber.

Eight single digestion trials were made with the sheep on this material, four in combination with hay (500 grams hay, 150 grams oat feed), and four with hay and gluten feed (500 grams hay, 150 grams gluten feed, 150 grams oat feed). The results of three of the trials were so much below the others in almost all respects that they are not included in the average. The average of the other five shows a digestibility comparable with timothy hay.

Oat Hulls.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	13	9	31.30	15.74	negative	49.64	28.94	negative
XXIV	13	11	36.23	9.46	12.10	51.45	36.13	14.38
Average			33.77	12.60	-	50.55	32.54	-

These coefficients have also been published in Bulletin 200.

The oat hulls contained the following percentages in dry matter: ash 6.37, protein 2.52, fiber 32.66, nitrogen-free extract 57.44, and fat 1.01. Fiber and nitrogen-free extract constitute the larger part of the hulls. The total dry matter is about one-third digestible, which places them among the lowest grades of cereal by-products.

Peanut By-Products.

A study has been made of three peanut by-products, viz., peanut meal, peanut shells and peanut skins. Peanut meal is the ground residue from the extraction of edible oil or soap oil stock. In the former instance it consists of the ground residue from the kernels only, and is specifically known as peanut oil meal. In the manufacture of soap-stock oil the whole peanut is extracted, and the ground residue should be known as peanut feed, a product much inferior to the peanut oil meal, due to the admixture of shell and skin. Peanut shells are the ground or unground outer hull of the nut; while peanut skins are the thin, waxy inner coat of the endosperm or kernel.

Analysis.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Peanut meal	92.33	5.27	39.74	5.09	33.67	16.21
Peanut shells	96.70	3.28	8.91	63.16	18.88	5.77
Peanut skins	94.59	3.46	18.75	8.48	40.01	29.29

Peanut meal, as indicated by the analysis, is a high-grade protein feed with considerably more fat than is contained in most concentrates. The shells are composed of nearly two-thirds fibrous material. The skins contain a reasonable amount of protein and nitrogen-free extract, comparatively little fiber, and a very high percentage of fat.

Coefficients of Digestibility.

(*a*) *Peanut Meal.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	19	9	74.62	negative	80.81	59.43	77.59	87.84
XXV	19	11	80.53	5.34	85.47	47.52	84.02	93.94
Average			77.58	-	83.14	53.48	80.81	90.89
German data[1]			83.00	-	90.00	(9)	84.00	90.00

(*b*) *Peanut Skins.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	8	11	38.48	negative	49.49	negative	28.80	90.16
XXV	12	15	8.43	34.93	negative	negative	2.70	93.47

(*c*) *Peanut Shells.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	16	9	32.83	34.24	69.35	8.63	29.25	83.32
XXV	16	11	25.19	12.61	67.72	.69	55.68	84.83
Average			29.01	23.43	68.54	-	42.47	83.58

[1] Mentzel & Lengerke Landw. Kalender 1922, results of seven single trials with four samples.

While the digestion results with peanut meal are not as high as the average results secured by German observers, the utilization of the protein, nitrogen-free extract and fat, of which it is largely composed, shows that the meal should be placed among the best of the protein feedstuffs.

The digestion results secured with the peanut skins are neither concordant nor very satisfactory. However, in each case they show that the fat, which comprises nearly 30 per cent of the skins, was quite fully utilized. When the skins were fed with hay (period 8), the digestion of the fiber of the ration seemed to be noticeably depressed or interfered with; and when fed with hay and gluten feed (period 12), none of the organic ingredients except the fat was digested. One might therefore conclude that the fat interfered with the utilization of the protein, fiber and nitrogen-free extract. On the basis of the above results, their value as a cattle feed is questionable. In order to utilize them economically, it may be possible to extract the oil and use the residue for litter or for packing purposes.

Peanut shells are shown to have a low digestibility, inferior even to oat hulls. While the small percentage of protein and fat which they contain seems to be well utilized, the fiber which comprises over 60 per cent of the dry matter apparently is little if any digested. The shells, therefore, are of little value as a feed.

Velvet Bean Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII . . .	8	12	82.06	41.48	76.64	81.07	89.71	86.69
XXIII . . .	8	13	71.48	28.52	73.96	51.09	81.82	74.41
XXIII . . .	9	9	70.96	22.97	68.56	46.60	80.35	72.79
XXIII . . .	9	11	81.16	33.24	78.02	71.06	86.83	85.63
Average			76.42	31.55	74.29	62.46	84.68	79.88
Wheat bran, for comparison			66.00	-	77.00	39.00	71.00	63.00

Velvet bean feed consists of the ground seed and pod of the velvet bean, a rank-growing tropical legume which is cultivated extensively in Florida, Alabama and Mississippi. It has appeared at different times in Massachusetts, and a full report on its merits may be found in Bulletin 197.

Its composition on a dry matter basis is as follows: dry matter 88.16, ash 5.79, protein 18.94, fiber 14.50, nitrogen-free extract 56.16, fat 4.62. It resembles wheat bran in composition, but has slightly more protein and considerably more fiber, due to the presence of the pods. The average of the four trials shows about the same amount of digestible protein as is found in wheat bran. The fiber, nitrogen-free extract and fat are, however, somewhat more digestible, and on the basis of total digestible nutrients the velvet bean feed has about 11.5 per cent greater feeding value than bran.

Summary.

In the table following, the average composition of each feeding stuff is given, together with the average coefficients of digestibility and the limits of error, calculated by Bessel's formula. The error limit is large in some cases, the cause therefor being explained in the discussion of results on pages 53-61. In case of oat hulls and peanut shells the results vary so widely that the limits of error are not stated. The coefficients indicate that much difficulty was experienced in digesting these materials and that they possessed comparatively little nutritive value. The coefficients for the ash in all cases are of uncertain value because it is now recognized that a considerable portion of the digested mineral matter is excreted through the feces, whereas in case of organic nutrients the end products of digestion are eliminated through the lungs, skin and urine. Where the percentage of fat in the feed is small — 1 per cent or less — the coefficients have little meaning.

Composition and Coefficients of Digestibility of Feeding Stuffs.

Feedstuff.	Number of Tests.	Number of Animals.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
English Hay, composition	–	–	89.67	6.07	7.95	33.81	49.52	2.65
Coefficients, lot 1	2	2	58.40±0.33	45.37± 0.14	47.81±0.31	62.67±0.52	59.98±0.21	45.44
Coefficients, lot 2	8	7	56.98±0.82	36.99± 2.29	46.52±0.98	64.70±0.66	55.92±1.08	31.01± 1.79
Coefficients, lot 3	9	9	60.55±0.53	33.32± 1.60	56.13±0.70	65.86±0.51	61.72±0.53	46.25± 0.81
Average coefficients	19	9	58.82±0.49	36.13± 1.32	51.21±0.90	65.03±0.39	59.09±0.66	39.75± 1.42
Gluten Feed, composition	–	–	90.00	3.35	27.56	6.83	59.16	3.11
Coefficients	9	6	86.68±1.54	–	85.78±0.81	92.08±2.44	91.10±1.83	74.18± 4.68
Dried Apple Pomace, composition	–	–	94.70	1.55	5.88	19.22	68.64	4.71
Unground, coefficients	4	4	65.61±1.77	–	–	73.10±3.62	74.93±1.13	37.16±2.25
Ground, coefficients	3	3	71.44±2.25	–	–	63.65±5.73	77.57±2.16	34.58± 3.26
Both lots, coefficients	7	4	68.11±1.50	–	–	69.05±3.18	76.06±1.08	36.05± 1.76
Barley Screenings, composition	–	–	89.73	6.30	9.98	19.51	61.08	3.13
Coefficients	2	2	57.45±2.12	22.51± 4.91	73.92±5.94	38.45±2.83	62.14±1.25	9.48± 0.33
Carrots, composition	–	–	12.00	9.91	8.92	8.33	71.61	1.23
With hay, coefficients	3	2	77.31±1.23	11.75± 2.52	72.06±3.78	64.83±3.66	92.16±1.03	67.62± 2.79
With hay and gluten feed, coefficients	4	2	80.31±1.64	42.94± 3.08	56.40±1.57	105.27±8.84	89.60±1.24	16.78± 4.90
Coffee Refuse, composition	–	–	93.77	5.29	13.29	33.86	40.98	6.58
Coefficients	1	1	26.95	97.18	11.48	12.76	32.03	75.36
Cottonseed Meal, composition	–	–	92.90	7.40	39.35	20.05	25.33	7.87
Coefficients	2	2	72.29±1.85	83.95± 7.75	82.19±0.26	23.29±6.77	80.71±1.32	98.03± 3.18
Feterita, composition	–	–	89.22	1.75	14.46	1.63	78.37	3.80
Coefficients	2	2	86.65±0.04	155.98±22.19	92.66±3.97	–	89.63±0.03	89.59± 0.66
Oat Feed, composition	–	–	93.11	6.48	6.20	29.18	55.82	2.31
Coefficients	5	4	52.17±1.18	47.19± 9.59	86.51±1.04	49.42±2.43	47.06±1.49	58.13±11.56
Oat Hulls, composition	–	–	91.75	6.37	2.52	32.66	57.44	1.01
Coefficients	2	2	33.77	12.60	–	50.55	32.54	–
Peanut Meal, composition	–	–	92.33	5.27	39.74	5.09	33.67	16.21
Coefficients	2	2	77.58±1.99	–	83.14±1.57	53.48±4.02	80.81±2.17	90.89±2.06
Peanut Shells, composition	–	–	96.70	3.28	8.91	63.16	18.88	5.77
Coefficients	2	2	29.01	23.43	68.54	–	42.47	83.58
Velvet Bean Feed, composition	–	–	88.16	5.79	18.94	14.50	56.16	4.62
Coefficients	4	4	76.42±2.03	31.55± 2.64	74.29±1.41	62.46±5.51	84.68±1.47	79.88± 2.46

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THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING

By J. B. LINDSEY and C. L. BEALS

Condensed (semi-solid) and dried buttermilk are by-products of the creamery industry, now widely advertised for use in pig feeding. An experiment with twelve growing pigs showed that condensed (semi-solid) and dried buttermilk when fed in limited amounts proved altogether too expensive to warrant their use for economical pork production. The semi-solid milk cost six cents and the dried article twelve cents a pound, and they were fed in the diluted form to the extent of from two to four quarts daily per pig.

Two experiments with lactic acid added to the grain slop in the amounts usually found in ordinary buttermilk showed no pronounced effect in promoting appetite or in causing an increase of growth.

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BULLETIN No. 217.

DEPARTMENT OF CHEMISTRY.

THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING.

BY J. B. LINDSEY AND C. L. BEALS.

Condensed and Dried Buttermilk as a Food for Pigs.

Buttermilk, as it comes from the creamery, has long been recognized as a valuable food for growing pigs and poultry. Some thirty-five years ago, the late Professor Goessmann of this Station showed that on the basis of total solid ingredients (dry matter), buttermilk and skim milk when fed to growing pigs possessed substantially equal values.

At the present time neither by-product is obtainable in regular supply in most sections of Massachusetts at prices which warrant its use, especially for pigs. In recent years buttermilk, from which a portion of the water has been removed by the use of a partial vacuum and which is of a pasty consistency, has been placed upon the market under the trade name of semi-solid buttermilk,[1] and offered at from five and one-half to six cents per pound in barrel lots. It is also put up in fifty-pound wooden pails, intended particularly for poultry. A completely dried buttermilk, of a creamy color and of a powdered or flaky appearance, is also to be had, costing from ten to twelve cents a pound.

Inasmuch as the condensed or "semi-solid" material is freely advertised and its use recommended and urged, it seemed worth while to test its economy by feeding it in limited amounts to two groups of pigs. The dried buttermilk was also similarly tried.[2]

Chemical Composition.

Material.	Water.	Ash.	Protein.	Lactic Acid.	Milk Sugar.	Fat.
"Semi-solid" buttermilk	67.63	3.25	12.43	7.02	8.77	.90
"Semi-solid" buttermilk	67.06	–	–	–	–	–
Dried buttermilk	6.64	8.29	32 71	–	51.91 [3]	.75
Liquid buttermilk	91.60	0.70	3.60	–	5.00 [3]	.10–.27
Skim milk,[4] for comparison	90.10	0.70	3.80	–	5.20	.20

[1] The Universal Products Sales Co., 165 Liberty St., New York, are wholesale distributors.
[2] Sample secured from the Merrell-Soule Co., Syracuse, N. Y. The Collis Products Co., of Clinton, Iowa, claim to be large manufacturers of dried buttermilk and offer it in paper-lined sax at $9.50 a cwt. delivered, or $10 a cwt. in barrels. The price, naturally, is subject to change.
[3] Including lactic acid.
[4] Centrifugal process of separation.

The first two analyses represent the composition of the "semi-solid" material as it was received in barrels. It was about two-thirds water, whereas ordinary liquid buttermilk as it comes from the creamery contains about nine-tenths water. Naturally, the semi-solid milk contains more protein, ash, lactic acid, milk sugar and fat because of the evaporation of a part of the water. The dried buttermilk contained scarcely 7 per cent of water. On the basis of dry matter, 300 pounds of "semi-solid" buttermilk would be equal in feeding value to about 100 pounds of dried buttermilk; and on this basis should sell for four cents a pound when a like amount of the dried article was costing twelve cents. Actually, however, the cost of the "semi-solid" buttermilk was six cents a pound as compared to twelve for the dried buttermilk. Freight and cartage also favor the latter article, if either is to be bought.

Plan of Experiment.

Twelve pigs, weighing from 33 to 50 pounds each, were divided into six lots of two each (sow and barrow), and *each lot* was fed on a definite ration. An ash mixture was kept continuously before each lot, composed of:

20 per cent Salt.
40 per cent Rock phosphate.
20 per cent Ground limestone.
20 per cent Wood ashes.

The several lots were fed as follows:

Lot I. — Nine ounces of grain mixture I to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture I.

20 pounds Ground oats.
40 pounds Flour middlings.
40 pounds Corn meal.

This was considered a check ration, and as good as could be made from purchased grain.

Lot II. — Nine ounces of grain mixture II to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture II.

90 pounds Grain Mixture I.
10 pounds Digester or pig tankage.

This was an improvement over the ration fed to Lot I in that it contained 10 per cent of high grade tankage testing 19.9 per cent of ash and 63 per cent of protein. It also could be considered a check ration.

Lot III. — Four quarts of diluted "semi-solid" buttermilk daily, plus nine ounces of grain mixture I to each quart of warm water in amounts to satisfy appetites. The buttermilk in all cases was diluted to the consistency of ordinary buttermilk.

Lot IV. — Eight quarts of diluted "semi-solid" buttermilk daily, plus the same grain ration fed to Lot III.

Lot V. — Twelve ounces of dried buttermilk stirred into four quarts of warm water daily, plus the same grain ration fed to Lot III.[1]

Lot VI. — Twenty-four ounces of dried buttermilk stirred into eight quarts of warm water daily, plus the same grain ration as fed to Lot III.

After the animals had reached about 100 pounds each in weight, the grain mixture received by Lot II was changed by reducing the tankage to 5 per cent, and correspondingly increasing the grain. Otherwise the experiment was continued to completion, covering 126 days.

[1] Owing to the fact that one of the pigs in this lot proved inferior, the results were discarded.

Results of the Experiment.

Rations, Food Consumption, Daily Gain, Dry Food Required to Produce Gain, and Cost of Gain.

Lot.	Ration.	Dry Food consumed (Pounds).	Daily Gain (Pounds).	Dry Food required to Produce 100-pound Gain.	Cost of 100-pound Gain.
I	Grain only	702.92	.95 / .96	293	$7 22
II	Grain+tankage	758.18	1.10 / .87	311	8 55
III	Grain+"semi-solid" buttermilk	812.96	1.07 / .92	327	14 47
IV	Grain+"semi-solid" buttermilk	924.46	1.22 / 1.09	319	18 91
VI	Grain+dried buttermilk	899.40	1.27 / 1.43	264	13 16

It is evident from the above data that, while the buttermilk products as a component of the ration aided in growth, their cost is too great to render their use financially advisable.[1] Pigs on the grain plus ash mixture made a very good growth, and must have found at least a fair amount of growth accessories (vitamins) in the ration fed.

Note. — Considerable quantities of evaporated buttermilk and skim milk are used in growing poultry. It is undoubtedly very efficient, furnishing mineral matter, desirable proteins and vitamins; and probably its use in reasonable amounts is economical in forcing pullets to early egg production. The writer, however, has no data on this subject. Other things being equal, the dried product should prove more economical than that which has only a portion of the water removed.

Lactic Acid — Its Value in Promoting Growth in Pigs.

The claim has been made that the addition of dilute lactic acid — the acid of sour milk — to the grain slop fed to pigs will improve the appetite and digestion and promote an increase in growth. Two trials were made to demonstrate the truth or fallacy of the claim.

Trial I, May 19–September 8.

Two lots of two pigs each (averaging 30 pounds each in weight) were placed in two separate pens and fed as follows:

Lot I. — Six ounces of corn meal to each quart of skim milk, in sufficient amounts to satisfy the appetite. When the lot reached a daily consumption of 72 ounces of meal and 12 quarts of skim milk, the ration was increased by the addition of the following mixture, in the proportion of 9 ounces to each quart of water:

28 pounds Corn meal.
28 pounds Wheat middlings.
28 pounds Ground oats.
16 pounds Digester tankage.

After the animals had reached a weight of about 100 pounds each, the skim milk was reduced to 8 quarts daily for the lot, and was supplemented with a grain

[1] The use of small amounts of "semi-solid" or dried buttermilk, or of dried skim milk may be worth while from the time young pigs are weaned until they attain a weight of 25 to 30 pounds, when the natural product is not available.

mixture of one-third each of corn meal, wheat middlings and ground oats to satisfy appetites. This was continued until the end of the trial. This ration, with its variations, was considered a standard or check ration suitable for promoting normal growth.

Lot II. — The same corn meal, middlings, oats and tankage mixture fed to Lot I. This was fed throughout the trial in the proportion of 9 ounces to each quart of water containing .7 per cent of lactic acid. Milk was omitted from the ration.

Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.
Number of days in trial	116	116
	Pounds.	Pounds.
Dry Matter in food consumed:		
Skim milk[1]	199.0	none
Corn meal	336.4	164.0
Wheat middlings	140.2	167.0
Ground oats	140.2	167.0
Digester tankage	4.8	76.0
Lactic Acid[2]	none	18.0
Total	820.6	592.0
Growth Produced:		
Weight at beginning	35 26	28 29
Weight at end	165 175	122 120
Total gain	130 149	94 91
Daily gain	1.12 1.28	.81 .78
Dry Matter per 100 pounds Gain	294.1	320.0

[1] Pigs 1 and 2 received 1,028 quarts of skim milk averaging 9 per cent solids. One quart was taken to equal 2.15 pounds.

[2] Pigs 3 and 4 received 1,224 quarts of water containing .7 per cent lactic acid. One quart was taken to equal 2.1 pounds.

A glance at the above table shows that Lot I, which received considerable skim milk in addition to the grain mixture, made a satisfactory growth. This may be attributed, in part at least, to the ease of digestion and assimilation of the milk, to the extra dry matter consumed, to the favorable proteins and also to the vitamin content of the milk. Lot II grew fairly well, but the pigs were not equal to Lot I because of the absence of the skim milk. The lactic acid did not seem to be helpful in growth production.

Trial II, September 22–December 1.

Six grade Chester White pigs were procured in September and fed upon skim milk and corn meal until each weighed between 20 and 30 pounds. They were then divided into three lots of two each and fed as follows:

Lot I. — Eight ounces of the following mixture to each quart of water, in amounts to satisfy the appetite:

30 pounds Corn meal.
30 pounds Wheat middlings.
30 pounds Ground Oats.
10 pounds Digester tankage.

Lot II. — The same grain mixture as Lot I, with sufficient lactic acid added to the water so that it tested .4 per cent of that ingredient.

Lot III. — The same grain mixture as Lots I and II, with sufficient lactic acid to make the solution test .8 per cent of that ingredient.

The experiment began September 22 and ended December 1, proceeding without any disturbances. The weighing, housing and general care of the pigs were the same as in the preceding experiments. For the first two weeks of the experiment, after the change was made from the corn meal and skim milk to the experimental diet, none of the pigs made much growth; but as soon as they adapted themselves to the new diet a reasonable growth was noted from week to week.

Dry Matter in Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.	Lot III. Pigs 5 and 6.
Number of days in trial	70	70	70
	Pounds.	Pounds.	Pounds.
Dry Matter in food consumed:			
Corn meal	79.4	77.8	79.4
Wheat middlings	80.2	78.6	80.2
Ground oats	80.8	79.2	80.8
Digester tankage	27.2	26.8	27.2
Lactic acid	none	5.0[1]	10.4[2]
Total	267.6	266.2	278.0
Growth Produced:			
Weight at beginning	29 28	21 21	25 23
Weight at end	67 66	62 57	60 65
Total gain	38 38	41 36	35 42
Average daily gain	.54 .54	.59 .51	.50 .60
Dry Matter per 100 pounds Gain	351.3	345.7	361.0

[1] Pigs 3 and 4 received a total of 604 quarts each of water containing .4 per cent lactic acid, 2.1 pounds per quart.
[2] Pigs 5 and 6 received a total of 616 quarts each of water containing .8 per cent lactic acid, 2.1 pounds per quart.

From the general appearance of the pigs, and from the above data, one is justified in concluding, in case of both trials, that the lactic acid was without any pronounced effect in promoting growth. It is possible that lactic acid may have some therapeutic effect in case of animals undergoing digestive disturbances, but under normal conditions its use is not advised.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 218 OCTOBER, 1923

THE

CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS

By HARLAN N. WORTHLEY

The squash vine borer is a widely distributed and very serious enemy of squashes and related plants. Because of the protected life of the larva, which burrows within the squash stem, insecticides have been considered useless in the control of this pest. The best direct remedy has been to cut the borers from infested vines, a tedious and impractical treatment in commercial plantings.

This bulletin reports the discovery and application of a spraying program for squash vine borer control which has given satisfactory results under Massachusetts conditions, and which kills the insect in the egg stage, thus protecting the plants against the slightest injury from borers.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

THE CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS.

By HARLAN N. WORTHLEY.

Distribution and Importance.

The squash vine borer[1] is a native of the New World, and apparently is of tropical origin. It has spread northward over that portion of the United States east of the Rocky Mountains, and into Southern Canada. It is found as far south as Argentina.

In many localities the squash vine borer is the most serious enemy of winter squashes. Pumpkins and summer squashes are also affected, and more rarely melons and cucumbers.

Description.

Egg. — The egg of the squash vine borer is shown in Plate I, figure 1 and Plate II, figure 2. It is about one-twenty-fifth of an inch in length, and is of a dark reddish brown color. As may be seen in Figure 1, the eggs are not laid in clusters, as in the case of squash bug eggs, but singly. Magnification, as in Plate II, figure 2, shows the chorion to be finely reticulated into tiny hexagonal figures.

Larva. — The larva, or "borer" (Plate I, figure 1 & Plate II, figure 3) as it is commonly called, is a fleshy, white, nearly hairless caterpillar with a black head and a dark brown to black thoracic shield. When full grown it measures about an inch in length. Newly-hatched larvae, which are commonly not detected in the field, are about one-sixteenth of an inch long, sparsely covered with hairs, and with a broad black head, from which the white body tapers away to the anal extremity. In appearance the borer is quite distinct from the larva of the striped cucumber beetle, with which, however, it is often confused. The latter is but three-tenths of an inch long and is very slender, with the head and anal plate dark brown.

Pupa. — The pupa (Plate I, figure 1) is contained in an earth-covered cocoon of very tough, black silk about three-fourths of an inch long. The pupa itself is about five-eighths of an inch long, and is of a dark shining brown color. The head bears a horn-like process between the eyes, and the abdomen bears circles of hook-like spines.

Adult. — The adult moth (Plate I, figure 1) is five-eighths of an inch or more in length, with a wing spread of an inch to an inch and a half. It is strikingly beautiful, with long narrow olive green fore wings, bearing a fringe of blackish hairs at the tips. The hind wings are transparent, bearing scales only along the veins. The abdomen is covered with red or orange scales, and is marked with transverse white lines and a longitudinal row of black or bronze-colored spots. The tarsi are banded with white, and the hind legs are covered with long black, white, and orange-colored hairs. The sexes are quite similar, the male being more brilliantly marked than the female, and with a narrower abdomen.

Life History and Habits.

The squash vine borer passes the winter as a full-grown larva. It is enclosed in the tough silken cocoon which it spins in the soil of squash fields, at a depth of from one to six inches below the surface of the ground. Pupation occurs within this cocoon in the spring, and lasts about three weeks. At the end of this time the pupa cuts through one end of the cocoon by means of the horn-like process on its head, and wriggles to the surface of the ground, being aided in this endeavor by the circles of spines around its abdomen. When it projects above the ground about three-fourths its length, motion ceases, and very shortly the pupal skin splits back

[1] *Melittia satyriniformis* Hübner (Lepidoptera, Ægeriidæ).

PLATE I.

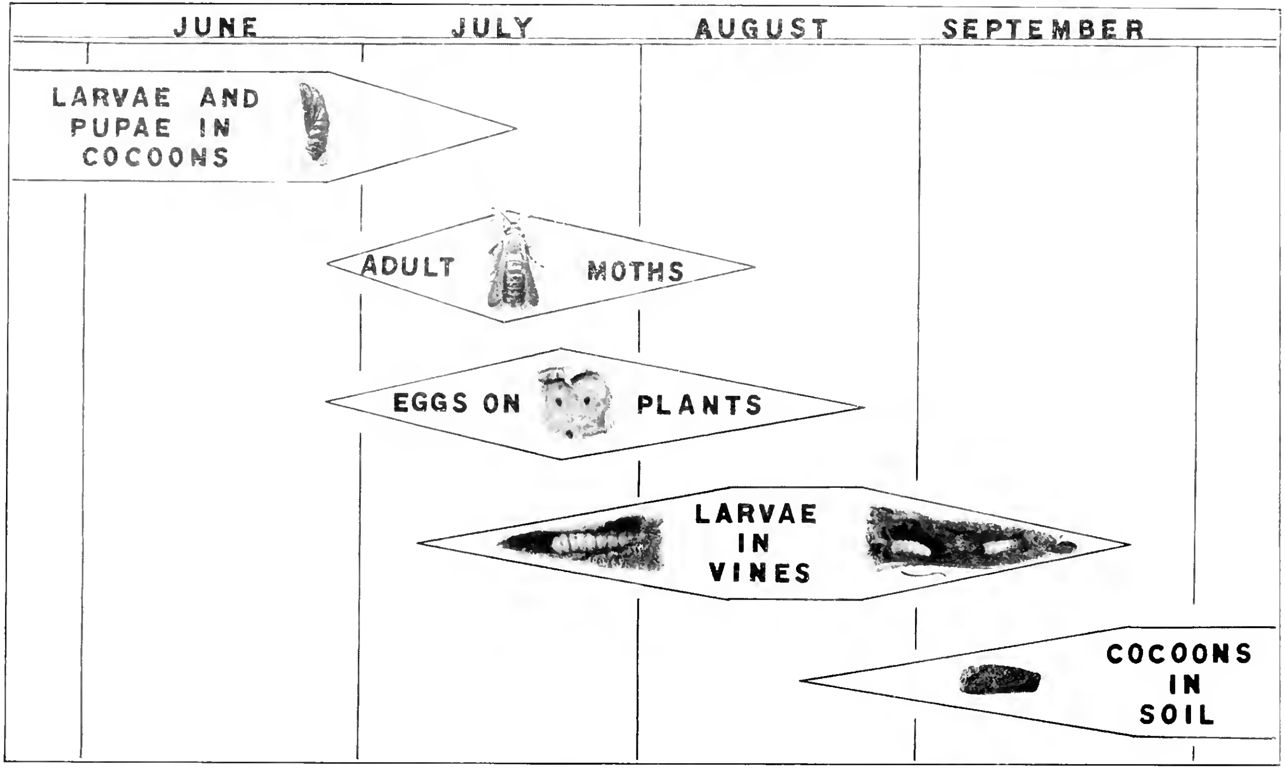

Fig. 1. Seasonal History of the Squash Vine Borer at Amherst.

from the head and the adult moth slowly drags itself forth. The emergence occupies in the neighborhood of five minutes, when the freed moth climbs upon some nearby object to expand and dry its wings in readiness for flight, which can be accomplished in a matter of fifteen minutes following emergence.

Plate I, figure 1, is a record of continuous observations from 1920 to 1923, and indicates an average seasonal occurrence of the different life stages of the insect at Amherst, and the average period of greatest abundance. The moths are present in numbers from the last of June until the first week in August. They dart from plant to plant in the heat of the day, and their rapidly vibrating wings and brilliant coloration cause them to be easily mistaken for wasps. They are fairly strong flyers, and the writer has known them to locate squash fields removed one-half mile from where cucurbits were grown the previous year.

The female moths lay their eggs singly, going from hill to hill, depositing one to several eggs on each plant. The eggs are attached by the flattened base, and are held in place by a cement-like secretion. Individual moths seem to have different tastes regarding the location selected for the eggs. In following moths from hill to hill, some are observed to seek the junction of the stem and the ground, some oviposit upon the leaf-stalks, and some even tuck the eggs down between the squash stem and the surrounding soil. Other moths lay their eggs indiscriminately upon main stem, leaves, leaf-stalks, and even upon tendrils and blossoms. The favorite location, however, appears to be the main stem near the base. Several counts have been made to determine the percentage of the total number of eggs laid on the different parts of the plant. The data are presented in Table I.

Table I. — *Location of Squash Vine Borer Eggs.*

	On Stem.	On Leaf-stalks.	On Leaves.	Total.
Lexington, 1922	377	299	10	686
Amherst, 1922	168	48	0	216
Littleton, 1923	48	5	7	60
Amherst, 1923	426	36	23	485
Total	1,019	388	40	1,447
Per cent of total	70.4	26.8	2.8	

Individual moths may lay as many as one hundred fifty to two hundred eggs. Theoretically, therefore, ten moths only, flying from plant to plant and each laying a total of one hundred fifty eggs, are necessary to cause a one hundred per cent infestation of fifteen hundred plants, which is perhaps the average number of plants per acre.

Eggs are to be found from late June or early July until mid-August, and even later in some seasons. The period spent in the egg stage has been placed by various investigators at from six to fifteen days. Breeding records at Amherst show a variation of from nine to thirteen days, but they are not extensive and may not represent the extremes for this climate.

Table II. — *Length of Egg Stage, Amherst.*

Number of Eggs.	Eggs laid.	Eggs hatched.	Number of Days.
10	July 29, 1920	Aug. 11, 1920	13
4	Aug. 4, 1923	Aug. 13, 1923	9
1	Aug. 5, 1923	Aug. 14, 1923	9

The records are those obtained from eggs laid by confined moths. Eggs collected in the field showed a high percentage of parasitism, which is discussed in another section of this paper, and were quite unsatisfactory for rearing.

When emerging from the egg, the young larva chews a ragged hole in one end and crawls forth upon the surface of the squash plant. Its subsequent action shows considerable variation in habit. In many cases it burrows directly into the host tissue. In other instances newly-hatched larvae have been seen to crawl to distances of eight to ten inches from the egg-shell, feeding here and there on the leaf or stalk before finally tunneling out of sight. Those which invade the leaf-stalks and main leaf veins gradually work their way toward the main stem. Since the average squash plant has not put forth runners when the majority of the eggs have been laid, the result of this movement is a concentration of injury in the main stem near the base.

The burrow made by the squash vine borer larva is a twisting one, and is frequently obstructed by a webbing of silk mixed with yellowish grains of excrement, called "frass". The greater part of the frass is pushed out through holes in the stem, where it clings in moist masses, serving to indicate the position of the borer within. The popular opinion seems to be that borers penetrate directly to the central cavity of the main stem along which they work, feeding at the walls of this cavity. This is not strictly the case. The larvae usually work in the tissue surrounding the central cavity of the stem, and often do not break through into this cavity until they are about half grown.

One borer can usually find food for its complete development at the base of the stem. When more borers are present, however, the mining is extended along the main stem and runners, into the bases of the leaf-stalks and, in rare instances, even into the fruit itself. Upon the death of one plant, the larvae are able to transfer their activities to one nearby.

Growth is completed in a month to six weeks, at the end of which time the full-grown caterpillar deserts its burrow in the squash plant and enters the soil nearby. After penetrating to a depth of from one to six inches it hollows out a cell, spins its cocoon of tough black silk and, gradually shrinking within its last larval skin, settles down to pass the winter.

There is but one generation of the squash vine borer each year in New England. It is partially double-brooded, however, in the latitude of New Jersey and Southern Ohio, and two full generations occur in Georgia and further south.

Nature of Injury.

In late July in Massachusetts, squash growers begin to notice plants with wilted, drooping leaves. This condition may be a result of excessive feeding in the root by larvae of the striped cucumber beetle. It is also a symptom of the disease known as bacterial wilt. The chief cause of this wilting, however, is found in the gradual destruction of the main stem of the squash plant near its base by the tunneling of squash vine borer larvae, which may be detected by the yellowish masses of frass which they push from their burrows.

The base of the main stem frequently fails to support all the borers present, and becomes a filthy, rotting mass, invaded by various sap-feeding beetles and filth-loving insects. See Plate II, figure 4. It is finally reduced to a few dried shreds, separated from the root by a light pull. See Plate II, figure 5.

The effect of squash vine borer infestation varies from a slight check in the growth and productiveness of the infested vine, to its death outright, and the loss of its partly-formed fruit. In the same field one may see a well-grown, thrifty vine which shows some borer injury, and nearby a dried, withered remnant of a vine, the shredded and distorted base and hardened masses of frass testifying to the cause of its death. A combination of factors is involved in this difference in the effect of infestation. First, a thrifty vine can often support one or two borers, while a less vigorous plant will be completely girdled. Second, plants which have been girdled do not always die. If the runners have developed far enough to "strike" numerous secondary roots from the nodes, and if these roots can find sufficient moisture and food, the vine may yet produce a fair crop. The crop is materially

PLATE II.

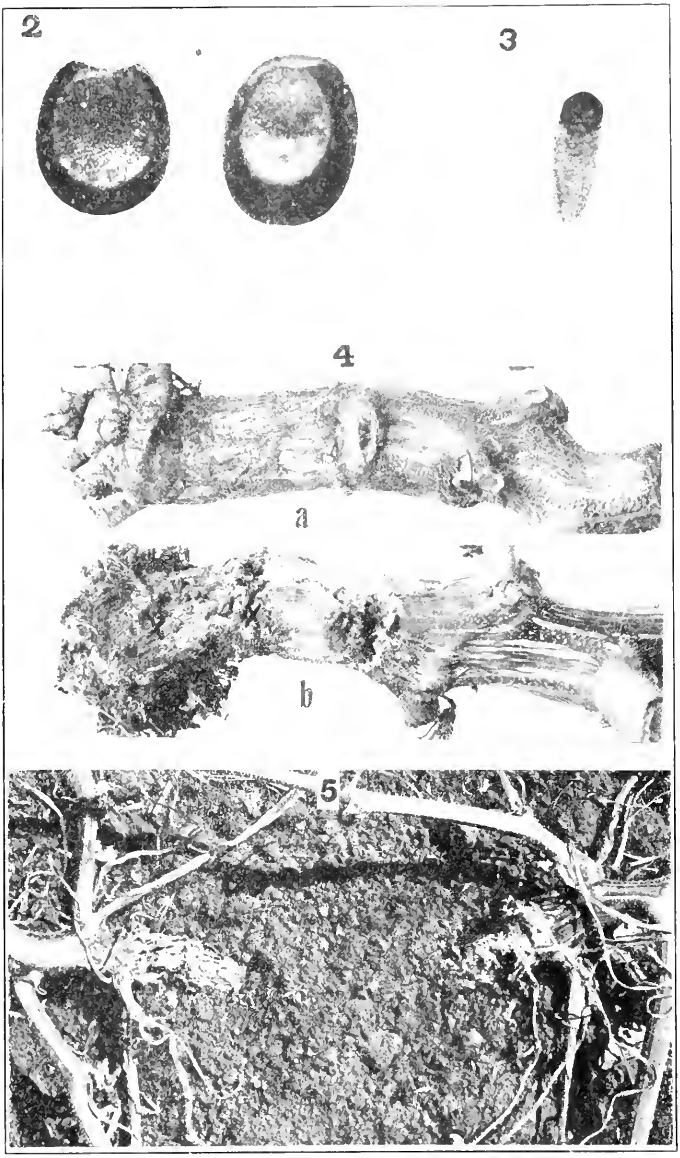

FIG. 2. Photomicrograph of squash vine borer eggs, x 24 (original).

FIG. 3. Newly hatched squash vine borer larva. Photomicrograph, x 13 (original).

FIG. 4. *a*. Healthy squash stem. *b*. Badly infested squash stem. Note burrows at "X." (Photo by R. L. Coffin.)

FIG. 5. Center of badly infested hill of squash. Note shredded condition of the bases of the stems. (Photo by R. L. Coffin.)

reduced, however, if not lost entirely in dry portions of the field or in dry years, or when fertilization of a naturally poor soil has been confined to the hill, as is so often the case. In the case of squashes planted late, or having a slow early growth, in which the runners have failed to root before the borers become half grown, the crop is very often a failure.

Natural Enemies.

No parasitic enemies of the adult moth have yet been recorded. It is the chance prey, however, of certain large robber flies (Asilidae) which have been observed to pounce upon the moths in the fields. The larvae in their tunnels in the squash stem appear to have escaped parasites, but are sometimes attacked by the larvae and adults of ground beetles (Carabidae). These agencies are of little economic importance.

The eggs of the squash vine borer are subject to a high degree of parasitism by a tiny wasp of the family Scelionidae, the members of which are exclusively egg parasites. The species has been identified by Mr. A. B. Gahan, of the United States National Museum, as *Telenomus* (*Prophanurus*) sp. The extent of the work of this tiny benefactor is evident from the following records of rearings.

Table III. — *Parasitism of Squash Vine Borer Eggs.*

Date.	Eggs.	Parasites.	Per Cent of Parasitism.
1920			
July 24	11	11	100
July 31	20	9	45
1922			
July 7	6	2	33.3
July 28	8	1	12.5
1923			
July 16	52	40	77

Control.

Cultural and Hand Methods.

Insecticides have heretofore been considered useless in the control of the squash vine borer, and consequently many cultural practises and hand methods have been advanced for the purpose of lessening the severity of the attack. A few of these are applicable under Massachusetts conditions, and are here discussed.

Trap Crops. — Winter squash, summer squash, pumpkins, melons, and cucumbers seem to be visited in the above order of preference by the egg-laying moths. Plantings of winter squash or summer crooknecks may draw the moths away from other cucurbits, and when used for this purpose should then be destroyed before the borers in them become full grown.

Fall Plowing. — Although many larvae doubtless penetrate below the plow line before spinning their cocoons, others are turned up, crushed, or exposed to the winter weather when squash fields are plowed in the fall following the removal of the crop.

Fertilization. — Many farmers seek to grow squashes on poor land with no application of fertilizer except in the hill. Borer damage is sometimes greatly enhanced by this practise. A note made by the writer in 1920 shows the effect of adequate fertilization, and is here quoted:

> The history of the squash crop this year is a good illustration of the effect of proper preparation of the land and care of the crop during early growth in offsetting the attack of the squash vine borer. The experimental plot was a sandy loam. In the spring a thirty-inch stand of rye had been plowed under. Lime was applied at the rate of three thousand pounds per acre, and a 4–8–4 fertilizer at the rate of fifteen hundred pounds

per acre. At planting, double furrows were opened up ten feet apart, and a good big forkful of manure was dropped every eight feet in the furrows. Over this manure, the seeds were planted. From the time the plants appeared until the runners closed the spaces between the rows, the ground was kept mellow by frequent cultivation. Before the plants started to run they were thinned to two plants in each hill. High fertilization and mellowness of soil promoted vigorous growth and the formation of secondary roots from the nodes of the runners. This formation of secondary roots was favored also by the unusually even distribution of rainfall throughout the summer. The importance of these secondary roots can be judged by the fact that every plant in the field was infested with borers, and the great majority suffered a complete rotting off of the main stem as a result. In spite of this, the harvest of squashes was declared to be satisfactory.

Covering the Runners. — Some growers make it a practise to insure the "striking" of secondary roots by covering the runners with earth at about a foot from the base of the plant. Fertilizer is sometimes added at these points. This practise is a useful one, and often serves to reduce materially the amount of damage done by the borers.

Cutting out the Borers. — The practises mentioned above, while they often aid in mitigating the severity of the squash vine borer attack, have no direct effect upon the borer itself. The best method heretofore practised for actually killing the borers has been the custom of cutting them from the vines. Slitting the stem lengthwise in both directions from the frass-clogged hole and bending back the cut portion will usually reveal the borer, which can then be removed and killed. If the stem is subsequently covered with earth, the operation will have little injurious effect upon the plant. By constant watchfulness from the middle of July to the first of September, a few plants in a home garden can be protected from excessive borer injury by this means.

The Use of Insecticides.

Certain insecticides have been tried in the past against the squash vine borer, and have been declared valueless. Among these were arsenate of lead painted thickly on the squash stems, and wrappings of tarred paper. Injections of various toxic substances have been tried at this station, but without success, both because of the nature of the burrows and of the webbing of silk and frass which obstructs them. Studies of the life history and habits of the species in 1920 led to spraying experiments in 1921 with the following materials: —

Material.	*Possible Action.*
Arsenate of lead powder, 3 pounds in 50 gals. water.	Poisoning of newly-hatched larvae.
Nicotine sulfate (Black-leaf "40"), 1 part in 100 parts of water.	Penetration and killing of the eggs — repelling of adult moths.
Bordeaux mixture, 4–4–50 formula.	Repelling of adults.

Preliminary experiments with these materials were conducted in 1921 and 1922 leading up to the successful field applications of 1923. On the basis of this work, the following sprays were applied in 1923: —

Material.	*Action of Spray.*
Black-leaf "40", 1–100, 1–250, and 1–500.	Toxic to eggs.
Arsenate of lead powder, 2 pounds in 50 gals. water; 3 pounds in 50 gals. water, plus "Kayso" sticker.	Poisons newly-hatched larvae as they chew at surface of squash plant.

The work was done on a commercial scale at Littleton, in coöperation with a squash grower, and at the Agricultural Experiment Station at Amherst. It is here reported in some detail.

The Littleton Experiment. — Mr. Homer Richards, a truck gardener and orchardist living in Littleton, offered the use of a one-acre field of winter squashes and, in addition, his assistance in the application of the sprays. The field contained twenty rows planted fifteen feet apart, and twenty-five hills six feet apart in each row. Plots were marked off as follows: —

Rows.	Treatment.	Rows.	Treatment.
1-2	Check	13-14	Check
3-6	Black Leaf "40", 1-500	15-18	Black Leaf "40", 1-100
7-8	Check	19-20	Check
9-12	Lead Arsenate, 2.5-50		

Four applications were made: on July 5, July 12, July 19, and July 26. Compressed air sprayers of three-gallon capacity were used for the first three applications. Each was fitted with a short spray rod and a 45° angle disc nozzle, pictured in figure 1. All portions of the plants were thoroughly sprayed, particular attention being paid to the base of the stem. The fourth application was made with a power sprayer and one lead of hose bearing the short spray rod and angle nozzle. A pressure of 100 to 125 pounds per square inch was maintained.

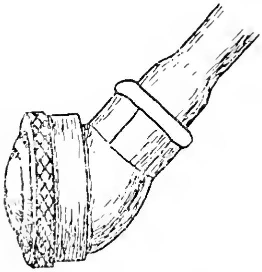

Fig. 1. 45° Angle-disc Nozzle Used in the Experiments.

Examinations to check the progress of the infestation and the effect of the treatment were made by the writer on each trip to Littleton. On July 13, a count of eggs on about twenty-five plants in each treatment gave the following results: —

Table IV. — *Squash Vine Eggs at Littleton, July 13, 1923.*

Treatment.	Eggs per Plant.
Check	1.04
Black Leaf "40", 1-500	.77
Lead Arsenate, 2.5-50	.94
Black Leaf "40", 1-100	.80

The difference in number of eggs exhibited by the check and treated plots is attributed to the mechanical effect of the spray in knocking some eggs from the plants. The writer has noticed frequently that while some eggs are firmly attached to the plants, others may be dislodged at a touch. The difference exhibited between the lead arsenate treatment and the Black-leaf "40" is attributed to a possible slight repellent effect of the nicotine sprays, the odor of which can be detected on the vines for about twenty-four hours following their application.

The effectiveness of the treatments was determined by counts of the number of borers and number of plants in treated and check plots. The final count was made on August 13 and 14, at which time the oldest larvae were ready to leave the vines, and the youngest ones were large enough to make their presence known. Every plant in the experimental field was carefully examined for borer injury, and the number of plants and number of borers in each hill recorded. The detailed results of this count are given in Table V. A summary of these counts, translated into borers per thousand plants, is also given.

TABLE V. — *Effectiveness of Treatments, Littleton, 1923.*

TREATMENT.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1-2	221	50	50	326
Black-leaf "40", 1-500	3-6	387	100	81	162
Check	7-8	187	50	50	148
Lead arsenate, 2.5-50	9-12	335	100	69	130
Check	13-14	132	50	46	134
Black-leaf "40", 1-100	15-18	375	100	18	18
Check	19-20	159	50	47	126

Summary

MATERIAL.	BORERS PER THOUSAND PLANTS.		Per Cent of Control.
	Check.	Treated.	
B. L. "40", 1-100	910	48	94.8
B. L. "40", 1-500	1,138	420	63.1
Lead arsenate, 2.5-50	909	388	57.4

The Amherst Experiment. — The experimental field at the Massachusetts Agricultural Experiment Station contained twenty-eight rows, twelve feet apart, with nine hills, eight feet apart in each row. Each treatment was applied to each of three separate plots, and each treated plot was flanked by a check plot with which its infestation was compared. The plan was as follows: —

Rows.	Treatment.	Rows.	Treatment.
1-2	Check	15-16	Black Leaf "40", 1-250
3-4	Black Leaf "40", 1-100	17-18	Lead Arsenate, 3-50
5-6	Black Leaf "40", 1-250	19-20	Check
7-8	Check	21-22	Black Leaf "40", 1-100
9-10	Lead Arsenate, 3-50	23-24	Black Leaf "40", 1-250
11-12	Black Leaf "40", 1-100	25-26	Check
13-14	Check	27-28	Lead Arsenate, 3-50

Four applications were made: on July 7, July 17, July 23, and August 2. The first application was made with a compressed air sprayer, and the other three with a power outfit. Before the last application it was found necessary to move some runners from the path of the spray rig as it passed between the rows.

On July 24, a count of eggs and larvae present in the different plots gave the following results: —

TABLE VI. — *Status of Infestation, Amherst, July 24, 1923.*

TREATMENT.	Eggs per 100 Plants.	Eggs already Hatched.
Check	41	17+
Black Leaf "40", 1-100	16	0
Black Leaf "40", 1-250	19	0
Lead Arsenate, 3-50	16	3+

The difference in the number of eggs found in the checks and in the treated plots is greater here than at Littleton (see Table IV). This difference is doubtless due to the greater force with which the spray stream is applied with a power sprayer than with a compressed air sprayer. It seems clear that the difference is due to the mechanical action of the spray stream in knocking eggs from the plants rather than to any marked repellent qualities of the spray materials themselves. Lead arsenate has not been demonstrated to be repellent to insects, and yet no more eggs were found in the plot sprayed with this material than in the plots treated with the nicotine sprays. In view of this fact, it is impossible to attribute definite repellent qualities to the Black-leaf "40", in this connection.

The number of larvae found compared with the number of eggs present, as expressed in the last column of the table, indicates the toxic effect of the spray materials. The counts in the check plots may be taken as a normal progression of development of the eggs. The counts in the plot treated with lead arsenate indicate a kill of about 50 per cent, while those in the plots treated with both strengths of Black-leaf "40" indicate 100 per cent control.

The final count was made on August 20 and 21. The detailed results are recorded in Table VII, and are summarized below.

TABLE VII. — *Effectiveness of Treatments, Amherst, 1923.*

Treatment.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1–2	65	16	13	33
Black-leaf "40", 1–100	3–4	61	18	2	2
Black-leaf "40", 1–250	5–6	69	18	7	9
Check	7–8	82	18	18	82
Lead arsenate, 3–50	9–10	70	18	10	19
Black-leaf "40", 1–100	11–12	55	18	0	0
Check	13–14	39	17	16	32
Black-leaf "40", 1–250	15–16	69	18	3	3
Lead arsenate, 3–50	17–18	63	18	7	10
Check	19–20	61	18	17	58
Black-leaf "40", 1–100	21–22	69	18	0	0
Black-leaf "40", 1–250	23–24	76	18	7	8
Check	25–26	66	17	14	36
Lead arsenate, 3–50	27–28	54	18	7	12

Summary.

Black-leaf "40", 1-100.	Borers per Thousand Plants.		Per Cent of Control.
	Check.	Treated.	
Rows 3–4	481	33	93.2
Rows 11–12	837	0	100.0
Rows 21–22	953	0	100.0
Average	757	11	97.7

Black-leaf "40", 1-250.	Borers per Thousand Plants.		Per Cent of Control.
	Check.	Treated.	
Rows 5–6	995	131	86.9
Rows 15–16	837	43	94.9
Rows 23–24	547	53	90.4
Average	793	76	90.5

Summary — Concluded.

Lead Arsenate, 3–50.	Borers per Thousand Plants.		Per Cent of Control.
	Check.	Treated.	
Rows 9–10	995	280	71.9
Rows 17–18	953	159	83.4
Rows 27–28	547	223	59.3
Average	832	221	73.5

The high degree of effectiveness exhibited by Black-leaf "40" at the above dilutions is undoubtedly due to its ovicidal action, since, as shown in Tables VI and VII, eggs were found in the plots treated with these materials in great excess of the numbers of larvae found later in the same plots. Substantiation of these observations has been sought by laboratory tests.

In these tests Black-leaf "40" at the strengths of 1-100 and 1-250 killed all the eggs which were not parasitized. It is interesting to observe that Black-leaf "40" does not destroy the egg parasites. Parasitized eggs included in the experiments yielded the adult wasps even when sprayed with the greatest strength of Black-leaf "40".

Recommendations. — The experiments here recorded indicate that almost complete relief from squash vine borer attack can be gained by four applications in July of Black-leaf "40" at a strength of 1 part in 100 parts of water, where the applications are made with a power sprayer. At the same strength, the material is over 90 per cent effective applied with a low-pressure, small-capacity outfit such as the compressed air sprayer. Applied at a strength of 1 part in 250 parts of water with the aid of a power sprayer, the material is also over 90 per cent effective. Lead arsenate gives too small a percentage of control to warrant its use.

On the basis of the experimental evidence, the following recommendations are made for the use of nicotine sulfate against the squash vine borer.

1. If a compressed air sprayer, knapsack pump, or other small capacity, low-pressure outfit is to be used, apply Black-leaf "40" at the rate of 1 part in 100 parts of water (1.3 fluid ounces per gallon) making 4 applications, one week apart in July.
2. If a machine capable of maintaining a pressure of 100 to 150 pounds per square inch is to be used, such as a good barrel pump or a power outfit, apply Black-leaf "40" at the rate of 1 part in 250 parts of water (3.2 pints in 100 gallons), making 4 applications, one week apart in July.
3. In spraying, be sure to drench all sides of the stem at the base. See that the leaf-stalks, and the under and upper surfaces of the leaves are thoroughly sprayed. When the plants have started to run, it is hardly necessary to spray the runners beyond three or four feet from the center of the hill.
4. Thorough spraying will largely free the sprayed fields from borers. Extermination may then be made complete by an examination of the plants in mid-August, cutting out those borers that have escaped the spray.

Spraying may be begun during the first week in July. It would be better, however, to examine a few plants closely every day during the last week in June, in order to discover the first eggs. The first spray should be applied not later than a week after eggs are discovered.

Cost of Treatments Versus expected Profits.

Nicotine sulfate is a relatively expensive insecticide, and any spraying operation using this material at a strength of one part in one hundred parts of water, or one part in two hundred fifty parts of water, is a costly treatment, which will be quite likely to prove impractical under certain conditions of squash culture (*i.e.*, where the squash vine borer is not a serious pest).

The expense of treatment can be materially reduced by following the suggestions given below.

1. To facilitate spraying squashes, plant in wide rows with the hills close together in the row. This type of planting allows free passage of the spray rig between the rows, and little time is lost in stepping from hill to hill.

2. Thin to the desired number of plants in each hill as early as is compatible with good farm practise. In this way, no spray material is wasted on plants that are later to be destroyed.

3. Equip the four-foot spray rod with a 45° angle disc nozzle with a small hole in the disc. This breaks the spray up into a very fine mist which covers quickly and thoroughly with a minimum of waste. In addition, equip the base of the spray rod with an automatic shutoff of the spring-grip type, so that the stream can be stopped instantly, thus allowing no wastage when passing between hills. This type of equipment can be used as well with a compressed air sprayer or one of the knapsack type as with a barrel pump or power outfit. With a power outfit, regulate the pressure at from 100 to 150 pounds per square inch.

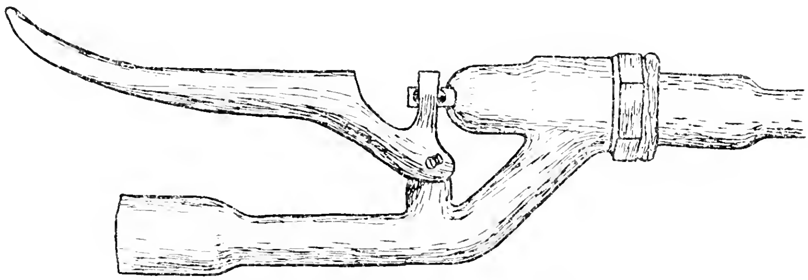

FIG. 2. — Automatic Shutoff Used in Experiments.

What may be called the average cost of spraying squashes has been figured from the records kept of the experimental work. The cost per acre can be seen to vary enormously, depending on the type of planting (hills per acre and plants per hill) and the stage of growth of the plants during the period of spraying. The figures given below are for four treatments, one week apart in July, applied to an acre containing one thousand squash plants of average growth.

1. Using compressed air or other small capacity, low-pressure outfit. Black-leaf "40", 1–100 recommended.

Dilute spray material, 150 gallons containing Black-leaf "40", 1.5 gallons at $12.50	$18 75
1 man, 24 hours at $.40	9 60
Total cost per acre of one thousand plants	$28 35

2. Using a barrel pump or power outfit giving a fairly large delivery at 100 to 150 pounds pressure. Black-leaf "40", 1–250 recommended.

Dilute spray material, 275 gallons containing Black-leaf "40", 1.38 gallons at $12.50	$17 25
3 men — 1 horse, 6 hours at $1.55	9 30
Total cost per acre of one thousand plants	$26 55

If the type of planting calls for more than 1,000 plants per acre, the cost of treatment is increased accordingly.

In an effort to discover the average increase in yield which might reasonably be expected from the use of the above treatment, and the relation of the value of this increase to the cost of treatment, letters were sent to prominent squash growers in various parts of the State. The replies received from those portions of the State where the borer is well established have been tabulated as follows:

TABLE VIII. — *Average Expected Increase in Yield of Winter Squashes.*

	Average Yield Per Acre (Tons).	Estimated Per Cent Increase from Borer-free Plants.
1	–	100
2	8.0	20
3	12.0	5
4	–	100
5	8.5	10
6	3.0	50
7	8.5	30
8	6.0	60
9	10.0	10
10	5.0	200
Average	7.6	59.5

The average increase thus estimated is 4.5 tons per acre. The average wholesale price of winter squashes during the sales-from-harvest period, September 1 to November 15, appears to be $.03 per pound or $60. per ton.[1] The value of the expected average increase of 4.5 tons per acre is therefore $270. Subtracting from this figure the cost of treatment leaves an estimated average net profit of from $241.65 to $243.45 per acre.

SUMMARY.

The squash vine borer is a serious native enemy of winter squashes and related plants, for which no adequate remedy has previously been devised. The adult insect is on the wing during July, laying its tiny, reddish eggs upon the squash plants. The borers developing from these eggs cause the vines to droop and die by tunneling in the stem and girdling the plant, throwing masses of yellow frass out through holes in the stem, and causing the stem to rot. These larvae leave the vines in the fall, and spin cocoons in the soil. A number of cultural practises, such as fall plowing of infested fields, adequate fertilization to promote growth and to aid the secondary roots, and covering the runners with earth, have been recommended, as has the practise of cutting the borers from infested vines.

Experiments at this Station indicate that nicotine sulfate (Black-leaf "40"), at the strength of 1 part in 100 parts of water, kills over 97 per cent of the eggs, and, at the strength of 1 part in 250 parts of water, kills over 90 per cent of the eggs. Spraying should be done four times, at weekly intervals beginning the first week in July, using the stronger dosage with compressed air sprayers or similar machinery, and the weaker dosage with barrel pumps or power sprayers. When thoroughly done, spraying will largely eliminate borers from the fields. Complete extermination is then possible by cutting out the remaining borers during the middle of August.

The treatment is estimated to cost between $25. and $30. per thousand plants. Thus intensive methods of culture and careful, economical spraying must be the rule where the treatment is to be found practicable on a commercial scale. However, estimates of various squash growers regarding the expected increase in yield from borer-free plants indicate an average net profit of over $200. per acre from the use of this treatment. For the home gardener, to whom cost of production is a small item, it offers a ready means of successfully fighting this most troublesome enemy of squashes.

[1] Computed from the Boston Produce Market Reports, 1920–1923.

MASSACHUSETTS

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COMBATING APPLE SCAB

Spraying and Dusting Experiments in 1923 with Summary of Three Years' Results

By WILLIAM L. DORAN and A. VINCENT OSMUN

Recently completed studies on apple scab and its control show that development of this disease may be prevented through the use of a number of different materials — lime-sulfur, dry lime-sulfur, or copper sprays followed by lime-sulfur, may be effectively used, as also dusts of various kinds. Scab development is governed largely by weather conditions; possibility of successful control, by the proper timing of protective treatment and efficiency in the actual spraying and dusting work. These facts are brought out in this bulletin, which is the final report of a three-year investigation. Tabulated results of the work carried on in 1923 are presented, likewise a summarization of all data collected during the course of the study.

Publication of this Document approved by the Commission on Administration and Finance

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

COMBATING APPLE SCAB.

SPRAYING AND DUSTING EXPERIMENTS IN 1923[1] WITH SUMMARY OF THREE YEARS' RESULTS.

By William L. Doran and A. Vincent Osmun.

Introduction.

Scab has long been a disease to reckon with in the apple orchards of Massachusetts, but not until the advent and extensive planting of the McIntosh, a variety particularly susceptible to attack by the scab fungus, did it become a menace of large proportions. As more and more of the McIntosh orchards came into bearing, an increasing number of growers experienced difficulty in controlling the disease and losses became so large as to seriously threaten the orchard industry. Finally, in 1920, appeal was made to the Station by the growers, and in the fall of that year the Station entered into a cooperative agreement with the Nashoba Fruit Producers' Association under which experiments on the control of scab were planned and undertaken by the Department of Botany.

The results of the spraying and dusting experiments of the first two seasons already have been reported by Krout (1) (2).[2] The present report is on the work of 1923, together with such references to the work in Massachusetts in 1922 and 1921 as will assist in making points clear. The results of the three years' experiments are summarized in Table III (page 17). Other references in this report are for the most part to spraying and dusting experiments conducted within the last two years, especially in the northeastern states.

The general objectives of the investigations in 1923 were to secure more light on the following questions in regard to the control of apple scab:

1. What is the effect of the addition to the spray schedule of a prepink application?
2. How does dry lime-sulfur compare with liquid lime-sulfur in fungicidal efficiency?
3. What is the ratio of dry lime-sulfur to water, at which this fungicide is dependable?
4. What is the effect of the addition of calcium caseinate spreader to the fungicide when applied as a dust and as a spray?
5. How does a spray schedule consisting of lime-sulfur throughout the season compare with a schedule in which Bordeaux mixture is substituted for the application or applications before flowering?
6. How does Atomic Sulphur compare with dry and liquid lime-sulfur for the control of scab?
7. Does the addition of lime or of calcium caseinate to the combination lime-sulfur-lead arsenate spray improve the mixture?
8. For the control of apple scab, what is the fungicidal efficiency of sulfur dust? What is the effect of substituting a copper-lime-arsenic dust for the prepink and pink applications?

The rainy summer of 1922 was especially suitable for the experimental work, because of the abundant infection on unsprayed trees. The summer of 1923 was much drier; there was a rainfall of only 7.29 inches in May, June and July, as compared with 20.14 inches in the same period in 1922. This naturally resulted in less infection, but there was sufficient infection on unsprayed trees in every case but one to justify the drawing of conclusions as to the relative values of the several treatments applied.

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[1] The experiments here described were conducted in the orchards of Harry L. Knights of Littleton, H. L. Frost of Littleton, Stephen W Sabine of Groton, and A. N. Stowe of Hudson. The superintendents of these orchards are Roy C. Wilbur of the Frost Farm, John J. Collins of the Stowe Farm, and J. W. Ames of the Knights Farm. Acknowledgment is due these men for placing their orchards at the disposal of the Experiment Station, and for cooperating in the investigations. Acknowledgment is also due to the Nashoba Fruit Producers' Association for their cooperation.

[2] Numbers in parenthesis refer to literature cited, see page 13.

The results, as given in tables I and II, and in the text, are expressed in percentage of scabby apples present in the check and in each sprayed or dusted plot. In interpreting the results of any spraying or dusting experiments, the percentage of infection in the check is of primary importance. If this is low, the data are correspondingly of less value, since it cannot be said that the fungicidal treatment was put to a real test. The percentage of infection on the unsprayed trees in the Sabine orchard where some of the spraying experiments were conducted was so low that the results in that orchard are not considered in this report.

Methods and Materials Used.

The trees used for these experiments were of the McIntosh variety. Each orchard was divided in such a way that the check plot was as nearly as possible like the treated plots in every way except fungicidal treatment received. The check plots received no treatment for scab control, but did receive a calyx application with insecticides only. All check plots were surrounded by or contiguous to the treated plots. In dividing an orchard for a dusting experiment, it is difficult to so locate the check plot that it will not receive some dust as the dust drifts through the orchard. If it were possible to prevent this entirely, the percentage of scabby fruits on the dust checks would probably be larger.

The following treatments were tested or compared:

1. Dry lime-sulfur 3–50 for the pink, calyx and one later application.
2. Dry lime-sulfur 3–50 with calcium caseinate added for the pink, calyx, and one later application.
3. Dry lime-sulfur 2–50 for the pink, calyx and one later application.
4. Dry lime-sulfur 4–50 for the pink, calyx and one later application.
5. Dry lime-sulfur 3–50 for the prepink, pink, calyx and one later application.
6. Bordeaux mixture 3–10–50 for the prepink and pink applications followed by liquid lime-sulfur 1–50 for the calyx and one later application.
7. Bordeaux mixture 3–10–50 for the pink application followed by liquid lime-sulfur 1–50 for the calyx and one later application.
8. Atomic Sulphur for the pink, calyx and one later application.
9. Liquid lime-sulfur for the pink, calyx and one later application.
10. Bordeaux mixture 3–10–50 for the pink application followed by dry lime-sulfur 4–50 for the calyx, and one later application.
11. Liquid lime-sulfur with lime added for the pink, calyx and one later application.
12. Copper dust for the prepink and pink applications followed by sulfur dust for the calyx and two later applications.
13. Sulfur dust for the prepink, pink, calyx and two later applications.
14. Sulfur dust with calcium caseinate added for the prepink, pink, calyx and two later applications.

In one orchard, the dusting schedule began with the pink instead of the prepink application.

An examination of Tables I and II will show which treatment each of the thirty-five plots received, including the fungicide and its dilution used at each application, together with the date of each application.

Rates of Application.

About four gallons of spray per tree per application were used for trees twelve to fifteen years old. About one and one-half pounds of dust per tree of this size were used at each application.

Liquid lime-sulfur was used at the rate of one gallon in fifty gallons of water. Dry lime-sulfur was used at the rate of two, three or four pounds in fifty gallons; this is expressed in abbreviated form in the text as dry lime-sulfur 2–50, 3–50, etc. It was not found necessary to add water to this material before placing it in the spray tank; in fact, to do so resulted in increased lumpiness. A more satisfactory method is to sift this material into the nearly filled spray tank with the agitator running.

Calcium caseinate spreader (which is sold under various trade names, such as Kayso, Spraccin, etc.) was used at the rate of 1 pound in 100 gallons, or it was added to sulfur dust so that the dust mixture would contain 5 per cent calcium caseinate.

The copper dust (used only before the flower buds opened) contained 11 per cent dehydrated copper sulfate. The sulfur dust contained 92 per cent sulfur and 8 per cent inert ingredients. When it was desired to apply an arsenical also to dusted trees, a dust containing sulfur and lead arsenate in the ratio 90:10 or 85:15 was used.

Arsenate of lead and nicotine sulfate (Black Leaf 40) in the usual proportions were added to the sprays for each application, except for the fourth summer spray when nicotine sulfate was omitted.

The spraying was done with power sprayers with about 200 pounds pressure, using Pilot rods or regular spray rods.

The dusting was done with power dusters, either Perfect or Niagara. The duster was driven along both sides of each row of trees, so that dust was applied to each tree from opposite sides. Dusting is not a pleasant operation, because of the pain caused by the sulfur getting into the eyes. Goggles, although somewhat of a nuisance, appear to be a necessity when much dusting is to be done. Some difficulty was experienced in thoroughly dusting the tops of tall trees. Krout (2) and Childs (3) both mention this. The tops of taller trees cannot be thoroughly coated with dust when any wind is blowing. The dusting was done early in the morning, beginning about five o'clock in most cases. The foliage was not always wet, however. There is no experimental evidence of the necessity of dusting only when the foliage is wet.

Friez hygro-thermographs and rain gauges were maintained in the Frost and Sabine orchards. The data on rainfall secured in the orchards is not considered complete, and the precipitation data given in this report are from the Concord observer for the United States Weather Bureau as recorded in Climatological Data for New England.

Because of the large yield of fruit, it was manifestly impossible to examine every apple in a plot at picking time. For this reason, four representative trees were selected from each plot for examination of the fruit. About 150,000 apples were examined. Since much of the infection was late, most of the scabby apples even on the check plots were marketable. Apples designated as scabby in the data include both marketable-scabby, and unmarketable scabby.

Effect of the Addition of a Prepink Application to the Schedule.

The delayed dormant application is made just as the buds are breaking or when the first tips of green show. The pink application is usually understood to mean that which is applied as soon as the blossom buds separate in the clusters, while they show pink, but before they begin to open. Any application of a summer-strength fungicide made between the delayed dormant and the pink applications may be spoken of as a prepink application. The interval between the prepink and pink applications, which will depend upon the weather and consequent rapidity of growth, is bound to be short. In the case of large orchards, there is likely to be no interval, so that an application begun as a prepink will end as a pink, as regards the development of the flower buds. The first summer application, either prepink or pink, should be made when the tree is first in danger of infection, that is, before the first discharge of winter spores from the dead leaves beneath the tree. It is probable that many of the failures to control apple scab in Massachusetts have occurred because this first summer spray was too long delayed. The prepink cannot be regarded as a substitute for the pink application. If a prepink application is necessary, a pink is none the less so, because new growth has exposed new and unprotected leaf surface to the danger of infection.

The beginning of the period when the tree is in danger of infection can be determined only by "trapping" the winter spores on adhesive-coated glass slides inverted over the dead leaves and microscopic examination of the slides, after the method described by Wallace (4) and Childs (5). In some years, winter spores are mature and ready to be discharged, if the dead leaves containing them are wet, while the apple buds are only beginning to swell. In such years, it is evident that if the first application is deferred until the flower buds show pink, some infection is likely to occur before that time. Because a prepink application is proved necessary or unnecessary one year, it does not follow that the reverse may not be true the next year. A prepink application made in the absence of information as to the development and condition of the winter spores is to be regarded as insurance.

Krout (2) in 1922 tested the addition of a prepink application to the spray schedule. In the first orchard, the addition of the prepink application was not followed by a decrease in the percentage of scab but rather by an increase of 3 per cent. In each of two other orchards the prepink spray apparently reduced the scab 1 per cent. It is evident, therefore, that in 1922 no real benefit from the use of the prepink spray was shown, as compared with a schedule which included only a pink application before the flowers opened.

In 1923, spray schedules with and without a prepink application were tested in two orchards. In the Frost orchard trees sprayed with lime-sulfur beginning with the pink application yielded 7.06 per cent scabby fruit and when this material was used beginning with the prepink application, there was only 1.2 per cent scab, a significant reduction. Where Bordeaux mixture was used for the pink application, followed by lime-sulfur for the later applications, there was 1.7 per cent scabby fruit, and on the plot where this schedule was modified by the addition of a prepink application of Bordeaux mixture, only 0.6 per cent scabby fruit was produced. Here again there was a reduction in the percentage of scab, although such a small one as to be probably without significance.

In the Knights orchard, trees sprayed with dry lime-sulfur 4–50 beginning with the pink application, yielded 1.7 per cent scabby fruit, and where dry lime-sulfur 3–50 was applied beginning with the prepink spray, there was 4.8 per cent scabby fruit. Since the strength of the material was different the addition of a prepink application was not the only changed factor affecting the control of the disease. When the cost of the material and the cost of the labor for each application are considered, however, it is evident that three applications of dry lime-sulfur 4–50 beginning with the pink were a more profitable treatment than four applications of dry lime-sulfur 3–50 beginning with the prepink. There was 1.06 per cent scabby fruit on the trees sprayed with Bordeaux mixture beginning with the pink application and dry lime-sulfur 4–50 for the later applications. As compared with this there was 4.9 per cent scabby fruit on trees sprayed with Bordeaux mixture for the prepink and pink applications followed by liquid lime-sulfur for the later applications. Since, as is shown elsewhere in this report, we may regard liquid lime-sulfur as of equal fungicidal efficiency with dry lime-sulfur 4–50, it is evident that the addition of a prepink application did not reduce the percentage of scab; instead, it was followed by an increase of 3.84 per cent. The need of a prepink application is not shown by the data of either 1922 or 1923.

When we consider dusting, however, the case may be entirely different. In the two orchards where the dusting schedule began with a prepink application, a good control of scab was secured. In the orchard where only one application, the pink, was made before the flower buds opened a much poorer control resulted. Satisfactory experimental evidence on this point, however, would necessitate that the two schedules, with and without a prepink application, be used in adjoining parts of the same orchard with one check for the two.

The Use of Dry Lime-Sulfur.

Arguments for and against the use of dry lime-sulfur as compared with the liquid form include, of course, considerations of the relative costs, convenience in handling, and effect on the pump. But the first question to consider is, does it control scab? For if it does not, further consideration is needless. In the experiments here described, trees sprayed with dry lime-sulfur 4–50, beginning with the pink application, produced an average of 1.3 per cent scabby apples as compared with 60.7 per cent on the unsprayed trees. In the same orchards, on trees sprayed with liquid lime-sulfur, the percentage of scabby apples was 2.7. The conclusion from this is that dry lime-sulfur is fully as dependable for the control of apple scab as is liquid lime-sulfur.

In two successive years, Krout (2) secured as good control of apple scab with dry lime-sulfur as with the liquid. Gardner (6) found dry lime-sulfur as effective as liquid lime-sulfur against apple scab. In most of the experiments of Keitt and Jones (7), the results with dry lime-sulfur in controlling apple scab were similar to those obtained with liquid lime-sulfur. Massey and Fitch (8) had practically the same results with dry as with liquid lime-sulfur.

Dry lime-sulfur is less bulky to transport. But the material necessary to make 100 gallons of spray costs about twice as much in the dry form as in the liquid. The so-called free sulfur in dry lime-sulfur does not redissolve in water, and this, according to Sears (9), wears out pumps and nozzles more rapidly than does liquid lime-sulfur. It may be added that if this objection is valid, it will hold none the less for dry-mix sulfur-lime, or any sulfur fungicide other than a solution. It seems that the orchardist must decide for himself whether to use dry or liquid lime-sulfur, but he may be sure that the fungicide in either form is efficient for the prevention of infection by the apple scab fungus.

Concentration at Which to Use Dry Lime-Sulfur.

Trees sprayed with dry lime-sulfur 4–50 yielded on the average 1.3 per cent scabby apples as compared to 60.7 per cent on unsprayed trees; while trees sprayed with dry lime-sulfur 2–50 and dry lime-sulfur 3–50 yielded 3.9 and 5.8 per cent scabby apples respectively, as compared to 67.6 per cent on unsprayed trees. The indications are that the use of less than 4 pounds of dry lime-sulfur in 50 gallons will be followed by a slight increase in the percentage of scabby apples.

Krout (2) secured similar results. The check plot yielded 41 per cent scabby fruit, the dry lime-sulfur 4–50 plot yielded 2 per cent, and the dry lime-sulfur 3–50 plot yielded 4 per cent scabby fruit. The difference was slight in 1922 as it is in 1923, but the variation is in the same direction.

Whether liquid or dry lime-sulfur is used, the protection afforded is dependent upon the amount of sulfur present in the diluted spray. The percentage of sulfur is of course not always the same in all dry lime-sulfurs. But in general it may be said that not less than 4 pounds of dry lime-sulfur in 50 gallons are required to supply the same number of pounds of sulfur as are present when 1 gallon of commercial concentrated lime-sulfur, of the usual strength tested in degrees Baumé, is diluted to 50 gallons. According to Dutton (10) the amount of dry lime-sulfur necessary to furnish the equivalent amount of sulfur in 50 gallons is 4.4 pounds, and according to Eustace and Pettit (11), it is 4.8 pounds.

The evidence submitted indicates that reducing the amount of dry lime-sulfur below 4 pounds to 50 gallons is a practice of doubtful economy.

Effect of a Calcium Caseinate Spreader on Control of Scab.

The percentage of scabby fruit was reduced slightly by the addition of calcium caseinate spreader to lime-sulfur. At Frost's, this reduction was from 7.06 to 5.08 per cent scabby fruit; and at Knights', the reduction was from 4.6 to 0.68 per cent. It is a question whether these reductions are in themselves large enough to be significant, but the results are consistently in favor of the use of the calcium caseinate.

The addition of calcium caseinate to sulfur dust did not result in a reduction in the percentage of scabby apples, as compared with the plots dusted with sulfur alone, in either the Frost or the Sabine orchard; and in the Stowe orchard the results were practically the same. In the Frost orchard, the addition of calcium caseinate spreader to sulfur dust was followed by a considerable increase in the percentage of scabby apples.

In the spreader tests of Stearns and Hough (12) the addition of calcium caseinate did not increase the effectiveness of the spray in protecting fruit and foliage from disease and insects. Keitt and Jones (7) secured slightly better control of scab when calcium caseinate was added to lime-sulfur than when the latter was used alone, but it was not considered that the commercial value of its addition was determined. Trees sprayed with lime-sulfur by Parrott, Stewart, and Glasgow (13) yielded 2.1 per cent scabby apples, while trees sprayed with lime-sulfur with calcium caseinate added yielded 4.8 per cent scabby apples. In the experiments of Massey and Fitch (8) trees sprayed with lime-sulfur yielded 1.2 per cent scabby apples, and those trees which were sprayed with lime-sulfur with calcium caseinate added yielded 1.1 per cent scabby apples. In their dusting experiments, trees which received sulfur yielded 2.6 per cent scabby apples and those which were dusted with sulfur with calcium caseinate added yielded 2.4 per cent scabby apples.

The claim is made that calcium caseinate spreaders improve the adhesiveness of sprays, but it should be noted that Butler and Smith (14) found that the adhesiveness of Bordeaux mixture is not affected by the addition of calcium caseinate. Whatever may be said in favor of the use of calcium caseinate, and there are sound arguments in its favor, it cannot be said that there is sufficient or satisfactory evidence as to its increasing the fungicidal efficiency of lime-sulfur against apple scab to a point of commercial importance. It is probable, however, that the more imperfect the spraying, the greater the benefit to be derived from the use of a calcium caseinate spreader.

Calcium caseinate is further considered in connection with its effect on compatibility of ingredients in combination sprays.

Bordeaux Mixture as Compared with Lime-Sulfur for Applications Before Flower Buds Open.

The Bordeaux mixture used in these experiments was an excess-lime Bordeaux mixture containing 3 pounds of copper sulfate and 10 pounds of lime in 50 gallons of water. This is referred to in the abbreviated language of practice as 3–10–50 Bordeaux mixture. It was used, rather than a Bordeaux mixture containing copper sulfate and lime in the ratio 1:1, because it has been found to be somewhat safer to the sprayed tree.

In the preparation of Bordeaux mixture, the diluted copper sulfate solution and the diluted milk-of-lime may be poured together into a third barrel or into a spray tank, and this is a method quite generally followed. But it requires some special equipment and involves unnecessary labor. It is important that at least one of the stock solutions, either copper sulfate or lime, be diluted before the other and concentrated one is added to it, but as Butler (15) has shown, it is not necessary that both be diluted before mixing. In practice, it is sufficient to place the copper sulfate stock solution in the spray tank when it is about three-fourths full of water; then, with the agitator running, add the undiluted stock solution of the lime, and fill the tank with water. The Bordeaux mixture used in these experiments was prepared in this way.

In many experiments where Bordeaux mixture and lime-sulfur have been compared, it has been found that the former has a somewhat greater fungicidal efficiency than the latter against apple scab. Unfortunately, Bordeaux mixture usually burns the fruit and foliage of the apple. The results of many experiments are well illustrated by those of Krout (2) who found that even an excess-lime Bordeaux mixture of 3–10–50 formula, when used for all applications, russeted the fruit and burned the foliage severely. For this reason, the use of Bordeaux mixture throughout the spraying season was not attempted in 1923. It was, however, used on certain plots for the pink, or the prepink and pink applications, followed by lime-sulfur for later applications.

The plot in the Frost orchard which received three applications of liquid lime-sulfur yielded 2.1 per cent scabby apples, while the plot which received Bordeaux mixture for the pink application and liquid lime-sulfur for the calyx and last applications yielded 1.7 per cent scabby apples. This is too small a difference to have any significance. The plot which received the prepink and pink applications of Bordeaux mixture followed by liquid lime-sulfur for the later applications yielded 0.6 per cent scabby fruit. This reduction in the amount of scabby fruit cannot be attributed entirely to the substitution of Bordeaux mixture for lime-sulfur since this plot received one extra application; namely, the prepink. The results in Frost's orchard do not show that any benefit is to be derived from the substitution of Bordeaux mixture for lime-sulfur for the early application.

At the Knights orchard, Bordeaux mixture was substituted for dry lime-sulfur in one case and for liquid lime-sulfur in another for the pink or prepink and pink applications. The plot sprayed with dry lime-sulfur throughout the season yielded 1.7 per cent scabby fruit, and the plot on which Bordeaux mixture was substituted for dry lime-sulfur at the time of the pink application yielded practically the same; namely, 1.06 per cent scabby fruit. No benefit from the substitution of Bordeaux was proved in this case. The plot sprayed with liquid lime-sulfur throughout the spraying season beginning with the pink application produced a slightly smaller percentage of scabby apples than did the plot which received Bordeaux mixture at the prepink and pink applications followed by liquid lime-sulfur for the calyx and fourth summer spray.

We have no evidence at either of these orchards that Bordeaux mixture is preferable to lime-sulfur for the prepink and pink applications. The labor involved in preparing Bordeaux mixture is sufficient to swing the scale against it in the absence of more evidence in its favor.

Dr. O. R. Butler states (in correspondence) that in his experiments in New Hampshire in 1922 where a spray schedule of lime-sulfur alone was followed, there was 67.5 per cent scabby fruit; while the substitution of Bordeaux mixture for the pink application reduced the amount to 49.2 per cent. Krout (2) reports that in the Sabine orchard in 1922 the substitution of Bordeaux mixture for lime-sulfur at the pink application did not reduce the percentage of scabby fruit, as compared with results following the use of lime-sulfur alone; in fact, in the case of both dry and liquid lime-sulfur, when Bordeaux mixture was substituted there was a larger percentage of scab. At the Knights and the Frost orchards, however, there was a slight decrease in the amount of scab when Bordeaux mixture was substituted for the pink application; in the case of liquid lime-sulfur this decrease was from 4 to 2 per cent in one orchard and 2 to 0 per cent in another, and in the case of dry lime-sulfur the decrease was from 8 to 3 per cent in one orchard and 2 to 1 per cent in another. We may conclude that although Bordeaux mixture under some conditions may prove slightly superior to lime-sulfur for the pink spray, there is, nevertheless, abundant evidence of the completely satisfactory control of apple scab by lime-sulfur throughout the spraying season; and it does not appear, therefore, that we have sufficient reason to devote extra labor to the preparation of Bordeaux mixture.

Atomic Sulphur.

The proprietary sulfur fungicide, Atomic Sulphur, was used in two orchards with a view to comparing it with lime-sulfur for its fungicidal efficiency and its toxicity to the sprayed tree. Enough of this material to make 100 gallons costs more than three times as much as the liquid lime-sulfur necessary to make an equal amount. Atomic Sulphur, therefore, needs to show very decided advantages over lime-sulfur if it is to compete with it in the spraying of apples.

There was this year no injury to fruit or foliage on trees sprayed with lime-sulfur or with Atomic Sulphur. It was, therefore, impossible to compare them as regards toxicity to the sprayed tree.

Mason (16) found that when apple trees were sprayed with a combination Atomic Sulphur-lime-lead arsenate spray, the foliage was uninjured, while under the same climatic conditions, foliage and fruit were burned by the lime-sulfur-lead arsenate combination.

Atomic Sulphur was used by the writer at the rate of 7 pounds to 50 gallons of water, and when it was used in combination with arsenate of lead, 4 pounds of lime slaked into a milk were added to each 50 gallons, as directed by the manufacturers. At one of the orchards, the results were as follows: Atomic Sulphur, 4.2 per cent scabby fruit; liquid lime-sulfur 2.1 per cent scabby fruit; dry lime-sulfur 4–50, 1.03 per cent scabby fruit. At this orchard, the control secured by Atomic Sulphur was somewhat surpassed by both dry lime-sulfur and liquid lime-sulfur. At the other orchard, the percentages of scabby fruit were as follows: Atomic Sulphur, 3.9 per cent; dry lime-sulfur 3–50, 4.6 per cent. At this orchard also, the results with the two materials are very nearly alike.

If Atomic Sulphur has any advantages over lime-sulfur, they are not to be found in relative efficiency in scab control, but rather in degrees of difference in toxicity to the sprayed plant. Apple orchards in which peaches are planted as fillers are sometimes sprayed with Atomic Sulphur because of the known danger to peaches in leaf from the use of commercial lime-sulfur. When this is done, we may be sure that the apples have received treatment with a fungicide which can protect them against scab infection.

Compatibility of the Ingredients in the Combination Spray as Affected by Addition of Lime, Calcium Caseinate, and Order of Mixing.

Apples are not often sprayed with lime-sulfur alone. They are now more often sprayed with a mixture of lime-sulfur, lead arsenate, nicotine sulfate, and calcium caseinate. The reaction between lead arsenate and lime-sulfur has been studied by Ruth (17) and others, and it is known that both of these materials are somewhat decomposed, one of the results being the formation of the black sludge, lead sulfide. Relative blackness of the mixture is an indicator of its lack of desirable qualities. So far as is known, the addition of nicotine sulfate does not affect this reaction. It has been shown by numerous investigators that the addition of arsenate of lead to lime-sulfur increased the fungicidal value of the latter. Although the use of such a combination spray controls apple scab as well or probably better than lime-sulfur alone, the formation of soluble arsenic as a result of the reaction increases the danger of foliage burning.

It has been found by Robinson (18) that by the addition of lime to this combination spray, the percentage of the soluble, and therefore dangerous, arsenic in the combination spray can be reduced. After standing two days, most of the lime-sulfur with lime added remained unchanged, while in lime-sulfur alone, the desirable polysulfide sulfur had all been changed into lead sulfide or thiosulfate. Bourne (19) modified Robinson's method by adding milk-of-lime to lead arsenate and then adding the two together to diluted lime-sulfur. He found this resulted in very little sediment or blackening. He diluted lime-sulfur till the spray tank was nearly full. Lime (at the rate of 10 pounds to 100 gallons of the total mixture) was slaked and water added to make a milk. Arsenate of lead was stirred into the milk-of-lime, which was then strained into the spray tank with the agitator running. Krout (2) compared liquid lime-sulfur with liquid lime-sulfur plus lime in the field. In each of the three orchards where he used it, there was no russeting of the fruit by either lime-sulfur alone, or lime-sulfur with lime added, and so the benefit of the addition of lime in reducing burning was not shown. In each of the three orchards sprayed by Krout, the addition of lime to lime-sulfur was followed by an increase in the percentage of scabby fruit over the percentage on trees sprayed with lime-sulfur without lime, the increases being 10, 3, and 8 per cent, respectively.

In the experiments of 1923, there was no russeting or burning on trees sprayed with lime-sulfur or on those sprayed with lime-sulfur plus lime. Hence in 1923, as in 1922, it was impossible to prove that the addition of lime to lime-sulfur reduced the toxicity of the fungicide to the sprayed tree. In both of the orchards where these materials were compared in 1923, a larger percentage of scabby apples was produced on trees sprayed with lime-sulfur plus lime than on trees sprayed with lime-sulfur without lime added, the increase being 1.2 per cent in one case and 5.3 per cent in the other. The indications are that the addition of lime to the lime-sulfur-lead arsenate combination spray reduces somewhat the fungicidal efficiency of the latter. In seasons when climatic conditions result in toxicity to the sprayed tree by the lime-sulfur-lead arsenate combination spray, it is possible that any small decrease in fungicidal efficiency coincident with the addition of lime would be more than offset by the decreased danger of burning described by Robinson (loc. cit.) and Bourne (loc. cit.). However, further experimental evidence is needed.

According to Regan (20) the addition of calcium caseinate spreader to lime-sulfur-lead arsenate combination spray prevents the usual decomposition and formation of black sludge. He found two pounds of calcium caseinate to be more effective in preventing this decomposition than ten pounds of hydrated lime. Lovett (21) also reports that the addition of calcium caseinate materially delays the reaction between lime-sulfur and lead arsenate in the combination spray.

Laboratory tests were made by the writer to compare the formation of black sludge in the combination spray with and without the addition of calcium caseinate. Without calcium caseinate, the color of the mixture was dark citrine[1] and with it the color was yellowish citrine, that is, considerably lighter. After standing three minutes the sludge precipitated without calcium caseinate was nearly twice

[1] Colors determined by comparison with Ridgway, Robert. Color Standards and Nomenclature. Washington, 1912.

as much as the sludge in the mixture containing calcium caseinate. Apparently the addition of calcium caseinate physically improves the mixture.

In filling the spray tank, five ingredients are or may be used, *i.e.*, water, lime-sulfur, lead arsenate, nicotine sulfate and calcium caseinate. After the water is in the tank, there are twenty-four different orders in which the other ingredients may be added. The manufacturers of calcium caseinate recommend that it be added to the water in the spray tank, with the agitator running, before the other materials are added. According to Anderson and Roth (22) the lime-sulfur is first diluted, the lead arsenate added to it with agitation, and then the nicotine sulfate added. After putting the calcium caseinate in the water in the spray tank, this is probably the order most commonly followed. Britton (23) recommends the following order for filling the spray tank: first, clean water; second, nicotine sulfate; third, calcium caseinate (if used); fourth, lead arsenate; and fifth and last, lime-sulfur. He says that when mixed in this order, especially if calcium caseinate is present, little or no discoloration or precipitation of brown sludge follows.

In laboratory tests made by the writer, the ingredients were mixed in the order named by Britton; the resulting mixture was buffy olive in color, with little precipitation. In another test they were mixed in the following order: water, calcium caseinate, lime-sulfur, lead arsenate, and nicotine sulfate. The color of this mixture was ivy green, considerably darker, with more precipitation. Several other orders of mixing were compared and the best results, based on a color test and relative sludge formation, were obtained by the following sequence after the water: first, calcium caseinate; second, nicotine sulfate; third, lead arsenate; and fourth, lime-sulfur.

Spore germination tests made with the conidia of the apple scab fungus showed that the fungicidal efficiency of the combination spray is not impaired by any order of mixing tested. But the order of mixing does affect the physical qualities of the mixture and very probably the burning of the sprayed tree. It should be added that when light colored lime-sulfur combination spray is desired, special attention should be given to washing out the spray tank. The use of calcium caseinate results in a decidedly lighter colored mixture.

Results of Dusting Treatments.

A rather extensive literature on the results of dusting for the control of apple scab has come into existence. The results do not all agree, but perhaps they are no more inconsistent than the published results of spraying experiments. In general, the control of apple scab by the use of dusts has been surpassed by that of liquid sprays. This is not surprising when we consider that spraying is a much older orchard practice than is dusting. Our knowledge of the use of liquid sprays and the schedule for their application to the apple is relatively advanced. Dusts have been used in conformity with the spray schedule, rather than according to any special dusting schedule.

It should be noted that no experiments have been conducted in Massachusetts which directly compare the results of spraying with those of dusting. Owing to the topography and plan of the several orchards, spraying and dusting experiments have been carried on in separate orchards or in separate parts of the same orchard with one check plot for the spray treatment and another for the dust treatment.

In the orchards dusted by Krout (2) in 1922 the average percentage of scabby fruit in the check plots was 75.8 and the average percentage of scabby fruit in the plots dusted with sulfur was 17.2. In the orchards sprayed by Krout, the average percentage of scabby fruit in the check plots was 79.0 and the average percentage of scabby fruit in the plots sprayed with dry lime-sulfur 4–50 was 8.0. It is evident that the dust did not give a control equal to that of the spray. The results of Massey and Fitch (8) were: in one orchard, check 93.3 per cent scab, and sulfur dust 13.5 per cent scab; in another orchard, check 43.5 per cent scab and sulfur dust 3.1 per cent scab. In an orchard dusted by Parrott, Stewart, and Glasgow (13), the results were 83.9 per cent scab in the check, and 47.8 per cent scab in the plot dusted with sulfur. Results from other years and other states could be selected either in favor of or against dusting.

In 1923, the dusting experiments here reported were conducted in three orchards. At the Stowe and the Sabine orchards, the dusting schedule consisted of five applications, *i.e.*, prepink, pink, calyx, fourth dust and fifth dust. At the Frost orchard, the trees were dusted four times, no prepink application being used.

In the Stowe orchard, where check trees yielded 37 per cent scabby fruit, trees dusted with sulfur yielded 3.7 per cent scabby fruit. At the Sabine orchard, trees dusted with sulfur bore 0.5 per cent scabby fruit, and on the check trees 48 per cent of the fruit was scabby. At the Frost orchard, where no prepink application was used, trees dusted with sulfur yielded 16.9 per cent scabby fruit, as compared with 84.5 per cent scabby fruit in the check. Sulfur dust controlled apple scab satisfactorily when applications began with the prepink, but not when the prepink application was omitted.

Calcium caseinate was thoroughly mixed with sulfur at the rate of 5 pounds of calcium caseinate to 95 pounds of sulfur. This sulfur-calcium caseinate dust was used in three orchards in plots adjoining plots dusted with sulfur only. In every case, apple scab was controlled better by sulfur alone than by sulfur with calcium caseinate added.

Plots were also dusted according to a schedule which included the use of a copper dust for the prepink and pink, or the pink applications followed by sulfur dust for later applications. At two of the orchards, there was less scab following the use of sulfur throughout the season than when copper dust was substituted for sulfur for the applications before the flower buds opened. At the other orchard, there was only a negligible difference between the amounts of scab following the two different methods of treatment. No experimental evidence was secured to indicate an advantage in using copper dust instead of sulfur dust for the early applications.

Control of Primary Infection on Leaves.

As the season advances, the work of the fungicide and the conditions under which it acts become entirely different from what they were at the first of the spraying season. There is naturally and usually an increase in the mean temperature. At the time of the early applications, all infection is from the winter spores. As soon as scab lesions appear on the young leaves, there is an increasing possibility of infection by the summer spores. In some springs, the trees are for a few days, or even a few weeks, in danger of infection from both the winter and summer spores at the same time. In the absence of sufficient moisture the ejection of the winter spores may be prolonged until after the appearance of scab on the leaves.

In 1923, ejection of winter spores from the dead leaves beneath the trees was first observed on May 2. Spore ejection continued till June 16, after which none was observed. The first scab symptoms were found on the leaves May 22. It is evident from this that the first winter spores to be ejected did not infect the trees, for the incubation period with these spores of the apple scab fungus was found by Wallace (4) to be eight to fifteen days. During the period in which winter spore ejection continued, there was rain on ten days. Whenever the leaves were wet by rain, winter spore ejection was stimulated, but it was fully as abundant on certain days when the leaves were wet with heavy dew. Winter spores were not ejected in relatively great numbers at any time the last spring. Wallace (loc. cit.) reports that in order for winter spores to infect the trees, the trees must remain wet 8 to 10 hours. Such was the condition on May 12 and 21 and on June 8, and it is probable that much of the primary infection took place on these dates.

In order to secure more information on the relative fungicidal efficiency of the several treatments, the percentages of infected leaves on trees June 18 were determined. In the Frost sprayed orchard, there were at this time 39 per cent scabby leaves on the check trees, and from 0.1 to 0.3 per cent scabby leaves on the sprayed trees, with only negligible differences between the several spray treatments. All the spray treatments were practically successful in preventing the primary infection. The results were essentially the same in both of the Knights orchards, where there were 15 and 20 per cent scabby leaves on unsprayed trees, and 0.1 to 0.2 per cent scabby leaves on sprayed plots, again with negligible differences between the different spray treatments.

Upon examining the dusted orchards, it was found that the primary infection had not been as satisfactorily prevented. In one orchard where the dust treatments began with a prepink application, the check trees had 41 per cent scabby leaves, and the dusted trees had 8 to 9 per cent scabby leaves, with only minor differences between the different dust treatments. In another orchard dusted in the same way, there were 15 per cent scabby leaves on the check trees and 3 to 4 per cent scabby leaves on the dusted trees. In the third orchard, where no prepink application was used, there were at this time 53 per cent scabby leaves on the check and 21 to 24 per cent scabby leaves on the dusted trees. This indicates the necessity of a prepink application if dust is to control the primary infection. But even where both prepink and pink applications of dust were made, relatively more primary infection occurred than in the sprayed orchards. As is explained elsewhere, the dust treatments in the orchards where dusting began with a prepink application, were entirely satisfactory in preventing the further spread of scab, that is, in preventing infection later in the season by the summer spores. It would appear that if dust is equally as efficient as liquid spraying in controlling the spread of scab during the summer, it is less efficient in preventing the primary infection in early spring. If such is the case, then for those who own both duster and sprayer, a safer procedure would be to use the sprayer for the pink application and the duster for later ones. It should not be overlooked, however, that dust satisfactorily controlled scab on the fruit when the dusting schedule included both a prepink and pink application.

Effect of Fungicides on the Tree.

The literature contains references to increased dropping of the fruit following the use of lime-sulfur. There was this year in the experimental orchards no more dropping of the fruit following any of the several treatments than that which occurred on the check trees.

There was only a negligible amount of injury to fruit or foliage on any of the sprayed or dusted plots. The trees used are McIntosh. Although burning was absent in the experimental plots, it was seen on the fruit of Baldwins following the application of sulfur dust. Childs (3) and others report that sulfur dust may cause an injury to apple fruit similar to that of lime-sulfur solution. The relation of sulfur dust burning to temperature in the case of varieties susceptible to burning needs to be further considered. As has been pointed out by Safro (24) some cases of injury attributed to lime-sulfur are primarily cases of sunburn, and the same is probably true of injury by sulfur dust. The absence of spray injury from all plots made it impossible to learn to what extent the addition of lime to lime-sulfur decreases burning, and how the latter fungicide compares with Atomic Sulphur in this respect on the apple.

Relation of Temperature of the Season to the Fungicidal Efficiency of Sulfur.

We have as yet no data on the temperature necessary for sulfur to prevent the germination of the winter spores of the apple scab fungus. Doran (25) has shown that sulfur prevents the germination of the summer spores of this fungus when the temperature is 78.8° F. for five hours. If the temperature is higher, less time is necessary and if the temperature is lower, more time is necessary. This temperature or above it was recorded in the experimental orchards on fifty days between May 7 and August 31. As the results show, the temperature conditions of the season were such as to insure the fungicidal action of sulfur, and so prevent the germination of the conidia.

If there had been fewer days during this period when the temperature reached the necessary point, it is probable that the results with Bordeaux mixture and copper dust as compared with sulfur fungicides would have appeared relatively better than proved to be the case.

Summary.

A spray schedule beginning with the pink application controlled apple scab as well as a schedule beginning with the prepink application.

Sulfur dust controlled apple scab satisfactorily when it was applied five times beginning with the prepink application, but not when it was applied four times beginning with the pink application.

Liquid lime-sulfur 1–50 and dry lime-sulfur 4–50 proved of equal fungicidal efficiency for scab control.

Less than 4 pounds of dry lime-sulfur in 50 gallons did not on the whole control scab quite as well as dry lime-sulfur 4–50.

The addition of calcium caseinate spreader to the liquid spray was followed by a very slight decrease in the percentage of scabby fruit.

The addition of calcium caseinate spreader to sulfur dust did not result in a smaller percentage of scabby fruit than when sulfur dust was used alone.

Since there was no injury to the sprayed tree by lime-sulfur lead arsenate combination spray, it could not be proved that the addition of lime to this spray decreased its toxicity to the sprayed tree.

As good a control of apple scab was secured by the use of lime-sulfur throughout the spraying season as by substituting Bordeaux mixture for lime-sulfur for the applications before the flower buds opened.

Atomic Sulphur controlled the disease as well as did lime-sulfur. Because of the absence of burning it was impossible to determine how they compare in their effect on the sprayed tree.

Sulfur dust throughout the dusting season controlled apple scab as satisfactorily as when copper dust was substituted for sulfur dust for the applications before the flower buds opened.

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APPENDIX.

TABLE I. — *Showing Treatment of Dusted Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit.*

Orchard.	Plot No.	Prepink.		Pink.		Calyx.		Fourth (or Third) Summer.		Latest Summer.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
Stowe	1	Copper-lime-arsenic-dust	May 5	Copper-lime-arsenic-dust	May 10	Sulfur dust	May 21	Sulfur dust	June 11	Sulfur dust	July 18	2.9
	2	Sulfur dust	5	Sulfur dust	10	Sulfur dust	21	Sulfur dust	11	Sulfur dust	18	3.7
	3	Check (no treatment)										37.0
	4	Sulfur dust plus calcium caseinate	5	Sulfur dust plus calcium caseinate	10	Sulfur dust plus calcium caseinate	21	Sulfur dust plus calcium caseinate	11	Sulfur dust plus calcium caseinate	18	3.9
Frost	1	Check (no treatment)										84.5
	2			Sulfur dust	8	Sulfur dust	22	Sulfur dust	13	Sulfur dust	19	16.9
	3			Sulfur dust plus calcium caseinate	8	Sulfur dust plus calcium caseinate	22	Sulfur dust plus calcium caseinate	13	Sulfur dust plus calcium caseinate	19	30.7
	4			Copper-lime-arsenic dust	8	Sulfur dust	22	Sulfur dust	13	Sulfur dust	19	17.6
Sabine	1	Check (no treatment)										48.0
	2	Copper-lime-arsenic dust	4	Copper-lime-arsenic dust	9	Sulfur dust	24	Sulfur dust	12	Sulfur dust	17	4.8
	3	Sulfur dust	4	Sulfur dust	9	Sulfur dust	24	Sulfur dust	12	Sulfur dust	17	0.5
	4	Sulfur dust plus calcium caseinate	4	Sulfur dust plus calcium caseinate	9	Sulfur dust plus calcium caseinate	24	Sulfur dust plus calcium caseinate	12	Sulfur dust plus calcium caseinate	17	0.7

TABLE II. — *Showing Treatments of Sprayed Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit.*

ORCHARD.	Plot No.	PREPINK.		PINK.		CALYX.		LATEST SUMMER.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
	1		May	Dry lime-sulfur 3-50 plus calcium caseinate	May 7	Dry lime-sulfur 3-50 plus calcium caseinate	May 24	Dry lime-sulfur 3-50 plus calcium caseinate	June 13	5.08
	2			Dry lime-sulfur 3-50	7	Dry lime-sulfur 3-50	24	Dry lime-sulfur 3-50	13	7.06
	3			Dry lime-sulfur 4-50	7	Dry lime-sulfur 4-50	24	Dry lime-sulfur 4-50	13	1.03
	4			Dry lime-sulfur 2-50	7	Dry lime-sulfur 2-50	24	Dry lime-sulfur 2-50	13	5.07
	5	Dry lime-sulfur 3-50	3	Dry lime-sulfur 3-50	7	Dry lime-sulfur 3-50	24	Dry lime-sulfur 3-50	13	1.2
Frost	6	Check (no treatment)								76.0
	7	Bordeaux mixture	3	Bordeaux mixture	7	Liquid lime-sulfur	24	Liquid lime-sulfur	13	0.6
	8			Bordeaux mixture	7	Liquid lime-sulfur	24	Liquid lime-sulfur	13	1.7
	9			Liquid lime-sulfur	7	Liquid lime-sulfur	24	Liquud lime-sulfur	13	2.1
	10			Liquid lime-sulfur plus lime	7	Liquid lime-sulfur plus lime	24	Liquid lime-sulfur plus lime	13	3.3
	11			Atomic Sulphur	7	Atomic Sulphur	24	Atomic Sulphur	13	4.2

TABLE II.—*Showing Treatments of Sprayed Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit*—Concluded.

Orchard.	Plot No.	Prepink.		Pink.		Calyx.		Latest. Summer.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
Knights (A)	1	Bordeaux mixture	May 3	Bordeaux mixture	May 8	Liquid lime-sulfur	May 23	Liquid lime-sulfur	June 14	4.9
	2			Bordeaux mixture	8	Dry lime-sulfur 4-50	23	Dry lime-sulfur 4-50	14	1.06
	3			Liquid lime-sulfur plus lime	8	Liquid lime-sulfur plus lime	23	Liquid lime-sulfur plus lime	14	8.6
	4			Liquid lime-sulfur	8	Liquid lime-sulfur	23	Liquid lime-sulfur	14	3.3
	5	Check (no treat-ment)								45.5
	6	Dry lime-sulfur 3-50	3	Dry lime-sulfur 3-50	8	Dry lime-sulfur 3-50	23	Dry lime-sulfur 3-50	14	4.8
	7			Dry lime-sulfur 4-50	8	Dry lime-sulfur 4-50	23	Dry lime-sulfur 4-50	14	1.7
Knights (B)	1			Dry lime-sulfur 2-50	8	Dry lime-sulfur 2-50	23	Dry lime-sulfur 2-50	14	2.7
	2			Dry lime-sulfur 3-50 plus calcium caseinate	8	Dry lime-sulfur 3-50 plus calcium caseinate	23	Dry lime-sulfur 3-50 plus calcium caseinate	14	0.68
	3			Dry lime-sulfur 3-50	8	Dry lime-sulfur 3-50	23	Dry lime-sulfur 3-50	14	4.6
	4			Atomic Sulphur	8	Atomic Sulphur	23	Atomic Sulphur	14	3.9
	5	Check (no treat-ment)								59.3

TABLE III. — *Results of Three Years' Apple Spraying Experiments.*

Treatment.[1]	Per Cent Scabby Fruit —			
	1923.	1922.	1921.	Average.
Check	58.3	77.0	91.0	75.4
Liquid lime-sulfur	2.7	6.6	8.6	6.1
Liquid lime-sulfur plus lime	5.9	13.6	12.0	10.3
Dry lime-sulfur 4-50	1.3	8.0	6.0	5.1
Dry lime-sulfur 4-50 beginning with prepink	–[2]	0.0	–	0.0
Dry lime-sulfur 3-50	5.8	4.0	–	4.9
Dry lime-sulfur 3-50 beginning with prepink	3.0	–	–	3.0
Dry lime-sulfur 2-50	3.9	–	–	3.9
Dry lime-sulfur 3-50 plus calcium caseinate spreader	2.9	–	–	2.9
Atomic Sulphur	4.0	–	–	4.0
Bordeaux mixture at pink application followed by dry lime-sulfur 4-50	1.0	18.3	–	9.6
Bordeaux mixture at pink application followed by liquid lime-sulfur	1.7	6.0	6.0	4.5
Bordeaux mixture for prepink and pink applications followed by liquid lime-sulfur	2.7	7.0	–	4.8
Bordeaux mixture through season	–	8.6	–	8.6
Sulfur dust beginning with prepink application	2.1	17.2	–	9.6
Sulfur dust beginning with pink application	16.9	–	46.0	31.4
Sulfur dust plus calcium caseinate beginning with prepink application	2.3	–	–	2.3
Sulfur dust plus calcium caseinate beginning with pink application	30.7	–	–	30.7
Copper dust for prepink and pink applications followed by sulfur dust	3.8	–	–	3.8
Copper dust for pink application followed by sulfur dust	17.6	–	–	17.6
Copper dust through season	–	10.2	69.0	39.6

[1] Applications begin with pink unless stated as beginning with prepink.
[2] Blanks in table indicate that the treatment was not given in that year.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 220 NOVEMBER, 1924

CORRELATION STUDIES ON WINTER FECUNDITY

By F. A. HAYS, RUBY SANBORN and L. L. JAMES

In plant and animal breeding it is impossible to make or effect changes in one character without running the risk of profoundly modifying, sometimes unfavorably, other characters. Such is the common experience of poultry breeders, abundantly confirmed by scientific investigation. For this reason it is essential that the relation existing between the major character in which improvement is sought, and other characters with which it may be associated, be established. In this report the results of such a study in poultry breeding are presented. The bulletin is technical in its nature, and is addressed primarily to those poultry breeders who are attempting to make thorough study of the science on which their art is based.

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AGRICULTURAL EXPERIMENTAL STATION

AMHERST, MASS.

CORRELATION STUDIES ON WINTER FECUNDITY

By F. A. Hays, Ruby Sanborn and L. L. James

High winter egg production is very desirable from the poultry keeper's point of view for two reasons: first, prices for eggs are much more remunerative during the winter months than at any other season; second, winter egg yield is intimately correlated with annual egg yield (Hervey 1923).

The number of eggs that a pullet will lay from first egg to March first depends upon seven pairs of Mendelian factors as has been shown by Hays (1924). This being the case, winter egg production cannot be correctly considered as a simple physiological character but rather as the manifestation of the interaction of the characters of a complex. Such traits as sexual maturity, winter pause, intensity, and broodiness have a definite and measurable relation to the number of winter eggs when large numbers are considered. Each of these four major traits affecting winter fecundity is unquestionably subjected to and modified by varying conditions that we may call "environmental" for lack of a more specific term.

In the studies reported below an attempt has been made to measure by means of the coefficient of correlation the degree of association of some measureable variables with winter egg yield. The chief value of such a study lies in the fact that, knowing the relative importance of the variables considered in relation to winter production, the breeder should be able by controlling major variables such as age at first egg, hatching date, rate of growth, etc., to attain higher winter averages and to secure greater uniformity in the winter fecundity of his flock. For example, if the flock is mated in such a way as to secure only genetically early maturing pullets, the age at first egg will range from about 150 to 210 days, while in a flock such as ours that is not genetically pure for early maturity the age at first egg ranges from 150 to 300 days.

Data Available.

A total of 959 Rhode Island Red Pullets hatched in eleven weekly broods from March 25 to June 3, 1923 are studied. This flock includes rather heterogenious breeding when winter fecundity is considered. Included in this flock are birds bred for the following characteristics: high winter and annual fecundity, non-broodiness and broodiness, good color, inbred and outbred, and hatching power of eggs. Taken as a whole, this flock may be considered good, but not equal to the standards set by those birds bred for fecundity alone. The mean of 803 birds that have complete winter records is 45 eggs.

Coefficient of Correlation

Coefficient of correlation is here used as a measure of association or dependence of one trait upon another. For example, in a particular flock of pullets if the degree of correlation between age at first egg and winter egg record is −.64, such a constant indicates that large winter records depend on early maturity in 64 birds out of every hundred, and that sexual maturity is one very important factor in determining the winter record of such pullets. A + sign before the coefficient .64 would mean that late sexual maturity is associated with large winter egg records. Other factors, such as hatching date, 150-day weight, weight at first egg, daily gain in weight, etc., may be measured in a similar manner. A comparison of the coefficients of correlation for these different factors furnishes a measure of their relative importance. Selection based on the coefficient of correlation should be applied to flocks rather than to individual birds as is evident in tables 1 and 2.

The word *mean* has the same meaning as average. *Standard deviation* shows the range of variation of a group of individuals above or below the mean or average. If the mean hatching date is 6.68 and its standard deviation is ±2.95, the interpretation is that the average range in hatching date of the flock in question is from 3.75 (6.68 − 2.95 = 3.75) to 9.63 (6.68 + 2.95). The *probable error* is written with a ± sign after each coefficient of correlation. It is used as a measure of the reliability of the figure given. Thus the degree of correlation between hatching date and weight at 150 days is −.3293 ± .0194. The meaning is that if we add .0194 to the coefficient of correlation and also subtract .0194 from the coefficient of correlation, we obtain two figures, namely, .3099 and .3487. The chances are even that the true coefficient of correlation between hatching date and 150-day weight lies inside or outside of these limits. A coefficient of correlation at least three times as large as its probable error is considered as significant.

Hatching Date

Part of the data is presented below in tabular form to show the general relation of hatching date to weight at 150 days, weight at first egg, age at first egg, and winter production, together with the average number of birds concerned in all four cases. This table will be particularly useful for general reference.

Table 1.

Hatches	Avg. No. of Birds	Wt. at 150 Days—lbs.	Wt. at First Egg—lbs.	Age at First Egg—Days	Winter Egg Prod.
March 25 (1)	41	4.22	5.73	212	58
April 1 (2)	55	4.27	5.75	211	56
April 8 (3)	61	4.23	5.94	212	57
April 15 (4)	76	4.11	5.92	221	46
April 22 (5)	69	4.18	5.94	215	48
April 29 (6)	80	3.99	5.69	217	47
May 6 (7)	105	3.89	5.62	219	39
May 13 (8)	83	4.05	5.50	208	42
May 20 (9)	113	3.72	5.22	206	41
May 27 (10)	91	3.74	5.15	202	38
June 3 (11)	82	3.72	5.13	201	34

The 150-day weight is observed to decrease rather regularly as the date of hatching advances. This fact substantiates common observation that early hatching seems to be associated with rapid growth. The weight at first egg for the different hatches shows little consistency, but as a rule, the earlier hatched birds appear to be somewhat heavier than the late hatched. The inconsistency is no doubt due in large measure to the wide range in age at first egg. Age at first egg seems to be but little dependent upon hatching date. In the last three or four hatches, however, there appears to be a reduction in the average age at first egg. Hatching date is intimately associated with winter production. In other words, the early broods as a rule lay more winter eggs than later broods. In general, hatching date appears to influence the weight at 150 days and the winter production with probably some influence upon weight at first egg and age at first egg.

As already stated, the pullets were hatched at one week intervals beginning March 25 and ending June 3. Thus eleven different age groups are represented with a range in age of 70 days. Hatching date is studied in relation to weight at 150 days, weight at first egg, age at first egg, and winter production:

Hatching Date versus Weight at 150 Days

Number of birds	959
Mean hatching date	6.68
Hatching date standard deviation	±2.95
Mean 150-day weight	3.96
150-day weight standard deviation	±.56
Coefficient of correlation	−.3293±.0194

The fact will be noted that the mean hatching date is 6.68 (May 4) instead of 6.00 (April 29) as would be the case if each hatch had produced the same number of birds. The actual date may be calculated easily in each case. It is interesting to note that the pullets averaged 3.96 pounds at 150 days old.

The coefficient of correlation between hatching date and 150-day weight is −.3293±.0194. This is a significant correlation and substantiates common observation that early hatching tends to give larger pullets at a given age than does late hatching. In about one case out of three there was direct association between early hatching and heavy weight. In the other two cases out of three there was no relation between 150-day weight and hatching date. Other influences were operating in two cases out of three to overcome any effect of hatching date on weight at 150 days.

Hatching Date versus Weight at First Egg.

Number of birds	820
Mean hatching date	6.66
Hatching date standard deviation	±2.92
Mean weight at first egg	5.65
Weight at first egg standard deviation	± .75
Coefficient of correlation	−.3807±.0201

The mean weight at first egg is 5.65 pounds. The coefficient of correlation between hatching date and weight at first egg is −.3807±.0201. The correlation shows that early hatched pullets tend to be heavier when they lay their first egg than do their later hatched sisters. This fact is in accord with the observations on weight at 150 days. In four cases out of ten the weight at first egg is directly associated with hatching date. Possibly the degree of correlation between time of hatching and weight at first egg is greater than that between time of hatching and 150-day weight because late hatching tends to reduce the mean age at first egg as will be shown below.

Hatching Date versus Age at First Egg.

Number of birds	840
Mean hatching date	6.64
Hatching date standard deviation	±2.92
Mean age at first egg	210.99 days
Age at first egg standard deviation	±28.91
Coefficient of correlation	−.1487±.0228

The mean age at first egg is 210.99 days and its standard deviation is 28.91. Thus the age range is wide as will be observed from the relative magnitude of standard deviation and mean.

The coefficient of correlation is negative and amounts to .1487±.0228. Thus in one case out of seven late hatching is associated with early sexual maturity. Such a constant suggests that late hatching tends to reduce the length of growth period prior to laying and this is in part responsible for the lighter weight at first egg in late pullets compared with early ones as was pointed out in the previous section.

Hatching Date versus Winter Production.

Number of birds	802
Mean hatching date	6.59
Hatching date standard deviation	±2.97
Mean winter production	44.48
Winter production standard deviation	±23.06
Coefficient of correlation	−.2920±.0218

The mean egg production of the 802 birds studied up to March first is 44.48. The magnitude of the standard deviation shows a wide range in winter fecundity within the flock. This wide range in fecundity is to be expected because of the range in hatching date and because of the range in age at first egg as well as because of genetic differences in the individuals in winter pause, intensity, and broodiness.

A negative coefficient of correlation amounting to .2920±.0218 exists between hatching date and winter production. All other conditions being the *same*, there could not but be a negative correlation because the early hatched pullets have longer to lay. The fact that in less than one case out of three is early hatching directly associated with greater winter egg yield can be due only to the condition that a good percentage of early hatched pullets complete their winter cycle of laying and lose considerable time in winter pause while fewer later hatched pullets actually pause.

By reducing the range in age at first egg, a more accurate measure of the degree of association between early hatching and high winter egg production is obtained. The coefficient of correlation has been calculated between hatching date and winter egg record using only those birds beginning to lay at 206 days or less. The constants obtained on this group are as follows:

Number of birds	418
Mean hatching date	6.96
Hatching date standard deviation	±3.19
Mean winter production	54.93
Winter production standard deviation	±21.06
Coefficient of correlation	−.4790±.0254

In the above group of birds the 70 day range in hatching date is greater than the 50 day range in age at first egg. In other words, all birds maturing at 206 days or less are the same genetically for sexual maturity as was pointed out earlier (Hays 1924). With such a group of birds high winter fecundity is associated with early hatching in fifty per cent of the cases.

Evaluating hatching date entirely from the standpoint of desirable characteristics that are associated with winter fecundity, these deductions seem warranted from the preceding four correlation studies: 1. That early hatched pullets are heavier in weight both at 150 days old and when they lay their first egg than are late hatched ones; 2. that late hatching tends to reduce the age at first egg; and 3. that early hatching gives greater winter egg yields, but there must be a certain optimum hatching time which gives the most uninterrupted winter egg production.

Winter Production.

The total number of birds is divided into classes of winter producers with a range of ten eggs beginning with those laying from 0 to 9 eggs and ending with those laying from 130 to 139 eggs during the winter season. Winter production is studied in its general relation to hatching date, age at first egg, weight at 150 days, weight at first egg, and daily gain in weight between 150 days old and age at first egg.

Table II

Winter Egg Production	Avg. No. of Birds	Hatching Date	Age at 1st Egg	Wt. at 150 Days—lbs.	Wt. at 1st Egg—lbs.	Daily Gain Between 150 Days Old and Age at 1st Egg—lbs.
0–9 (1)	36	7.32(M.8)	266	3.65	5.95	.021
10–19 (2)	78	6.94(M.5)	244	3.87	5.97	.024
20–29 (3)	112	7.32(M.8)	219	3.92	5.68	.025
30–39 (4)	134	7.32(M.8)	212	3.89	5.52	.027
40–49 (5)	110	7.05(M.6)	205	3.92	5.37	.026
50–59 (6)	124	6.71(M.4)	203	4.05	5.47	.027
60–69 (7)	93	5.97(A.29)	196	4.16	5.46	.029
70–79 (8)	57	5.14(A.23)	193	4.17	5.46	.029
80–89 (9)	26	4.07(A.15)	189	4.27	5.51	.032
90–99 (10)	11	4.00(A.15)	177	4.67	5.61	.040
100–109 (11)	9	2.78(A.6)	179	4.37	5.30	.029
110–119 (12)	4	2.25(A.3)	182	4.19	5.25	.032
120–129 (13)	1	5.00(A.22)	165	4.57	5.75	.057
130–139 (14)	1	2.00(A.1)	165	4.27	4.75	.032

Some degree of association exists between low production and late hatching but there is lack of consistency. A striking and consistent degree of relationship is seen in table 2 between winter egg record and age at first egg. Winter egg record and 150-day weight also show considerable dependence. There is some evidence that the low producers are heavier at first egg than the high producers. The average daily gain in weight increases as we advance down the table to the heavy winter layers. The general deduction seems warranted from table 2 that low winter egg records depend in part upon late hatching, too great an age at first egg, light 150-day weight, and slow rate of gain in body weight between 150 days old and age at first egg. In order to determine specifically how important these various relations are it is necessary to resort to the coefficient of correlation.

Age at First Egg versus Winter Production.

The degree of correlation between age at first egg and annual production in Rhode Island Reds for a period of years was found to be $-.4380 \pm .0134$ (Hays and Bennett 1923). The fact that winter egg yield is definitely ended March first while annual egg record does not terminate until 364 days after a pullet lays her first egg makes the correlation more intimate between age at first egg and winter record than between age and annual production.

The correlation coefficient between age at first egg and winter production has been calculated on 803 pullets hatched in 1923 without regard to the difference in hatching date. Constants calculated from this study follow:

Number of birds	803
Mean age at first egg	210.96
Age at first egg standard deviation	± 28.62
Mean winter production	44.46
Winter production standard deviation	± 23.04
Coefficient of correlation	$-.6061 \pm .0151$

Mean age at first egg is 210.96 days. Standard deviation of age is 28.62 which exhibits the wide range in age at first egg. The mean winter production is 44.46 eggs with a standard deviation of 23.04. Again winter fecundity shows its extreme variability as would any trait dependent upon so many hereditary factors and environmental influences.

A significant negative coefficient of correlation of $.6061 \pm .0151$ appears. Thus in six cases out of ten in these pullets hatched over a period of seventy days, there is definite association between early age at first egg and high winter egg record. In other words, the length of time that a pullet has opportunity to lay previous to March first should be given very weighty consideration in breeding for winter fecundity.

To secure an exact figure on the degree of correlation between age at first egg and winter fecundity it would be necessary to make hatching date constant by studying only those pullets hatched at the same date. Such a study, we believe, would reduce the number of individuals to such an extent that the mathematical error of calculation would be inordinately large. Below are presented the constants calculated on the 154 birds in the first three hatches. The hatching date range is thus reduced to fourteen days. Constants are as follows:

Number of birds	154
Mean age at first egg	211.58
Age at first egg standard deviation	± 39.80
Mean winter production	56.90
Winter production standard deviation	± 27.61
Coefficient of correlation	$-.6413 \pm .0320$

When the range in hatching date is reduced from 70 days to 14 days the coefficient of correlation between age at first egg and winter production increases from $-.6061 \pm .0151$ to $-.6413 \pm .0320$. This fact clearly proves that hatching date is of far less importance from the winter fecundity standpoint than is age at first egg. There are two possible reasons for this: first, early sexual maturity is associated with high winter fecundity to a greater extent than merely the time element; second, late hatching has already been shown to reduce the age at first egg.

Weight at 150 Days versus Winter Production.

In selection of pullets to put into winter quarters or in deciding upon birds to be placed in egg laying contests, the breeder desires to know just how much stress should be laid on physical characters. Weight is one characteristic that can be definitely measured. The weight at 150 days old was secured on 800 pullets that later completed winter records. The degree of correlation has been determined between weight at 150 days and winter production. Constants calculated are as follows:

Number of birds	800
Mean weight at 150 days	3.99
Weight at 150 days standard deviation	±.54
Mean winter production	44.54
Winter production standard deviation	±23.02
Coefficient of correlation	+.2758±.0220

The mean 150-day weight on the 800 pullets is 3.99 pounds with a standard deviation of .54. The mean winter production is 44.54 with a standard deviation of 23.02. Weight records show the fluctuations at the age of 150 days to be between 13 and 14 per cent.

The 800 pullets show a positive correlation coefficient amounting to .2758 ±.0220. This may be interpreted that in about one pullet out of four there is direct association between heavy weight at 150 days and a large number of winter eggs. In this particular flock, selection for heavy winter records would be about 28 per cent accurate if made on greatest 150-day weight alone.

In order to reduce the effect of hatching date on winter egg yield, studies have been made on two hatches, namely, April 15 and 22. This gives a range of but seven days in hatching date, which is practically insignificant. Constants calculated on these two hatches follow:

Number of birds	135
Mean weight at 150 days	4.16
Weight at 150 days standard deviation	±.51
Mean winter production	47.31
Winter production standard deviation	±23.93
Coefficient of correlation	+.2475±.0545

The coefficient of correlation for the two hatches does not differ significantly from that for the 800 pullets. This is evidence that hatching date had little if any effect upon the relation between 150-day weight and winter fecundity.

Weight at First Egg versus Winter Production.

The question: may the weight of a pullet in any particular variety at the time she lays her first egg be associated with high or low winter record? is of interest and importance. Should the breeder who is striving for high winter records select the heaviest pullets at first egg? These questions may be answered in general by correlating weight at first egg with winter record. Such studies have been made on 793 pullets with weight records and winter egg records. The calculated constants follow:

Number of birds	793
Mean weight at first egg	5.74
Weight at first egg standard deviation	±.73
Mean winter production	44.56
Standard deviation winter production	±23.04
Coefficient of correlation	−.1894±.0231

Mean weight at first egg is 5.74 pounds with a standard deviation of .73. The range of variability in weight is about 13 per cent and is about the same as was found at 150 days. Here is evidence that pullets weighing the most at 150 days will in general weigh the most when they lay their first egg even though there is a wide range in age at first egg.

A negative correlation coefficient of .1894±.0231 exists between weight at first egg and winter egg record. There appears to be an association between light weight at first egg and winter fecundity in about 20 per cent of the flock. The coefficient is small but significant and suggests that weight at first egg is of no very great importance in selecting for high winter record, yet there is a tendency for smaller birds to lay more winter eggs than larger birds.

By tabulating only the first eight hatches the effect of hatching date on weight is somewhat reduced. Records on 529 pullets from the first eight hatches are available for study. The constants calculated on this group are as follows:

Number of birds	529
Mean weight at first egg	5.76
Weight at first egg standard deviation	±.73
Mean winter production	47.71
Winter production standard deviation	±24.34
Coefficient of correlation	−.2963±.0269

With this group of pullets light weight at first egg is associated with high fecundity in about one case out of three. Hatching date thus appears to affect the degree of correlation.

Weight Increase versus Winter Production.

Does the rate of daily gain of pullets between the age of 150 days and the time they lay their first egg show any relationship to the number of winter eggs they will lay? Can rate of gain in the fall be considered an index to future winter production? Records are available for study on 788 pullets from which the rate of daily gain has been tabulated against number of winter eggs. The following constants appear:

Number of birds	788
Mean daily gain	.027 lb.
Daily gain standard deviation	±.00846
Mean winter production	44.59
Winter production standard deviation	±23.03
Coefficient of correlation	+.2899±.0220

This study shows the mean daily gain to be .027 pound with a standard deviation of .00846 or a range of variation in gain of about 31 per cent. The length of time over which this gain was measured varies directly with the age at first egg. Very early maturing pullets would begin laying in a comparatively few days after their 150-day weight was taken, while late maturing pullets would not begin laying until more than two months after their 150-day weight was secured. The average daily gain over a two-months' period is scarcely comparable with the average daily gain over a two-weeks' period. Yet from the standpoint of age the two are absolutely comparable in that age bears such a vital relationship to winter fecundity.

The coefficient calculated for this group is positive and amounts to .2899 ±.0220. This factor shows that in about one case out of three heavy daily gains between 150 days old and time of first egg are associated with high winter record. Heavy gainers tend to be heavy winter layers to a certain extent. In a previous section we find that the weight at 150 days is fully as reliable a guide to future winter fecundity as is rate of gain from 150 days to time of first egg.

If we eliminate the genetically late maturing birds we should expect either a higher or lower degree of correlation between weight increase and winter production than was found for the entire flock depending on whether or not the pullets gain at a different rate shortly before laying than two months or more before they lay their first egg. The records of the 413 pullets that began to lay at 206 days or less have been tabulated to show the degree of correlation between gain in weight and winter fecundity. Constants derived are as follows:

Number of birds	413
Mean daily gain	.0292
Daily gain standard deviation	±.0090
Mean winter production	54.94
Winter production standard deviation	±21.09
Coefficient of correlation	+.2055±.0318

The mean rate of gain on this group of pullets beginning to lay at from 150 to 206 days old is slightly greater than that for the entire flock. This seems to indicate that there is a tendency for the rate of gain to increase shortly before laying. But the coefficient of correlation is .2055±.0318 as compared with a coefficient of .2899±.0220 for the entire flock. Such a difference must be interpreted as evidence that the rate of gain shortly before the first egg is a less reliable indicator of future winter fecundity than is the rate of gain over a longer period before the first egg.

Weight at 150 Days versus Age at First Egg.

In order to discover if the weight of a pullet at a particular age previous to the time she lays her first egg is an index to the probable age at which she will begin laying, the 150-day weights on 846 pullets have been tabulated with their respective ages at first egg. Constants obtained are as follows:

Number of birds	846
Mean weight at 150 days	4.02
Weight at 150 days standard deviation	±.54
Mean age at first egg	210.35
Age at first egg standard deviation	±27.74
Coefficient of correlation	−.2135±.0221

A negative coefficient amounting to .2135±.0221 was obtained. Such a constant indicates that heavy weight at 150 days is associated with early production in about one case out of five. In other words, if all other conditions were kept constant, selection on the basis of heavy weight at 150 days would be advantageous for winter production.

Weight at First Egg versus Age at First Egg.

Does body weight at first egg vary directly with age at first egg or are there other influences operating so that the element of time is not alone responsible for the weight? If the element of time were alone responsible for weight variation in any particular breed, selection for early sexual maturity would reduce body weight because sexual maturity tends to check skeletal development so that later weight accumulation is largely of adipose tissue. The degree of correlation between weight at first egg and age at first egg has been calculated on 821 pullets to discover how important a relationship does exist between weight and age. The constants obtained follow:

Number of birds	821
Mean weight at first egg	5.56
Weight at first egg standard deviation	±.69
Mean age at first egg	210.66
Age at first egg standard deviation	±28.34
Coefficient of correlation	+.4604±.0185

The coefficient of correlation here shows that about half of the large pullets owe their weight to the time element. The other half are large because they possess a different capacity for growth than the first. By developing those influences, factors, or whatever they may be, to a maximum, the mean body weight should not diminish in an early maturing flock. On the face of it, the major problem here seems to be to discover just what these influences are and to make all conditions optimum for their manifestation.

Daily Gain versus Days Between 150 *Days Old and Age at First Egg*

The degree of importance of the time element in relation to daily gains may be ascertained from the degree of correlation between daily gain and number of days between 150-day age and age at first egg. Records on 814 pullets have been tabulated for study. The constants derived follow:

Number of birds	814
Mean daily gain	.0269
Daily gain standard deviation	±.0084
Mean days between weights	60.78
Days between weights standard deviation	±28.12
Coefficient of correlation	−.4145±.0196

A negative coefficient of .4145±.0196 substantiates the opinion that pullets tend to accumulate weight very rapidly just before they begin laying. We have already shown that relative rate of gain is not of much importance in selection for winter fecundity, and that the 150-day weight is just as accurate a basis of selection as rate of gain and entails only half the labor.

Winter Production versus Annual Production.

It is important to know the degree of correlation between winter production and annual production since winter egg record may conveniently be used as a basis for selecting pullet breeders. Furthermore, winter record could be used as a basis of culling for high annual records and as a basis for determining the intensity of pullets. Annual records are not yet complete on the flock being studied, consequently the winter record of three previous flocks has been tabulated against their 365-day record. A total of 845 individuals hatched in 1920, 1921, and 1922 have been studied. Constants have been calculated as follows:

Number of birds	845
Mean winter production	70.26
Winter production standard deviation	±25.07
Mean annual production	193.95
Annual production standard deviation	±40.25
Coefficient of correlation	+.6214±.0142

The above coefficient shows that in approximately six cases out of ten high winter record is directly associated with high annual record. In other words, selection for annual egg yield would be about sixty per cent accurate if made on winter trap-nest records alone. This fact makes very evident that winter egg record is of very great importance in its relation to annual record and that it is of great value in selecting pullet breeders.

In previous sections the relative importance of different measurable characteristics in relation to winter production has been discussed and the degree of correlation calculated in each case. These findings help to make clear why winter egg record as determined on a calendar basis is subject to wide variation aside from the variation caused by hereditary factors known to affect it. Such facts being known, the difficulty and uncertainty of properly classifying the pullets in distinct genotypes becomes very apparent. Such variables as have been considered must be reduced to a minimum in order to make proper matings for purposes of reducing genetic variability to a minimum. When the genetic nature of each breeding bird is discovered, definite types of matings may be made and progress assured. There can be no short road in the establishment of a flock breeding *true* for high winter fecundity.

SUMMARY

Based upon the foregoing data, the following figures show the degree of correlation between the characters stated:

1.	Between hatching date and weight at 150 days (for the entire flock)	−.3293±.0194
2.	Between hatching date and weight at first egg	−.3807±.0201
3.	Between hatching date and age at first egg	−.1487±.0228
4.	Between hatching date and winter production (for the entire flock)	−.2920±.0218
5.	Between hatching date and winter production (for the genetically early maturing birds alone)	−.4790±.0254
6.	Between age at first egg and winter production (for the entire flock)	−.6061±.0151
7.	Between age at first egg and winter production (first three hatches only)	−.6413±.0320
8.	Between weight at 150 days and winter production (for the entire flock)	+.2758±.0220
9.	Between weight at 150 days and winter production (for the hatches of April 15 and 22 only)	+.2475±.0545
10.	Between weight at first egg and winter production (for the entire flock)	−.1894±.0231
11.	Between weight at first egg and winter production (for the first eight hatches only)	−.2963±.0269
12.	Between average daily gain, 150 days old to age at first egg, and winter production (for the entire flock)	+.2899±.0220
13.	Between average daily gain, 150 days old to age at first egg, and winter production (for the genetically early maturing group alone)	+.2055±.0318
14.	Between weight at 150 days and age at first egg	−.2135±.0221
15.	Between weight at first egg and age at first egg	+.4604±.0185
16.	Between average daily gain and number of days, from 150 days old to age at first egg	−.4145±.0196
17.	Between winter and annual production, for three previous flocks	−.6214±.0142

The most important single characteristic upon which to select pullets for winter production is age at first egg. Weight at 150 days and hatching date are of equal importance in such a selection, but of much less significance than age at first egg.

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