Bulletin 410 April, 1938

TOBACCO SUBSTATION AT WINDSOR

REPORT FOR 1937

P. J. Anderson
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Agricultural Experiment Station
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REVIEW OF 1937 SEASON

THIS Sixteenth Annual Report of the Tobacco Substation at Windsor is presented in compliance with the act of the General Assembly of the State of Connecticut approved May 5, 1921. This act requires that each year a report of the work done and results obtained shall be printed with the report of the Connecticut Agricultural Experiment Station.

The act does not limit research and experiments to the growing crop, but specifies that it shall extend to the "process of preparing the crop for market". For the most part, however, the work summarized in our previous annual reports has dealt only with the problems involved in growing the crop. In the present report, there appears a section on the fermentation, or "sweating" of tobacco, a processing operation of the packer with which the grower is not directly concerned. Nevertheless, any improvements that can be made in processing Connecticut Valley tobacco will ultimately benefit the grower also.

The direct service work of this Station, including testing seed for germination, testing soils and resultant conferences with growers on the fertilizer mixtures best adapted to their soils, diagnoses of diseases, insect and other troubles, farm visits and services of a like nature continue to increase.

One of the notable events of the year was the first appearance here of a new disease, Downy Mildew, which has caused great damage in the southern tobacco states for years. Previously New England tobacco had escaped this trouble. As soon as it was discovered on May 25, the Station began investigating and growers were supplied with all available information on methods of combatting it. Later, a bulletin (No. 405) was issued describing in detail the disease, its cause, and the known methods of controlling it.

Work on the control of insect pests of tobacco was continued, with Mr. A. W. Morrill, assistant entomologist U.S.D.A., in immediate charge. Progress of these investigations is described in another section of this report written by Mr. Morrill and Mr. Lacroix.

Most of the old fertilizer nitrogen field tests were continued this year without change and some new ones were started. The tests with soybean oil meal and with urea were expanded. The calcium plots were continued without change. Irrigation experiments could not be carried on this season because of excessive rains. Investigations on time of harvesting Havana Seed and Shade tobacco were continued and enlarged. This year saw the beginning of a new experiment on spacing tobacco. An experiment on the root-rot resistant type of Havana Seed No. 211 gave some interesting results as recorded in a later section. Further studies on nitrate production in the soil from different kinds of nitrogenous fertilizers were made. A considerable body of information on the leaching of mineral nutrients from the soil is accumulating from the lysimeter experiments.

The season of 1937 was a wet tobacco year. The rainfall at Windsor, as recorded in Table 1, was about 50 percent above the average of the last 15 years. Excessive rainfall while the crop is in the field is always reflected in reduced yields. Thus, on plots at the Station which received similar fertilizer treatment in 1936 and 1937, the average yield was 24 percent lower and the grade index 16 percent lower this year than for 1936. Reports from many growers indicate that crop reduction was about the same throughout most of the tobacco-growing area of the State although there were a few localities which escaped some of the storms and the yield was better. The excessively humid curing season in September and October also caused a great deal of damage from pole rot.

Increase in acreage of the three types of Connecticut tobacco (United States Bureau of Agricultural Economics estimates) was 9 percent for Broadleaf, 5.9 percent for Havana Seed, and 7.3 percent for Shade. Despite the acreage increase, the total production of tobacco for manufacture of cigars was undoubtedly less than for 1936.

There were no serious losses in 1937 from hail storms or from bad wind storms.

The Experiment Station has enjoyed splendid coöperation from the growers and packers during the year. Particularly we should mention the firm of Gershel-Kaffenburgh, which has placed at our disposal all the field space that we require for Shade experiments and also unlimited warehouse facilities for sorting and conducting fermentation tests. The Hartman Tobacco Company furnished our entomologists with a field for conducting wire worm experiments and supplied all necessary labor and materials for these tests without cost to the Experiment Station. These and other growers and packers deserve much credit for furthering the usefulness of the Station.

TABLE 1. DISTRIBUTION OF RAINFALL IN INCHES AT THE TOBACCO SUBSTATION, WINDSOR, 1937

By 10-day Periods

Year	May			June			July			August		
	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31
1937	.03	3.17	.89	1.48	2.09	2.11	1.08	1.79	1.53	.56	2.54	3.71

By Months

Year	May	June	July	August
Av. for preceding 15 years	3.40	3.38	3.32	4.26
1937	4.09	5.68	4.40	6.81

QUANTITY OF FERTILIZER NITROGEN REQUIRED FOR AN ACRE OF TOBACCO

How much nitrogen should be used in the fertilizer is a question over which tobacco growers have argued ever since commercial fertilizers came into use. After years of trial and error and after completion of five years of field tests at Poquonock by Director Jenkins of the Experiment Station, from 1892 to 1896, the majority of growers gradually adopted the practice of using in the neighborhood of 200 pounds to the acre. Many, however, still claim that there is an advantage in using a larger supply, up to 300 pounds, while some cut the amount to as little as 150 pounds.

An iron-clad rule for all farms in the Valley is obviously impossible, because variations in situations and conditions may alter the requirements. Some soils are more retentive of nitrogen and require a smaller supply than others where one must allow for considerable leaching. A field where cover crops are used regularly does not need so much nitrogen as one on which cover crops are never used. The supplementary use of manure changes the requirement. An amount that is adequate in a dry year may be too small for a wet year. The form of carrier in which the nitrogen is supplied and its rate of becoming available have an influence on the amount which should be applied. The type or strain of tobacco grown also probably introduces a variable.

Therefore it is evident that a fixed figure to represent the optimum quantity of nitrogen for all situations cannot be stipulated. This is probably the reason for the dearth of controlled scientific experimentation on this subject.

Previous to the beginning of the experiments recorded here, the only published tests on quantity of nitrogen required for tobacco in New England were those conducted at Poquonock from 1892 to 1896 and described by E. H. Jenkins in the annual reports of the Connecticut Agricultural Experiment Station for those years. The quantities of nitrogen compared were 105, 175 and 210 pounds to the acre, furnished either in cottonseed meal or castor pomace, one plot of each for each quantity of nitrogen. Jenkins states in his summary of the five years:

> "210 pounds of fertilizer nitrogen either in the form of castor pomace or cottonseed meal, have given a larger crop of tobacco annually for five years than either 105 or 175 pounds of fertilizer nitrogen.
>
> "This gain has been in the wrapper leaf altogether; the more valuable part of the crop.
>
> "Where 210 pounds of fertilizer nitrogen were used the leaves were slightly heavier than those raised with smaller amounts.
>
> "The tobacco from plots having the largest quantity of fertilizer nitrogen, whether cottonseed meal or castor pomace has been. . . . . .of better quality than that from plots with smaller amounts of fertilizer-nitrogen."[1]

Recently the results of another series of experiments on quantity of nitrogen at the Massachusetts Agricultural Experiment Station during 1927 to 1931 were published[2]. In these experiments the quantities compared were 61.8, 123.5, 164.7 and 205.9 pounds of nitrogen to the acre.

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[1]Conn. Agr. Exp. Sta. Report, p. 311. 1896.

[2]Beaumont, A. B. and M. E. Snell. Nitrogenous fertilizers for growing tobacco. Mass. Agr Expt. Sta. Bul. 346. October 1937.

The highest yield of tobacco was obtained with the 205.9 application, but the best grading came with the 164.7 pound application and the writers considered this the more profitable rate.

In view of the lack of experimental evidence at hand, and despite the disturbing and uncertain factors of variation mentioned above, the present writers were of the opinion that valuable information could be obtained by conducting quantitative field tests on a typical *average* tobacco soil, with a good standard tobacco formula, properly replicated and continued over a long enough period of years to overcome seasonal irregularities. The first series of such tests was therefore begun in 1932.

The results of the first three years of the first series were fully described in Connecticut Station Bulletin 367, pages 113 to 117, and the interested reader is referred to this bulletin for more complete information on the details of the experiment. Five different rates of nitrogen application were compared, with all plots in triplicate: 100, 150, 200, 250 and 300 pounds of nitrogen to the acre. The formulas also supplied to all plots 200 pounds of potash, 150 pounds of phosphoric acid, and 50 to 60 pounds of magnesia. To eliminate seasonal differences in leaching as much as possible, all the nitrogen was in standard organic materials. The composition of the fertilizer mixtures is shown in Table 2. The desired rates of nitrogen were

Table 2. Composition of the Fertilizer Mixtures Used on the Quantity of Nitrogen Plots

Ingredients of the fertilizer	Pounds of ingredients per acre in formulas furnishing nitrogen at rate of:				
	100 lbs.	150 lbs.	200 lbs.	250 lbs.	300 lbs.
Ground tobacco stems	1000	1000	1000	1000	1000
Cottonseed meal	925	1478	2000	2560	3120
Linseed meal	186	300	400	525	613
Dry ground fish	138	220	300	388	460
Cottonhull ash	360	324	300	270	231
Precipitated bone	215	157	100	39	...
Magnesian lime	100	100	100	100	100

obtained by varying the quantity of cottonseed meal, linseed meal and fish meal. Since each of these materials contains, besides the nitrogen, also some phosphorus, potash and magnesia, it was necessary to equalize these by changing the amounts of cottonhull ash and precipitated bone.

A second series was started on a different field (Field I) in 1935 with the double object of comparing the results on a different soil and of using different increments in the quantity of nitrogen. The rates of application on this field were 80, 120, 160, 200 and 240 pounds of nitrogen to the acre and all plots were in duplicate.

The purpose of the present article is to summarize the five-year test on the first series and compare results with those of three years on the second series. Also, subsequent to the first report on these experiments, certain tests and analyses have been made of fire-holding capacity, size of leaves, rate of nitrate production in the soil and chemical composition as influenced by quantity of nitrogen, and the results are recorded here.

3. QUANTITY OF NITROGEN TESTS. AND INDEXES. SUMMARY OF 5 YEARS. POMEROY FIELD 1932-1936

Plot No.	Pounds nitrogen per acre	Acre yield						Grade index					
		1932	1933	1934	1935	1936	Av.	1932	1933	1934	1935	1936	Av.
N54		1613	1642	1931	1602	1574		.174	.392	.364	.230	.237	
54-1	100	1562	1593	1505	1531	1675	**1605**	.130	.386	.100	.222	.253	**.245**
N54-2		1467	1483	1453	1602	1658		.166	.403	.100	.262	.255	
N55		1728	1899	1877	1924	2003		.294	.497	.413	.307	.370	
N55-1	150	1748	1750	1745	1909	1921	**1831**	.295	.425	.353	.333	.365	**.359**
N55-2		1899	1607	1832	1782	1836		.296	.379	.414	.322	.330	
N56		1836	1973	2113	2067	2310		.359	.460	.465	.324	.393	
N56-1	200	1823	1785	1902	2102	2165	**1976**	.374	.440	.430	.342	.391	**.394**
N56-2		1802	1696	1922	1969	2171		.345	.432	.424	.351	.380	
N57		1859	1857	2008	2308	2359		.351	.443	.439	.338	.382	
N57-1	250	1784	1734	1935	2220	2268	**2031**	.340	.441	.395	.325	.376	**.385**
N57-2		1872	1718	1841	2264	2435		.348	.415	.433	.369	.387	
N58		2048	1984	2145	2132	2387		.340	.445	.427	.337	.347	
N58-1	300	1926	1817	2172	2279	2400	**2106**	.330	.440	.451	.331	.351	**.379**
N58-2		1895	1762	2029	2297	2315		.354	.431	.389	.354	.366	

Havana Seed tobacco was used in all of these tests and it was transplanted, cultivated, harvested, cured and sorted in the customary way without variations between plots. Immediately after harvesting the crop each year, the fields were seeded with oats for a winter cover crop.

Field Observations. Frequent observations were made annually throughout the growing seasons and since they were quite similar each year, and for both series, they may be briefly summarized without discussing each period separately.

During the early part of the seasons, no differences could be observed in the rate of growth, color, size or other characteristics of the plants of the different plots. Beginning about the middle of July, however, depending somewhat on the amount of rainfall, the tobacco on the plots with the lowest rates of application (80, 100, 120 pounds) began to fade to a yellowish green, indicating a lack of sufficient nitrogen. The same symptoms started somewhat later on the plots of 150 pounds nitrogen. This fading became progressively more pronounced as the season advanced until harvest, at which time the lower leaves were distinctly yellow and in dry seasons some of them died prematurely. Progressing toward the higher applications the plants appeared darker with each increment in nitrogen. At the highest rate of application they were abnormally dark. Plots with 200 to 250 pounds had the shade of green usually considered normal by growers.

Paralleling the color variation was a less pronounced variation in the luxuriance of growth of the plants. Those with larger nitrogen supply filled out the rows better and appeared more leafy.

Results from the First Series, 1932 to 1936

The soil on which this series was located (Pomeroy Field) is an average Merrimac sandy loam with a coarse sandy subsoil, of good drainage, level and uniform in topography—in every respect like many other fields of the Connecticut Valley on which Havana Seed tobacco is grown.

The acre yields and grade indexes for each plot for each of the five years, and the averages for each treatment for the whole five years are presented in Table 3. In Table 4 the average percentage of each grade for all replications in location and years has been computed. Since for every treatment there were thus 15 replications, and the results were fairly consistent, the following observations and conclusions seem warranted:

1. Each addition of nitrogen increased the yield, the maximum yield corresponding with the maximum rate of 300 pounds of nitrogen to the acre. The greatest *rate* of increase in yield was between the 100 and the 150 pound plots.

2. The highest percentage of low grades (short seconds, short darks, brokes and fillers) was on the plots with the lowest nitrogen (Table 4). The high percentage of brokes was due to the starved, yellow, dead condition of these leaves which made them unfit for good grades. The high percentage of these grades is responsible for the low grade index of these plots.

3. The highest percentage of the best grades (lights, mediums and long seconds) was on the plots of 200 pound application. It should be noted,

TABLE 4. AVERAGE PERCENTAGE OF GRADES FOR FIVE YEARS AND THREE REPLICATIONS. (FIRST SERIES)

Pounds nitrogen per acre	Percentage of grades								Grade index
	L	M	LS	SS	LD	DS	B	F	
100	1.0	1.0	14.3	4.0	20.3	12.6	33.0	13.7	.247
150	3.3	4.5	25.7	1.9	34.9	4.6	11.3	13.8	.359
200	4.3	6.2	27.6	2.4	40.1	2.4	5.0	12.0	.395
250	3.3	5.7	26.6	2.1	43.4	2.9	3.9	12.1	.385
300	2.9	4.5	25.6	2.3	48.4	1.5	3.7	11.1	.379

however, that the 250 pound plots were a very close second to the above so that the grade index was almost as high. This could mean that the optimum might lie somewhere between 200 and 250 pounds.

4. The percentage of long darks increased each time the nitrogen was increased, demonstrating the tendency of nitrogen to produce darker, heavier leaves. The decrease in short darks, as the nitrogen increases, merely shows how nitrogen increases the length of leaves.

5. The highest grade index was obtained by applying 200 pounds of nitrogen.

Results of the Second Series, 1935-1937

The objects of this second series of tests, on a different field with different increments in quantity of nitrogen, are stated on page 336. The results from this field are not as conclusive as those from the first series for several reasons: These plots were only in duplicate and have been continued for only three years, giving six yields as compared with fifteen on the first series. Moreover, during the first year of the second series, growth of some of the plots was apparently influenced by previous fertilizer treatment and by washing. The results, although not entirely consistent, for the most part confirm those of the first series.

TABLE 5. QUANTITY OF NITROGEN PLOTS ON FIELD I. SUMMARY OF YIELD AND GRADE INDEX FOR THREE YEARS

Pounds N per A.	Plot No.	Acre yield				Grade index			
		1935	1936	1937	Av.	1935	1936	1937	Av.
80	N62	1823	1844	1586	1718	.321	.330	.233	.269
	N62-1	1696	1683	1673		.204	.242	.283	
120	N63	1788	1866	1636	1746	.298	.337	.261	.288
	N63-1	1676	1716	1793		.201	.314	.315	
160	N64	1816	1973	1716	1901	.332	.351	.291	.326
	N64-1	1926	2002	1977		.268	.358	.357	
200	N56-3	1751	2196	1898	1979	.225	.338	.318	.327
	N56-4	1851	2079	2100		.362	.387	.331	
240	N65	2133	2296	2126	2152	.351	.391	.358	.365
	N65-1	2045	2200	2112		.355	.399	.337	

Observations made in the field and on the sorting bench were essentially the same as those for the first series and confirmed the previously stated conclusions in every way.

Table 5 shows the yields and grade indexes for each plot each year, and the averages for all. Again it is seen that each increment in nitrogen produced an increase in yield. The grade index here, however, was highest at 240 pounds of nitrogen instead of at 200 pounds as on the first series. Otherwise the results of the two series are very similar.

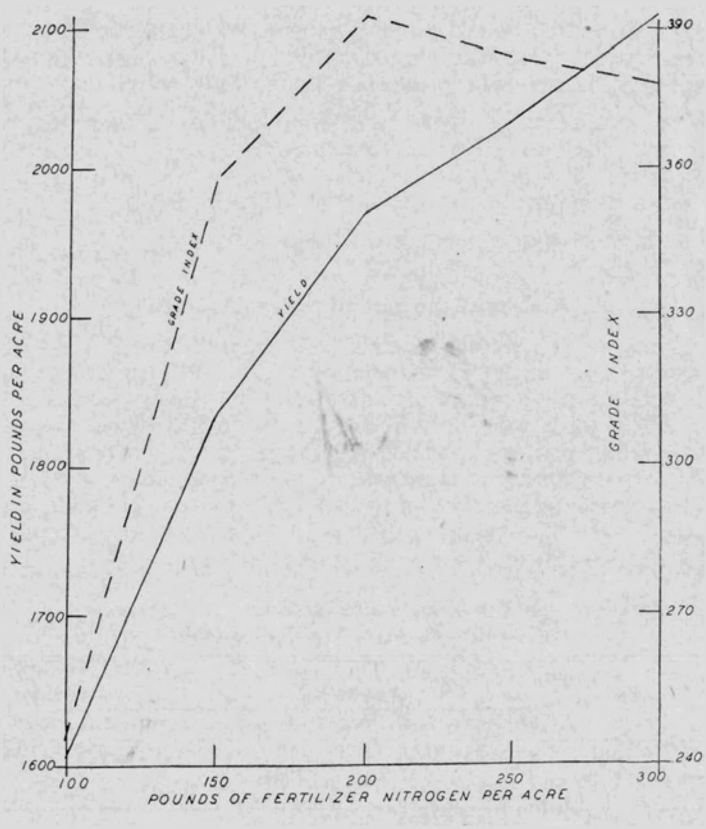

FIGURE 30. Influence of quantity of fertilizer nitrogen on yield and grade index.

Effect of Quantity of Fertilizer Nitrogen on Size, Shape, Weight and Thickness of Leaves

The five-year experiment on quantity of nitrogen on Pomeroy Field shows that with each increase in quantity of fertilizer nitrogen, up to 300 pounds to the acre, there has been an increase in the weight of the crop. Is this due to increase in the length or width of the individual leaves—all of them, or of those on certain portions of the stalk—to an increase in thickness of the leaves, or to an increase in vein size in proportion to the blade?

In order to answer these questions and others, the following measurements were made:

When the tobacco of the plots treated with different quantities of nitrogen (plots N54–1 to N58–2 of the crop of 1936) was taken down for stripping in the curing shed, 15 plants were taken from each plot, and all the leaves from each position on the stalk were stripped, tied together and labelled. For example, on Plot 54–1, starting at the bottom of the stalk, all the first leaves from the 15 stalks were tied in one hand, all the second leaves in one hand, and so on up to the fifteenth leaf. Then, in the laboratory, each leaf was carefully measured in length and width. Each hand of leaves, from each position, was weighed in the pliable condition necessary for handling. Then the midribs were carefully removed and weighed separately from the blades (moist condition). Both midribs and blades from each hand were then placed in a paper bag and thoroughly desiccated in a hot oven (80° C.) for two or three days. Then they were weighed again.

From all these measurements the following averages for each leaf position and for each nitrogen treatment were calculated:

1. Length of leaf.
2. Width of leaf.
3. Ratio of width to length.
4. Total weight of leaf, moist condition as sorted.
5. Weight of midribs, as sorted.
6. Weight of midribs, oven-dried.
7. Weight of blades, as sorted.
8. Weight of blades, oven-dried.
9. Ratio of weight of midrib to weight of blade, both as sorted and desiccated.
10. Loss of moisture on desiccation, midrib and blade.

From the data thus obtained, Table 6 was prepared. Each figure in this table is an average of 195 determinations, 13 leaves on 15 plants. The two bottom leaves were not included because many of them were badly mutilated in harvesting. Also since some of the plants from the low nitrogen plots had only 15 leaves, all those above that position were discarded in these calculations. From this table it is apparent that:

Each increase in nitrogen in the fertilizer increased both the average length and width of the leaves. The *ratio* between length and width, however, remained remarkably constant. The quantity of nitrogen apparently does not change the shape of the leaf.

The average weight of leaf also increases with increase in nitrogen. Both the blades and the midribs follow the same curve of increase.

The ratio between the weight of the midrib and that of the blade does not change materially and the small changes recorded do not show any definite trend. This is interesting as bearing on our usual observation

TABLE 6. EFFECT OF QUANTITY OF FERTILIZER NITROGEN ON THE LENGTH, WIDTH AND WEIGHT OF LEAVES AND THE PERCENTAGE OF LOSS ON DRYING. CROP OF 1936

Lbs. N per acre	Dimension of leaf (inches)			Weight of leaf (grams)							Loss on drying %		Thickness of leaf blade (inches)
				Total	Midribs		Blades		Ratio				
	Length	Width	Ratio	as sorted	as sorted	Dried	as sorted	Dried	as sorted	Dried	Midribs	Blades	
100	19.21	9.47	2.03	5.92	1.54	1.13	4.29	3.41	2.82	3.05	26.2	20.5	.0310
150	21.27	10.33	2.06	7.12	1.91	1.37	5.09	3.90	2.65	2.85	29.8	23.1	.0342
200	21.90	10.53	2.08	8.00	2.24	1.67	5.73	4.40	2.56	2.65	26.6	23.0	.0365
250	21.96	10.59	2.07	8.95	2.35	1.76	6.52	4.89	2.77	2.86	25.0	23.8	.0382
300	22.51	11.04	2.04	8.76	2.32	1.77	6.38	4.93	2.75	2.77	23.8	22.8	.0397

that the plots with the most nitrogen had a tendency toward coarse or larger veins. If weight and size of veins are correlated, these data do not support the above observation but indicate that at least the midveins become heavier only in proportion to the size of the leaves.

The percentage of moisture loss on drying of the blades in the oven is remarkably constant for all rates of nitrogen application with the exception of the lowest rate where the loss was least. This is obviously because of the high proportion of dead yellow leaves which do not readily take on moisture. Since also the midribs seem to lose slightly less moisture as the nitrogen increases, it is apparent that the increased yield from higher applications of nitrogen is not in any way due to higher moisture content of the leaves.

During the sorting, the leaves from the high nitrogen applications gave the impression of being thicker, having more body, than those from the low application plots. An attempt was made to measure the thickness of leaf blades with a caliper. To do this, strips from similar parts of leaves growing in the same position on the stalk were used, avoiding even the finest veins. Even with all these precautions, there were wide variations and the figures recorded in Table 6 should not be regarded as entirely reliable. They do show a trend toward increased thickness of leaf with the larger amounts of fertilizer nitrogen and, coupled with the observations mentioned above, probably warrant the conclusion that the leaves become a little thicker when more nitrogen is applied. This conclusion also agrees with the previously quoted observation of Jenkins, that with the highest application of nitrogen the leaves were slightly heavier, as determined by the number of leaves in a pound.

In order to see whether the increase in size of leaf is general for the entire height of the plant or whether it is confined to, or more pronounced in, the leaves at certain heights, the averages for each position and each treatment were computed and are graphically shown in Figure 31. From this figure it will be seen that the differences in length and width of the lowest leaves of the plant are not pronounced or consistent. The difference becomes most pronounced in the middle third of the plant. From about the seventh or eighth leaf, the size on the 100-pound plot drops rapidly. On all the other plots the maximum leaf size is at about the tenth leaf and then drops rather rapidly and regularly to the sixteenth. Figure 32 shows the same curve for the weight of leaves.

From these data we may conclude that the increase in yield produced by additional nitrogen is largely due to increase in size and weight of the center leaves of the plants.

Effect of Quantity of Nitrogen on Nitrate Production in the Soil

As part of the study on the first series (Pomeroy Field), nitrate nitrogen levels in the soil were determined at weekly intervals during the seasons of 1935 and 1936. These determinations were made on the second and third replications of the series, the first group being omitted because of some irregularities of soil and topography. The data presented here are only averages of the two replications for the two years, as the principal reason for their presentation is to show the effect of quantity of nitrogen application.

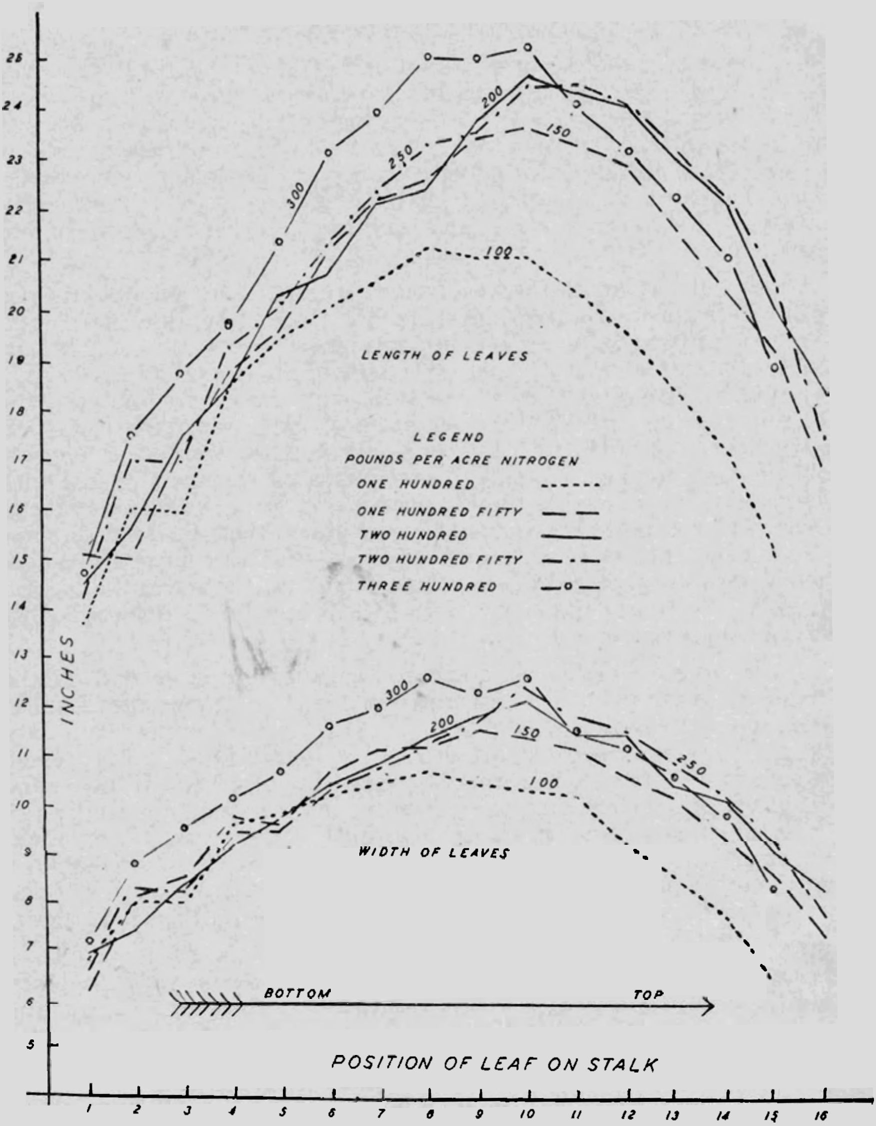

FIGURE 31. Influence of quantity of fertilizer nitrogen on length and width of successive leaves on the stalk.

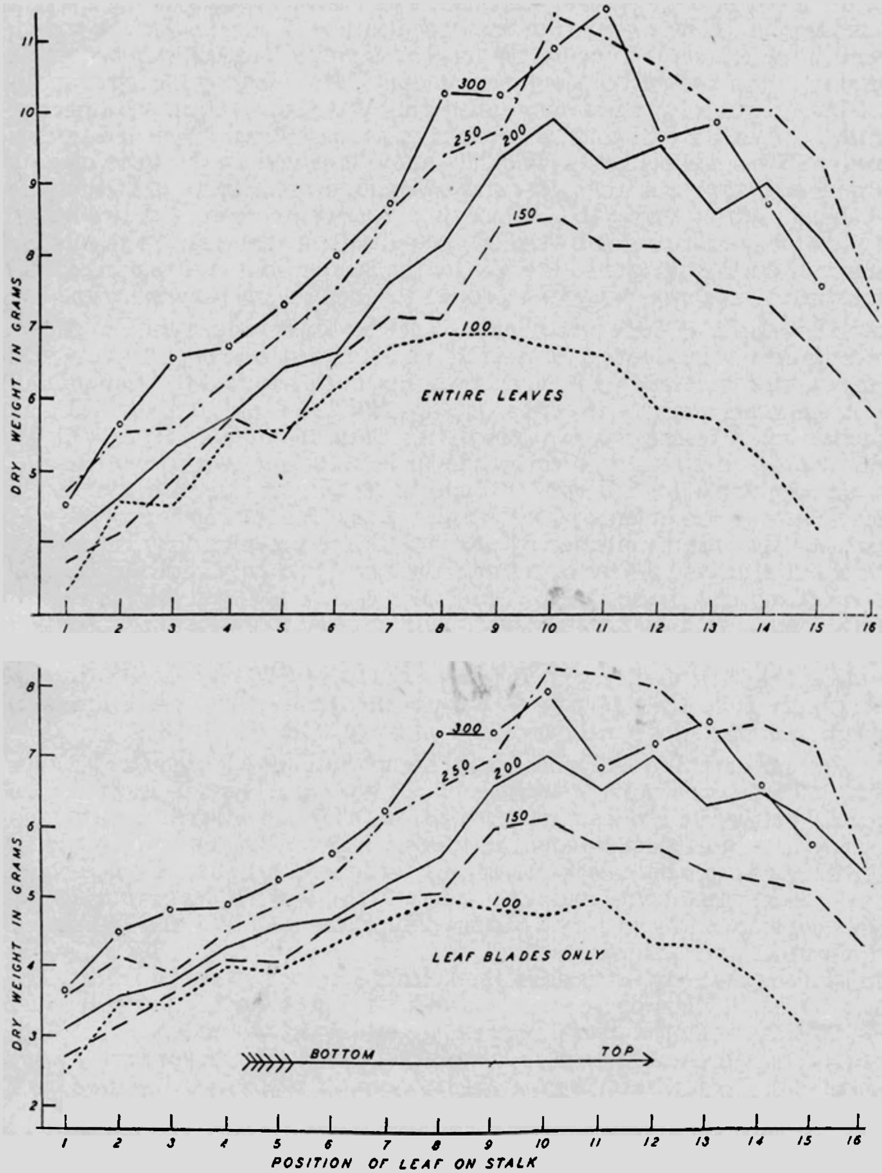

FIGURE 32. Influence of quantity of fertilizer nitrogen on weight of successive leaves on the stalk.

The characteristics of the two seasons were quite dissimilar. Rainfall in 1935 was heavy, especially in the last part of June and again in the last ten days of July. The maximum concentration of nitrates for the season was in the middle of June for the fertilizer applications below 200 pounds, and the latter part of June for larger amounts. Recovery by the lower applications was hardly satisfactory at any time after June. Over two inches of rain between July 21 and 28 brought the nitrate level on *all* treatments below 15 pounds per acre. The 250- and 300-pound applications made a rapid recovery, but the 150- and 200-pound treatments showed little residual nitrates during the balance of the growing season. Oddly enough, they were both exceeded by the 100-pound rate at this stage. The relative demand on the nitrates of the soil by the smaller plants of the minimum treatments was apparently low enough to permit some accumulation.

The season of 1936 was characterized by lower total rainfall. There were heavy rains during the middle of June, but a drought of over 30 days duration succeeded it, and it was not until late in July that rainfall was again adequate. Irrigation on July 12 at the rate of about 1.5 acre inches was necessary to supplement the natural rainfall. Nitrate levels did not rise as abruptly in early June as in 1935, due to dry weather, but were stimulated by the rains of June 10 to 20 and maintained a higher level through the balance of the growing season. The irrigation of July 12 reduced the surplus nitrates by amounts increasing with the quantity of fertilizer nitrogen, the losses between the July 6 and July 13 readings being respectively 8.0, 12.3, 21.7, 29.7 and 34.2 pounds nitrogen for the several increments. The much improved plant growth following the irrigation prevented any great rise of soil nitrates during the balance of the growing season. Shortly after August 1, treatments below 200 pounds were unable to supply more than 10 pounds nitrate nitrogen per acre and starvation conditions prevailed until harvesting on August 18.

A consideration of Table 7 and Figure 33, showing averages of four determinations per date, disclose some interesting relations. Early season levels (before the fertilizer was applied) were low for all treatments, indicating little gain from residual fertilizer. Differences due to quantity of fertilizer nitrogen become apparent early in June. With some discrepancies, the various treatments maintain separate and distinct levels during the growing season. From July 21 to the time of harvest, 100- and 150-pound applications are almost identical, with the lower rate having a higher, immediate post-harvest residue than either 150- or 200-pound rates. The 200-pound application approached an ideal curve for the entire period. At no time while the plants were in the field was there a deficiency of nitrates. The drop at harvest time was to about 18 pounds per acre, a very satisfactory point to insure normal ripening. Post-harvest production of nitrates was not excessive.

For applications above 200 pounds per acre the nitrates remaining in the soil above crop use and drainage loss were consistently high. For 250-pound application, the level during the growing season was not excessive, but the drop at harvest time was hardly satisfactory to insure proper maturity of the leaves. Further evidence is to be found in the average sorting records shown in Table 4, where the percentage of long darks exceeds that of the 200-pound treatment by 3.3 percent, and lights, mediums and long seconds are correspondingly reduced.

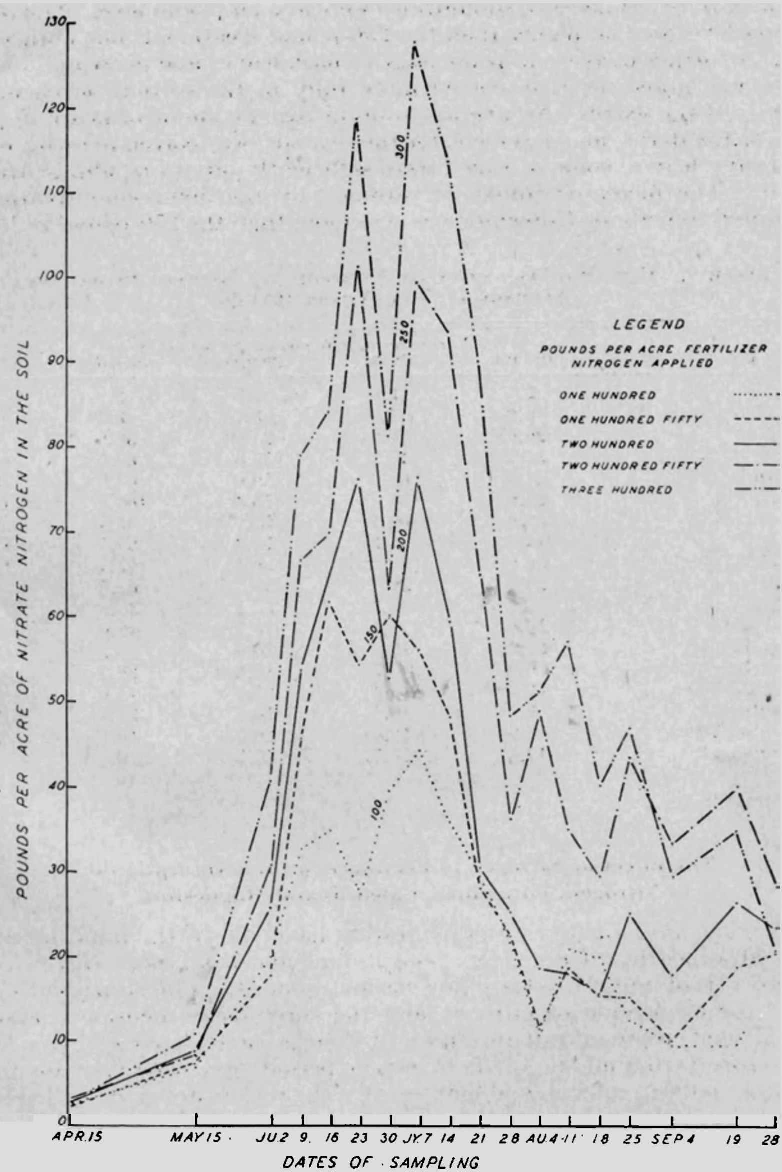

FIGURE 33. Graph showing nitrate nitrogen levels in the soil with varying quantities of fertilizer nitrogen. Data are averages for 1935 and 1936.

The 300-pound treatment resulted in a lavish surplus of nitrates at all times. Even at harvest, soil nitrates were at a 50-pound level. The post-harvest level was no higher than the 250-pound treatment, but both were high. A further increase in percentage of dark leaves and decrease in light leaves was noted, as is discussed more fully in the section on chemical analysis of the leaves. An average total nitrogen content of nearly 5 percent for the darks, and 4 percent for the seconds, was correlated with dark and heavy leaves, some of which were sufficiently oily to be almost translucent. The increased intake of nitrogen by the 300-pound treatment amounted to perhaps 15 pounds per acre more than the 250-pound in 1936.

Table 7. Effect of Quantity of Nitrogen on Nitrate Production. Average of Two Years 1935-36

Average Date	Nitrate nitrogen in pounds per acre of N 100 lbs.	150 lbs.	200 lbs.	250 lbs.	300 lbs.
April 15	2.4	2.0	2.5	2.9	2.7
May 15	6.9	7.2	8.7	8.3	10.6
June 2	20.0	17.9	25.6	30.9	40.7
June 9	32.9	45.7	53.6	66.7	79.0
June 16	34.9	61.9	50.0	69.9	84.2
June 23	27.6	54.2	76.4	101.1	118.7
June 30	39.6	60.1	52.7	63.4	81.3
July 7	44.3	56.2	76.3	99.5	127.9
July 14	36.0	48.2	59.4	93.4	113.8
July 21	29.5	28.2	30.3	65.0	90.8
July 28	21.7	22.2	25.1	36.3	48.4
August 4	10.6	11.3	18.7	49.0	51.2
August 11	21.0	18.7	18.0	35.2	57.4
August 18	20.0	15.5	15.8	29.7	50.1
August 25	12.3	15.4	25.2	43.6	57.0
September 4	9.7	10.1	18.0	33.3	29.8
September 19	9.9	19.0	26.5	40.1	35.1
September 28[1]	17.7	20.7	23.5	28.6	20.8

[1]Only in 1936.

The Effect of Nitrogen in Fertilizers on the Absorption of Nitrogen, Potassium, Calcium and Magnesium

Previous investigations at this Station have shown the importance of bases absorbed by tobacco, *viz.*, potash, lime and magnesia. In this connection it is of interest to learn how various quantities of fertilizer nitrogen affect the absorption of nitrogen and the three bases mentioned above. To this end, representative samples of "darks" and "seconds" from the 1934 crop (in the middle of the five-year period) were analyzed for total nitrogen, potash, calcium and magnesia[1]. The results are given in Table 8.

Nitrogen absorption. As shown in this table, total nitrogen increases in the leaf as the supply of nitrogen is increased in the soil. With respect to the distribution, the "darks," representing the upper part of the plant, contain considerably more nitrogen than the "seconds," which represent the lower leaves. The average differences between the upper and lower leaves for the various treatments of 100, 150, 200, 250 and 300 pounds nitrogen per acre are, respectively, .93, 1.37, 1.36, 1.42 and 1.61 percent;

[1]Analyses made by the Department of Analytical Chemistry, New Haven.

thus the least difference is at the lowest, and greatest at the highest application of nitrogen. This is reflected in the percentage of "darks" and "seconds" as seen in the sorting data of Table 4 where the average percentage of "darks" increases regularly with additional fertilizer nitrogen, while the percentage of seconds remains fairly constant. The percentages of total nitrogen in the leaves, as influenced by the amount of fertilizer nitrogen,

TABLE 8. PERCENTAGE OF NITROGEN, POTASH, CALCIUM AND MAGNESIUM IN LEAVES (WITHOUT MIDRIBS) FROM QUANTITY OF NITROGEN PLOTS. POMEROY FIELD. CROP OF 1936

Chemical element	Grade of leaves	Replicate	Pounds of nitrogen applied per acre				
			100	150	200	250	300
Nitrogen (N)	Darks	A	3.74	4.08	4.34	4.50	4.72
		B	3.17	4.16	4.12	4.34	4.40
		C	3.42	3.78	3.96	4.18	4.84
	Seconds	A	2.70	2.58	3.06	2.88	2.88
		B	2.42	2.72	2.90	2.90	3.12
		C	2.40	2.61	2.37	2.98	3.12
		Average	**2.97**	**3.32**	**3.46**	**3.63**	**3.85**
Potash (K_2O)	Darks	A	5.11	4.79	4.82	4.69	4.66
		B	4.37	4.17	4.69	4.17	4.21
		C	3.66	4.89	5.30	5.03	4.90
	Seconds	A	4.99	4.88	4.28	4.43	4.10
		B	4.26	4.45	3.95	3.63	4.71
		C	3.91	5.03	4.84	4.92	4.48
		Average	**4.38**	**4.70**	**4.65**	**4.48**	**4.51**
Calcium (CaO)	Darks	A	5.56	5.86	6.30	6.20	6.25
		B	5.56	6.06	6.35	6.16	6.22
		C	5.83	5.66	6.05	6.34	5.65
	Seconds	A	6.67	7.22	7.77	8.23	8.52
		B	7.56	7.37	7.91	8.08	7.45
		C	7.10	6.97	7.70	8.05	7.80
		Average	**6.38**	**6.52**	**7.01**	**7.18**	**6.98**
Magnesia (MgO)	Darks	A	1.30	1.16	1.32	1.39	1.81
		B	1.21	1.21	1.49	1.66	1.59
		C	1.14	1.18	1.32	1.41	1.50
	Seconds	A	1.29	1.65	1.61	1.58	2.36
		B	1.34	1.58	1.93	2.21	1.98
		C	1.38	1.39	1.72	1.79	2.12
		Average	**1.28**	**1.36**	**1.56**	**1.67**	**1.89**

are very similar to those found by Jenkins in the Poquonock tests of 1896 (Station Report for 1896, page 325). Where he applied 105 pounds of nitrogen to the acre, he found an average of 2.84 percent in the leaves as compared with our average of 2.97. With 210 pounds of fertilizer nitrogen, he found 3.49 percent in the leaf as compared with our average of 3.46 for the 200-pound application.

Potash absorption seems to be relatively unaffected by the various nitrogen applications. In this connection it is of interest to recall that potash is readily absorbed in the proportion it is available in the soil

(Station Bul. 334, page 182). The availability of potash *per se* is influenced by organic matter content of the soil,[1] as well as by the relative amounts of bases other than potash. If either calcium or magnesium compounds, or both, are too abundantly present, they exert an antagonism toward potassium. Ammonium ions under similar conditions probably produce the same effect. It is possible that, in the present test, where all the nitrogen was applied in the form of meals, ammoniacal nitrogen was produced to such an extent as to antagonize the absorption of potassium. Some indication of this possibility is shown by the fact that the potash content has a tendency to *decrease* rather than increase with increased nitrogen applications to the soil. Sufficient amounts of nitrate nitrogen—in the present case, a larger proportion of nitrate nitrogen than ammonia nitrogen—should rather stimulate the absorption of potash. In support of this assumption is the finding by Davidson[2] that sodium nitrate applied to wheat plants in soil and water cultures increased the potash content of the plants. Moreover, it should be noticed in Table 8 that the potash is pretty evenly distributed between "darks" and "seconds", which further emphasizes the poor correlation between total nitrogen and potassium in the present test.

Calcium increased fairly constantly with increased applications of nitrogen up to the 250-pound treatment. The percentage of CaO is higher in the "seconds" than in the "darks", thus in an inverse relation to the nitrogen. The average differences in percentage for the various applications are 1.46, 1.23, 1.56, 1.89 and 1.88 percent. There is apparently some irregularity in the individual replications, since a better progression is found in Series A, *viz.*: 1.11, 1.36, 1.47, 2.03 and 2.27 percent, respectively.

The reason for the increased absorption of calcium undoubtedly is due to the formation of calcium nitrate in the soil, i.e., calcium was probably released from more difficultly soluble compounds by the nitric acid formed through the nitrification processes in the soil. It has been pointed out previously (Station Bul. 350, page 476) that calcium is most freely absorbed when applied to the nutrient medium in the form of nitrate. The largest application of nitrogen, 300 pounds per acre, caused the highest absorption of calcium only in one of the replicates (A). The irregularity was probably due to soil differences, such as variation in the content of replaceable calcium.

Magnesia absorption showed a more regular increase due to the various nitrogen applications than did calcium, since there was an even progression from the lowest to the highest treatments. The differences in MgO-content of "darks" and "seconds" are in the same direction as for calcium. The following average percentage differences for respective treatments, .12, .36, .37, .37, .52, are remarkably similar in magnitudinal distribution to those of the nitrogen (see page 349). It is likely that the magnesia in the soil was released in the same manner as calcium but to a much smaller degree. Moreover, the total supply of replaceable magnesia in the soil must have been considerably less than the other two bases discussed, as judged by the magnitude of the percentages of this element.

[1]Bartholomew, R. P. Jour. Amer. Soc. Agron. 20: 55-81.

[2]Davidson, Jehiel. Jour. Agr. Res. 46: 449-453. 1937.

Effect of Quantity of Fertilizer Nitrogen on the Fire-Holding Capacity

Since it is often said that too much nitrogen in the leaves has an adverse effect on the burn, samples of fermented leaves from the four principal grades of the crop of 1934 were tested. These strip tests were made in the usual way by ignition with an electric coil and measuring the duration of burn in seconds with a metronome. Twenty tests were made on each hand of tobacco. Since there were four grades and three replications, the figures in the right-hand column of Table 9 each represent an average of 240 tests, except that there were no lights and mediums on two of the replicates of the 100-pound plots, and one sample for the 250-pound plots was lost.

The results, presented in Table 9, do not show that there was any adverse influence from the high application of nitrogen. In fact the longest duration of burn was on the plots to which most nitrogen was applied. On the other hand, there was apparently a retarding effect from the lowest nitrogen application. The explanation of the poor fire-holding capacity of the low nitrogen tobacco might well be that, in the absence of sufficient nitrate, these plants in order to satisfy their anion requirements were obliged to absorb more chloride, sulfate and phosphate, all three of which are injurious to burn.

TABLE 9. QUANTITY OF NITROGEN SERIES ON POMEROY FIELD. CROP OF 1934. FERMENTED. DURATION OF BURN ON SINGLE LEAVES

Pounds nitrogen applied to acre	Leaf grade	Duration of burn Rep. 1	Rep. 2	Rep. 3	Average
	S	25.0	22.5	26.8	
100	L	37.8			26.3
	M	23.7			
	D	24.9	33.0	16.5	
	S	36.9	37.4	45.3	
150	L	52.7	37.5	58.5	39.6
	M	43.0	39.7	48.8	
	D	27.2	23.5	25.1	
	S	46.1	45.7	54.0	
200	L	49.2	51.0	47.2	47.5
	M	42.6	41.0	50.5	
	D	38.1	57.1	47.2	
	S	50.4	47.4		
250	L	46.4	43.3	31.9	42.7
	M	37.1	31.7	55.6	
	D	39.6	31.4	55.2	
	S	50.4	57.1	50.0	
300	L	49.8	49.2	59.4	48.9
	M	55.0	55.3	48.3	
	D	43.6	34.4	34.9	

In the Poquonock fertilizer experiments of 1892 to 1896, tests of fire-holding capacity of plots receiving 105, 175 and 210 pounds of fertilizer nitrogen to the acre were also made. In his summary in the Station Report for 1896, page 311, Jenkins states: "The difference in fire-holding capacity was too slight to have significance".

Discussion and Conclusions

Obviously conclusions drawn from the experiments summarized here can be applied strictly only to Havana Seed tobacco grown on this type of soil and with somewhat similar ingredients in the fertilizer formula. This soil, however, is typical of a considerable part of the tobacco-growing area of the Connecticut Valley and the formula is not essentially different from the usual tobacco formulas which supply most of the nitrogen in organic materials. The results, therefore, should be applicable to the majority of tobacco farms in this area. There seem to be no valid reasons why they should not apply to the Broadleaf variety on similar soils as well as Havana Seed. Shade tobacco presents a somewhat different proposition in that the weight of the crop removed is only two-thirds or less of that removed from a Havana Seed or Broadleaf field. Moreover, the stalks are all returned to the same land. This would indicate that a smaller application of nitrogen might suffice. On the other hand, the Shade crop grows more rapidly and is harvested earlier, and it is imperative that during its intensive development there should always be present in the soil a large supply of nitrogen in an available condition.

At first sight there appear to be certain discrepancies among the results of this experiment, those found by Jenkins at Poquonock, and those of Beaumont and Snell in Massachusetts. Our best results were obtained with the 200-pound application, while Jenkins finds the 210-pound rate best. Jenkins, however, did not test any rate between 175 and 210 pounds, and we did not have any rate between 200 and 250. If, in both locations, a greater number of rates at smaller intervals had been tried, the conclusions probably would have more nearly coincided. Moreover, as previously mentioned, the differences in results between our 200- and 250 pound rates were so small as to indicate that the real optimum might well lie somewhere between the two. The soil on which the Poquonock experiments were conducted is quite similar to that of the Windsor experiments, and the nitrogenous materials used were all organic. At best, the difference of 10 pounds of nitrogen is too small to be of serious consequence.

Beaumont and Snell obtained optimum results at 164.7 pounds of nitrogen to the acre. The soil on this field at Amherst is quite different from that of the Windsor plots, being heavier and more retentive of nitrogen, and this could well account for the lower nitrogen requirement. There are many fields in Connecticut also where growers of long experience have found that they produce satisfactory crops with 150 pounds of nitrogen. Such soils are usually of heavier texture, containing more clay and with a less leachy subsoil.

Under the conditions of the trials described here, we may briefly summarize the results:

Two hundred pounds of nitrogen to the acre gave the best results when all factors of quality and yield are taken into consideration. Nearly as good results with the 250-pound rate indicate that the optimum might be somewhat higher than 200 but not over 250.

If the maximum yield of leaf is desired, the rate should be increased to 300 pounds. This rate, however, increases the percentage of darks and has a tendency to make the leaves heavier and coarser.

Increased nitrogen application increases both the length and width of the leaves in the middle portion of the plant but does not change the shape of the leaf or increase the size of the midvein in proportion to the size of the blade.

Too little nitrogen makes the cured leaves dead, yellow, inelastic, and dry, and reduces the value and yield of the crop.

High rates of nitrogen application do not impair the fire-holding capacity of the leaves. Low nitrogen application, 100 pounds, reduces the fire-holding capacity.

Determinations of soil nitrates at weekly intervals disclosed distinct levels for each increment of fertilizer nitrogen. Applications of less than 200 pounds per acre dropped too low in soil nitrates during the last three weeks the crop was in the field. The 200-pound application was satisfactory in all respects while the higher applications tended to oversupply the plants in the critical ripening period.

Chemical analyses show that each increase in fertilizer nitrogen is reflected in further increase in total nitrogen in the leaf. Magnesia in the leaf increases in proportion to the nitrogen. Calcium has a somewhat similar relation to nitrogen but not so close as magnesium. Quantity of potash does not appear to have any relation to the percentage of nitrogen.

FURTHER TRIALS WITH SOYBEAN OIL MEAL

The experiments with soybean oil meal[1] were promising enough to warrant continuation in 1937 with a wider scope of investigation, including replication of plots and nitrification studies. In addition, the effect of variation in the water soluble part of the nitrogen in the oil meal was observed.

On Havana Seed Tobacco

The single plot on Field V, receiving soybean oil meal as the only source of nitrogen, in its third year with this treatment produced the highest yield per acre among 15 plots[2]. The average production on this field this year was 1,743 pounds per acre, while that for the soybean oil meal plot was 2,253 pounds. Corresponding grade indices were .307 and .341.

TABLE 10. TWO-YEAR SUMMARY OF SOYBEAN OIL MEAL TEST ON FIELD I

Replication	Source of nitrogen	Acre yield			Grade index		
		1936	1937	Av.	1936	1937	Av.
1	Cottonseed meal	2250	1969	2039	.372	.360	.350
2		2283	1645		.364	.304	
3		2298	1787		.382	.319	
1	Soybean oil meal	2313	1972	2097	.389	.361	.378
2		2218	2022		.376	.349	
3		2169	1888		.421	.368	

[1]See Report of 1936, page 75.
[2]These plots all received 200 pounds of nitrogen per acre from a single source, such as cottonseed meal, nitrate of soda, urea, castor pomace and others.

Definite conclusions, however, cannot be drawn from results of a single plot. Therefore, this test has been extended to Field I where triplicate plots were laid out in 1936. An equal number received nitrogen in the form of cottonseed meal. A summary of results for 1936 and 1937 is found in Table 10.

While the light, sandy surface soil on Field V has underlying sand as a subsoil, the subsoil of the plots on Field I is of a gravelly nature and probably as prone to leaching as the former. In this test there are no striking differences in yields produced by the cottonseed meal and the soybean oil meal, although results are slightly in favor of the latter. The grading, however, is higher for the oil meal.

In another comparison on Field XII, with a somewhat heavier type of soil than those previously discussed, the average of the two years' results are given in Table 11.

In this experiment it is seen that both yields and grading are on a higher level than in the tests reported above. Nevertheless, the oil meal gave higher yields and grade indices also in this comparison. In addition, the tobacco produced with soybean oil meal was superior in color, texture and vein structure to that produced with cottonseed meal.

In our experiments with organic nitrogen carriers, so far little attention has been given to the water soluble capacity of the nitrogen. It is known that this quality in carriers such as cottonseed meal, castor pomace, linseed meal, soybean oil meal and others, may vary considerably.

In order to observe the effect of a variation in the water soluble content of nitrogen in meals, a trial was made during the season of 1937. For this purpose soybean oil meals of four different contents of water soluble nitrogen were selected. Analyses of these were furnished by the Chemistry Department of this Station and are given below:

Sample No.	Total nitrogen %	Water soluble nitrogen %	Water soluble fraction of total nitrogen %
1	8.00	.72	10.10
2	7.29	1.28	17.56
3	7.74	4.40	60.00
4	8.33	6.48	78.75

These four types of soybean oil meal furnished the equivalent of 200 pounds of nitrogen per acre to as many one-fortieth acre plots on a field of a medium heavy soil type. Two plots were also included where the nitrogen was added in the form of cottonseed meal.

TABLE 11. TWO-YEAR SUMMARY OF SOYBEAN OIL MEAL TEST ON FIELD XII

Replication	Source of nitrogen	Acre yield			Grade index		
		1936	1937	Av.	1936	1937	Av.
1 2	Cottonseed meal	2483 2386	2100 2055	2256	.384 .444	.450 .473	.438
1 2	Soybean oil meal	2490 2559	2114 2311	2368	.463 .455	.481 .484	.471

Good, even growth was observed on all plots during the season, except on one (Number 2, treated with soybean oil meal of 17.56 percent water soluble nitrogen), where a back furrow occurred which disturbed the texture of the soil. Here the plants were somewhat shorter than on the rest of the field. This soil condition was reflected in the yield and grading, as will be learned from Table 12. In fact, the poorest showing was on this set of plots.

The results from any one of the soybean oil meals may be compared with the average result of the two cottonseed meal plots. The highest yield and grading was produced on Plot 3, which received oil meal containing 60 percent water soluble nitrogen. Next in value is the crop grown with soybean oil meal of 10.1 percent water soluble nitrogen. There seems to be no advantage in using meals with a very high content of water soluble nitrogen, as indicated by the results in the last treatment (4) reported in Table 12, where the meal contained 78.75 percent. The yield was about equal to that produced by the lowest percentage of water soluble nitrogen, and the grading was decidedly lower.

In an attempt to determine the rate of nitrification in the soil produced by the various soybean oil meals, soil samples were taken at weekly intervals during the season, and on these the nitrate content was determined. For comparison, one of the cottonseed meal plots (B) was also sampled. The results are given in Table 13.

At this Station it has been fairly well established that for proper growth and development of tobacco there should be a permanent content of at least 20 pounds per acre of available (nitrate) nitrogen in the soil during the growing season. In Table 13 the bold figures indicate levels below the requirements.

TABLE 12. YIELD AND GRADING RECORDS, CROP OF 1937. A COMPARISON BETWEEN THE EFFECT OF COTTONSEED MEAL AND SOYBEAN OIL MEAL OF VARYING CONTENT OF WATER SOLUBLE NITROGEN

Replication and number	Source of nitrogen	Acre yield		Grade index	
		Plot	Av.	Plot	Av.
	Cottonseed meal	2100 2025	**2063**	.450 .473	**.462**
1	Soybean oil meal, 10.1% W. Sol. N	2114		.481	
2	" " " 17.56 " " "	1900		.373	
3	" " " 60.00 " " "	2311		.484	
4	" " " 78.75 " " "	2132		.447	

The growth period fell between the dates of June 5 and August 20. It is seen that during this time the nitrate level went below the critical point once for the soybean products and twice for the cottonseed meal, the last two weeks before harvest. While there is an advantage in having a relatively low supply of nitrogen in the soil just before harvest, in order to facilitate the ripening of the leaves, it is detrimental to proper development of the crop if the nitrate level drops low too far ahead of harvest.

Leaching rains occurred during the season of 1937 (see page 334) resulting in considerable losses of nitrogen. These losses, however, must have been less serious where soybean oil meal was used than where the nitrogen was furnished in the form of cottonseed meal, probably because the soybean oil meals were more efficiently nitrified than the cottonseed meal.

TABLE 13. NITRATE LEVELS ON PLOTS WITH SOYBEAN OIL MEAL OF VARYING WATER SOLUBILITY IN COMPARISON WITH COTTONSEED MEAL. POUNDS PER ACRE.

Plot No.	Date of sampling															
	April 16	May 17	June 1	June 7	June 14	June 21	June 29	July 6	July 13	July 19	July 26	Aug. 2	Aug. 9	Aug. 16	Aug. 24	Sept. 6
	Nitrate production in pounds per acre															
1	**7.0**	**15.7**	**17.6**	137.4	135.0	136.2	95.0	41.0	38.4	26.6	53.0	49.2	**9.2**	29.0	**6.4**	**12.4**
2	**11.4**	**7.0**	**15.8**	86.2	124.2	105.4	50.6	43.0	42.0	24.4	57.0	57.2	43.0	**7.4**	**9.6**	**34.0**
3	**14.5**	**7.1**	**19.0**	100.6	153.8	109.0	104.4	63.6	85.2	40.6	39.6	52.2	28.6	**19.4**	**7.6**	**12.2**
4	**10.4**	**8.3**	**18.8**	86.0	118.6	116.8	53.4	72.0	65.2	30.2	65.8	34.2	57.4	**10.2**	**8.4**	**15.1**
B		**4.7**	**10.0**	99.4	104.8	75.8	69.6	41.8	42.6	32.8	34.6	20.8	**4.6**	**5.0**	**5.6**	**18.8**

Bold figures indicate times when the nitrate level went below critical point.

On Shade Tobacco

The substitution of soybean oil meal for cottonseed meal as the largest component of the fertilizer mixture for Shade tobacco was made the subject of field experiments in 1936. A brief report appeared in Bulletin 391, pages 77-78, in which a condensed summary of the results on the first three pickings was presented.

This experiment was continued in 1937 on the same field of the Raymond Clark Plantation in Windsor. In addition, sorting records of tests on plantations of the Gershel-Kaffenburgh Tobacco Company were made available and are given. The summarized sorting record of the 1936 experiment is given in Table 14.

The added value of the crop raised with soybean oil meal rests largely with the improved grading and the consequently higher price per pound.

In 1937 the plots, instead of being 10 rows the length of the field, were widened to 20 rows half the length. Samples were taken from eight rows in the center of each block. The complete sorting record, with the exception of the first picking, is shown in Table 15. Only four pickings were taken, due to late rains.

The first picking was sized and then sorted. Only the weighted average price, based on the current price list for each size, and the proportion of each size, is given. The detailed price schedule for 1937 is shown in Table 16. The values employed for pickings above the first were computed from actual sizing records of every grade for the lots being studied. From the percentage of each size, and the values for the grade, an average price was determined.

TABLE 14. YIELD AND GRADING RECORDS OF SHADE TOBACCO. SOYBEAN OIL MEAL VS. COTTONSEED MEAL, 1936

Picking	Acre yield		Price per pound	
	Soybean	Cottonseed	Soybean	Cottonseed
1st	102	105	$1.636	$1.806
1½	207	199	2.307	2.152
1½A	243	257	2.043	1.915
2nd	264	260	1.374	1.285
2A	278	263	1.067	.981
Total yield	1094	1084		
Weighted average price			$1.648	$1.599
Total value			$1802.91	$1733.31

The designation of the pickings corresponds to trade practice, each successive three-leaf picking from the bottom of the plant being named as follows: First picking, 1st, 2nd, 3rd leaves; 1½ picking, 4th, 5th, 6th leaves; 1½A picking, 7th, 8th, 9th leaves; 2nd picking, 10th, 11th, 12th leaves; 2A picking, 13th, 14th, 15th leaves.

The first picking showed no net difference in value, but the proportion of leaves too short for sorting, 8.5 inch and 9.5 inch, was 16 percent for the soybean oil meal and 21 percent for the cottonseed meal. This difference counterbalanced a somewhat higher value of the cottonseed meal in the larger sizes.

TABLE 15. YIELD AND GRADING RECORDS OF SHADE TOBACCO. SOYBEAN OIL MEAL VS. COTTONSEED MEAL. 1937

Picking	Meal	Percentage of grades															Price per pound	Acre yield
		LC	LC_2	LV	LV_2	V	YL	YL_2	S2	VL	ML	KV	BB	XL	XL_2	XX		
1st	Cottonseed	Computed from weighted averages															$1.664	89
1st	Soybean						"	"	"		"						1.657	93
1½	Cottonseed		5.0		6.9	31.5	25.1	9.8			10.4		.4	3.5	6.9	.9	1.480	189
1½	Soybean	6.0	12.9	4.6	21.5	24.5	6.6	1.7			6.4			11.0	3.0	1.8	1.963	189
1½A	Cottonseed	5.1	17.8		13.8	23.2	17.5	4.5			6.4	1.0		8.3	1.9	.5	1.842	225
1½A	Soybean	7.6	19.5		11.0	19.7	18.1	3.8			8.5	.5	.8	6.4	4.0	.1	1.855	223
2nd	Cottonseed				.8	37.1	3.2	13.3	2.2	1.6	25.5	3.6	.8		8.0	3.9	1.118	230
2nd	Soybean		1.0		11.6	37.2	8.1	7.3	.1	2.2	17.8	2.0	1.9	6.2	3.1	1.5	1.573	224

SUMMARY

	Total Yield	Average Price	Crop Value
Cottonseed	733	$1.513	$1109.41
Soybean	729	1.771	1291.22

TABLE 16. SHADE TOBACCO VALUES. 1937

Grade	Size and price per pound				
	10½	11½	12½	13½	15 and up
L	1.75	4.00	5.25		
LL	1.75	3.50	4.75		
LC	1.50	3.00	3.50		
LC_2	1.25	2.00	2.50		
LV	1.50	3.00	3.50		
LV_2	1.00	2.00	2.50		
V	.50	.60	1.75		
YL	.60	1.00	1.75		
YL_2	.40	.60	1.00		
VL	.50	.50	.50	1.00	
ML	.40	.40	.40	.60	
KV	.30	.30	.50		
D	.20	.20	.20		
S1	.30	.30	1.00		
S2	.30	.30	.50		
BB	1.25	1.25	1.25	1.50	
XL	.40	.60	1.00	1.25	1.75
XL_2	.30	.40	.60	.75	1.00
XX	.10	.10	.15	.15	.15

In the pickings above the first, the characteristics of the tobacco grown with soybean oil meal were similar to those previously noted. While the crop as a whole was not outstanding, the soybean treatment produced leaves that were more elastic, had more uniform colors, and fewer mottled and starved leaves. In the 1½ picking, as will be noted from the detailed proportions of grades, light grades of high value, LC's and LC_2's, were present in larger numbers with soybean oil meal, while the olive grade of highest value, LV, was not present with the cottonseed meal treatment. The difference in price per pound on this picking was 48 cents in favor of soybean oil meal.

No particular differences, either in proportion of grades or average price per pound, are found with the next picking, the 1½A. Heavy rains had shortly preceded this picking, and the two lots were apparently in the same condition so far as nutrition of the plants is concerned. However, the failure of the cottonseed meal to resupply soil nitrates was particularly disastrous to the second picking, taken five days after the 1½A. The leaves were coarse and boardy, of poor color and texture, while the soybean oil meal treatment produced leaves which were elastic, and not dark for the picking. High value grades were practically absent from the cottonseed lot. The difference in price was 45 cents a pound.

The summary of this table disclosed that there was no essential difference in yield, a matter of four pounds per acre in favor of the cottonseed meal. However, the difference in average price favored the soybean oil meal by 26 cents a pound and the total crop value by $182 per acre.

A summary of sorting records of other lots is to be found in Table 17. These were small random samples tagged at the time of picking. Yield data are omitted, as the samples represent too small an area to be accurately computed.

These data indicate that the soybean oil meal produced tobacco which was 40 cents a pound more valuable than cottonseed. In interpreting this difference, it must be borne in mind that the superior ability of the soybean oil meal to produce nitrates may have been a more important factor in an excessively wet year than in an average season. Some of these comparisons were made on fields from which the soil nitrates are very easily leached. Undoubtedly the cottonseed meal fertilizer was not able to maintain a level of soil nitrates above the critical point, while the soybean oil meal more closely approached the proper level. A further difference was introduced in the case of the Hilliard lot, which was new land with a previous cropping to grass. The decomposition of the organic matter of the grass roots further depleted the nitrate supply available to the crop.

TABLE 17. GRADING RECORDS OF SHADE TOBACCO, GERSHEL-KAFFENBURGH COMPANY. SOYBEAN MEAL VS. COTTONSEED MEAL. 1937

Designation		Picking	Price per pound	
			Soybean	Cottonseed
Old Hollow, Farm	4	1½	$2.112	$1.869
" " "	4	1½A	1.946	1.583
Hilliard, Farm	4	1½	1.998	1.322
" "	4	1½A	1.746	1.516
Field 7, Farm	3	1½	2.185	2.081
" 7, "	3	1½A	2.622	1.835
Average value			2.101	1.701

Summary

The experiments with soybean oil meal so far have shown that this material produces somewhat higher yield and better quality of Havana Seed tobacco than does cottonseed meal. These results are correlated with a higher rate of nitrification for the soybean product than for the cottonseed meal, i.e., the former maintained a higher level of nitrates in the soil all through the season. In other words, the soybean oil meal was the more efficiently nitrified of the two.

A study of the effect of variation in the water soluble content of nitrogen did not suggest any advantage in using meals with too high a percentage of water soluble nitrogen.

Results of two years' fertilizer tests with soybean oil meal on Shade tobacco indicate that it will produce superior tobacco as compared with cottonseed meal. The yield of this type of tobacco was not improved, but the leaves are thinner and more elastic, the colors more uniform and the percentage of high value grades correspondingly increased. Depending upon the growth conditions, differences of as much as 40 cents a pound were found.

NITRATE NITROGEN AND SOIL ACIDITY PRODUCTION BY NITROGENOUS FERTILIZERS

II. Effect of Liming

O. E. STREET

The effect of liming on production of soil nitrates has been studied extensively. It has generally been considered that liming stimulated nitrification, but some recent evidence tends to modify this conclusion.

This report is a continuation of the study of nitrate nitrogen and soil acidity production by single sources of nitrogen reported in Station Bulletin 386, pages 552-574: Report of 1935. The only change in the treatment of the plots has been the application in varying amounts of calcic hydrated lime in May of 1936. The schedule of applications was as follows:

Plot No.	Nitrogen fertilizer	Reaction [2] (pH)	Application of lime Lbs. per acre
N11	Cottonseed meal	5.10	800
N11-1	" "	5.00	800
N11-2	" "	5.00	800
N31	Castor pomace	4.50	2000
N31-1	" "	4.66	2000
N32	Linseed meal	4.40	2000
N33	Dry ground fish	4.49	2000
N36	Corn gluten meal	4.56	2000
N67	Peruvian guano	5.60	none
N66	Soybean oil meal	5.94	none
N12	Nitrate of soda	6.10	500[1]
N13	Sulfate of ammonia	3.81	3200
N14	Urea	4.32	2000
N34	Cal-nitro	4.83	2000
NC1	Cyanamid 1/5		
	Cottonseed meal 4/5	5.50	240

[1]Gypsum applied to this plot.
[2]Sampled March 26, 1938.

No attempt was made to adjust the lime applications to small differences in soil reaction. All plots with reactions between 4.30 and 4.83 pH were treated with 2000 pounds per acre, while those above 5.00 pH received less. The Peruvian guano and soybean oil meal plots were located on an old Adco manure plot and, as they still showed some effect of that treatment, they received no lime.

In an attempt to compare the nitrate levels before and after liming, the average of 1936 and 1937 will be compared with the average of the four preceding years. Figures for the latter are to be found on page 563 of the Report for 1935, to which earlier reference was made.

The comparative rainfall records for the 1932-35 and 1936-37 periods indicate that the average for the later years was somewhat greater in May, June and August, equal in July, and less in September. If the July irrigations in 1933, 1934 and 1936 are added, the earlier period had a higher average for that month than the later period.

In many respects the wet years of 1935 and 1937 resembled each other closely in rainfall distribution, total precipitation in June and July being almost equal. The distribution by 10-day periods in these two months was also similar for the two years. However, 1937 had much higher mid-May and middle and late August rains. September rains were heavy in both years. The 1936 season was characterized by a drought from June 20 to July 20 in which only .54 inch of rainfall was recorded. An irrigation of perhaps 1.50 acre inches was applied to these plots on July 11. The distribution of rainfall was not at all uniform, heavy rains from June 12 to 19 totaling 2.20 inches, and from July 21 to 25, 2.03 inches. May rainfall was below average and August and September were very nearly normal. The

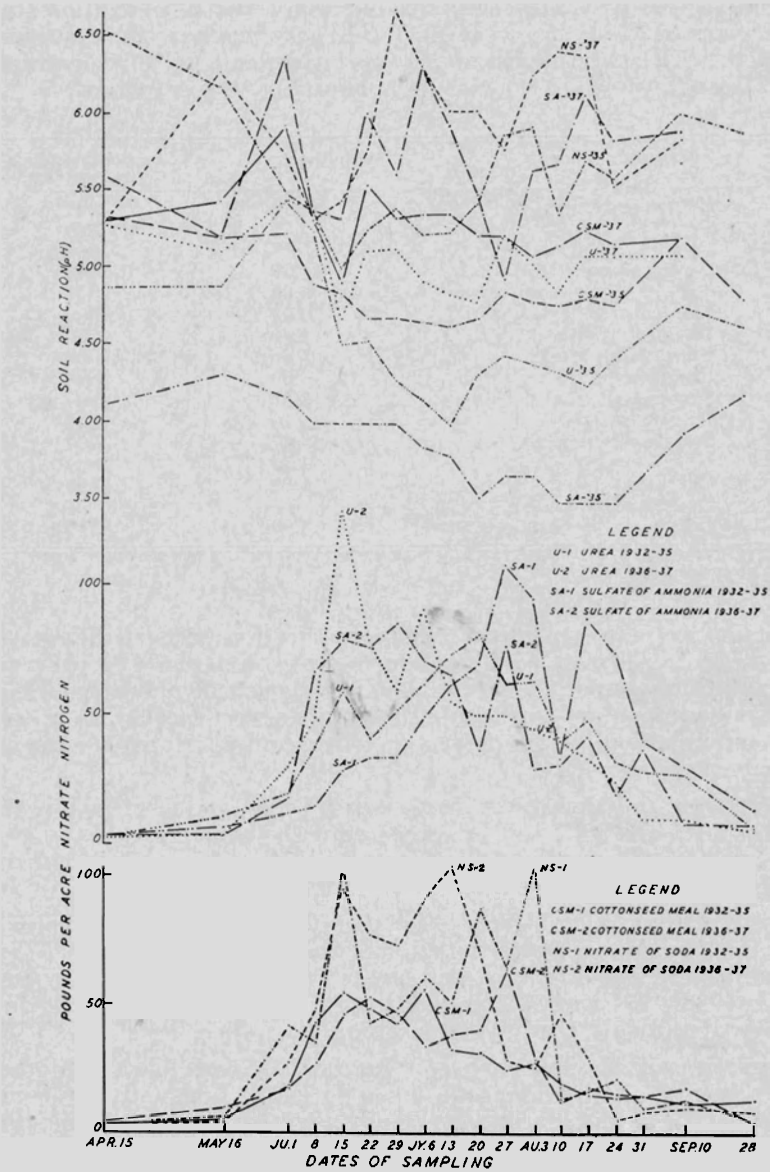

FIGURE 34. Graph showing average effect of liming on nitrate nitrogen levels in the soil for the period 1932-35, before liming; and 1936-37, after liming, at several rates. The comparative soil reactions for 1935 and 1937 are also shown.

TABLE 18. AVERAGE EFFECT OF VARIOUS NITROGENOUS FERTILIZERS OF NITRATE PRODUCTION. 1936-37

Average Date	Cotton-seed meal	Castor pomace	Lin-seed meal	Dry ground fish	Corn gluten meal	Peru-vian guano	Soybean oil meal	Nitrate of soda	Sulfate of ammonia	Urea	Calnitro	Cyanamid[1]	No nitrogen
Apr. 15	3	3	5	4	13	3	3	3	3	2	3	3	3
May 16	5	5	5	5	3	4	6	4	3	3	4	6	4
June 1	18	17	15	18	19	33	30	27	17	29	112	12	7
June 8	42	71	42	42	36	72	86	48	66	48	113	22	11
June 15	54	57	84	83	51	83	67	94	78	128	153	38	10
June 22	48	94	93	90	64	70	76	76	76	78	133	40	12
June 29	42	53	73	46	58	62	38	72	85	59	62	47	8
July 6	55	95	68	86	75	56	53	90	70	90	114	47	11
July 13	32	57	66	57	30	28	58	103	65	55	51	39	17
July 20	31	47	43	52	29	26	33	69	35	49	57	28	12
July 27	24	44	60	32	41	10	32	28	76	49	34	24	9
Aug. 3	27	29	28	39	34	24	32	25	28	44	76	20	6
Aug. 10	19	41	19	31	19	25	20	46	30	39	76	20	20
Aug. 17	15	34	15	29	26	30	26	28	41	32	37	15	12
Aug. 24	14	50	20	24	8	10	14	5	18	23	17	10	4
Aug. 31[2]	15	20	21	19	16	11	23	8	36	9	53	8	5
Sept. 10	12	26	31	23	16	6	12	10	7	9	7	18	5
Sept. 28[2]	13	10	15	9	8	10	13	8	6	4	8	11	5

[1]Cyanamid used to supply one-fifth of the nitrogen, cottonseed meal four-fifths.
[2]Determination on this date only in 1936.

characteristics of 1936 and 1932 were not dissimilar, and if the July irrigation of 1936 is added to the natural rainfall, the seasons are very similar. As 1933 and 1934 also benefited by irrigations, which always tend to relieve extreme differences, the water supply in the two periods, 1932-1935 and 1936-1937, was not sufficiently different to be a vitiating factor.

Effect of Liming on Nitrate Production

In comparing the nitrate levels for the two periods, the nitrate of soda treatment furnishes a useful comparison, as no lime was added to this plot. The average results for 1936-37 are to be found in Table 18 and comparisons of several materials are shown graphically in Figure 34. The fertilizers chosen—cottonseed meal, nitrate of soda, urea and sulfate of ammonia—represent the four classes of fertilizers in the series and also several rates of liming.

The relative nitrate levels for nitrate of soda in 1936-37 varied considerably from those in 1932-35. From June 22 to July 13, all 1932-35 levels were lower by 30 to 50 pounds per acre, while from July 20 to August 3 they were higher. Late season levels fluctuated considerably, favoring neither period. The average difference from June 1 to August 24 was in favor of the 1936-37 period by four pounds per acre.

With cottonseed meal the curves for the two years coincided rather closely. Deviations corresponded to those with nitrate of soda in time and direction of occurrence, but were much less marked. The average difference was one pound per acre in favor of the 1932-35 period.

The effect of liming on urea seemed to be a stimulation of early season nitrification, up to July 6, and a retardation of later levels. This behavior was similar to that observed with nitrate of soda, but was entirely consistent, whereas the nitrate of soda curves intersected frequently. The average effect of liming was to increase the nitrates four pounds per determination, the same as nitrate of soda.

The greatest effect of liming should make itself apparent with sulfate of ammonia, both because of the quantity of lime applied and the original high acidity of the soil. As may be seen from the curves, the behavior was very similar to urea in early stimulation, perhaps more marked. However, the late season drop was also marked and the net effect over the season was an identical total production of nitrates. An early stimulation of nitrate production by sulfate of ammonia is advantageous to its use, as it is a slow starting source under strongly acid conditions. With urea, which never was deficient in early nitrification, this stimulation was no benefit, while a drop from July 6 to the time of harvest might prove serious.

It cannot be concluded that the liming of these soils has had any marked effect on nitrification. The net changes were all of small magnitude, especially with the organic sources. Linseed meal averaged one pound more per determination and dry ground fish one pound less as a result of liming. Nitrate of soda displayed as great a difference as any of the plots which were limed. The early stimulation of the more acid materials, such as sulfate of ammonia, was a real benefit.

More definite conclusions on sulfate of ammonia are available from an experiment located on a heavier soil on field I, where limed and unlimed

TABLE 19. EFFECT OF LIMING ON NITRATE PRODUCTION BY SULFATE OF AMMONIA

NITRATE NITROGEN IN POUNDS PER ACRE ON VARIOUS DATES

1935

Treatment	Apr. 15	May 15	June 3	June 10	June 17	June 24	July 1	July 8	July 15	July 22	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 26	Sept. 7	Sept. 23
Limed	5.4	16.4	27.3	34.6	57.3	63.3	40.4	93.6	105.8	32.7	16.9	90.0	79.1	50.2	36.1	12.6	16.1
Unlimed	1.9	8.3	14.0	16.5	27.8	25.8	19.3	54.9	58.6	40.2	21.7	35.3	57.4	51.4	52.0	15.3	9.1

1936

Treatment	Apr. 15	May 15	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Aug. 24	Aug. 31	Sept. 14	Sept. 28
Limed	1.5	8.7	36.5	51.8	53.9	112.4	105.2	160.0	80.7	104.8	49.5	96.8	61.5	74.0	93.7	60.7	40.4	22.4
Unlimed[1]	2.7	4.8	12.5	24.8	15.2	26.4	25.4	78.2	67.9	64.9	52.3	62.4	60.5	26.3	25.2	26.5	43.4	19.3

[1]800 pounds hydrated calcic lime in 1936.

sulfate of ammonia plots occupied adjoining positions. The experiment ran from 1932 through 1936. The yield and sorting results of the first two years are reviewed in Station Bulletin 359, pages 355-360, Report for 1933. Applications of 1000 pounds per acre of calcic limestone in 1932, of 1200 pounds per acre of magnesia lime in 1933, and 2000 in 1934, were made to two plots. No lime was applied in 1935, but in 1936, 2800 pounds of hydrated calcic lime were applied to these plots. An application of 800 pounds of the same material was made on the check plots because of their extremely acid condition.

Previous to 1935, determinations of soil nitrates on these plots were made on only three dates: June 27, 1932, and July 10 and September 5, 1933. All of these data indicated a higher nitrate level for the unlimed plots by differences of 8 to 50 percent. During 1935 and 1936, samples were taken at regular intervals and the averages of two plots for each treatment are shown in Table 19.

It is first apparent from Table 19 that if lime is withheld sufficiently long from a strongly acid soil, repression of nitrate formation will ensue. In 1935, up to July 15, the nitrate levels of the limed plots were almost exactly twice those of the unlimed. After that date, the accumulation proceeded as rapidly on the unlimed soils, but the total recovery was undoubtedly lower.

Even more pronounced differences appear in the early season of 1936, despite the moderate liming of the acid plots. The lag in nitrate formation due to acidity extended throughout the period of sampling with only minor exceptions.

Where such extreme differences are produced, as is possible with the application of 7000 pounds of lime in five years in comparison with 800, many disturbances to the biologic activities of the soil must occur. It has been noticed that very acid soils sometimes fail to recover nitrifying ability for some time after liming due to a depletion of soil flora.

Effect of Liming on Soil Reaction

The reactions of the soils for the several dates of sampling in 1937 are given in Table 20. Comparisons of 1935 and 1937 reactions are also shown in Figure 34 for the same four materials for which nitrate levels are presented. These two years were chosen instead of the averages of the periods for several reasons: 1. Both were wet years; 2. the determinations of soil reaction in the first season after liming were erratic; 3. as 1935 was the last year before liming, it shows the soils in their most acid condition.

A comparison of the reaction levels with nitrate of soda indicates that from June 14 to August 16, less acid readings were obtained in 1937 than in 1935, averaging .67 pH unit higher. Results for two other materials which received no lime in 1936, Peruvian guano and soybean oil meal, disclose only .04 pH unit higher average readings for the same period. As the fertilizer mixtures employing these latter sources are nearly neutral because of the use of cottonhull ashes, it would indicate little change in the acidic level of the soils. On the other hand, the nitrate of soda has made the soil less acid.

TABLE 20 EFFECT OF VARIOUS NITROGENOUS FERTILIZERS ON SOIL REACTION IN 1937. (pH).

Date	Cotton-seed meal	Castor pomace	Lin-seed meal	Dry ground fish	Corn gluten meal	Peru-vian guano	Soybean oil meal	Nitrate of soda	Sulfate of ammonia	Urea	Calnitro	Cyanamid*	No nitrogen
April 16	5.29	5.55	6.15	6.15	5.40	6.12	5.55	5.28	5.59	5.28	6.21	5.28	5.18
May 17	5.42	5.00	5.16	4.95	5.61	5.72	5.90	6.26	5.18	5.08	5.39	4.22	4.98
June 1	5.90	6.49	6.10	5.59	6.11	5.92	5.75	5.72	6.35	5.42	5.51	5.96	5.45
June 7	5.29	6.29	5.42	5.06	5.05	6.06	6.09	5.29	5.35	5.35	4.85	5.66	4.71
June 14	4.88	4.89	4.89	5.10	4.80	5.49	5.41	5.42	5.30	4.65	5.12	5.05	5.26
June 21	5.51	5.75	5.92	5.32	6.52	6.59	5.71	5.75	5.98	5.08	6.15	5.80	5.86
June 29	5.30	5.78	5.81	5.36	5.49	6.05	5.41	6.65	5.58	5.10	5.70	5.95	6.19
July 6	5.33	5.18	5.11	5.36	6.39	6.25	6.48	6.29	6.29	4.88	6.01	4.85	5.00
July 13	5.33	5.65	5.00	5.10	5.00	6.45	6.06	6.00	5.90	4.81	5.50	4.92	5.40
July 19	5.18	5.61	5.41	5.30	5.59	6.30	6.25	6.00	5.45	4.75	5.65	4.86	5.30
July 26	5.17	5.75	5.65	5.55	5.69	6.45	6.15	5.75	4.91	5.19	6.28	4.79	5.20
Aug. 2	5.05	5.41	5.65	5.26	5.39	6.00	6.00	6.22	5.61	5.00	5.78	4.88	5.02
Aug. 9	5.13	5.35	5.69	6.00	6.15	6.42	6.29	6.38	5.65	4.82	5.99	5.41	5.25
Aug. 16	5.22	5.41	5.50	5.40	5.45	6.11	5.69	6.35	6.09	5.05	5.86	4.89	5.05
Aug. 24	5.13	5.30	5.78	5.78	5.52	6.02	6.02	5.50	5.80	5.05	5.65	5.21	5.41
Sept. 7	5.17	5.45	5.75	5.75	5.75	6.30	6.10	5.80	5.85	5.05	6.00	5.15	5.30

*Cyanamid used to supply one-fifth of the nitrogen, cottonseed meal four-fifths.

Cottonseed meal, with an 800 pound lime application, averaged .48 pH unit less acid for the same period, while castor pomace, linseed meal, dry ground fish and corn gluten meal, all with 2000 pound lime applications, were less acid by the following amounts: 1.14, 1.10, .98 and 1.15 pH units respectively. As with other organics, the fertilizer mixture was nearly uniform, cottonhull ashes being the only major constituent besides the nitrogen source.

Among the inorganics, urea and cal-nitro each received 2000 pounds of lime. For the summer period, these sources were .64 and 1.26 pH units less acid in 1937. This indicates the more acid character of urea and the less acid character of cal-nitro, as compared with organics limed at the same rate. The application of lime on the cyanamid plot was only 240 pounds, because of the alkaline character of the material, yet the average rise in pH was .55 unit. Sulfate of ammonia received a 3200 pound application and averaged 1.95 pH unit less acid. No nitrogen was .12 pH unit higher.

It is thus apparent that among organics limed at the same rate, the change produced was very similar. Urea continued to disclose its acidic character, while cal-nitro was less acid than organics. Cyanamid and nitrate of soda were basic.

In the tests of sulfate of ammonia on field I, it is interesting to note that the unlimed plots were more acid than the limed plots to the extent of 1.91 pH units during 1936.

Summary

1. The effect of liming on nitrate nitrogen and soil acidity production by various nitrogenous fertilizers is discussed.

2. The nitrate production in two years after liming did not vary greatly from that in four years previous to liming. The least effect was noted for organic fertilizers. A stimulation up to mid-July and a repression for the balance of the season was noted for urea and sulfate of ammonia.

3. Limed sulfate of ammonia plots produced lower nitrate levels than unlimed plots during the first two years of a five-year experiment. During the last two years of the test, liming greatly stimulated nitrate production. The extreme concentration of acids in the unlimed soil was detrimental to biologic activity.

4. The decrease in soil acidity was as much as 1.95 pH units with sulfate of ammonia. The acidic character of all the organics were similar. Urea was more strongly acidic, cal-nitro less, and cyanamid and nitrate of soda were basic in their effect on soil reaction.

TIME OF HARVESTING HAVANA SEED TOBACCO. III

When the first blossom of the seed head opens, it is time to break the top out of the plant. Since most growers agree in this practice and it is supported by the results of experiments here, Station Bulletin 297, we may consider it a rather definitely fixed point. But there has been considerable diversity of opinion as to how long the tobacco should stand in the field *after topping* before it can be harvested with the maximum gain in yield and quality. In order to measure the changes in yield, and the various factors of quality induced by a longer or shorter period of ripening after topping, a series of field tests was started here in 1935 and has been repeated for three successive years. The results for the first two years were published in Station Bulletin 386, page 585, and Bulletin 391, page 73. The object of the present discussion is to add the results of the 1937 tests and summarize the findings to date.

The general plan of the experiment has remained the same. From a uniform field of tobacco, set on the same day, fertilized and cultivated alike, and topped on the same day, one plot of three or four rows is harvested one week after topping; another plot of an equal number of plants (300) is harvested two weeks after topping, and a third, three weeks after topping. All are hung in the same shed, in the same tier, cured and sorted alike, and results in yield, grading and size of leaf computed.

The experiments of previous years were tried on a field where the soil is quite sandy and "leachy" (field V). The 1937 experiment was repeated on this field and the same test tried twice on another field (field I) where the soil is not so sandy and does not leach seriously. In the new situation, two different strains of Havana Seed were compared since it seemed possible that there might be variation in the rate of maturing the two. One of these was the Brown strain, so called because the seed first came to the Station from the late Stanton F. Brown of Windsor, having been handed down to him by his father. Tests at this Station and elsewhere showed this to be the best of a number of Havana Seed strains in a series of trials some 10 years ago, and it has been used on the Station farm ever since. The other seed tried this year was Havana Seed No. 211, a rootrot resistant strain, one of a large number that has been under test here for several years and has been judged the best. Besides being resistant to rootrot, it also gives a high acre yield and good grading. Another change introduced this year was that in the two trials on field I, a fourth plot was harvested *four* weeks after topping. Previous results demonstrated the advantage of letting the tobacco stand for at least three weeks, and the 1937 test was to see what the effect of four weeks would be.

All of the plants were set in the field on June 2. On account of the heavy rains during June an extra application of fertilizer to supply 30 pounds of nitrogen to the acre was made as a side dressing on June 23. On field V, the dates of harvesting were August 5, 12 and 19; on field I for the Brown strain, the dates were August 2, 9, 16 and 23, and for the No. 211 strain, they were August 4, 11, 18 and 25. During the cure it was observed, as in previous years, that the tobacco harvested first cured most slowly and that the riper it was when harvested the more quickly it cured.

The observations made during the process of sorting confirm those of previous years. The tobacco harvested one week after topping was of a more greenish color and was thinner than that harvested later. With each week that it stood in the field there was less of the green cast and the leaves were heavier, or had more body.

The grading records and the acre yield for all three tests are given in Table 21.

A study of all the data on this year's crop leads to the following conclusions:

1. **Increase in weight.** In each of the three series there was a steady increase in weight each week the tobacco was left in the field up to three weeks. This increase was more pronounced on the lighter soil of field V than on the heavier soil of field I. On field V the increase in two weeks was 503 pounds; for the No. 211 on field I, it was 212 pounds; and for the Brown strain on field I, it was 265 pounds. In neither series where one of the plots stood for four weeks was there any increase in weight beyond the third week—in fact, in both cases there was a slight loss. The loss in weight at this stage of development is probably explained by (1) the advanced maturity of the leaves causing a cessation of any further expansion; (2) translocation of the mineral elements and some of the organic compounds from the leaf into the stalk and the rapidly growing suckers, and (3) respiration of some of the organic compounds which is initiation of the curing process.

TABLE 21. TIME OF HARVESTING HAVANA SEED. YIELD AND SORTING RECORDS. 1937

Type	Weeks after topping	Acre yield	Percentage of grades								Grade index
			L	M	LS	SS	LD	DS	F		
Havana Seed	1	1766	2	1	30	11	34	7	15		.370
No. 211	2	1872	4	2	32	10	35	6	10	1	.402
Field V	3	2269	7	3	37	6	34	3	9	1	.446
Havana Seed	1	2000			37	7	38	5	10	3	.380
No. 211	2	2031	3	2	38	6	38	2	10	1	.417
Field I	3	2212	6	3	34	4	40	1	10	2	.428
	4	2187	5	6	35	4	37	1	10	2	.433
Brown	1	1672			35	8	25	6	17	9	.347
Havana Seed	2	1852			40	5	37	1	14	3	.385
Field I	3	1937			37	3	39	1	13	7	.369
	4	1844	2	1	44	3	26	1	11	12	.402

2. **Increase in the size of leaf.** Just as in the two previous years, there was a weekly increase up to the end of the third week in length of leaf (see Table 22) as determined by the sizing records. Undoubtedly this was accompanied by a similar increase in width since extensive measurements on other plots (page 342) show that the ratio between length and width tends to remain constant. During the fourth week, however, there was no increase in length of leaf on the No. 211 strain, but a slight increase on the Brown strain. In this fourth week it seems likely that the leaves have reached such an advanced stage of maturity that they are no longer capable of expansion.

3. **Increase in grading.** In both tests on the No. 211 Havana there was a regular increase each week in the grade index. This was also true of the Brown strain test except for the third week, when for some unknown reason, the index sank below the second week. Even the fourth week increased the grade index somewhat in both series, thus indicating that the quality of the tobacco may be increased by letting it stand in the field up to four weeks.

4. **Influence of maturity on pole rot and bundle rot.** During the sorting it was observed that most pole rot and bundle rot was on the plots which were harvested at the earliest stages. Bundle rot is apparently the same disease as black rot, or canker, which occurs during fermentation in the case. This trouble has been reported by growers as quite common in the Valley in 1937. Our observations this year corroborated by those made previously indicate that losses from both of these maladies might be reduced by harvesting tobacco at a more mature stage. This may be influenced by the more rapid cure of the later harvested tobacco and thus it would be exposed a shorter time to the danger of pole rot infection. Differences in the chemical make-up of the mature leaves may also have an influence.

5. **Comparison of the Brown strain with Havana Seed No. 211.** Both of these strains were used in 1937 in the time of harvesting experiments in adjacent plots on the same field and were treated identically in every respect. The sorting and yield results given in Table 21 show that under the same conditions, the No. 211 strain yielded 279 pounds of tobacco per acre more than the Brown strain, and that the grade value was about 10 percent better.

A difference in susceptibility to insect attack was apparent. As has been published in our previous reports, the No. 211 strain is quite resistant to flea beetles, a difference observed this year both in the field and on the sorting bench. Moreover, for the first time we noticed that thrips injury was much more abundant on the Brown strain than on the No. 211 strain.

When tobacco stands for three weeks or longer in the field, it incurs certain disadvantages and dangers that should be mentioned.

1. The crop is exposed for a longer time to possible injuries by hail storms, winds, insects and diseases.

2. It involves more labor in suckering. After the top suckers are broken out, suckers come from the lower axils and these are more troublesome to remove than the top suckers.

3. More suckering operations mean more breakage of the leaves unless the workmen are very careful.

These disadvantages, however, we believe are outweighed by the advantages discussed above.

Since the results of the tests in 1937 are very similar to those of the two preceding years, we may briefly summarize the conclusions from all tests to date:

1. There is a large and continuous increase in weight of the crop after topping, up to three weeks but not to four weeks.

2. The grading shows corresponding improvement also during these three weeks. In the two tests of 1937, this improvement in grading extended to the fourth week.

3. The increase in yield is apparently due to increase in leaf size and thickness subsequent to topping.

4. The color (too green at first week) improves each week.

5. The longer it is left in the field after topping, the more quickly it cures and also the less it is affected by pole rot and bundle rot.

TABLE 22. LENGTH OF LEAF AS INFLUENCED BY TIME OF HARVESTING

Type	Weeks after topping	Percentage of sizes							Weigh. Av.
		15″	17″	19″	21″	23″	25″	27″	
Havana Seed	1	21	13	25	32	9	—	—	18.90
No. 211	2	14	11	21	32	19	3	—	19.80
Field V.	3	11	8	15	32	23	10	1	20.64
Havana Seed	1	14	9	19	28	24	6	—	20.14
No. 211	2	12	6	15	25	26	14	2	21.04
Field I	3	11	4	10	26	25	17	7	21.58
	4	11	4	15	22	28	15	5	21.34
Brown	1	22	12	22	30	13	1	—	19.06
Havana Seed	2	15	5	13	23	26	17	1	20.90
Field I	3	15	4	13	23	26	17	2	21.00
	4	12	4	11	23	27	20	3	21.42

Some Effects of Time of Harvesting on the Chemical Composition of the Leaves

The changes in physical characteristics of the leaves after topping, as discussed above, are undoubtedly coupled with certain internal changes in the chemical structure. The whole story of the changes as they occur might be obtained by complete chemical analyses of the leaves at weekly intervals after topping. To determine *all* the elements and their combinations would involve more time and work than we could apply to it at this time. Nevertheless, as a beginning, samples of darks and seconds from each week's harvest and from both strains of tobacco used on field I were analyzed for four of the important elements. The samples of each week, after curing, were stripped (midrib removed), oven dried, ground and analysed by the Analytical Chemistry Department of the Station.[1] The results of the analyses are shown in Table 23. In Table 24 the removal in pounds per acre of each of the four elements is computed from the percentages in Table 23 and the total yields of Table 21. These figures show some quite definite trends in the changes in quantity of the various constituents during the time after topping.

TABLE 23. CHEMICAL ANALYSES OF HAVANA SEED LEAVES FROM TIME OF HARVESTING PLOTS. CROP OF 1937. MIDRIBS REMOVED. PERCENTAGE OF DRY WEIGHT

Element	Grade	1 week			2 weeks			3 weeks			4 weeks		
		211	Br	Av.	211	Br	Av.	211	Br	Av.	211	Br	Av.
Nitrogen (N)	D	5.38	4.84	4.76	4.92	4.63	4.41	4.96	4.10	4.03	4.36	4.10	3.93
	S	4.61	4.20		4.14	3.96		3.54	3.52		3.78	3.47	
Potash (K_2O)	D	5.08	4.81	4.87	4.88	4.40	4.55	4.36	3.92	4.25	3.59	3.16	3.54
	S	4.88	4.72		4.77	4.17		4.81	3.92		3.53	3.87	
Calcium (CaO)	D	5.18	6.01	5.87	5.83	6.34	6.51	5.93	6.64	6.95	6.62	7.23	7.16
	S	6.07	6.20		6.60	7.25		7.26	7.95		7.03	7.78	
Magnesium (MgO)	D	1.31	1.75	1.53	1.38	1.48	1.47	1.24	1.69	1.56	1.15	1.49	1.45
	S	1.27	1.77		1.40	1.63		1.54	1.78		1.44	1.70	

[1]We are indebted to Dr. E. M. Bailey of that department for the analyses presented in Table 23.

TABLE 24. TOTAL POUNDS OF NITROGEN, POTASH, CALCIUM AND MAGNESIUM IN THE LEAVES OF AN ACRE OF TOBACCO AS INFLUENCED BY THE TIME OF HARVESTING

Weeks after topping	Strain	Acre yield[1] (oven dried)	Nitrogen N		Potash K_2O		Calcium CaO		Magnesium MgO	
				Av.		Av.		Av.		Av.
1	211 Br	1500 1254	75.0 56.7	65.9	74.7 59.8	67.2	84.5 76.4	80.4	19.3 22.1	20.7
2	211 Br	1524 1389	69.0 59.7	64.4	73.6 59.6	66.5	94.8 94.5	84.6	21.2 21.7	21.4
3	211 Br	1659 1452	70.5 55.3	62.9	76.1 56.8	66.5	109.5 106.0	107.7	23.1 25.1	24.1
4	211 Br	1641 1383	66.8 52.4	59.6	58.4 48.7	53.6	112.1 103.7	107.9	21.3 22.1	21.7

[1]Calculated by deducting 25 percent from the barn-cured weight for moisture.

The percentage of *nitrogen* decreases regularly each week so that in three weeks it has dropped from 4.76 to 3.93 percent, a loss of 18 percent of the total nitrogen of the leaves. Table 24 shows that, despite the increase in crop weight each week, there was an actual loss in the total nitrogen in an acre of leaves. This loss is readily accounted for by translocation of nitrogen from the leaves to the suckers which are removed before harvesting.

The behavior of *potash* is very similar to that of nitrogen, decreasing regularly in percentage each week. The total quantity per acre, however, shows very little decrease until the fourth week, when it drops rather suddenly. The potash is translocated with the nitrogen into the growing suckers and removed from the plant. The relatively low percentage of potash in these samples and the fact that the percentage in seconds was not higher than in the darks—a condition not previously observed in our Station tobacco—indicated that the supply of potash was running low for this crop and it was being freely translocated to the younger parts of the plant for re-utilization.

Calcium presents a quite different picture. It shows a decided increase in percentage each week: in three weeks from 5.87 to 7.16 percent, an increase of 22 percent in the amount of calcium in the leaf tissue. The quantity per acre also increases sharply as shown in Table 24. Calcium in the leaves occurs as pectates in cell walls and as calcium oxalate and other difficultly soluble compounds in the cells, and therefore is not readily translocated. Obviously calcium continues to enter the leaves during four weeks after topping and most, if not all, that enters remains in them permanently. Calcium for the growing suckers probably comes from a new supply from the roots.

The percentage of magnesia remains about the same and the small changes shown from week to week do not show any definite trend and no explanation for them is apparent.

Comparing the Brown strain with the No. 211 strain, there are regularly very evident differences in the chemical composition of the two. Table 23 shows eight separate comparisons for each element. In all of the eight, the No. 211 strain contains more nitrogen, and, in seven of the eight, more potash than the Brown strain. On the other hand, every comparison of the calcium and magnesium shows these elements higher in the Brown strain. These findings suggest an interesting field of speculation and subject of further investigation as to the differences that probably exist in the various strains of tobacco of the same type that we grow in Connecticut and their influence on the quality characteristics that are present or claimed for each.

No chemical investigation of this nature has been undertaken or recorded for Connecticut tobacco. For instance, the higher calcium content of the Brown strain may have some relation to the greater susceptibility of this strain to black rootrot, a disease that becomes more severe with application of lime to soil. Moreover the greater resistance of the No. 211 strain to flea beetle and thrips injury may possibly be explained on the basis of its peculiar chemical make-up.

TIME OF PICKING SHADE TOBACCO

Shade tobacco is not harvested by cutting down the whole stalk, as in the case of the Havana Seed type described in the preceding article. The stalk is left standing in the field but the leaves, beginning at the bottom, are picked off as they become ripe, three or four at a time. The pickings or primings, succeed one another at intervals of four to seven days, the length of interval depending on the weather and the grower's judgment. As the leaves become more nearly mature, they take on a lighter green or more yellow-green color. If this fading process goes too far, however, they become over-ripe and depreciate in value. It requires long experience to know exactly when they have reached the stage that insures highest quality after curing. There are no rules to follow, no sharply defined symptoms to guide the grower, and there is a resultant lack of uniformity of practice which inevitably leads to heavy losses from "green" tobacco on the one hand, or over-ripe tobacco on the other. It would be greatly to the advantage of growers to have some criterion on which to base the proper date of the first picking particularly.

Obviously one cannot set the date from the number of days the plants have been set, because plants develop more slowly some years than others. On the other hand, the degree of maturity of the leaf is probably correlated with the stage of development of the plant—not, however, with its size or height. The first fixed and unmistakable stage of development in the field plant is the appearance of a cluster of flower buds at the apex. Assuming that all plants in this particular stage have leaves in the same physiological condition, it is reasonable to believe that the date of the first picking could be timed in relation to the number of days after the bud cluster first appears. Such is the basis of the experiments described here.

Experiments have been conducted in the past in which early picked, medium picked and late picked leaves have been compared. Unfortunately every grower has a different idea of what is early picking or late picking, and since the experimenters did not tie up their designations with any physiological stages of development, the results are of little value because they cannot be interpreted and cannot be applied to actual practice.

In an attempt to make a more thorough comparison of the effect of early, medium and late picking, and at the same time to relate the picking dates to stages of plant development so that any grower can recognize them and duplicate the results, the following experiment was undertaken.

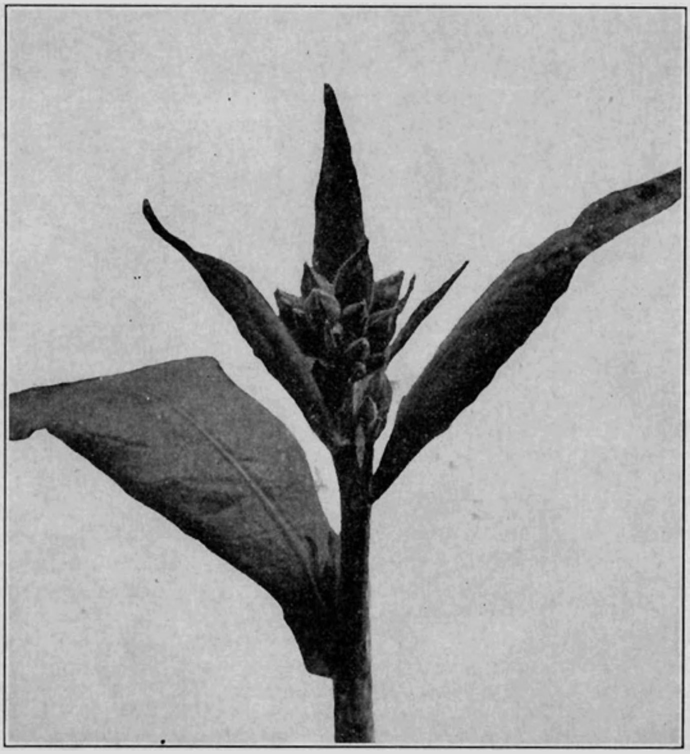

FIGURE 35. Budding stage of Shade tobacco. Showing stage at which "Time of Picking" experiment was started in 1936.

The experiment was started in 1936 in Mr. Raymond Clark's field which is adjacent to the Tobacco Substation. On July 13, 600 plants were selected and tagged. All of them had buds in the cluster stage as indicated in Figure 35, but none showed the color of the flower. Figure 36 shows an infloresence at the time of regular first picking. [Note the elongated stalk and enlarged and partly-open buds. In practice, this part is removed in budding at about the stage of Figure 35.] The plants were of good growth and fairly uniform size, ranging from 3 to 3.5 feet in height. None was budded at that time, but some of the larger plants in the same field were budded on July 11.

The selected plants were divided into three lots, designated for early, medium and late picking. The first picking of three leaves on the early lot was taken on the same date, July 13. On the medium lot it was taken on July 16, the date of the regular first picking; and on the late lot on July 20, the time of the regular 1½ picking. This schedule was followed throughout the picking season, as shown in Table 25.

FIGURE 36. Infloresence at time of regular first picking. Note elongated stalk and enlarged buds.

The later pickings were delayed somewhat by heavy rains on July 24 and 25, and again on August 8 and 9.

The tobacco was fermented with the regular tobacco from the field, and assorted in the Gershel-Kaffenburgh warehouse. The sorting results are shown in Table 26. Due to the loss of one lot of the 1½A picking in handling, the data for this picking are omitted from the results.

TABLE 25. SCHEDULE OF DATES OF PICKING, 1936

Picking	Early	Medium	Late
1st	July 13	July 16	July 20
1½	" 16	" 20	" 30
1½A	" 20	" 30	Aug. 11
2nd	" 30	Aug. 11	" 21
2A	Aug. 11	" 21	" 26

TABLE 26. TIME OF PICKING SHADE TOBACCO, 1936

Picking and treatment		Yield pounds per A.	Percentage of grades																Price per pound
			LL	LC	LC_2	LV	LV_2	YL	YL_2	V	VL	S2	ML	S1	BB	XL	XL_2	XX	
1st	Early	97		6.3	6.3	8.4	53.7	2.1		19.0						2.1	2.1		1.797
	Medium	108		7.7	18.5	11.5	33.1	6.9	1.5	13.1						3.1	4.6		1.817
	Late	129			19.5	2.3	15.0	25.3	18.4	5.7		3.5				2.3	8.0		1.343
1½	Early	206	0.5	12.1	9.5	24.4	36.5	0.5		8.5						4.8	3.2		2.670
	Medium	218	4.5	28.9	22.8	11.1	18.4	3.9		1.1		2.2		1.1	0.6	3.3	2.2		2.801
	Late	224	8.2	14.9	19.4	3.5	23.1	2.2		12.7					3.0	3.5	6.7	0.8	2.444
1½A[1]														ML_2					
2nd	Early	265					1.9			34.2	12.1		35.2	12.1		1.5	3.0		1.053
	Medium	276					8.8			40.6	18.9		25.0	2.7		1.3	2.0	0.7	1.293
	Late	268			3.3					38.3	18.4		33.3			5.0	1.7		1.212
2A	Early	291								31.4	23.4		34.2	8.5		0.5	2.0		1.067
	Medium	299					4.9			38.4	10.8		34.6	6.0		0.5	3.2	1.6	1.143
	Late	272							1.4	17.8	8.9		43.2	19.2		2.7	6.1	0.7	.854

SUMMARY

Time of picking	Yield—4 pickings[1]	Weighted average[1] price per pound	Crop value[1] per acre
Early	859	1.531	1314.87
Medium	901	1.671	1505.48
Late	893	1.431	1277.81

[1]1½A picking had one lot lost in sweating, hence is left out.

Early picking decreased the yield by about 10 percent and the average price was about 14 cents a pound lower. The decrease in yield was largely in the pickings of the lower leaves, while the grading was poorer in those above the first.

Late picking of the lower leaves increased the yield but was disastrous to quality. A delay of 10 days beyond the normal time in the next to the top picking caused only a slight shift in the distribution of grades, but the leaves in the corresponding grades were poorer. The late top picking deteriorated rapidly in grading and in yield during the five extra days it remained in the field.

Early picking produced thin tobacco of greenish cast, but of high quality from the lower stem. Higher up, prominent veins and greasy dark leaves were noted.

In the late picking the leaves low on the stem were not only spotted and yellow but thicker than is desirable for Shade tobacco. This last factor became increasingly objectionable toward the top of the plants.

Pickings that were started when the infloresence had developed to the point of showing color and an occasional blossom had begun to open, were the best in every case. This was usually five days to a week after the more mature plants had reached the cluster stage and been budded. It was also very near the time of the budding of the less mature plants. The crop value of four medium pickings exceeded early picking by $190 per acre, and late picking by $227 per acre.

In 1937, the experiment was continued in the same location. The number of plants per treatment was increased from 200 to 400. The plants were tagged on July 14, all in the cluster stage as in 1936. They were from three to four feet high, an average in that field. The largest plants had been budded July 9. The second budding of the taller plants occurred on the same date as the tagging. No mosaic-infected plants were tagged.

The schedule of pickings is shown in Table 27.

A heavy rain on July 26 delayed picking and prolonged the period between the regular 1½ and 1½A picking to 12 days, as compared with 10 days in 1936. The next interval was shortened to 5 days since the leaves showed signs of starvation and rapid ripening. No top picking was taken on the general tobacco in this field, because heavy rains and high winds broke the tops of the plants and damaged many leaves. However, the experimental plants were finally picked after 30 days, as compared with 10 days in 1936.

Table 27. Schedule of Dates of Picking 1937.

Picking	Early	Medium	Late
1st	July 14	July 17	July 21
1½	" 17	" 21	Aug. 2
1½A	" 21	Aug. 2	" 7
2nd	Aug. 2	" 7	Sept. 2
2A	" 7	Sept. 2	" 7

Shed and warehouse treatment was the same as that given the balance of tobacco from the field. The sorting record is shown in Table 28.

TABLE 28. TIME OF PICKING SHADE TOBACCO. 1937

Picking and treatment		Yield pound per A	Percentage of grades																Average price
			LL	LC	LC_2	LV	LV_2	V	YL	YL_2	S2	VL	ML	KV	BB	XL	XL_2	XX	
1st	Early	91	Computed from weighted averages																$1.912
	Medium	121	" " " "																1.669
	Late	131	" " " "																.816
1½	Early	179		1.5	10.9		8.0	26.5	20.8	8.2			3.1		0.4	9.2	9.8	1.6	1.611
	Medium	182		3.6	14.3	1.3	15.1	27.0	16.0	5.6			3.0		0.7	5.5	7.3	0.6	1.825
	Late	215		4.5	18.6		3.7	11.7	25.8	7.2			4.1		1.8	11.6	10.0	1.0	1.685
*	Late X	180			15.0		14.2	18.4	18.4	12.8					3.6	7.5	10.1		1.690
1½A	Early	208		11.0	19.7	12.8	22.4	8.9	12.7	2.0		1.5				7.0	1.2	0.8	2.366
	Medium	227	1.6	7.7	17.3	2.8	6.3	17.6	19.1	6.0		8.5	0.8		2.7	4.7	4.5	0.4	1.871
	Late	220			2.6		1.1	8.7	16.8	35.0	3.7	6.2	9.8	0.3	1.9	10.3	2.6	1.0	1.247
2nd	Early	218			2.0		9.0	38.2	7.0	3.5	2.3	1.0	25.8	3.7		2.5	4.3	0.7	1.352
	Medium	216					2.8	29.7	10.0	18.0	3.8	0.8	16.0	2.1	0.7	3.1	11.5	1.5	1.218
	Late	210								12.5	21.2		13.4	3.7	0.2		27.7	21.3	.558
2A	Early	228						35.0	2.8	2.8		7.8	35.7	8.8	0.5	2.2	3.3	1.1	1.067
	Medium	221									12.4		13.8	67.5				6.3	.280
	Late	215									8.4			82.7				8.9	.217

*1½ picking on part of the late lot on same day as first picking.

SUMMARY

Time of picking	Yield	Weighted average Price per pound	Crop value per acre
Early	924	$1.615	$1492.50
Medium	967	1.327	1283.78
Late	991	.915	906.35

Early picking again was instrumental in decreasing yield. The grading was superior to medium in several pickings, notably the first, the 1½A and the second. In the case of the first picking, the increase in yield of medium picking more than counterbalanced the lower price. The early 1½A picking was taken before a rain of 1.53 inches, while the medium succeeded it with a resulting increase in yellow leaves and a thickening of olive colored leaves. The early picked lot had a phenomonal proportion of LV's, 12.8 percent, and this raised the average value.

In the case of the second picking, the early lot was taken from the field before the full depleting effect of the heavy rains, five or six days previous, had made itself felt. As a consequence, the medium or regular picking showed more YL's and five times as many YL_2's, both mottled grades. A similar effect is noted in this bulletin in the section on soybean oil meal for Shade tobacco. The two experiments were located on adjoining bents of the same field and the pickings for the fertilizer experiment were taken on the dates of the medium pickings. In the case of the fertilizer experiment, the superior nitrifying ability of the soybean oil meal was instrumental in producing better tobacco.

The medium top picking was not taken until 23 days after the early top picking. During that time the tobacco became almost worthless and no fair comparisons can be made. While the early picked tobacco was quite dark, it was much better than the average top picking and was not thick or boardy.

A comparison of values for the first three pickings indicates that the early pickings averaged in price $1.997; the medium, $1.809; a difference of about 19 cents a pound. For the first four pickings the difference in favor of early treatment was 16 cents, as compared with 35 cents for all pickings. However, the corresponding differences in total crop value were $4.32 in favor of medium for three pickings because of higher yield, and $89.20 and $208.72, respectively, in favor of early for four and five pickings, because of higher grading.

Late picking of the first three leaves was most detrimental, cutting the price in half. The leaves were very heavy and dark; the colors muddy. On part of the late picking area, about 50 plants had the 1½ picking removed on the same day as the first. This tobacco yielded about the same as the medium picking on the same date, but did not grade so well. It was thin and papery and too dark for good grades, indicating that these leaves did not mature while the bottom leaves were left on the plant. Compared with medium picking, the 1½ picking on the late lot gave better yield and lower grading. The total value of late picking was 10 percent greater, but the high percentage of yellow and mottled leaves and broken tobacco made the tobacco difficult to sell. Except for the 1½ priming, late picking continued to produce the poorest tobacco. The 1½A picking, taken on the same date as the regular 2nd, was of slightly higher value, having a few more light leaves. However, it was not equal to the regular 1½A taken five days earlier.

Both the 2nd and 2A pickings of the late treatment were taken in September. The 2nd late was better than the 2A medium, but not much good, while the 2A late was over 80 percent KV's, a 20 cent grade.

On the basis of average values, the medium exceeded the late by 49 cents a pound for three pickings, 52 cents a pound for four pickings, and 41 cents a pound for all pickings. The corresponding crop values for three pickings were $216.30 more for the medium, for four pickings, $362.21 more, and for five pickings, $377.43 more.

Medium picking tobacco was superior in elasticity and lightness of color in all of the first three pickings. These factors are considered of greater importance than any others in the ready sale of leaves. The early 1½A picking was favored because it was primed before a rain and was thin, silky and not too dark, but the medium picking was also very good.

Under the circumstances which prevailed during the past growing season, a number of factors interfered with the regular schedule of pickings. These combined to the great detriment of late picking and the considerable detriment of medium picking. Up to August 2, the growing conditions were quite suitable. By that date, four pickings were off the early lot and three off the medium. Severe nitrogen starvation occurred between that date and August 7, and at no time after that was there an adequate supply of soil nitrates. Undoubtedly, the lower the leaves remaining on the plant by August 7, the greater the starvation. Omitting the September pickings, the loss in value by medium picking as compared with early was $89.20. The decrease in value due to remaining in the field from July 21 to August 2 was $67.40, and from August 2 to August 7 was $31.65. which more than overbalanced the earlier advantage of medium picking.

Summary

The results of two years tests on the best time for picking Shade tobacco are presented. Considerable differences were found in the behavior of the tobacco in the two years. The conclusions follow:

1. In both years, pickings that were started three days after the second budding of the plants, and five to eight days after the first budding, (medium picking) were about equal, in value of the first three primings, to the pickings that were started on the date of the second budding (early picking).

2. In 1936 medium picking was more valuable for top primings, while in 1937 early picking was much more valuable.

3. Late priming was (almost without exception) the poorest. It caused a loss of $227 as compared with medium in 1936, and a loss of $377 as compared with medium, and $586 as compared with early, in 1937.

4. In a season of normal to dry weather conditions, an interval of four days between first and 1½ pickings, with ten day intervals between succeeding pickings, depending on rains, was suitable.

5. In a season of heavy and depleting rains, hastening the late pickings to avoid harvesting starved tobacco, seemed to be the best procedure.

THE RÔLE OF COVER CROPS IN THE MAINTENANCE OF THE FERTILITY OF TOBACCO SOILS

M. F. Morgan and O. E. Street

As grown in the Connecticut Valley, tobacco is a crop that is planted on the same fields for many successive years. There are numerous instances of tobacco cropping for 60 or more years without interruption. Until the present generation, fields were usually left bare from one season to another. At that time the crop was practically confined to level, sandy terrace lands where soil erosion by water movement does not occur. The more extremely sandy types, such as are now more extensively planted to Shade tobacco, were not utilized until the early part of the present century. Hence, few fields were then on land subject to wind erosion if unprotected. Manure was rather generally used; fertilizers were almost exclusively of organic materials, supplying from 2000 to 3000 pounds of organic matter per acre. Under such conditions, it must have been possible to maintain soil fertility without cover crops under continuous tobacco. Previous studies[1] have shown no evidence of decline in soil organic matter on these old tobacco fields.

In the period of rapidly expanding tobacco acreages about the time of the World War, many fields on rolling to hilly topography were taken up. The necessity of affording some protection against water erosion on such areas was soon realized and cover cropping began to be practiced more extensively. At about the same time the development of Shade tobacco encouraged the use of many sandy soils that needed cover crops to prevent blowing losses. At first, timothy was the crop most extensively seeded between tobacco crops. When sown during the latter part of August, it developed a reasonably good sod before winter, and the added spring growth provided a fairly dense mat of fibrous roots and succulent tops to be plowed under in May.

Anderson[2] reported in 1925 that more than half of the tobacco land was cover cropped and timothy was used on 90 percent of this acreage. He pointed out that there was no experimental evidence to justify the choice of this species, and cited evidence that timothy might have undesirable features, such as the encouragement of brown root rot and the decrease of available nitrogen in the soil incident to the plowing under of material with a high carbohydrate content. In Massachusetts, Jones[3] had found that the timothy cover crop gave both decreased yield and quality.

A series of cover crop experiments was conducted on the sandiest portion of the Substation farm at Windsor from 1926 to 1931. The organic matter content is here significantly lower than on most tobacco soils. The data, previously cited in detail[4], are summarized in Table 29.

[1] Morgan, M. F., 1927. Organic Matter in Tobacco Soils. Tobacco Station Bul. 10, Conn Agr. Expt. Sta. Pages 66-71.

[2] Anderson, P. J. Cover Crops for Tobacco. Tobacco Station Bulletin 6, Conn. Agr. Expt. Sta. Pages 55-59. 1925.

[3] Jones, J. P. Havana Seed Tobacco as Influenced by Timothy Cover Crop. Mass. Agr. Expt. Sta. Circ. 73. 1925.

[4] Anderson, P. J., Swanback, T. R. and Street, O. E. Cover Crops. Bul. 335, Conn. Agr. Expt. Sta. Pages 227-231. 1931.

TABLE 29. SUMMARY OF COVER CROP EXPERIMENTS—WINDSOR, 1926-31*

Field VII Cover crop	Yield lbs. per A.	Grade index**	pH (average)	Organic Matter—percent 1927	1931	Change '27–'31
None	1237	.311	5.29	1.478	1.322	-.156
Timothy	1327	.345	5.31	1.522	1.391	-.131
Barley	1300	.363	5.22	1.492	1.437	-.055
Rye	1432	.415	5.36	1.563	1.476	-.087
Oats	1442	.428	5.27	1.628	1.430	-.198
Vetch	1448	.424	5.15	1.647	1.495	-.152
Field V Cover crop						
None	1278	.358	5.06	1.435	1.374	-.061
Alfalfa	1322	.390	4.96	1.507	1.521	+.014
Red Top	1274	.395	5.22	1.469	1.558	+.089
Wheat	1271	.376	5.08	1.498	1.485	-.013

* The crop of 1929 was destroyed by hail.
** Not including 1926.

There appeared to be a significant improvement in both yield and quality for all cover crop treatments. Timothy, while less desirable than most others, failed to show the adverse effects apparent in other trials. Vetch, oats and rye were significantly better than the rest. While not indicated by the grade index, vetch gave somewhat darker tobacco, perhaps due to the higher level of nitrates resulting from its residues. Rye must be plowed under earlier than other cover crops to avoid excessive drying of the soil by the undecomposed stems.

The growth of cover crops did not result in any significant increase or decrease in the pH of the soil. However, it is of interest to note that the two legume crops, vetch and alfalfa, seemed to produce a slight acid tendency.

The data with respect to organic matter showed that both in 1927 and 1931 the cover crop plots contained slightly more than those in which the soil remained fallow between tobacco crops. However, all plots on field VII and both "no cover crop" and "wheat" plots on field V showed a definite decline in organic matter content from 1927 to 1931. Apparently, even with cover crops, organic matter was not maintained on this sandy soil under continuous tobacco culture. This agrees with earlier observations[1] that the very sandy soils have been somewhat depleted by tobacco culture. However, the decrease in organic matter content from 1927 to 1931 was lessened by the growing of cover crops in eight of the nine cases. The one exception was oats, for which the percentage in 1927 appeared to be somewhat higher than expected.

On the basis of the above results, and the experience of farmers in the Connecticut Valley who had been using it for a number of years, the oats cover crop has come into general use during the past decade. It makes the most luxuriant fall growth of any of the crops that have been tried. Although it is winter-killed about December first, it leaves a protective mat over the ground during winter and spring months. It is readily in-

[1] Morgan, M. F. 1927. Organic Matter in Tobacco Soils. Tobacco Station Bul. 10, Conn. Agr. Expt. Sta. Pages 66-71.

corporated into the soil at any time during the spring. In some seasons it is badly infected with rust, but usually too late to cause much damage to the growth.

Rye is frequently used by tobacco growers who have live stock to pasture, and when spring growth is grazed down, it may be plowed later without danger to the tobacco crop. As was shown in Table 29, rye gave very good results in the cover crop trials at Windsor.

Italian rye grass was tried at Windsor for one season. It made an unusually irregular growth on various parts of the field and appeared to be rather sensitive to the lack of moisture and available nitrogen in the sandier areas. Hence, it made its poorest growth where a cover crop was most needed.

Most of the agricultural literature with respect to cover crops tends to emphasize the superiority of leguminous species. For most farm crops, this is undoubtedly sound. The nitrogen thus added to the soil through nitrogen-fixation may amount to 50 pounds or more per acre, at no cost to the farmer except the additional expense of seed. The residues from leguminous cover crops decompose more readily, due to their higher nitrogen content, without tendency to consume soil nitrates in the process, as with residues high in carbohydrates and low in nitrogen. However, with decreasing nitrogen costs and increasing legume seed costs, it has become questionable whether it may not be as desirable to grow non-legume cover crops, well fertilized with nitrogen, thus supplying a greater residue of organic matter of more fibrous character, which may exert more lasting benefits on the soil.

In tobacco culture there are several factors that have operated against the utilization of legumes as cover crops. None of the non-hardy species, such as soybeans or crimson clover, makes a sufficient fall growth to provide good winter coverage. Red clover and alfalfa, while hardy, also fail to supply good protection against wind and water erosion. Vetch appears to be the only possibility. However, as previously noted, it tends to produce dark tobacco. It is possible that a combination of rye and vetch would eliminate this difficulty.

Nitrate depression following the plowing under of non-legume cover crops is less serious with tobacco than with most cultivated crops, since the application of nitrogen in the fertilizer is so liberal. Much more nitrogen is applied than can be utilized during the first few weeks after setting, and much of the nitrates temporarily used up in the decomposing cover crop residue are restored to the soil solution by the time the tobacco begins to make heavy demands upon the soil.

Experiments on nitrogen sources carried on at Windsor for the past 10 years have shown that urea may be substituted for a large part of the organic materials, such as cottonseed meal, castor pomace, and fish, without sacrifice to yield or quality. While the trend to urea as a source of nitrogen in tobacco fertilizers must operate against a practice of several generations, it appears inevitable that this cheaper nitrogen source will gradually replace materials now supplying as much as a ton of organic matter per acre. Hence, the cover crop as an annual source of fresh organic residues becomes increasingly important.

Conservation of Plant Nutrients by Cover Crops

In addition to their value as a means of maintaining organic matter and protecting the soil against wind and water erosion, cover crops also serve to conserve plant nutrients against leaching, for gradual liberation to succeeding crops.

With the fertilization ordinarily practiced at present, the following amounts of the various applied constituents are left behind in the field when both stalks and leaves are removed, per acre, per year:

Nitrogen	80 to 100 lbs.
Phosphoric acid	40 to 80 lbs.
Potash	70 to 80 lbs.
Magnesia	0 to 20 lbs.

Lime (CaO) may be removed by the crop in excess of the amount supplied, especially on treatments containing neither precipitated bone, dolomitic hydrated lime or limestone.

Lysimeter studies conducted at Windsor during the past six years have indicated that soils that are left bare between successive tobacco crops lose these constituents to the drainage water in approximately the following amounts, per acre, per year:

Nitrogen	60 to 70 lbs.
Phosphoric acid	Trace only
Potash	75 to 80 lbs.
Lime (CaO)	80 to 100 lbs.
Magnesia	20 to 30 lbs.

At the cheapest prices for these constituents in tobacco fertilizer materials, the annual loss of these plant nutrients amounts to not less than $12.00 per acre.

After the tobacco crop is removed, there remains a period of several weeks of warm weather, favorable for the biological processes involved in liberation of available nitrogen and increased solubility of the mineral nutrients. Hence, even though the soil solution is in a depleted condition at the time of tobacco harvest, it is rapidly replenished except when autumn rainfall is excessive. The roots of cover crops growing during this period take up a considerable amount of these available nutrients. As a consequence of transpiration by the cover crop, the soil dries out more between rains than on fallow soil. Thus, the amount of water passing through the soil during fall rainy periods is materially lessened.

With the onset of winter, non-hardy cover crops, like oats, cease their activities. The dead plants suffer little decomposition until spring. The hardy cover crops, like rye and timothy, remain practically dormant during cold weather, and transpiration is negligible. The mat of vegetation tends to hold snow against drifting, and may decrease the depth of frost in the soil.

When the soil thaws, the water previously frozen throughout its pores is released, and much of the accumulated winter precipitation leaches downward to the water table within a short period. The thaws are usually accompanied by heavy rains, augmenting the volume of leaching. Plant nutrients, that have not been withdrawn from the soil solution by the cover crop, are now subject to severe leaching. Nearly one-third of the total leaching for the entire year occurs during the month of March, based on an average of the six years ending May 25, 1937. (March, 4.43″; annual, 13.90″). The cover crop sometimes increases the volume of this "spring thaw" type of leaching if more snow has been retained on the surface, to be later melted into the soil.

Under Connecticut conditions, the spring growth of hardy cover crops becomes active by about April first, giving approximately six weeks as the maximum spring growing period before the land must be plowed for tobacco. This is usually more than ample for rye to be turned under in good condition. A significant difference might be expected between the volume of leaching under oats, lying dead during this period, and cover crops in an active vegetative state. However, analysis of the data fails to reveal this, as shown by Table 30.

Table 30. Spring Leaching (April 1–May 15) With and Without Cover Crops
Average Annual – 1931-37

	Acre–inches
Fallow, between tobacco crops	2.15
Oats cover crop	2.69
Rye cover crop	2.71
Timothy cover crop	2.70
Rainfall during period	4.80

It is not surprising that the oats cover crop has permitted more leaching during this period, since the mulching effect of the dead tops would tend to prevent the drying out of the soil between rains. If the vegetative cover crops, rye and timothy, give as much leaching as with oats, then they must afford a considerably greater degree of leaching, more than compensating for transpiration during this period. Such a balance of transpiration and reduction of direct evaporation from the soil had not manifested itself during the fall growing period, perhaps due to higher temperatures, more active vegetative growth and less complete ground coverage.

However, this slightly increased volume of spring leachate under cover crops has been more dilute in nitrates and other soluble constituents, giving actually smaller losses than under no cover crop, as shown in Table 31.

After the cover crop is turned under, there is little further leaching through the entire soil column until after the tobacco crop is removed. Without doubt, heavy summer rains wash soluble salts from the surface into the subsoil, but they do not penetrate to the depth of 30 inches, except in insignificant amounts.

Leachings collected from May 16 to May 25, and from May 26 to August 15 reflect to a considerable degree the amounts of available nitrogen in the surface soil during the previous spring period. Data in Table 31 show nitrate nitrogen to be leached in the following amounts, from May 16 to August 15, for the various treatments, under the Windsor N-1 Formula:

	Nitrate Nitrogen Lbs. per A.
No cover crop	2.87
Oats cover crop	3.60
Rye cover crop	2.68
Timothy cover crop	2.41

While the preceding amounts are small, they reveal the earlier liberation of nitrogen from oats than from rye or timothy.

From data in Table 31, it is seen that the oats cover crop has decreased the annual leaching loss of nitrate nitrogen by 50.7 lbs. under the calurea[1] treatment, and by 43.4 lbs. under the Windsor N-1 treatment, or an average of 47.0 lbs. per acre. These amounts are somewhat less than previously reported[2], since the earlier figures were based upon the first two years, with unusually heavy leachings under no cover crop. The present values are almost exactly in line with the determined utilization of 47.7 lbs. of nitrogen by the fall growth of the oats cover crop in 1931. Rye, used only upon the Windsor N-1 formula, has been slightly more effective than oats in conserving nitrate nitrogen against leaching. Under rye, this loss has been decreased by 47.3 lbs. per acre per year. Slightly greater fall losses than under oats have been more than counterbalanced by lessened winter and spring leaching under rye.

Timothy, under the Windsor N-1 formula, was much less effective in checking leaching losses. This crop held back only 29.8 lbs. yearly.

It is also to be observed that the combinations tobacco-oats and tobacco-rye have given less leaching than under grass sod, when the latter was fertilized with nitrogen in top-dressings. Hence, it appears that either oats or rye has effected practically the maximum possible resistance to drainage losses.

Only a small portion of the nitrogen that has been saved from leaching is utilized by the tobacco crop. From data in Table 30 the cover crops have increased the annual nitrogen intake of tobacco by the following amounts, per acre:

Oats	10.8 pounds
Rye	10.7 "
Timothy	1.6 "

It is reasonable to believe that more than these amounts of nitrogen were liberated by the decomposing cover crops. However, with nitrogen liberally applied in the fertilizer, the crop was not appreciably limited by lack of this element in any case. The crop yields, and their percentages of nitrogen, are presented in Table 32.

[1] Calurea is essentially a combination supplying 80 percent of the nitrogen as urea and 20 percent as calcium nitrate.

[2] Morgan, M. F. and Street, O. E., 1933. Conservation of Plant Nutrients by Cover Crops. Bul. 350, Conn. Agr. Expt. Sta. Pages 482-488

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TABLE 31. SUMMARY OF NITROGEN REMOVAL FROM SOIL
WINDSOR LYSIMETERS – SERIES "C" 1931-1937

Treatment	Leaching by Periods						Annual		
	May 26–Aug. 15	Aug 16–Nov. 25	Nov. 26–Feb. 28	Mar. 1–Mar. 31	Apr. 1–May 15	May 16–May 25	Leached	In crop	Total
No Nitrogen									
Fallow	1.83	23.54	18.21	10.33	4.05	.38	58.34		58.34
Tobacco, no cover crop	.48	7.99	9.62	6.26	2.58	.41	27.34	22.96	50.30
Grass sod, mowed	.17	2.75	.32	.47	.22	.47	4.40	13.07	17.47
Calurea (200# of N)									
Fallow	.57	116.30	49.04	52.85	8.55	.68	227.99		227.99
Tobacco, no cover crop	.63	22.55	16.83	16.78	6.68	.74	64.21	108.59	172.80
Tobacco, oats cover crop	1.51	3.17	3.11	2.75	2.10	.92	13.56	115.14	128.70
Grass sod, mowed (200# of N)	1.65	11.61	8.87	3.74	2.36	.76	28.99	79.50	108.49
Windsor N-1 Formula (200 of N)									
Tobacco, no cover crop	2.12	15.17	16.79	17.32	6.62	.75	58.77	87.60	146.37
Tobacco, oats cover crop	2.49	4.00	2.65	2.64	2.46	1.11	15.35	98.42	113.77
Tobacco, rye cover crop	1.82	6.36	1.34	.76	.31	.86	11.45	98.32	109.77
Tobacco, timothy cover crop	1.65	11.61	8.87	3.74	2.36	.76	28.99	89.21	118.20
Fractional Nitrogen (167# of N)									
Tobacco, no cover crop	.67	13.99	16.26	17.69	6.41	.61	55.63	99.32	154.95

TABLE 32. CROP YIELDS AND PERCENTAGES OF NITROGEN IN THE CROP
WINDSOR LYSIMETERS, SERIES "C" 1931-37

	Leaves, stems and stalks Average Annual Yield per acre-dry wt.-lbs.	Nitrogen percent
Tobacco—no nitrogen—no cover crop	2070.2	1.11
" —nitrogen as calurea		
no cover crop	4724.2	2.30
oats cover crop	5082.4	2.27
" —nitrogen in Windsor N-1 Formula		
no cover crop	4429.7	1.98
oats cover crop	4674.4	2.11
rye cover crop	4751.2	2.07
timothy cover crop	4753.0	1.88
" —fractional nitrogen (167# N)		
no cover crop	4390.9	2.26

The leaching of basic constituents (lime, potash and magnesia), leached largely in combination with nitrates, has in general followed the same trends. Increased crops resulting from cover crop practice have resulted in additional removal of bases. However, except in case of magnesia, the total loss of basic constituents has been retarded by cover crops. The data are summarized in Table 33.

In the decomposition of cover crops, carbon dioxide is liberated. Some of this combines with water and bases to form bicarbonates in the soil solution. Analyses of the leachates for bicarbonate concentrations have revealed the comparative extent of this action for the various cover crops. This is presented in Table 34.

Both rye and timothy have resulted in greater increases in bicarbonates than those resulting from oats. This is reasonable, since some decomposition of the latter crop takes place in the soil surface, where it is entirely liberated into the atmosphere.

In all cases, it is evident that only a very small portion of the carbon dioxide resulting from the decay of the crop residues contributes to the composition of the soil solution.

Effect of Cover Crops on Soil Reaction

The soils in the lysimeter tanks have been tested for pH both in the spring and late fall of each year. The following table presents the average of four measurements on each of the duplicate tanks during the last two years (1935-1937), for the various treatments under annual tobacco crop:

Treatment	No cover crop	Oats cover crop	Rye cover crop	Timothy cover crop
Calurea	5.37	5.50		
Windsor N-1 Formula	5.52	5.58	5.71	5.73

The foregoing data indicate that the cover crops have a slight tendency to maintain the soil in a less acid condition (at a higher pH level). This is to be expected as a consequence of the decreased loss of basic constituents

TABLE 33. EFFECTS OF COVER CROPS ON THE CONSERVATION OF BASIC CONSTITUENTS
WINDSOR LYSIMETERS – SERIES "C" 1931-1937
(Yearly Average in Lbs. per Acre)

Treatment	Lime (CaO) Leached	Lime (CaO) In Crop	Lime (CaO) Total	Potash (K_2O) Leached	Potash (K_2O) In Crop	Potash (K_2O) Total	Magnesia (MgO) Leached	Magnesia (MgO) In Crop	Magnesia (MgO) Total
Calurea									
No cover crop	136.4	95.6	232.0	83.5	125.0	208.5	32.7	33.1	65.8
Oats cover crop	89.0	104.0	193.0	69.4	127.9	197.3	21.5	36.7	58.2
Diff. due to oats	–47.4	+8.4	–39.0	–14.1	+2.9	–11.2	–1.2	+3.6	–7.2
Windsor N-1 Formula									
No cover crop	84.1	64.0	148.1	80.8	112.9	193.7	19.7	33.2	52.9
Oats cover crop	53.3	71.3	124.6	58.6	125.8	184.4	12.7	37.4	50.1
Diff. due to oats	–30.8	+7.3	–23.5	–22.2	+12.9	–9.3	–7.0	+4.2	–2.8
Rye cover crop	57.4	73.1	130.5	61.7	125.6	187.3	18.2	38.4	56.6
Diff. due to rye	–26.7	+9.1	–17.6	–19.1	+12.7	–6.4	–1.5	+5.2	+3.7
Timothy cover crop	67.8	68.0	135.8	72.2	117.0	189.2	19.2	35.6	54.8
Diff. due to timothy	–16.3	+4.0	–12.3	–8.6	+4.1	–4.5	– .5	+2.4	+1.9

TABLE 34. EFFECT OF TOBACCO CROPPING AND COVER CROP UPON THE DEVELOPMENT OF BICARBONATES IN THE SOIL
WINDSOR LYSIMETERS – Series "C" 1931-1937

	Bicarbonates Leached lbs. per acre per year			
Treatment	No Cover Crop	Oats Cover Crop	Rye Cover Crop	Timothy Cover Crop
Calurea	71.2	99.5		
Increase for cover crop		28.3		
Windsor N-1 Formula	79.6	120.8	153.9	131.3
Increase for cover crop		41.2	74.3	51.7

by leaching. Some investigators have found temporary increases in acidity resulting from the plowing under of green manures and cover crops. However, this was not ascertained in the present experiment as no measurements were made during the summer season.

Changes in Soil Organic Matter under Six Years of Tobacco, with and without Cover Crop

Samples of the surface soil (upper 7 inches) of Lysimeter Series "C" taken in the spring of 1937 were analyzed for organic matter (Carbon x 1.724). These represent the effects of six years of treatment. The data are presented in Table 35.

TABLE 35. ORGANIC MATTER IN WINDSOR LYSIMETER SOILS
SERIES "C" 1931-37

	Organic Matter Percent	Organic Matter lbs. per A.	Annual Gain in organic matter lbs. per A.	Annual Gain for cover crop lbs. per A.
Original Soil, 1931	1.983	39,660		
Samples of April, 1937 Calurea				
no cover crop	2.069	41,380	286	
Oats cover crop	2.103	42,060	400	114
Windsor N-1 Formula				
no cover crop	2.155	43,100	573	
Oats cover crop	2.207	44,140	747	174
Rye cover crop	2.302	46,040	1063	490
Timothy cover crop	2.379	47,580	1320	747

On the basis of these data, it appears that the residual organic matter from the cover crops has been somewhat effective in improving the humus content of the soil. Oats has resulted in the least annual net gain, averaging only 144 lbs. better than without cover crop. Rye and timothy leave significantly more humus in the soil. This difference is due in part to their greater dry matter production, but the richer nitrogen content and the lower lignin content of the oats at the time of its premature death by frost are particularly favorable to its more complete disintegration.

It is of interest to note that the Windsor N-1 Formula, without cover crop, has definitely added to the organic content of the soil, as compared with calurea. This is doubtless due to the formation of humus in the decay of the cottonseed meal and castor pomace supplied by the former treatment. It is also important to observe that the tobacco crop residues resulting from a treatment supplying no organic matter have more than prevented any depletion in this six-year period.

It was not possible to make measurements of the amounts of fresh organic residues contributed by the cover crops. However, the following estimates should be reasonably good approximations of the amounts of actual organic matter in the various crops at the time of their deaths by winter killing or plowing under, in lbs. per acre:

Oats	1500 lbs.
Rye	3000 lbs.
Timothy	3000 lbs.

Approximately 2000 lbs. of organic matter per acre were supplied in the Windsor N-1 formula. The crop residues from the tobacco, in "stub" and roots, may be estimated at approximately 1200 lbs. per acre, varying somewhat in proportion to the harvested yield.

On the above basis, the following proportions of the organic substances entering the soil may be calculated as contributing to the humus supply:

Tobacco residues	23.8%
Organic fertilizers	14.3%
Oats	11.6%
Rye	16.0%
Timothy	24.5%

Summary

As in previously conducted plot experiments with cover crops, the lysimeter experiments herein reported show increased tobacco yields.

In the present case erosion control was not a factor, although it is an important one on many Connecticut tobacco fields. Cover crops making active fall growth assimilate considerable quantities of nitrate nitrogen and associated basic constituents, which are conserved against drainage losses. In part, the decrease of drainage loss under cover crops is due to decreased volume of leaching during the fall period, but it is chiefly effected by cover crop assimilation.

The cover crop protects the soil from the excessive drying action of the windy days of the spring months, and despite transpiration losses, a more favorable soil moisture status is provided. Residual organic matter from previous cover crops may be a factor in this case.

Yearly conservation against losses by leaching has been approximately as follows, for oats or rye cover crop, during the six year period:

Nitrogen	45 to 50 lbs. per A.
Potash	15 to 20 lbs. per A.
Magnesia	2 to 5 lbs. per A.
Lime	25 to 50 lbs. per A.

Under heavy tobacco fertilization, tobacco does not utilize more than a small portion of the nitrogen and lime thus held back in the soil. But much of the potash is withdrawn by the crop, and increased tobacco growth with cover crop may remove from the soil more than the amount held against leaching.

Tobacco fertilization now commonly practiced in this section supplies 200 lbs. of nitrogen, about four-fifths of which is from organics like cottonseed meal. Phosphorus carriers are frequently omitted since more than 50 lbs. of P_2O_5 is supplied by the organics. Two hundred pounds of potash is supplied by sulfate or nitrate of potash or cottonhull ash. Fifty pounds of magnesia is furnished by either magnesium sulfate or dolomite lime.

Lysimeter experiments under such fertilization have indicated that when cover crops, such as oats or rye, are grown between successive tobacco crops, approximately the following amounts of the fertilizer constituents applied are in excess of removal by both crop and leaching:

Nitrogen	80 to 90 lbs.
Phosphoric acid	30 to 40 lbs.
Potash	5 to 10 lbs.
Magnesia	None

In case of lime, there is a yearly depletion of 60 to 70 lbs. when no special lime-supplying material is used in the fertilizer.

Both oats and rye have been found superior to timothy from the standpoint of fertility maintenance, under cover cropping conditions.

Soil analyses for organic matter have given definite evidence of the rôle of crop residues, organic fertilizers and cover crops in maintaining the humus content of the soil. A soil containing approximately 40,000 lbs. of organic matter per acre is apparently being improved to the extent of about 750 lbs. per year by a combination of these factors, under the oats cover crop. Such an accumulation of humus could account for approximately 40 lbs. of the fertilizer nitrogen that is neither leached nor removed by cropping.

MALNUTRITION SYMPTOMS DUE TO DEFICIENCIES OR EXCESSES OF PLANT FOOD ELEMENTS

Tobacco is a very exacting crop. It demands a well balanced nutrient supply to produce leaf of certain desired qualities which are far more important than yield.

Slight variations in the fertilization are reflected in the growth of the crop and in the character of the finished (cured and fermented) leaf. Since tobacco is extremely responsive to nutrient treatments, it is possible to recognize and distinguish between the symptoms caused by either too little or too much of each nutrient absorbed.

Over a number of years, observations and experiments have been made at this Station on the effect of deficiencies and of an over supply of various nutrient elements. A brief summary of the results is presented below with the elements discussed in alphabetical order.

Aluminum

Although aluminum is present in most green plants* it is not considered essential for normal growth.

* An average of 24 analyses of tobacco from Station plots showed a content of about .06 percent aluminum; in some cases three times this amount.

It is, however, sometimes held that aluminum facilitates the absorption of iron and it is considered an essential agent in production of the coloring pigments in flowers.

In using water cultures with chemicals free from aluminum it has not been possible to establish the need of this element.

Depending on culture media, the tobacco can tolerate a varied supply of aluminum. In water solutions and in sand the plants can withstand only 20 parts per million of aluminum. The only toxic effect observed as a result of too much aluminum, was a stunting in growth (see Figure 37).

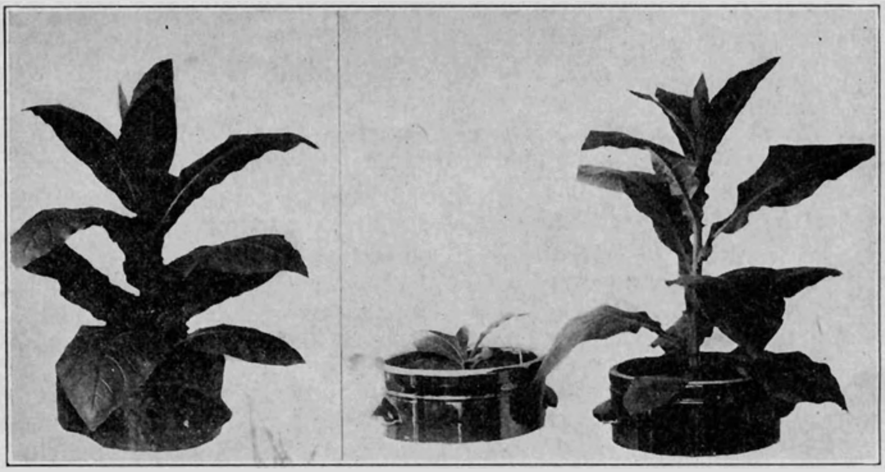

FIGURE 37. Aluminum toxicity. Plants of equal age and nutrient treatments, except that the plant to the left, grown in *soil*, received in addition, an equivalent of 4000 pounds aluminum sulfate per acre; the small plant, grown in *sand*, equivalent to 250 pounds aluminum sulfate. Plant to the right, grown in sand without aluminum sulfate.

No toxic effect was observed in soil cultures to which had been added the equivalent of 4000 pounds aluminum sulfate to the acre (see Figure 37). The explanation of this undoubtedly lies in the fact that soon after the material is added to the soil, the aluminum radical is fixed, through anion exchange, presumably in insoluble aluminum phosphates. In support of this theory is the acidifying effect of aluminum sulfate, since the sulfate ions set free must produce the acidity. An application of 1000 pounds aluminum sulfate per acre may decrease the pH-value one-half unit. The activity of aluminum increases with the acidity in the soil, hence proper liming is recommended to overcome such a trend.

No actual injury to tobacco in the field from excess of aluminum has ever been reported.

Boron[1]

In recent years considerable work has been done with boron on a great variety of crops. Tobacco normally contains from .01 to .03 percent boron

[1] Commonly known compounds of boron are boric acid and borax.

(B_2O_3). Boron is essential to plant growth and its function seems to be confined to cell division, i.e. development of shoots, leaves and roots. It is not known how this function is carried out in the plant, but observations from work with boron point toward the above assumption.

The symptom of boron deficiency (see Figure 38) in tobacco is reflected in arrested top growth, i.e. new leaves in the terminal bud cannot develop, but darken and die. Leaves already developed before all available boron is used up in the plant become thick, crinkled and brittle. The elongation of roots also ceases, as shown by the rotting off and browning of the tips.

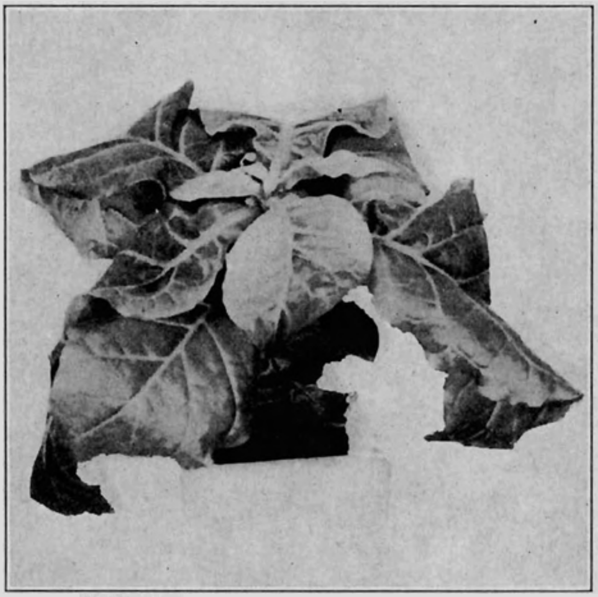

FIGURE 38. Boron deficiency.

The boron requirement in the soil is satisfied at a content of about one pound per acre. No deficiency of boron has ever been observed in the tobacco soils of Connecticut, but it has been reported in those of Maryland. There is probably little danger of its occurrence here since a great bulk of organics is used in the fertilizers annually, thus steadily replenishing the supply of boron.

Boron is injurious to growth if compounds of it are present in the growing media above a certain maximum. The injury varies with the nature of the media. While in water solutions and in sand injuries may occur at slight increases above the minimum requirement, 15 to 50 pounds of borax may be added to soils without toxic effects. This depends, however, on the reaction, since the possibility of toxic effect increases with the acidity of the soil. Injury to tobacco from excess boron manifests itself in the wilting and burning of the plant (Figure 39).

Calcium

Calcium is the principal element in lime and landplaster, and is also present in large quantities in several materials, such as bone phosphates, used in fertilizers. It is essential to plant growth. Tobacco contains from 4.5 to more than 8 percent of calcium (CaO).

The functions of calcium in plants may be many. Three are fairly well established, namely: neutralizing acids absorbed or produced by the plant; forming calcium pectate, an essential constituent in cell walls; serving as a vehicle in translocation of nitrates and other anions.

FIGURE 39. Showing the effect of excess boron, (left) and a normal plant.

A minimum of about 2 percent of CaO should be found in the cured leaf of normal growth. Insufficient calcium in the soil causes stunted growth; leaves in the terminal bud turn brownish and curl up. These leaf symptoms have never been observed on any tobacco fields in Connecticut. However, on a plot at this Station which through continuous applications of sulfate of ammonia had reached the very acid reaction of pH 3.5, the writers have observed distinct symptoms of calcium hunger. Roots turn brownish with the tips rotted off and root hairs cease to develop, symptoms similar to or identical with brown rootrot.

While about 5 percent CaO in the cured leaf corresponds to optimum growth, the content varies, partly with the content in the soil, partly with the magnitude of other bases (potash and magnesia) which may retard the uptake of calcium.

Too high a content of calcium will decrease the acidity in the soil to a point beyond which the land may be unsuitable for tobacco on account of a possible occurrence of black rootrot (pH 5.6 or 6.0 and above).

Aside from this disease factor, an abundant supply of calcium may adversely affect the uptake of potash and magnesia. Therefore, *excessive* amounts of calcium may result in starvation symptoms of either one of the other two bases. Furthermore iron, manganese and phosphates, at least temporarily, may be tied up in the soil. Sometimes it is reported (for other crops than tobacco) that a shortage of boron occurs due to overliming.

Chlorine

Although chlorine is present (as chlorides) in tobacco and most green plants, it is not considered an essential element. Since, however, chlorides are more readily absorbed than nitrates, the growers have made use of this fact in the flue-cured tobacco districts where chlorides (muriates) are included in the fertilizers to keep the uptake of nitrogen at a desirable minimum and to prevent drought injury to the leaf. Thus chlorine may be an agent substituting for nitrates in their function of translocation of bases within the plant.

An abundant supply of chlorine is known to be injurious to burn of tobacco, although this effect decreases with increase in potash.

An excess of chlorine causes plasmolysis of the green plant. For cigar tobacco chlorides should never be used, since our more abundant nitrogen fertilization amply performs the same physiological functions accredited to chlorides. Moreover, we cannot afford to risk even a small impairment of the fire-holding capacity.

Copper

Copper is considered by some investigators to be essential to the growth of green plants. The function of copper is sometimes considered to be that of facilitating the use of iron within the plant. Tobacco and most green plants contain traces of this element. Since, however, infinitely small amounts (a mere fraction of a pound per acre) are needed to satisfy the requirements, it is doubtful whether copper is of practical importance. Stimulating effects through the application of copper sulfate have been reported for several crops including southern tobaccos. A small trial at this Station, however, on Havana Seed tobacco, did not give similar results.

Copper may be toxic to plants if more than 50 pounds of copper sulfate per acre is used.

Iron

Iron is needed for growth and proper development of all green plants. Its function is of a so-called catalytic nature, i.e. iron takes part in forming chlorophyll (the green matter) in plants, without entering into the composition. Tobacco contains from .1 to .3 percent iron (Fe_2O_3).

Deficiency of iron in plants is shown by a chlorosis starting at the tip of the plant. It is a fading out of the green color and, in complete absence of iron, all traces of green disappear and the entire leaf takes on a cream color. In addition, the plant is stunted in growth but remains alive for a considerable length of time.

Iron deficiency has not been observed on tobacco soils in this Valley. Undoubtedly our soils contain sufficient amounts and receive some annually through impurities in the fertilizers. The content of active iron in the soil increases with the acidity and, as mentioned above under "calcium", overliming may tie up iron.

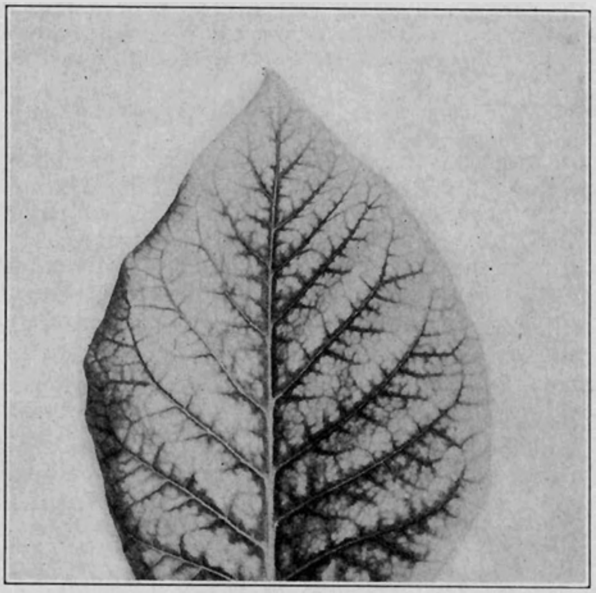

FIGURE 40. Symptoms of magnesium deficiency ("sand drown").

Magnesium

Magnesium is necessary for normal growth and development of green plants; it is a constituent of chlorophyll. It has received much attention in recent years, since a deficiency of this element has occurred in the Eastern United States, not only on tobacco soils but on land used for various other crops.

Insufficient supply of magnesium in the soil causes a malady on tobacco commonly known as "sand drown" (Figure 40). It first appears on the lower leaves, progressing upwards. On the leaf it begins at the tip and margin and progresses toward the midrib and base. The green color fades out between the ramifications of the veins. These remain greener than the rest of the blade for a longer period.

The symptoms on tobacco occur when the soil content of available magnesium (replaceable magnesium) runs below 25 pounds per acre. Actual tests have shown that the severity of the malady increases as the content of magnesia in the soil decreases below the amount mentioned above.

The proper use of magnesia for tobacco is described in detail in the report for 1932, Station Bulletin 350.

Excess of magnesia in the soil restricts the absorption of potash and calcium. Since the latter is less mobile in the soil and thus less active than potassium, the symptoms of magnesia injury resemble calcium deficiency. The plant becomes stunted, with top leaves turning brown. In addition, however, the margins of the leaves curl down (cf. potash deficiency below) with deep grooves along the veins.

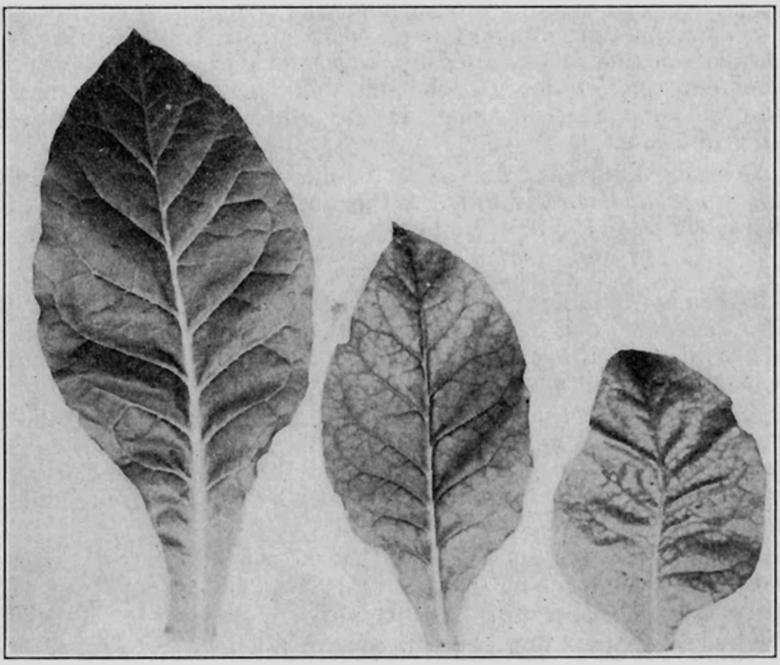

FIGURE 41. Symptoms of manganese deficiency. To the left is a normal leaf.

Manganese

Tobacco and other green plants are dependent on manganese for proper growth and development. Its rôle in nutrition is not definitely established. Since, however, the lack of this element in the growing media causes a chlorosis, it is possible that one of its functions is related to chlorophyll formation. It has also been observed that manganese has a controlling action on the absorption of calcium and the utilization of iron within the plant.

The symptoms of manganese deficiency (Figure 41) first appear on the leaves about two-thirds of the way up the plants. It is evidenced by the gradual disappearance of the green color between the *finest* ramifications of the veins. The entire veinal system is more plainly outlined than in the case of magnesium deficiency (see above). In later stages the leaves may crinkle. The root system is usually stunted with a few lateral roots of normal size.

About one-half pound of active manganese per acre is sufficient for normal growth. Soils of the Connecticut Valley, however, contain an average of more than 80 pounds to the acre. The amount of active manganese increases with the acidity of the soil and over-liming may render the manganese unavailable.

While tobacco normally contains from .01 to .2 percent manganese (Mn_2O_3), toxicity symptoms are correlated with 0.4 percent. It may occur in soils containing 150 to 160 pounds of active manganese per acre.

The first symptoms of manganese toxicity appear on the top leaves, and the injury resembles that caused by the lack of this element. There is one marked difference, however, in that the yellow color is more pronounced toward the tip of the leaf, where in later stages there appear numerous small dead spots.

Concerning the undesirable effect of manganese on smoking qualities of tobacco, the reader is referred to this Station's report for 1935, Station Bulletin 386, page 578-579.

Nitrogen

Nitrogen is primarily a component part of protoplasm, chlorophyll and protein of plants, and in tobacco it enters into the structure of nicotine. The necessity of nitrogen is so much evidenced that in Connecticut soils this element is the primary growth-limiting factor.

Deficiency of nitrogen causes stunted growth and a fading of the green color, the severity of which will be proportional to the decreasing rate of supply in the soil. The starvation symptoms first occur on the lower leaves. The entire leaf and plant gradually take on a lighter green color and in the complete absence of a nitrogen supply they turn yellow.

A tobacco leaf should contain more than 2.6 percent nitrogen to maintain a healthy green color. This requires a permanent soil supply of at least 20 pounds per acre of readily available nitrogen (nitrates).

Excess of nitrogen will produce an abnormally deep green color. Young tobacco plants are sensitive to ammonia nitrogen, the excess of which causes a decay of the roots. This type of injury sometimes takes place in tobacco beds of high fertility which have been seeded too soon after steam sterilization. The steam releases a considerable part of the ammonia nitrogen furnished as manure or meals, cottonseed meal, fish meal and others. Usually, beds should be left 10 days after sterilization to allow any free ammonia to escape and nitrifying bacteria to get back into the soil, for the purpose of transferring the nitrogen into a non-toxic form.

Plants may withstand considerable quantities of nitrogen in the form of nitrates, and injury takes place only because of too high salt concentration (plasmolysis).

A tobacco crop utilizes from 100 to 125 pounds of nitrogen per acre, but 200 pounds annually are recommended to allow for reasonable losses in leaching and possible limitation in efficiency of the materials used.

Phosphorus

Phosphorus is just as important as any of the essential elements in plant life. It enters into the composition of many protein substances. It is always found in the embryonic cells (nucleoproteins).

While a shortage of phosphorus produces stunted growth, definite symptoms of deficiency are not visible until there is a complete absence of available phosphorus in the soil. A tobacco plant deprived of available phosphorus shows, besides much stunted growth, leaves that are dark green, leathery and somewhat shiny. The leaf tends to become narrow at the base, thus giving it a somewhat spatulate shape (Figure 42). Observed from an oblique angle the leaves appear to be a bronze color.

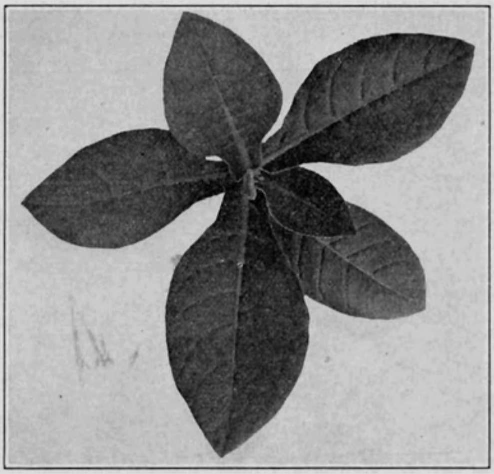

FIGURE 42. Phosphorus deficiency. Note spatulate shape of leaves.

Tobacco leaves should contain more than .4 percent phosphorus (P_2O_5) for normal growth and development and rarely over one percent P_2O_5. Hence tobacco normally varies between these limits. A supply of about 120 pounds P_2O_5 per acre provides normal growth, and excess of phosphorus in the soil has never proven fatal to plant growth. The uptake is limited because of low mobility of phosphates, the size of the molecules and fixation in the soil.

Potassium

Potassium is essential to plant growth in general, and because of certain qualities, it is specifically essential to cigar tobaccos. It is believed that its most important rôle is to aid in the formation of carbohydrates and proteins. The importance of potassium in tobacco growing is more fully discussed in a previous bulletin of this Station, 334, Potash Requirements of the Tobacco Crop.

Symptoms of potassium deficiency are correlated with a decrease falling below 2 percent of potash (K_2O) content in the leaf. They are readily distinguishable from symptoms caused by a deficiency of other nutrient elements (Figure 43).

The lower leaves are first affected, and in the earliest stages they are mottled with yellow near the margins and tips, resembling somewhat the early stages of ripening. Later on, the blade becomes puckered, i.e. there is an expansion of the areas between the larger veins. In later stages the mottled areas die and may fall out or break; the margins of the leaves, speckled with numerous white spots, turn downward, giving the leaves a rim-bound appearance. The gradual dying off of the leaves indicates that the plant needs steadily to renew its supply of potash from the soil which should contain about 200 pounds potash (K_2O) per acre for proper growth. Several times this amount, however, is required to secure satisfactory burn and other qualities in cigar tobacco. This is called luxury consumption.

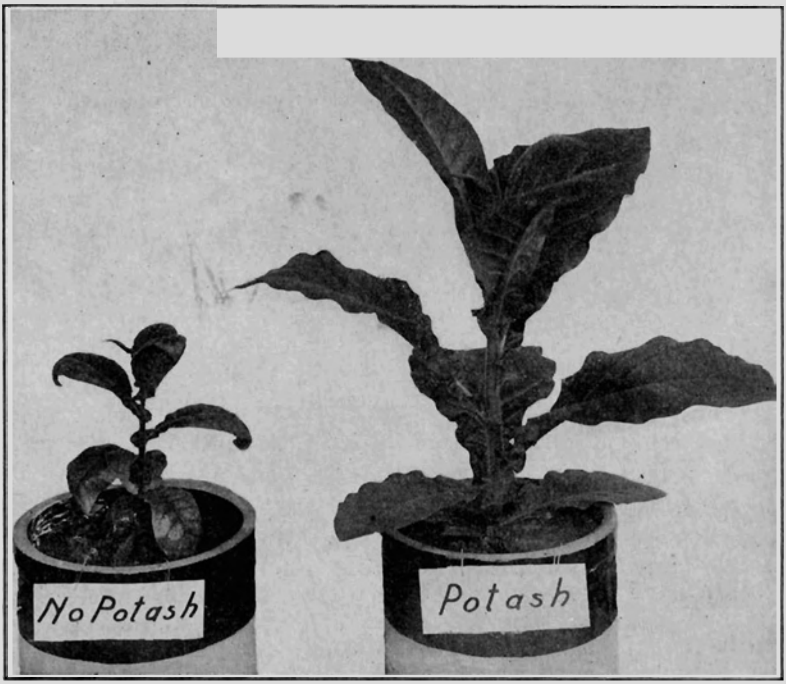

FIGURE 43. Potash hunger. Note stunted growth of plant to the left with curved tips and margins of leaves as compared with normal plant on the right.

An over-supply of potash in the soil is not directly injurious to growth of tobacco unless the salt concentration is so great as to cause actual plasmolysis. It will, however, reduce growth, probably because an excess of potash retards the uptake of calcium and magnesium. Annual applications of 300 pounds potash to the acre, in experiments at the Tobacco Substation at Windsor, have shown a tendency to decrease yields.

Sodium

It has never been demonstrated that sodium is essential for plant growth. We include this element, however, in an attempt to clarify its effect on tobacco, especially since it is included as a base in at least one fertilizer material—nitrate of soda—that is used for tobacco.

Sodium is not readily absorbed by the tobacco plant as shown by experiments previously reported, Bulletin 335, page 251, Tobacco Substation at Windsor, Report for 1931. From data presented at that time it is evident that about 240 pounds of soda (Na_2O) per acre, supplied as nitrate of soda, for three years, produced a content of soda in the tobacco leaf of only .168 percent.

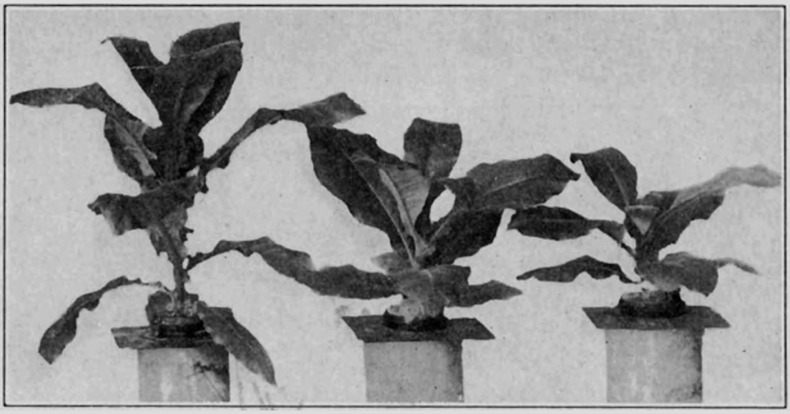

FIGURE 44. Plants showing the effect of excessive sodium in water cultures. From the left: no sodium, 400 ppm, and 800 ppm.

In water culture experiments, where a combination of sodium phosphate ($NaHPO_4$) and sodium hydroxide ($NaOH$) was used, no visible injury, other than stunted growth (Figure 44) was observed, and that appeared first at a concentration of 500 parts per million of Na_2O. A thousand parts per million further decreased growth, but caused no other visible injuries. The plant material contained respectively .8 and 1.7 percent soda.

The quantities just mentioned, corresponding to about one-half and one ton, respectively, of soda per acre, or about four times as much if calculated as nitrate of soda, are never used in practical farming. It is of interest, however, to point out that on a plot at the Experiment Station at Windsor that has received an annual application since 1926 of about 500 pounds soda in nitrate of soda per acre, the growth and quality of the tobacco produced is as good, if not better, than where soda was not applied. Therefore, it does not appear that any injury is likely to result through the use of materials containing even large amounts of soda.

Sulfur

Sulfur is essential because it is contained in albuminoid compounds in plants. It occurs in some of the by-products of protein production and also as sulfates of bases—especially potassium—in the cell sap.

Sulfur is usually required in such limited quantities that the seeds sometimes may furnish all that is needed for normal development of the plant through a considerable period.

It is generally accepted that sulfur must be supplied as a sulfate of a metal, such as potassium, magnesium, calcium, sodium or aluminum. Usually an abundance beyond the physiological need of sulfate is absorbed by the plants. This is stored in an unaltered form in many cells.

Any protein substance contains only from .4 to 2 percent sulfur, hence the sulfur requirement is very small. To this, tobacco is no exception.

A deficiency of this element can hardly occur in nature since all soils contain various amounts of sulfur. Besides, the annual precipitation enriches the soil with an average of about 12 pounds of sulfur per acre, and considerably more in agricultural areas close to industrial centers.

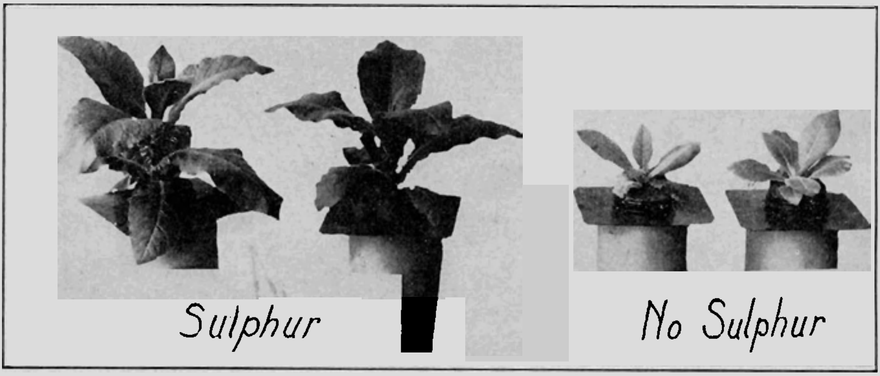

FIGURE 45. Sulfur deficiency causes stunted growth, chlorosis and white veins.

In fact, it is difficult, even under best controlled conditions, to obtain symptoms of sulfur deficiency. In water cultures where pure salts were used with inclusion of all essential elements except sulfur, it was possible to obtain deficiency symptoms on tobacco plants after about two weeks (Figure 45).

In the complete absence of sulfur, further growth did not occur and the leaves became chlorotic. This condition (chlorosis) may be described as a faded green color of the blade, while the veins were almost white. In this respect it differs from symptoms of iron deficiency (see above) where the entire leaf takes on a cream color. This indicates that the lack of sulfur does not seem immediately to affect the formation of chlorophyll, but might be of some importance in its production. An over-supply of sulfur in the soil does not affect the growth of tobacco since this element is not readily absorbed by the plant. Tobacco normally contains an average of about .5 percent sulfur (S).

Great excesses of sulfur in the soil may bring the content up toward one percent. In this connection it should be mentioned that the burn of tobacco decreases with increasing amounts of sulfur in the leaf.

It is doubtful that sulfur at any time may be directly injurious to the growth of tobacco. Larger quantities of active sulfur in the soil, however, increase the acidity, whereby many substances may be liberated which adversely affect growth.

Thallium

Thallium is one of the rare elements of the earth and it is not essential to growth of plants. On the contrary it is a plant poison, since infinitely small quantities, 5 ppm. or less, present in the growing media are toxic to growth.

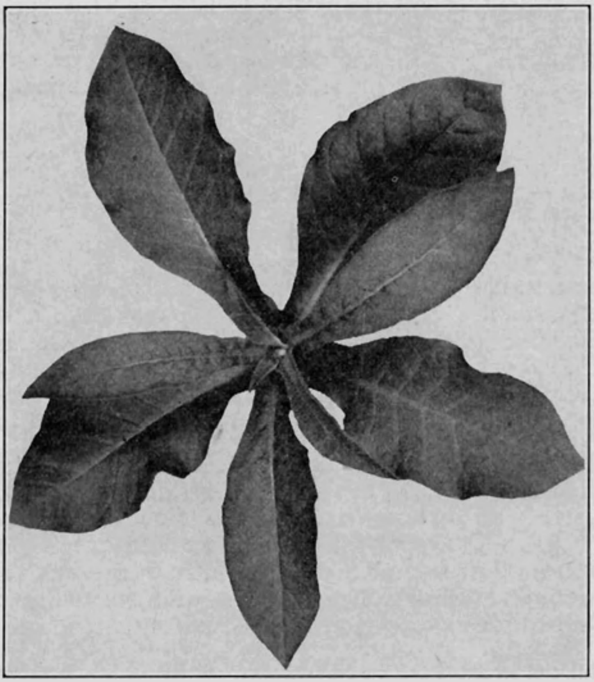

FIGURE 46. Thallium injury.

Thallium is included in this article because in recent years considerable attention has been given to the remarkable resemblance between thallium poison and the disease of tobacco known as "frenching". This disease has been described in previous publications, Station Bulletin 335, pages 256-260, and Bulletin 364, page 773.

The principal symptoms of the malady are readily recognized. The leaves are thick, narrow and strap-shaped with a wavy or crinkled margin. In severe cases the stalk fails to elongate properly and the whole plant appears as a bush of numerous, dagger-like leaves set close together. When the disease is less severe, only the top leaves may be affected. Sometimes the new shoots or suckers, which appear after topping the plant, may show frenching symptoms. However, in addition, these are accompanied by a chlorosis, a fading out of the green color, particularly in the interveinal tissue. This type of the disease, in fact, may serve as a description of a malady that occurs when small amounts of soluble thallium salts are added to the growing media of tobacco plants. (Figure 46)

The observation of thallium toxicity was first made by McMurtrey in 1932[1]. It was studied extensively by Spencer[2] in 1935 and 1936.

As pointed out by Spencer, the methods by which frenching and thallium toxicity may be controlled are very similar. Both occur at a pH-value above 6.0, and lowering the reaction through additions of aluminum sulfate has controlled the maladies. Additions of potash and nitrogen have sometimes been beneficial. The real difficulty, however, in identifying the two maladies, lies in the fact that there are no known methods of measuring and comparing the amounts of thallium contained in frenched tobacco leaves and in those known to be injured by thallium.

TOBACCO DISEASES IN 1937

P. J. Anderson

Due to the unusually wet season, some of the diseases were more destructive than usual in 1937. The pathologist spent most of the time which he had available for disease work on the downy mildew. Observations and studies were made, however, on other diseases and disorders, some of which were unusual. It seems worth while to record such observations each year for the cumulative value they will have as time passes.

Downy Mildew (*Peronospora tabacina*). This disease appeared here for the first time on May 25 of this year and within three weeks had spread to all the tobacco-growing towns of the State. Since the writer has already published a bulletin (No. 405) which has been distributed to all growers, describing in detail the progress of the disease, its symptoms, cause, history and known methods of control, it would be superfluous to discuss it further here, and the reader is referred to this bulletin for further information.

Malformation of seedlings in the seedbed. A peculiar and puzzling malformation of young shade plants occurred on three different plantations. Since in all cases the germination was poor and a large proportion of the seedlings died in very young stages, the beds were worthless and entailed considerable loss. Most of the plants made an abnormal growth. The first two leaves, cotyledons, became abnormally large and thick, while the next leaves, called true leaves, either failed to develop at all or started very late. When they did start, frequently only one leaf came out and grew quite large before any others appeared, giving the plants a peculiar, three-leaf appearance. In later stages the leaves which did develop came out irregularly and grew in a cluster from the same point, without the usual elongation of the stalk. In a large number of the plants there was a strong tendency to double-leaf formation, the two leaves being joined

[1] J. E. McMurtrey, Jr. Effect of thallium on growth of tobacco plants. Science N.S. 76: 86. 1932.
[2] Ernest L. Spencer. Studies on frenching of tobacco. Phytopath: 25: 12. 1935.
Ernest L. Spencer. Frenching of tobacco and thallium toxicity. Am. Jour. Bot. 24: 1. 1937.

either back to back along the lower side of the midribs, or side to side by the margins. In some of the plants all the leaves were double. Some of these malformations are shown in Figure 47.

FIGURE 47. Malformation of Plants in the Seedbed. Large normal plant in the center for comparison. Plant in upper right shows the leaves grown together by the backs of the midribs. Plant in the lower center shows leaves grown together by the margins. Same in lower right. Unusually elongated cotyledons without development of the chit shown in the small plants in upper center. Abnormal development of single true first leaf shown in upper left and lower left. Development of leaves in irregular position and size shown in others.

An adequate explanation of this trouble is not at hand. The seed from these three plantations came from the same source. The soil was thoroughly analyzed but showed no excesses or deficiencies to account for it. The fertilizer was the same as that used on other adjacent beds which produced normal plants. Different fertilizers were used, however, at the different plantations. The occurrence of the trouble on three widely separated plantations and the common source of the seed indicates that something in the seed was responsible. This might be some genetic irregularity, or some injury to the embryo induced by gas, or chemical, or other injury to the entire lot of seed. Some of the plants which were transplanted at the Station recovered and were quite normal in later stages.

Bed rot (Rhizoctonia and other organisms). An unusually large number of cases of this trouble were observed this year, probably due to wet weather which prevailed during the seedbed period. This disease usually comes when the plants in the bed are more than half grown and is worst when they are ready for setting and are crowding each other in the beds. Great patches of plants rot off, starting with the stalks just above the ground, but soon involving the leaves until the whole patch falls into a brown,

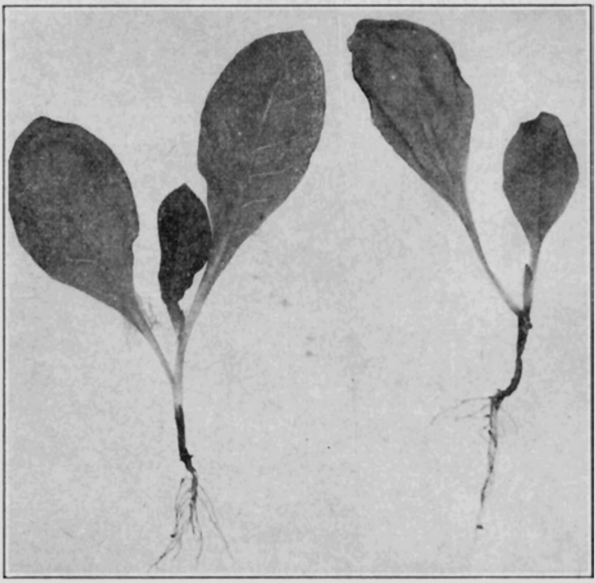

FIGURE 48. Bed rot. Note blackened and rotted bases of stalks.

watery, slimy mass. Two particularly virulent cases, one in Glastonbury and one in Rockville, were studied more carefully this year, because they caused almost total losses of the beds on these two plantations and were different from the usual type of this disease. Starting from brown lesions on the stalk, the rot ran up into the leaves, which at first took on a dark-green, water-soaked appearance. It then spread to the leaves of other plants which were in contact, until areas several feet in diameter were destroyed. As these areas dried out, the dead plants formed a flat, coal-black crust over the surface of the ground.

Microscopic examination of the dead tissues failed to show mycelium of Rhizoctonia or any other of the fungi usually associated with this trouble here. Even when kept in moist chambers for several days no fungus mycelium developed on the surface. All the rotten tissues were swarming with bacteria, however.

Wildfire (*Bacterium tabacum*). Only two cases of this disease were observed in 1937, one in a seedbed in Suffield, the other late in the season on Broadleaf tobacco that was in the process of being harvested in South Windsor. A few other cases were reported by growers, but the damage as a whole was negligible. This is interesting in view of the fact that the season was unusually wet, and wet weather is favorable to wildfire infection and spread.

FIGURE 49. Sore shin. Causing a black canker at the base of the stalk.

Sore shin. (Rhizoctonia and other fungi). This disease was observed in a number of fields this year but not in destructive amount. The appearance of the black canker at the base of the stalk is shown in Figure 49. With a strong wind, the stalk is apt to break at this point, frequently the first indication to the grower that the disease is in his field. Affected plants, however, may be easily distinguished by the sickly yellow color which they assume when the canker develops. Microscopic examination shows the presence of mycelium of Rhizoctonia in the cankers. The trouble here has never been sufficiently prevalent to warrant special control measures.

An unusual outbreak of hollow stalk wet rot. (*Bacillus carotovorus*). This rot usually starts from the upper end of the stalk where the plant has been topped and reduces the pith to a black mush which later shrivels and leaves the stalk hollow. Late in the season this year, a grower of Havana Seed brought in some leaves which had the midribs rotted out, and also had large rotted holes in the blade. The dead tissue was examined microscopically and found to be swarming with bacilli. The condition being rather unusual, a visit was made to the field for further observation. The tobacco was large and overgrown and had suffered some breakage from windstorms and heavy rains. The worst damage was on the lower wet places in the field. Many of the midribs were so rotted that the leaves fell from the stalk during the operations of harvesting. In many cases the infection clearly started from the broken top of the stalks. More often, however, it started in the axils of the leaves, beginning in the scars where the suckers had been broken out. Sometimes the lesions started from broken midribs or even torn places on the blades of the leaves. The disease, from a causal standpoint, however, was obviously the same as the

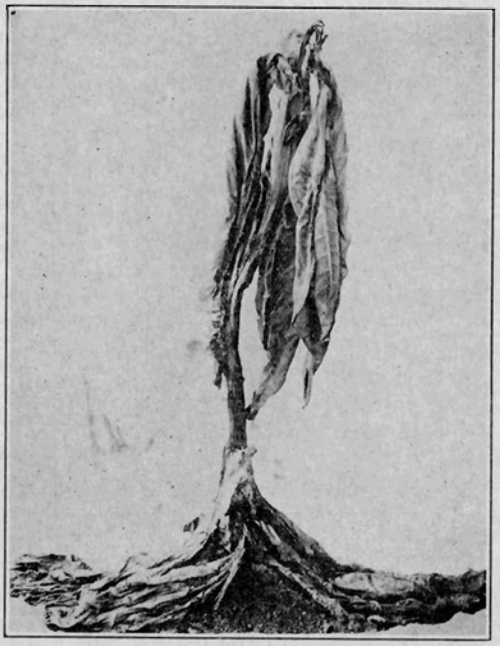

FIGURE 50. Hollow Stalk. Mature Havana Seed plant in the last stages. The disease has passed out into the midribs of the lower leaves, causing them to drop down on the ground.

usual hollow stalk. The wet weather, the injuries in topping, suckering and from the storm, and the overgrown condition of the crop, all contributed to make this serious enough to cause considerable financial loss to the grower.

Although other fields were not studied by the writer, several growers reported similar losses this year.

Pole rot. This was by far the most destructive disease of 1937, the actual monetary loss exceeding that of all other diseases combined. The character of the weather during the curing season accounted for its destructive proportions. During a considerable part of this unusually warm period, the humidity was excessively and continuously high even while there was no rain at all. Though all the ventilators and doors of the curing sheds were open, the leaves failed to dry. Leaves that were already cured out were continuously "in case". Firing was neglected by a considerable part of the stalk growers or was postponed until it was too late. Even the shade growers, who regard firing as a routine operation never to be omitted, suffered some from pole rot this year, although the loss was small compared with that of the stalk growers.

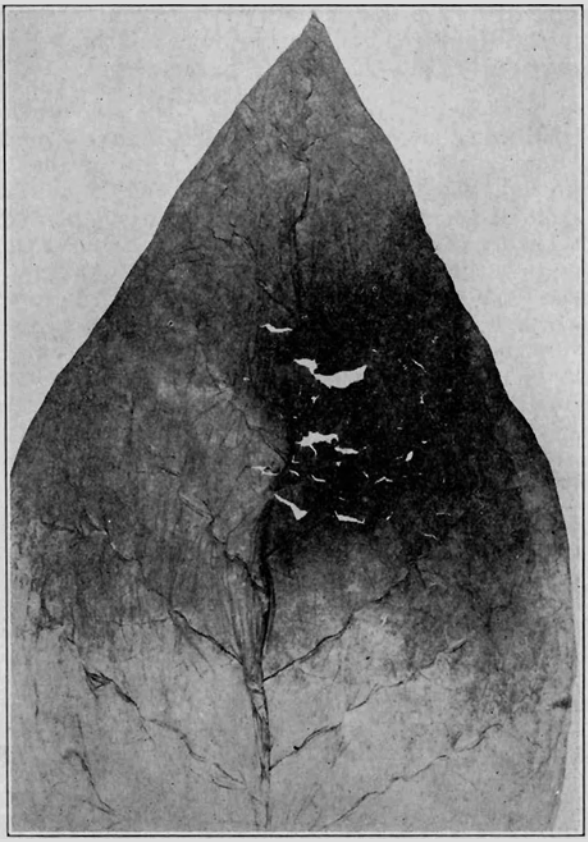

FIGURE 51. Pole rot. The web-rot type ruins the leaves, causing large, indefinite, darkened patches of rotted blade.

The most common pole rot observed this season was the web-rot type (Figure 51). Large areas in the blades of the leaves, especially on the tip half, became dark and "tender" without the appearance of the small, local lesions that characterize the freckle-rot type. Such areas are either hard and brittle, or are "tender" when the tobacco reaches the sorting benches. Many crops were so badly affected that they were not worth sorting and had to be sold for "stemming". The vein-rot type, in which the rot started from the midribs and worked out into the web, was also rather abundant this year.

Bundle rot. This rot appears to be due to the same organism (Aspergillus) which produces black-rot or "canker" in the case. It works in the bundle after the tobacco has been taken down from the shed and stripped. It is favored by two factors: (1) when the tobacco is harvested too green, and (2) when it is bundled too moist. Both of these conditions prevailed in many of the sheds this year. The rot spreads from one leaf to other leaves in contact with it so that a relatively small rot "pocket" may ruin dozens of leaves. Many reports from growers and buyers indicate that there was a great deal of loss this year from bundle rot.

Brown spot and "firing" of Broadleaf. About the middle of August, growers of Broadleaf tobacco in Suffield reported that the bottom leaves of the plants were dying and dropping off, and fearing that another new disease had started, asked that it be investigated. A visit to the fields showed that from one to six leaves on nearly every plant were affected in various stages, many of them entirely dead and gone. In the most advanced stages the whole leaf had turned brown and was dead. In the less advanced, large areas—from several inches to a foot or more across—at the tip on one or both sides were dead. In the earliest stages, however, the disease took the form of definite spots. The younger ones were rather circular in outline, a quarter-inch to an inch or more in diameter. They were dark brown or in some cases ashen gray. In the youngest spots the outline was quite sharp, but in older ones the brown spread more irregularly or gradually into the surrounding tissue. Usually there was some appearance of a concentric, target-board effect, with a yellow, indefinite chlorosis around the margins in the younger spots. Most of the affected leaves were losing the green color, and many of them were entirely yellow. In contact with the moist soil, the brown areas quickly passed into a wet rot and completely disintegrated. The youngest spots were always located between the veins. Some had dark centers, due to the massing of fungous spores.

CAUSE

A microscopic examination of these spots in all stages showed the presence of spores and mycelium of *Alternaria tenuis*. No other fungi were found.

In seeking an explanation of the cause of this trouble, it is necessary to keep in mind the character of the weather in Suffield in 1937. After a very rainy June, July and the first part of August were dry and hot, so much so that tobacco suffered. Such conditions commonly cause "firing" of the lower leaves of Broadleaf, i.e., the lower leaves become overmature, dry up and gradually die. Just as the plants were entering this stage, however, the weather changed; the humidity was constantly high and the rains frequent. The fungus, Alternaria, a weak parasite, was able to attack these leaves which were now weakened and on the point of "firing". This condition is the same as that of partly-cured leaves in the shed, where the fungus produces "pole rot". In fact the trouble can well be explained as pole rot in the field.

A similar destruction of leaves in the field was described by Tisdale and Wadkins in Florida under the name of "brown spot", and by Ghimpu in Roumania. The latter writer enumerates the three conditions which favor the occurrence of the disease as very high humidity, high temperature and an advanced stage of maturity of the leaves. All of these conditions were present in the fields under consideration in Suffield.

No remedy for brown spot can be suggested except to harvest the tobacco as soon as possible and, if the moist weather continues after it is put in the shed, to cure as rapidly as possible by charcoal fires.

Many similar spots were found later in the season both on Havana Seed and on Broadleaf plants and were diagnosed as brown spot. In some of these the original injury appeared to be due to sunburn during some excessively hot periods.

THE RÔLE OF YEASTS IN THE FERMENTATION OF TOBACCO

I. Preliminary Studies

O. E. Street

No phase of tobacco culture is more completely steeped in tradition than the operations subsequent to the shed curing of the leaf. The common names "sweating" and "fermentation" are derived from analogous reactions which occur in hay, straw, leaves or manure in the first case, and a mistaken parallel with true fermentation of sugars in wines in the second case.

The processing of Connecticut Valley types differs completely for Shade and sungrown varieties. Starting about September 1, as soon as the leaves are completely cured and a damp spell permits their handling, the Shade tobacco is brought to the warehouse in loosely packed bundles. Good practice dictates that the tobacco should not be overdamp when taken from the shed, otherwise it is necessary to dry it out somewhat before bulking. It is seldom too dry as it comes from the shed.

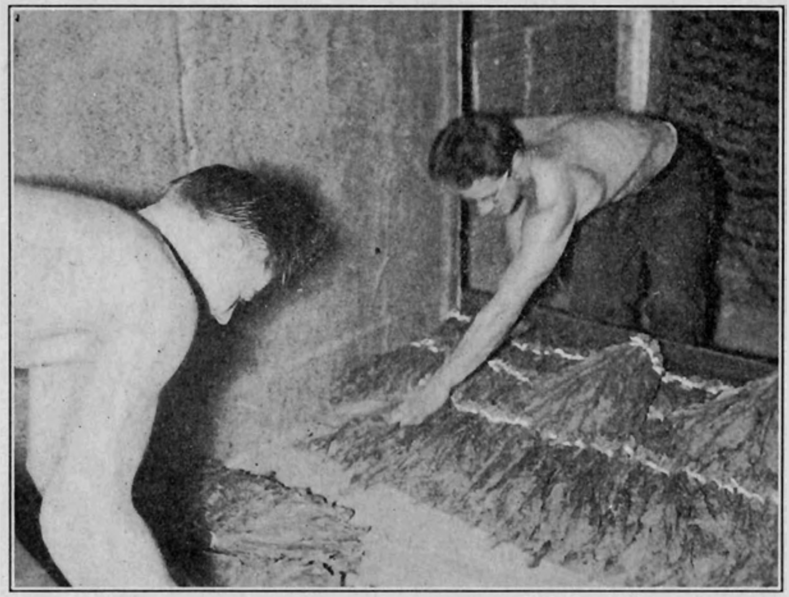

Figure 52. The start of "bulking", showing the overlapping rows of hands.

"Bulking" consists of packing the hands in a frame consisting only of a platform about 6 feet by 12 feet, with ends about 6 feet high. Starting from the outer edge of the sides, the hands are placed in parallel rows, each inner row overlapping the next outer row by about half the length of the hands. Care is taken to keep the center of the bulk higher than the outsides. Successive tiers are added until the bulk is from four to six feet high and contains from 2,500 to 5,000 pounds of tobacco. Thermometers are inserted in tubes which run to the center of the bulks. Figure 52 shows the start in building a bulk and Figure 53 shows a completed bulk, with an empty bulk frame in the foreground.

As soon as the tobacco is in the bulk, fermentation starts and heat is generated. The temperature rises rapidly and within 6 to 12 days, depending on the characteristics of the tobacco, has reached a point between 108 and 116° F. It is then necessary to "turn" the bulk. This consists of removing the tobacco, shaking out the hands, and repacking as before. A complicated ritual is followed in this operation. Tobacco from the top of the bulk is placed in cases for packing in the center of the bulk. This, together with all the tobacco from the outer one or two rows, and a few hands from the ends of each row, is designated as "cold" tobacco. The balance of the bulk is considered "hot" tobacco and occupies the position of the "cold" tobacco when the turn is completed. A change in position from top to bottom of the bulk is also involved in the operation.

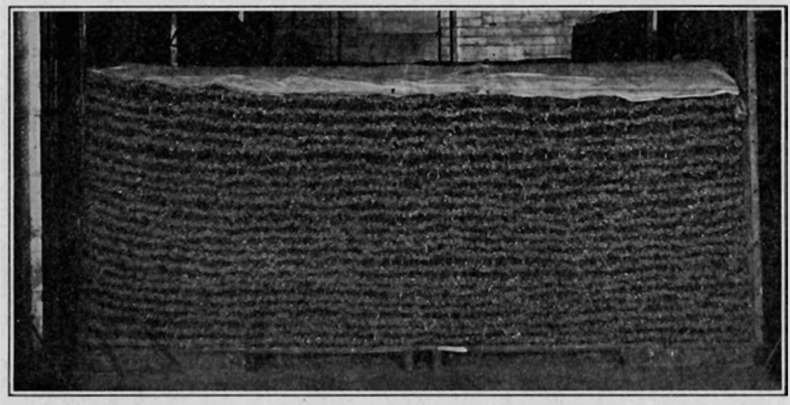

FIGURE 53. A completed bulk. Note thermometer tubes, and papers and blankets on top of the bulk to prevent drying out.

At successive intervals of six to eight days, depending on the temperature, the bulk is turned. With each successive turn after the second, the rate and extent of temperature rise diminishes, until after four to six turns the fermentation is adjudged complete. Bulk rooms are maintained at constant temperatures from 80 to 85° F. and relative humidities of 70 to 85 percent.

Subsequent to fermentation, the tobacco is moistened, the hands opened and the leaves separated, the tobacco graded according to size, and assorted according to color, texture and soundness. It is then packed in wooden cases, usually of a standard 28-inch cross section and varying in length from 36 to 42 inches. Depending on the length and thickness of the leaves, equal weights of tobacco from 150 to 175 pounds, are packed in the cases, which are then returned to a warm, moist room for the second fermentation or "mulling". This is allowed to proceed from four to six weeks. Unless the moisture content is too high, there is no great rise of temperature and it is not necessary to repack the tobacco during this stage.

The final step in the warehouse operations is baling. The tobacco from the mulling room, now nearly as dry as it can be handled, is packed in a special collapsible case. A different technique of packing is followed, alternate layers being packed with the butts of the hands outward and with the hands parallel to the outer walls. Figure 54 illustrates the method of packing and the case employed. A waxed paper (next to the tobacco)

FIGURE 54. A baling case filled and ready for pressing.

and a woven fibre cover are at the bottom, and similar coverings are placed on the top. Strips of waxed paper are placed under the butts of the hands to prevent breakage of the dry tobacco. The tobacco is then subjected to great pressure, as shown in Figure 55, after which the sides of the case are unbolted and removed. Figure 56 illustrates this stage, and also shows the covers, the ends of the protective paper strips, and the alternate layers of hands. After a few minutes the screw press is raised and chains placed around the bale. It is then ready for the sewing shown in Figure 57. After a few hours with the chains in position, these may be removed, and the bale is ready for storage in a moderately warm room until it is sold and shipped to the customer.

The tobacco in the bale would generate a great deal of heat if it were not packed at a low moisture content. The compression of the tobacco from 28 inches to about 11 inches creates a pressure perhaps equal to a bulk.

The fermentation of Havana Seed and Broadleaf tobacco usually occurs at a different point in the sequence of the post-curing process. Some time during October or November, when the weather is moist, the tobacco is taken down, stripped and packed in bundles. At any convenient time after that, it is brought to the warehouse, conditioned, sorted and sized. About the first of the year, fermentation is started. Occasionally, the tobacco is placed in bulks until the first turn, and then packed in standard cases. More frequently, it is packed directly in the cases, at a somewhat higher moisture content than is common with Shade tobacco.

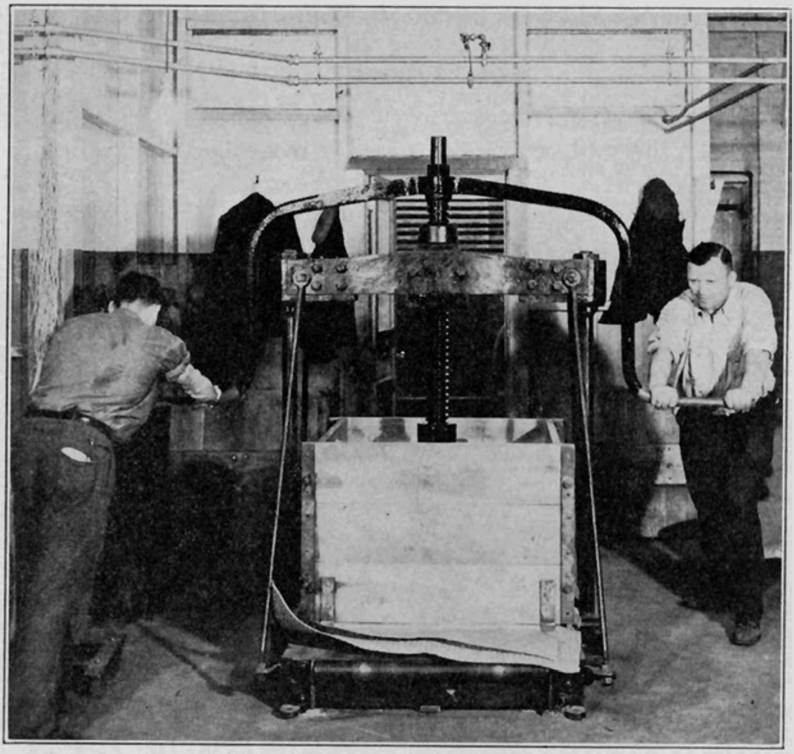

FIGURE 55. Pressing a bale.

These cases are stacked three or four high in a sweat room maintained at temperatures up to 95° F. and 40-60 percent humidity. Occasionally, one or more boards are left out at the ends for aeration. The cases may be repacked two or three times to stimulate the fermentation, or if the temperatures go above 110 to 115°, but are usually not disturbed until ready for sampling. The tobacco remains in the sweat room for several weeks. It may be remoistened and a second fermentation induced in the sweat room, or it may be placed in an outdoor shed during the summer months, either in cases or bundles, and a natural sweat will ensue. Not until the following winter is it considered ready for shipment to the manufacturer, and frequently four or five years elapse before it is used. During all this time, some changes of an oxidative nature are occuring, though not at a perceptible rate, and the tobacco is becoming sweeter and more mellow.

What goes on in fermentation of tobacco? Undoubtedly some of our hardy ancestors did not bother to ferment their smoking tobacco, but it is easy to imagine the circumstances under which the plant might be left in storage under such conditions that, without design, it was fermented naturally. And it is possible that, after discovering the improved qualities of such tobacco, the growers adopted this as a regular practice. The physical changes which accompany the chemical reactions are quite striking. The leaves become more elastic and pliable; the colors become clearer and more uniform; the greenish-yellow or dark-greenish shades of cured cigar-leaf turn to purer yellows, browns, and olives; and the roughness of the leaf surface is greatly diminished. The almost complete disappearance of "gum", a thick, almost waxy coating on the leaves, which is especially abundant on the outdoor types, is a readily recognized change.

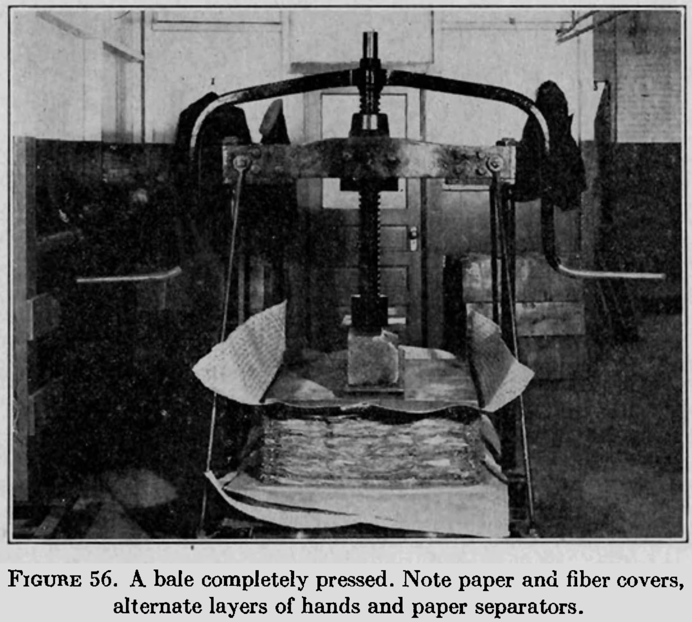

FIGURE 56. A bale completely pressed. Note paper and fiber covers, alternate layers of hands and paper separators.

The smoking qualities of the leaf are markedly different. Before fermentation, the leaf has a bitter taste and an odor like smouldering hay or other vegetable matter. After thorough fermentation, the tobacco has a mild or sweet taste, and the aroma is pleasant and mellow.

From a chemical viewpoint, fermentation of tobacco is a process of respiration and aerobic fermentation, which exhausts or diminishes the content of certain compounds associated with coarseness of the leaf and bitterness of the tobacco, and increases or makes more apparent some aromatic substances. Within certain limitations, the processes are a continuation of the phenomena of starvation associated with curing. It was recognized by Nessler[1] in 1867 that these two processes, curing and fermentation, were not simply drying of the tobacco. Yet the view that they are simply drying processes is popularly held to the present day. To Jenkins[2] belongs the credit for the first determination of some of the chemical changes. He found dry matter losses of 4.5 to 9.6 percent for three grades of an outdoor type during fermentation. The chief loss of dry matter was in the fractions of nicotine, albuminoids and amide bodies,

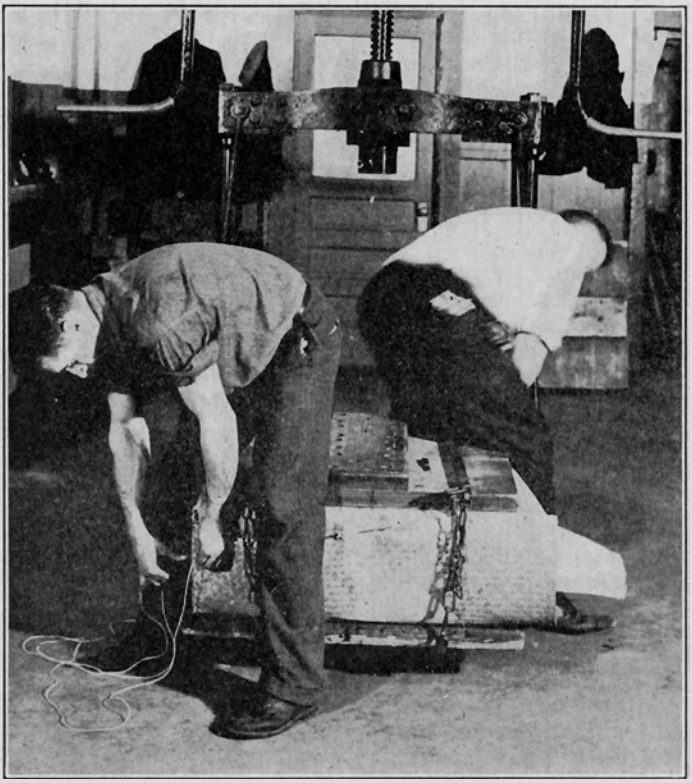

FIGURE 57. Sewing the finished bale. Pressure is maintained by chains around the bale.

nitrogen-free extract and to a much lesser extent, ether extract. Losses of ammonia, starch and fiber were negligible, while nitrates even gained in one instance. The fraction to which he assigned the "gums" lost heavily.

Undoubtedly some changes occur during fermentation in the amounts of all constituents except cellulose, and even that may be affected if high moisture contents prevail and true decomposition starts.

[1] Nessler, J. Der tabak, Seine Bestandtheile und Seine Behandlung. 151 pp. Mannheim, 1867.

[2] Jenkins, E. H. Chemical changes in tobacco during fermentation. Conn. Agr. Expt. Sta. Ann. Rept. for 1892: 28-31, 1893.

Carbohydrates of the less complex forms, such as sugars, largely disappear during the prolonged curing period of cigar leaf tobacco. Starch may also be exhausted, but if it remained after curing, it would soon be broken down to sugars and these would be oxidized. Vickery and Pucher[3] report the destruction of 81 percent of the soluble carbohydrates during curing, but do not report the loss during fermentation. Smirnov[4] has exhaustively summarized the knowledge of curing and fermentation in a monograph published in 1933. He discusses the usual carbohydrate changes, mentions the possible formation of diacetyl, and discusses the changes in pentosans. As reported by Petrik[5], the pectins are broken down to methyl alcohol during curing and fermentation, in proportions varying with their amount and their content of metoxyl groups. He also reports the absence of nicotine and other volatile bases in the air of a warehouse, but the presence of methyl alcohol, carbon monoxide and volatile, oily products of unknown nature.

The nitrogenous compounds have been studied most extensively by Vickery and Pucher[3]. Unfortunately, the material on which they reported has been fermented by the Heber Process, in which a solution of secret composition is sprayed over the leaves, which are then packed in standard cases and subjected to heat up to 110° C. Possibly as a result of this treatment, there were increases between curing and fermentation in total solids (largely inorganic), total nitrogen, nicotine, nitrates and ammonia. Decreases were noted in amides and amino-acids. While Smirnov[4] noted little change in protein nitrogen, he found decreases in the water-soluble fractions, especially nicotine. It is reasonable to expect some loss in total nitrogen, although some of the fractions might be temporarily increased.

The change in organic acids during curing has been studied by Vickery and Pucher[6], who found more citric acid, less malic acid, little change in oxalic acid and a great decrease in unknown acids. Behrens[7] reports succinic acid only in fermented tobacco, while Schmuck[8] identified oxalic, fumaric and malic acids in fermented tobacco. Schmuck and Piatnitski[9] found citric acid and caffeic acid and possibly chlorogenic acid.

The ether-soluble fraction contains the oils and hydrocarbons which are part of the "gum". While Shade tobacco has less "gum" than outdoor types, a decrease in that fraction was reported by Vickery and Pucher[3]. The discovery of methyl alcohol as a product of fermentation by Petrik[5] might indicate a vigorous breakdown of some of these compounds as well as the pectins.

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[3] Vickery, H. B. and G. W. Pucher. Chemical investigations of the tobacco plant. II. The chemical changes that occur during the curing of Connecticut Shade-grown tobacco. Conn. Agr. Expt. Sta. Bul. 324: 207-240, 1931.

[4] Smirnov, A. I. The physiologicol-biochemical principles of tobacco curing and fermentation. (In Russian) Krasnodar, 1933.

[5] Petrik, S. M. The loss of volatile products during the process of curing and fermentation of tobacco. (In Russian). U. S. S. R. State Inst. for Tobacco Inves. Bul. 63: 1-24, 1930.

[6] Vickery, H. B. and G. W. Pucher. Chemical investigations of the tobacco plant. I. A preliminary study of the non-volatile organic acids of tobacco leaves. Conn. Agr. Expt. Sta. Bul. 323: 155-202, 1931.

[7] Behrens, J. Landw. Vers. Sta. 43: 271, 1894.

[8] Schmuck, A. Investigations of the acids of tobacco. U. S. S. R. State Inst. Tobacco Inves. Bul. 50. 1929.

[9] Schmuck, A. and M. Piatnitski. Studies in tobacco acids II. U. S. S. R. State Inst. Tobacco Inves. Bul. 69: 19-27, 1930.

The formation of aromatic compounds is a peculiar feature of the fermentation of tobacco. The formation of complex ethereal oils during fermentation has been reported by Smirnov[4], as well as a change in the properties of resinous alcohols due to oxidation.

A great number of enzymes in fermenting tobacco are reported by Smirnov[4]. A more complete discussion of the activity of enzymes will appear later in the paper but it is well to note that the following have been found: Oxidase, peroxidase, catalase, carboxylase, deaminase, pectase, saccharase, glucosidases, peptidases and a nicotine-splitting form.

Experiments designed to alter the characteristics of the tobacco during fermentation have proceeded along two general lines. These have been laid down by the adherence of the investigator to either the microbial hypothesis or the enzymic and chemical hypothesis.

The bacterial theory of fermentation was strongly advanced by Suchsland[10] in 1891, who claimed the ability to develop the flavor and odor of a specific type of tobacco by introduction of the proper organisms. Numerous other workers of the same period followed his lead.

The first attempt to refute the findings of Suchsland was made in 1899 by Loew[11] who found almost negligible numbers of bacteria present on fermenting tobacco. In papers which followed shortly[12,13] he developed the enzymic theory of fermentation, concentrating his attention on the oxidizing enzymes, oxidase, peroxidase and catalase. The work of Loew was so convincing that the microbial theories were discredited for a great number of years. Not until the work of Johnson[14] appeared in 1934, was there any further support of the rôle of organisms. The most active agents were found to be fungi of the Aspergillus and Penicillium groups, with bacteria much less effective in producing temperature gains in Dewar flasks. A second refutation of Loew's findings has just appeared in a brief note from the Pennsylvania Station[15]. They list several fungi not mentioned by Johnson, and a number of bacterial organisms.

The presence of organisms on the surface of the leaf, or of chemical constituents in the cells, has encouraged the development of many methods for altering the rate or degree of fermentation. "Petuning", as practiced in Cuba, consists of the use of extracts of fermented tobacco which are allowed to ferment for several days, and in which the butts of the hands are immersed. The petuning fluid may also be used as a spray, with or without the addition of ammonium carbonate. An almost endless variety of substances such as rum, wine and fruit juices, are employed either in the ageing or processing of smoking and chewing tobacco. Aromatic compounds such as methol eugenol and enzymes such as pepsin, trypsin and papain, have also been employed. Mechanical mixture of the tobacco with chemical compounds, cultures of organisms, syrups, liquors, gly-

[10] Suchsland, E. Ueber tabaksfermentation. Ber. Deut. Bot. Gesell. 9: 79-81, 1891.

[11] Loew, O. Curing and fermentation of cigar leaf tobacco. U. S. Dept. Agr. Rept. 59, 34 pp. 1899.
[12] ———— Physiological studies of Connecticut leaf tobacco. U. S. Dept. Agr. Rept. 65, 57 pp., 1900.
[13] ———— Catalase, a new enzyme of general occurrence, with special reference to the tobacco plant. U. S. Dept. Agr. Rept. 68, 47 pp., 1901.

[14] Johnson, J. Studies on the fermentation of tobacco. Jour. Agr. Res. 49: 137-160, 1934.

[15] Reid, J. J., D. W. McKinstry and D. E. Haley. The fermentation of cigar-leaf tobacco. Science 86: 404. 1937.

cerine, artificial fruit flavors and the like, is not practiced with cigar leaf tobacco. Physical methods, either artificial heat in moist conditions, or a semi-distillation by dry heat have had trials both here and abroad.

The earliest reference to the addition of yeast to fermenting tobacco was by Koller[16] in 1858. Summaries of the work of several German investigators are to be found in the publication of Wagner[17] and Kissling[18].

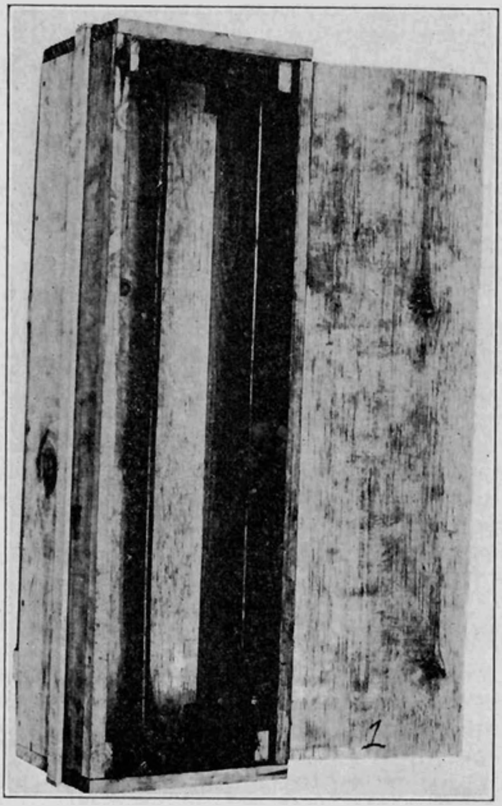

FIGURE 58. Case showing details of construction including perforated, paper wrapped, copper tube used for temperature records and withdrawal of gas samples.

Details are given for the use of yeast in numerous ways, including even the improvement of midribs for fillers. No evidence of the use of yeast in fermentation of tobacco has been published in this country.

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[16] Koller, J. B. C. Der Tabak in Naturalwissenschaftlicher. Landwirtschaftlicher U. Technischer Beziehung: 134 pp, Augsburg, 1858.

[17] Wagner, L. V. Tabak kultur, Tabak-und Zigarrenfabrikation: 248-249 Weimar, 1884.

[18] Kissling, R. Handbuch der Tabakkunde, des Tabakbaues, und der Tabakfabrikation. Ed. V, Berlin, 1925.

The addition of living yeast cells to tobacco may be interpreted as either a biological or biochemical method. Yeasts are simple forms of fungi in the classification of plants and parallel reactions are common.

Experiments on Havana Seed Tobacco

The primary object of the experiments on Havana Seed tobacco was to determine the effect of yeast, sprayed on the leaves, on the rate and completeness of fermentation, aroma and quality. Sorted and sized Havana Seed tobacco of the 1936 crop produced at the Tobacco Substation was used. The first test was made on 21-inch leaves of the grade known as "seconds", and the second test on 23-inch "darks".

These experiments were conducted in one of the constant temperature and humidity chambers previously employed for studies of curing. A description of this equipment is to be found in Station Bulletin 326: pages 411-418, Report for 1930. Small wooden cases were specially constructed of 10-inch cross section and 36 inches long, and slotted on the sides to a width of .5 inch. A copper tube, perforated at the center, ran the length of the cases and served as a thermometer tube. Later these tubes were also used to withdraw gases for analysis. Figure 58 is a photograph of one of the cases showing details of construction. Figure 59 is a view of the constant temperature and humidity chamber with cases and instruments in position, and aspiration tubes in the cases.

The chambers were maintained at an air temperature of 90° F. and a relative humidity of 75 to 85 percent throughout the experiments. The experiments on seconds ran for 25 days total, and the one on darks for 26 days. Complete records of temperature gains in the cases were obtained with tested thermometers. The weight of tobacco in the cases averaged 30 pounds for the seconds and 33 pounds for the darks.

Rates of treatment. The initial applications made to the seconds were 10 ounces of water (as a check), .5 percent bakers' yeast suspension and 1 percent bakers' yeast suspension, respectively. After five days in the cases, it was apparent from the temperature gains that the activity of fermentation was very limited and samples were withdrawn for moisture determination. After another six days, samples were again withdrawn for moisture content. As none of the samples was much in excess of 25 percent moisture content, it was decided to remoisten the tobacco with the appropriate solutions, in the theoretical amounts to produce a 30 percent moisture content.

The tobacco used for the test on darks was treated with water, and 5 percent, 10 percent and 20 percent suspensions of bakers' yeast. Preliminary moisture determinations were made, and sufficient solution added to raise the weight to the computed figure for 30 percent water. This was more effective than adding the solutions in theoretical amounts, as nearly one-half of the solutions fail to reach the tobacco.

It is to be noted that the rates of application given are based on concentration of the suspensions. Later it became apparent that the same concentration of solution might be applied at an infinite variety of rates. In order to obtain results which could be duplicated, it would be necessary to compute the applications in terms of actual concentration of yeast. As the bakers' yeast used was the usual moist cake containing 70 percent water, the results were computed to this basis, and appear in Table 36.

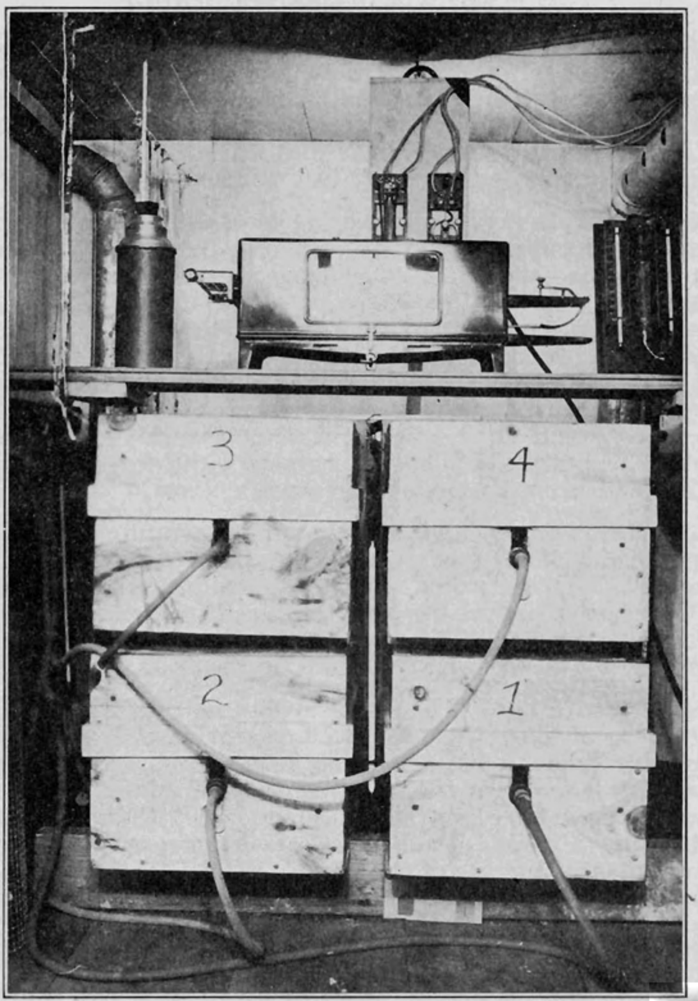

FIGURE 59. View of constant temperature and humidity chamber, with cases and instruments in position, and aspiration tubes in the cases.

The lack of uniformity in this series is due to the fact that the darks had approximately twice as much solution applied per pound of tobacco.

In subsequent sections the actual concentration of yeast on the tobacco will be stated, rather than the concentration of solution.

TABLE 36. PERCENTAGE OF ACTUAL YEAST ADDED TO HAVANA SEED TOBACCO

	Seconds		Darks		
Concentration of solution %	0.5	1.0	5.0	10	20
Actual concentration of yeast %	0.026	0.046	0.365	0.741	1.492

Moisture content and weight changes. In all references to moisture content in this work, the basis used is water as percent total weight. This is preferable to water as percent dry weight, because tobacco is never handled in a water-free state; hence to use such a base would complicate weighings. The samples used for Havana Seed were entire leaves dried to constant weight at 80° C., while those employed for Shade tobacco were stemmed leaves dried at 105° C. Aluminum moisture cans were used as containers in the later work. The moisture contents of Havana Seed tobacco at various stages are shown in Table 37.

It will be noted that the seconds were not as uniformily treated, nor did they approach the 30 percent water content desired for these experiments.

Weight losses of the seconds from the eleventh to the twenty-fifth days were three-fourths pound in each case. With the darks the losses in 26 days were respectively: Water, 1⅜ pounds; .365 percent yeast, 1⅝ pounds; .741 percent yeast, 1⅝ pounds; 1.492 percent yeast, 1¾ pounds. As there was no evidence of a great change in gross moisture content during the fermentation of the darks, it is obvious that considerable water must have been formed during the period of fermentation. It is also evident that considerable loss of dry matter occurred, a consideration that will be discussed more fully in the section on carbon dioxide production.

TABLE 37. MOISTURE CONTENTS OF HAVANA SEED TOBACCO

	Treatments					
Description of sample	Water treatment	.026% yeast	.046% yeast	.365% yeast	.741% yeast	1.492% yeast
Seconds						
Fermented 5 days	23.00	24.20	23.60			
" 11 "	23.18	24.19	25.05			
End of fermentation	25.25	27.30	26.68			
Darks						
Before using	24.95			24.95	24.95	24.95
After moistening (computed)	28.94			30.06	30.13	30.17
End of fermentation	28.75			30.06	29.07	30.63

Temperature gains. In order to obtain more accurate base temperatures, a blank case in the first run was packed with excelsior and placed in the chamber. The four cases were rotated in position daily to overcome further the effect of position.

Temperature gains of the seconds, up to the time the tobacco was remoistened, were rather low, the highest being 5.4° on the third day for the .046 percent treatment. Gains in the succeeding six-day period were at a still lower level. The peak of temperature gain was again reached on the third day after remoistening for the yeast treatments, but on the fifth day, for the water treatment. On the third day, the .046 percent yeast was 9.8° F. higher than the blank, the .026 percent yeast 9.3°, and the water 6°. The peak for water was 8.05° on the afternoon of the fifth day. From these high points, the gains declined rapidly, with no one treatment remaining at the highest temperature for more than a day or so. At the termination of the run, the gains were from 2 to 3 degrees.

No blank case was employed in test on darks, as the control remained unchanged in the chamber. One significant difference in the experiment was made, however, and had a pronounced effect on the temperature gains. This was the withdrawal of air from the cases at a moderate rate for one hour a day, for analysis of carbon dioxide and ammonia. The effect of the removal of the gaseous products of oxidation and their replacement with fresh air was to prolong greatly the period of high temperature gains.

In the first run, temperature gains above 5° F. were maintained for two and seven days in the two parts of the run. In the experiment on darks, as may be seen in Figure 60, the 5° F. level was exceeded for 18 days. The maxima were also reached more slowly, the 1.49 percent yeast treatment showing a gain of 10.7° on the ninth day, .74 percent yeast a gain of 10.9° on the tenth day, .36 percent yeast a gain of 10.0° on the eleventh day, and water 9.5° on the twelfth day. The difference between the water treatment and the lowest yeast treatment was less than with seconds. Under the influence of daily aeration all treatments were able to maintain high temperatures for protracted periods. The .74 percent yeast treatment maintained high temperatures for the longest period, and the water treatment for the shortest. Gross maxima of 102° were reached by both .74 percent and 1.49 percent treatments, with net gains favoring the .74 percent rate by 0.2°, due to difference in base readings.

It is notable that in each experiment the lowest gains were made by water treatments.

Production of carbon dioxide and ammonia. As a result of preliminary measurements conducted near the end of the first experiment, it was decided to determine carbon dioxide and ammonia evolution daily on all treatments of the test on darks. A blank of the chamber air was also included. Figure 61 shows the gas absorption assembly used from the ninth day to the end of the run, while Figure 62 shows the manometer assembly used to regulate the suction. The period of aspiration was exactly one hour a day, an ordinary water suction pump being regulated to deliver one liter per minute. Previous to the ninth day of this test, the Dreschel gas absorption towers, shown on the right of Figure 61, were used for both carbon dioxide and ammonia determinations. On the ninth day, the Meyer bulbs, shown on the left, were substituted for carbon dioxide determinations. The increases in amount of carbon dioxide collected with the revised equipment were as much as 500 percent, consequently the data for the first eight days were not included in Table 38. In this table, results are shown as the average of four-day periods. As the cases were rotated daily to eliminate the effect of position on temperature, any one case would occupy all possible positions during a four-day period. The day

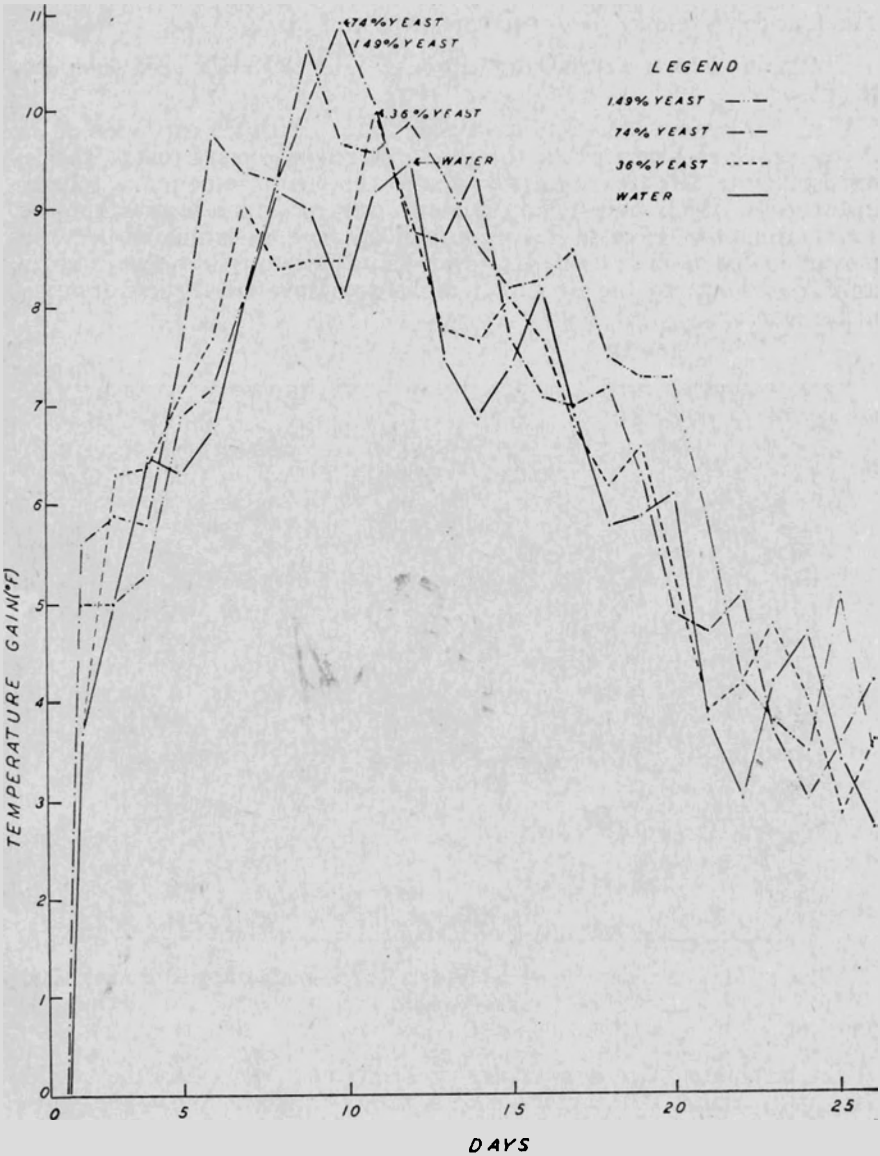

FIGURE 60. Temperature gains of Havana Seed "darks" fermented in small cases in a constant temperature chamber with varying applications of bakers' yeast.

to day fluctuations in amount of carbon dioxide were rather wide, due to slight differences in rate of aspiration with an ordinary suction pump. The four-day averages displayed consistent trends.

Determinations were made by titration of N/2 NaOH used to collect the gas.

Figure 63 presents the data in graphic form. With the exception of the .36 percent yeast treatment, the results were quite consistent. The inconsistency of this treatment was due to the greater amount of tobacco in this case, which made it impossible to secure comparable gas samples. In an attempt to decrease the pressure in this case, several hands were removed on the seventh day. However, this failed to relieve the pressure, as indicated both by the low carbon dioxide readings and the higher manometer readings.

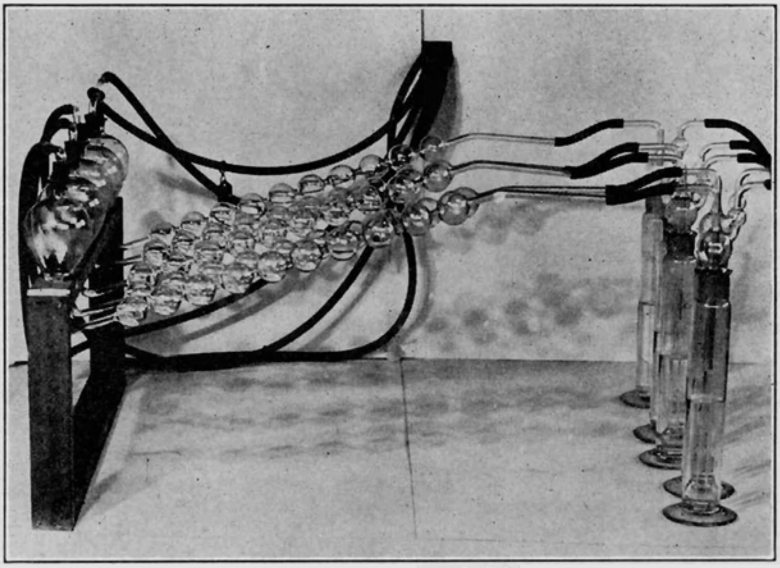

FIGURE 61. Gas absorption assembly used for carbon dioxide and ammonia collections.

The maximum of carbon dioxide evolution was reached on the twelfth day, with nearly 1200 milligrams for the .74 percent yeast and water treatments. Undoubtedly this single day's determination was obtained with slightly greater suction, but it serves to illustrate the great activity of fermentation that existed. A further illustration of the enormous activity is shown in the determinations for the seventeenth day. On this day, because of an error in preparing the solutions, a second aspiration of one hour was run immediately after the customary hour period. The results showed no appreciable decrease from the previous day, readings as high as 700 milligrams on the .74 percent yeast treatment being obtained.

TABLE 38. CARBON DIOXIDE EVOLUTION OF FERMENTING TOBACCO

Period of test	Average amount in milligrams				
	Water	.36% yeast	.74% yeast	1.49% yeast	Blank
9-12	700.6	532.4	835.5	530.2	2.2
13-16	530.1	341.5	748.8	585.1	2.2
17-20	376.1	299.3	535.2	494.1	2.2
21-24	259.7	227.6	401.4	380.2	2.2
25-26	230.5	188.6	330.2	310.6	2.2

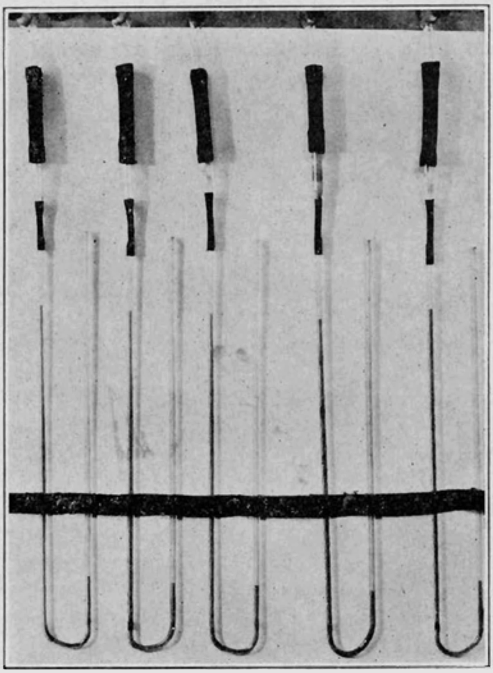

FIGURE 62. Manometer assembly used to regulate suction.

The retarding effect of a 1.49 percent yeast suspension, is apparent in these data. During the 9 to 12-day period, the concentrated treatment was the lowest of all, and it was only during the second half of the fermentation that it showed pronounced activity. In this respect, the carbon dioxide and temperature readings were somewhat parallel.

These data indicate first that carbon dioxide is produced at a high rate during fermentation of tobacco. There are also definite indications that moderate amounts of yeast stimulate katabolic activity above the level of the water treatment. These differences are of a sufficient magnitude to render it extremely unlikely that the yeast cells themselves furnished much of the material for this activity.

The gas drawn from the cases after passing through the N/2 sodium hydroxide in the Meyer bulbs, was passed through acid to trap any ammonia given off. These tests were run every day from the second to the end, and in no case was any trace of ammonia detected. The solutions were Nesslerized, using the Nessler-Folin reagent as modified by Koch-McMeekin[1], and read in a Klett Biocolorimeter against a 0.1 p.p.m. standard. Aliquots of the eighth day were checked by Dr. George W. Pucher of the Agricultural Experiment Station at New Haven, using a Pulfrich spectrophotometer, and no ammonia was detected. It is extremely unlikely that any free ammonia would be evolved unless the samples were alkaline, a condition which would not exist in normal fermentation of tobacco. The aroma associated with fermenting tobacco is more likely to be due to methyl alcohol and other secondary products of fermentation.

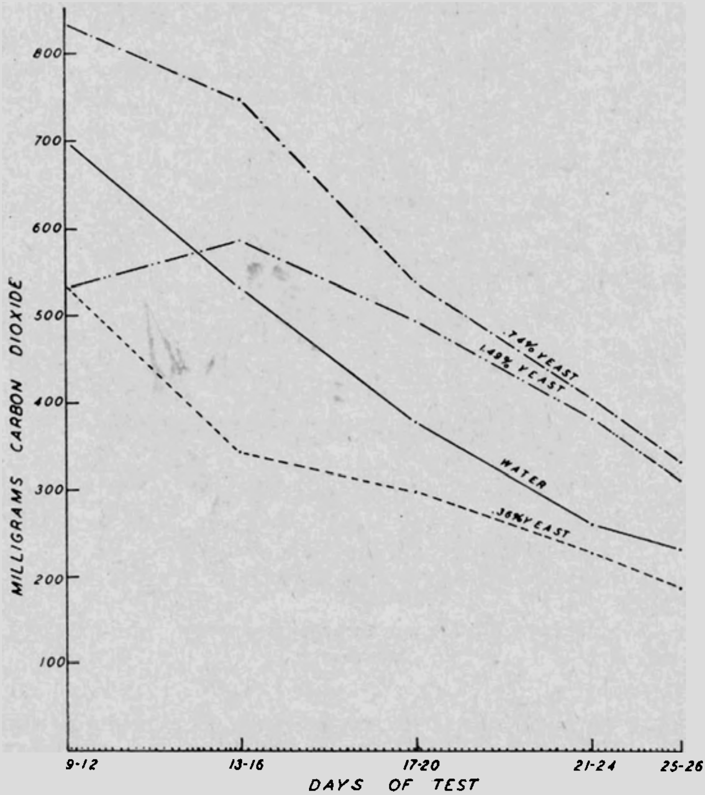

FIGURE 63. Carbon dioxide production by fermenting Havana Seed tobacco treated with varying applications of yeast. Average of four daily periods of one hour each.

Changes in reaction during fermentation. The acidity of samples from various stages in the fermentation of Havana Seed darks and seconds was determined at the end of the runs, using a Coleman glass-electrode

[1] Koch, F. C. and T. L. McMeekin. Jour. Am. Chem. Soc. 46: 2066, 1924.

assembly. An arbitrary procedure was chosen, 50 mls. of distilled water being added to 5 grams of shredded, air-dry tobacco, and the mixture allowed to stand 15 minutes. The supernatant liquid was decanted into the solution cup and the test completed. Results of these tests are shown in Table 39.

The initial reactions for the two grades differed considerably, the darks being more acid. While the seconds became more acid during the early stages of fermentation, the acidity decreased in the last two weeks. The darks displayed a decrease in acidity during fermentation, with no significant differences due to treatment in either group. None of the samples reached neutrality, although the .74 percent yeast approached it quite closely. In this connection it is interesting that Pucher, Vickery and Leavenworth[20] report that ammonia is not given off at 85° C. by the evaporation of a very dilute ammonium sulfate solution, at reactions below pH 6.95. Hence it would be necessary to create a condition of neutrality, either by chemical treatment or possibly by prolonged fermentation, before free ammonia could be detected. Undoubtedly, the decomposition of simpler nitrogenous compounds leads to the formation of ammonia, but it is immediately combined with acid ions at the prevailing reactions.

TABLE 39. REACTION OF TOBACCO AT VARIOUS STAGES OF FERMENTATION

REACTION (pH)

Sample	Seconds			Darks			
	Water	.026% yeast	0.46% yeast	Water	.36% yeast	.74% yeast	1.49% yeast
Unfermented	6.12	6.12	6.12	5.71	5.71	5.71	5.71
Fermented 5 days	5.70	5.70	5.68		6.10[1]		
" 11 "	5.60	5.90	5.87				
After fermentation	6.21	6.18	6.37	6.45	6.49	6.71	6.60

[1]Sample withdrawn after 7 days to relieve pressure in case.

Condition of the tobacco after fermentation. Immediately after the cases were opened, the tobacco was examined for appearance and aroma. Later, numbered but unidentified samples of each lot were examined by a commercial expert, Mr. Roswell Billings of the P. Lorillard Company, Windsor.

A summary of the immediate observations on the seconds disclosed considerable differences in favor of the yeast treatments. The water-treated tobacco was dark, streaked and mottled, and lacked elasticity and finish. More gum remained on the leaves; the aroma was sharp and the taste on a cigar, biting. The .026 percent yeast was superior in appearance, only the tips of the leaves seeming poorly sweated. The aroma was sweet, and more abundant than that which had received the water treatment. The taste on the cigar was good. Tobacco treated with .046 percent yeast had a well-fermented appearance, with light, uniform-colored leaves, elastic and not gummy. The aroma was sweet and the taste good. Mr. Billings considered that the water-treated tobacco had not been sweated much and that it needed considerably more fermentation. Both the yeast lots were considered at least 75 percent fermented.

[20] Pucher, G. W., H. B. Vickery and C. S. Leavenworth. Determination of ammonia and of amide nitrogen in plant tissue. Ind. and Eng. Chem. (Anal. Ed.) 7: 152-156, 1935.

The conclusions on the darks were less clearly defined because of damage from excessive moisture on the .36 and 1.49 percent yeast treatments. Both these treatments had moisture contents over 30 percent at the finish of the run, while the water and .74 percent yeast were below that level. Notwithstanding this fact, the yeast treatments induced more complete fermentation. The leaves were free from gum while the water-treated leaves felt gummy. The color, elasticity and texture were improved and the taste was not bitter, all of which contrasted with the check. Mr. Billings considered the .74 percent treatment the best of any of the lots. His general criticism was that the water content had been too high and treatments carried too short a time for complete fermentation.

Discussion of results. Numerous criteria were applied to measure the effect of yeast suspensions sprayed at varying rates on Havana Seed tobacco. Temperature gains were greater with yeast treatments for both experiments, and the periods of high temperature were more prolonged. Moisture levels were favorable for seconds, but it is obvious that the use of moisture contents above 30 percent was detrimental to darks. The growth of cellulose-destroying organisms, of the type which produces "black rot" or "canker", was encouraged and the leaves were tender and easily torn. The strong odor which accompanies fermentation at high moisture levels has also been noted by Johnson[1].

The production of carbon dioxide was at high levels, with the .74 percent yeast treatment the highest, followed by water and 1.49 percent yeast. The amounts of carbon dioxide produced hourly would indicate a great katabolic activity, sufficient to account for a large part of the weight loss during fermentation. The complete absence of ammonia is most surprising in view of the oft-repeated observation that ammonia is present in the air of sweat rooms. The discovery by the Russian workers of methyl alcohol as a product of fermentation is more easily reconciled with known chemical changes, which are notable for a disappearance of "gums" rather than a great drop in nitrogen content. The physiological effect of the gases in the room more nearly coincides with methyl alcohol than ammonia, in the opinion of the writer. A further clue is found in the acid reaction of the tobacco samples, which precludes the release of free ammonia.

The physical changes in the tobacco are the most conclusive evidence in favor of the yeast treatments. In both series, the contrast between treated and untreated samples indicated that some components or activities of the yeast cell had accelerated changes which were manifested in greater elasticity of the leaves, more uniform colors and a more complete disappearance of gums. The greater production of aromatic compounds and the lessened amounts of bitter compounds, as judged by smoking a cigar, were also apparent with the yeast treatments.

Experiments on Shade Grown Tobacco

Because of the encouraging results obtained on Havana Seed tobacco, it was decided to study the effect of spraying Shade tobacco with yeast suspensions. These experiments were made possible by the excellent coöperation of The Gershel-Kaffenburgh Tobacco Company, Hartford,

[1] Johnson, J. Studies on the fermentation of tobacco. Jour. Agr. Res. 49: 137-160. 1934.

Conn., who furnished the tobacco for the tests, and in whose warehouse the tests were conducted and the tobacco graded.

Lots ranging in size from 1350 pounds to 4200 pounds were selected from the different pickings as received in the warehouse. These lots represented the first, 1½ and second pickings, which are respectively the first to third, fourth to sixth, and tenth to twelfth leaves removed from the plant. In each experiment, the tobacco was divided into two lots as received. One lot was conditioned and bulked without further treatment, while an equal amount was sprayed with yeast, conditioned and bulked. In addition to the bulk experiment a supplementary experiment in the small cases used for the Havana Seed tests was conducted with the second picking lot.

Included in the small case tests was an application of autolyzed yeast. This is prepared by putting bakers' yeast in the moist cake form in an incubator at 45° C. for several hours. Under these conditions, auto-digestion by the yeast cells occurs, the glycogen first being used up, followed by the proteins. Eventually, the yeast cells die without the enzymes being destroyed. Sample No. 21070 from the Fleischmann Laboratories was used in this test.

The autolyzed yeast gave a higher temperature than did the bakers' yeast after the first six days. A peak of 5.5° was reached by the autolyzed yeast on the fourteenth day. The tobacco treated with autolyzed yeast was darker in color than the bakers' yeast treated tobacco, but well fermented.

Rates of treatment. In the first two experiments on Shade tobacco, a 5 percent suspension, made by suspending one pound of yeast in 20 pounds of tap water, was employed. The two lots were sprayed at different rates and as a consequence had different actual concentrations of yeast. The 1½ picking lot had so much water added to the tobacco that considerable difficulty was encountered in drying it sufficiently for bulking. It was then decided that some modifications in the technique were imperative. Instead of using suspensions of a definite strength, sufficient yeast to obtain a desired concentration of yeast on the tobacco was suspended in enough water to raise the moisture content of the tobacco by not more than 3 percent, as computed from the moisture content of the tobacco before spraying, and as regulated by weighing before and after spraying. The final check was obtained by moisture determinations on samples taken after the tobacco had been packed in cases for 24 hours, to allow uniform distribution of the moisture.

The rates of treatment in terms of actual concentration of yeast are given in Table 40.

The 1½ picking had an actual concentration of yeast more than twice that employed with the first picking. The second picking bulk test was computed for .75 percent yeast, and the small case lot .75 percent and 1.50 percent bakers' yeast. Fairly good agreement with theoretical concentrations was obtained, especially in the bulk lot. In several cases, either by accident or design, the concentrations are close to those employed with Havana Seed tobacco.

TABLE 40. RATES OF APPLICATION OF YEAST TO SHADE TOBACCO

Lot	Treatment	Concentration of Yeast percent	Type of Yeast
1st Picking	Bulk	.214	Bakers
1½ "	Bulk	.485	Bakers
2nd "	Bulk	.738	Bakers
2nd "	Small Case	.826	Bakers
2nd "	Small Case	1.485	Bakers

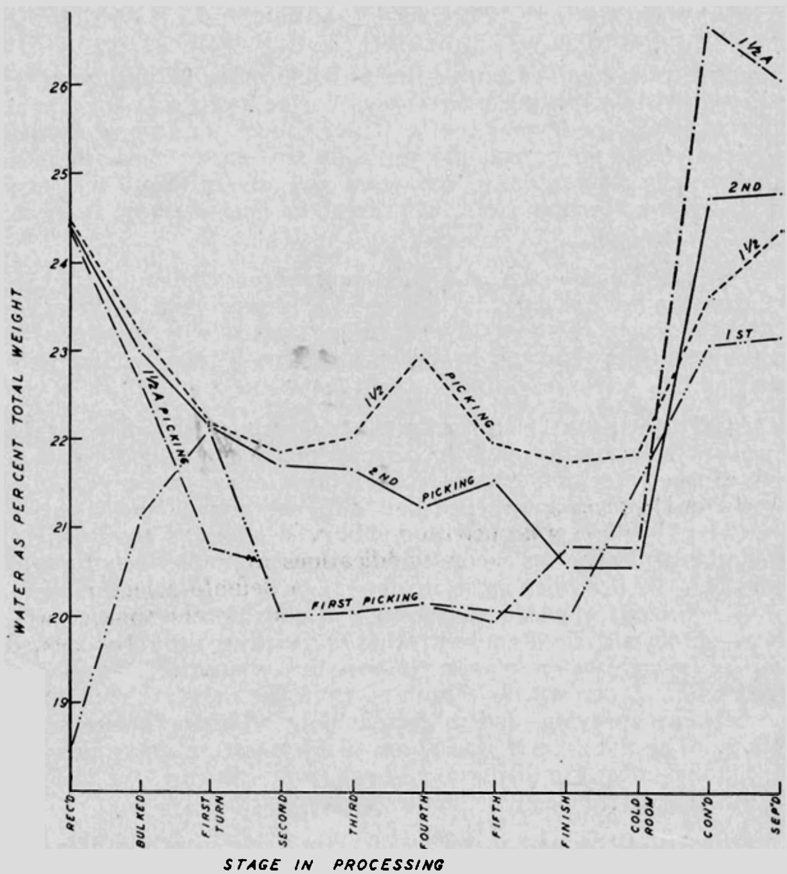

FIGURE 64. Average moisture content of Shade tobacco at varying stages in processing.

Moisture contents and weight changes. In the ordinary routine of the warehouse, more attention is paid to moisture content than to any other factor. Shade tobacco loses or gains moisture very readily and great care must be taken to maintain the proper levels for the various operations.

As previously mentioned, the tobacco is apt to be overdamp when received. In this warehouse, the preparation of the tobacco for bulking is done by an air conditioning type of installation, in which air at a definitely controlled temperature and relative humidity is circulated in a room equipped with conveyors for the tobacco. Relative humidities are expressed as the difference between dry and wet bulbs at a given temperature. Obviously, tobacco may be made either to gain or lose moisture while passing through the conditioning room.

The average moisture contents for the first four pickings for all steps up to sorting are shown graphically in Figure 64. This graph displays the averages of about 300 moisture determinations on both experimental and routine samples, and represents in generalized form the behavior of Shade tobacco during processing in the warehouse. Some irregularities due to inconsistencies in sampling are present.

All pickings except the first were received in rather moist condition in the warehouse. The moisture contents were adjusted for bulking to about 21 percent for first picking and 23 percent for later pickings. As the fermentation proceeded, there was a gradual loss in moisture until, at the finish of the fermentation, no tobacco contained over 21 percent water, and the first picking had only 20 percent. Storage in cases in a cold room for periods ranging from three days to six weeks had no effect on moisture contents.

Preparatory to sorting, the tobacco was again conditioned at relative humidities of 85 to 95 percent. The water content was raised from 3 to 6 percent, depending on the picking, with 4 percent a desirable gain. Unless the tobacco was overdamp, as the 1½A picking, it continued to take up water while being separated in rooms maintained at high humidities.

The experimental lots were treated in such a manner as to insure bulking of the treated and untreated lots at nearly equal moisture contents. This necessitated one or two conditionings at low atmospheric moistures after spraying. In the last series of tests, the entire lot was conditioned for bulking, and the yeast suspensions applied to half the tobacco. This was allowed to remain in cases 24 hours, conditioned at 64 percent relative humidity, and again conditioned after another day at 78 percent relative humidity. The last conditioning served mainly to loosen the hands.

The similarity of moisture contents obtained is shown in Table 41. In all but the bulk test of second picking, the untreated tobacco had slightly higher moisture content.

TABLE 41. MOISTURE CONTENTS AT TIME OF BULKING

Experimental picking	Treatment	Check	Yeast
1st	Bulk	20.10	19.85
1½	Bulk	23.35	22.95
2nd	Bulk	22.30	22.96
2nd	Small cases	23.46	22.90, 23.39.[1]

[1].83% Bakers' yeast, 1.48% Bakers' yeast respectively.

The data on losses of weight during fermentation were not conclusive on the first two tests. In the bulk test of second picking, the shrinkage was

6.2 percent for the check and 5.5 percent for the yeast. In the small cases, the water-treated tobacco dried out more rapidly than the yeast-treated lots during the first 15 days in the cases. It has been observed that yeast-treated tobacco remained in better moisture condition than untreated samples.

Temperature gains. Daily temperature records were obtained on all lots during the periods of fermentation. Not all of these will be given in detail as one table will suffice.

The interrelation of moisture contents and temperature gains is extremely close. In a bulk of first pickings which started at 22.60 percent water, a temperature of 119° F. was reached in four days after the first turn. It was necessary to dry out this tobacco by conditioning at 70 percent relative humidity, and to reduce the moisture content to 20 percent before it would sweat normally. In two cases, second picking bulks which rose to 104° F.

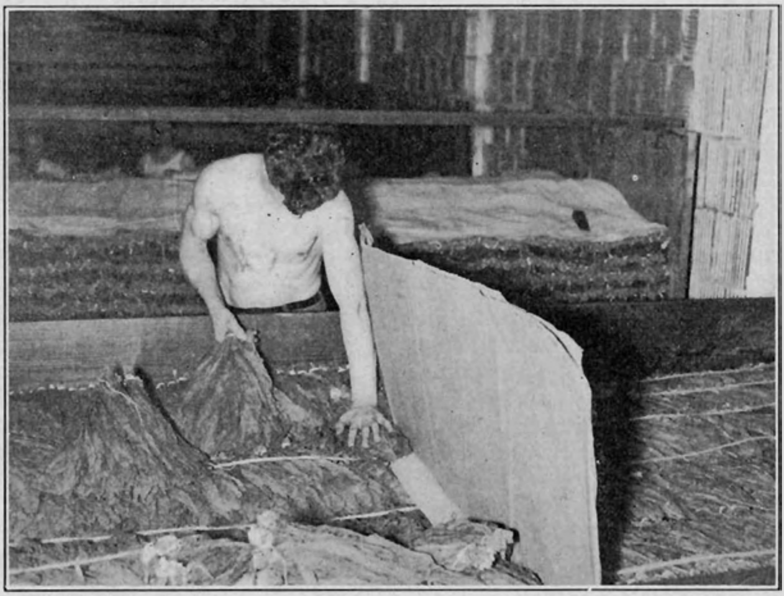

FIGURE 65. Cardboard separator used to divide the treated and check tobacco in the bulk.

in 12 to 14 days showed moisture contents of 18.42 and 19.86 percent. After conditioning at 84 percent relative humidity, the moisture contents were 21.40 and 23.34 percent, respectively, and when rebulked the tobacco made normal gains.

The first two experimental lots were of large size, 2625 and 4268 pounds, and consequently they were treated as entire bulks. The separation of the treated and untreated halves was in a horizontal direction. In each case the treated lot first occupied the upper half of the bulk, being separated by strings. With each successive turn of the bulk, the lots reversed positions. In the third bulk experiments, 1200 pounds of tobacco were equally divided between yeast treatment and no treatment. These lots occupied the same horizontal position in a bulk of other tobacco from which they were divided by strings. As shown in Figure 65, a cardboard partition served to separate the treated and untreated lots. This was more satisfactory, as it eliminated the effect of horizontal position on temperature gains.

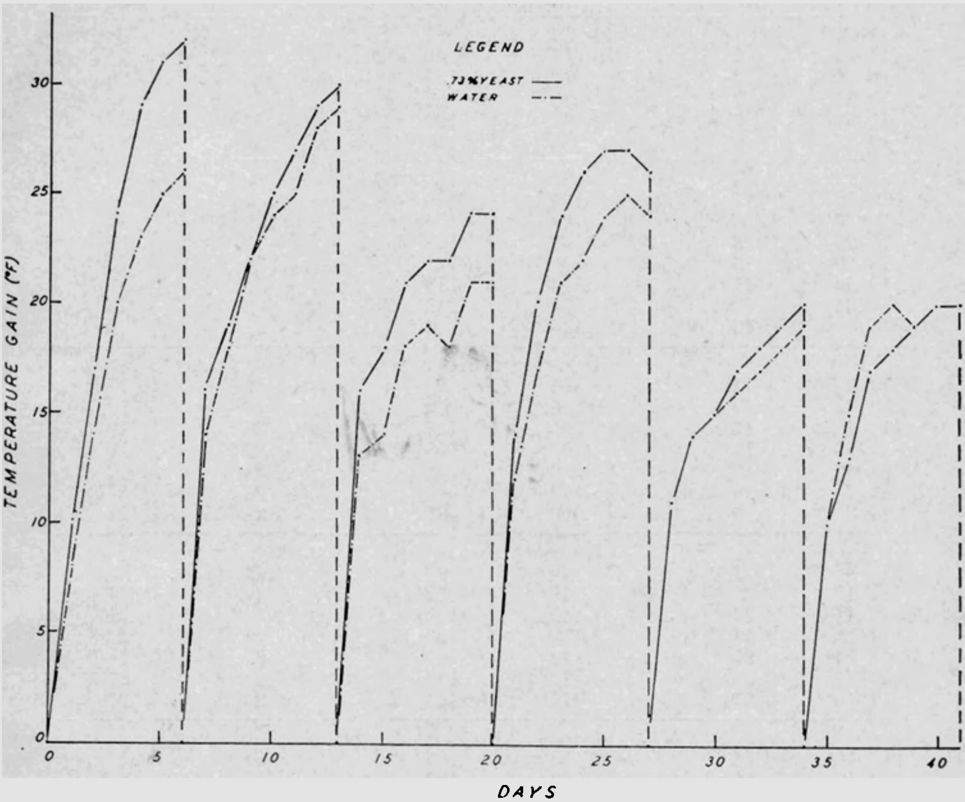

FIGURE 66. Temperature gains of second picking Shade tobacco during bulk fermentation.

Temperature gains in the first two tests rather consistently favored the untreated tobacco. In the first test, the yeast showed greater gains only after the second turn, reaching a maximum temperature of 113° F., a gain of 29°.

The untreated lot in the second experiment was rather consistently one to five degrees higher in temperature during the entire sweating period with a maximum of 117° on the fourteenth day, a gain of 33°. Moisture contents at the various turns favored the untreated lot by .4 to 1.2 percent.

The third bulk experiment permitted more careful comparisons of temperature records. Neither lot was favored by position in the bulk, and in addition, the room temperature and humidity were recorded with a Friez hygrothermograph, so that accurate gains could be computed. The complete record is to be found in Table 42 and a graphic representation in Figure 66.

TABLE 42. TEMPERATURE RECORDS OF SECOND PICKING BULK TEST ON SHADE TOBACCO

Date	Days in bulk	Temperature Yeast	Temperature Check	Gain in Degrees F. Yeast	Gain in Degrees F. Check
10-20	1	94	92	10	8
10-21	2	101	98	17	14
10-22	3	108	104	24	20
10-23	4	113	107	29	23
10-24	5	115	109	31	25
10-25	6	116	110	32	26
		turned	(top of bulk)		
10-26	7	100	98	16	14
10-27	8	104	103	19	18
10-28	9	108	108	22	22
10-29	10	112	111	25	24
10-30	11	114	112	27	25
10-31	12	114	113	29	28
11-1	13	114	113	30	29
		turned	(bottom of bulk)		
11-2	14	102	99	16	13
11-3	15	106	102	18	14
11-4	16	108	105	21	18
11-5	17	109	106	22	19
11-6	18	110	106	22	18
11-7	19	110	107	24	21
11-8	20	110	107	24	21
		turned	(top of bulk)		
11-9	21	99	97	14	12
11-10	22	105	102	20	17
11-11	23	109	106	24	21
11-12	24	112	108	26	22
11-13	25	112	109	27	24
11-14	26	112	110	27	25
11-15	27	111	109	26	24
		turned	(bottom of bulk)		
11-16	28	96	96	11	11
11-17	29	99	99	14	14
11-18	30	100	100	15	15
11-19	31	102	101	17	16
11-20	32	103	102	18	17
11-21	33	104	103	19	18
11-22	34	104	103	20	19
		turned	(top of bulk)		
11-23	35	94	94	10	10
11-24	36	98	100	13	15
11-25	37	102	104	17	19
11-26	38	103	105	18	20
11-27	39	104	104	19	19
11-28	40	105	105	20	20
11-29	41	105	105	20	20

The experimental lots were placed on top of a bulk in starting and at the first turn were transferred to the top of a smaller bulk. Temperatures rose rapidly, the maximum of 116° being reached by the yeast treatment on the sixth day. With each turn slightly lower peaks were reached until in the last two weeks the heat production was greatly diminished. Except for this last week, the yeast-treated tobacco maintained appreciably higher temperatures at all times. It is notable that the temperatures reached by the experimental tobacco were considerably higher when it was at the top of the bulk.

The yeast tobacco went in the bulk at .66 percent higher moisture content, but the average of determinations at each turn favored the yeast by only .21 percent. It would thus seem that the yeast raised the temperature of the bulk to a small degree, in this test, but usually in as large a mass of tobacco as a bulk, a relatively small difference in moisture content is sufficient to accelerate chemical changes and mask the smaller differences due to yeast.

In the small cases, temperature gains were of a low order. The .83 percent bakers' yeast maintained the highest temperature in the first six days. Both exceeded the 1.48 percent bakers' yeast, while the water was the lowest throughout, results which agree with the Havana Seed tests. Case temperatures fluctuated with room temperatures, and gains were only 4 to 5 degrees. After 15 days, the cases were opened, the tobacco tagged, and about one-fourth of each treatment repacked in a single small case with waxed paper separating the treatments. The balance of the lots was transferred to the appropriate halves of the experimental bulk of second picking tobacco. The single small case remained in a sweat room for 65 days longer, and still maintained a difference of 3.8° above room temperature. The relatively low moisture content at which Shade is bulked, the small mass of tobacco in the case, and the ready radiation of heat from the small cases preclude the possibility of high temperature readings.

Observations and results on the fermented tobacco. The experimental lots were subjected to the ordinary routine of the warehouse after fermentation, and at the appropriate time were conditioned, the hands opened and separated, and the tobacco sized and assorted. The identity of each lot was carefully maintained in each step, and random samples were taken for sorting. The grading of these samples was done by regular sorters and inspectors; the weights and percentages of grades were obtained, and the average value computed from current prices. Observations were made of the appearance of the tobacco and samples were retained for chemical and smoking tests.

The first picking was sized before sorting, hence samples were taken from each size of both lots. The detailed distribution of grades is not included, but a weighted average value was obtained for each lot. For the untreated lots this was $1.178 per pound; for the yeast-treated lots it was $1.284, a difference of over 10 cents a pound. The yeast-treated tobacco was consistently better in percentage of high value, light brown grades, rather consistently lower in the mottled grades, but not consistently better in the olive grades.

TABLE 43. SORTING RECORD OF SECOND PICKING BULK TEST ON SHADE TOBACCO

Treatment	Percentage of grades														Price per pound
	LC	LC_2	LV_2	V	YL	YL_2	S_2	VL	ML	KV	BB	XL	XL_2	XX	
Yeast	2.8	17.1	12.2	14.4	8.9	2.0		11.6	14.0	4.4		6.9	3.8	1.9	1.613
Check		10.5	7.9	17.2	6.8	2.5	.3	15.7	20.5	8.7	.1	4.6	4.7	.5	1.320

The second test, on 1½ picking, was made on an inferior lot of tobacco which had suffered greatly in the growing season from excessive rains. The content of stained and mottled leaves of a papery or tissuey character was very high. No real differences which could be attributed to the yeast were found, the final records indicating a price difference of two cents in favor of the untreated lot.

The experiments on second picking were conducted on a rather superior lot of tobacco. The sorting record of random samples is shown in Table 43.

The differences between the two lots resembled those found with first picking. Tobacco with the yeast treatment was lighter in color and it was apparent that the fermentation had proceeded to a greater degree. The leaves seemed to be thinner and more pliable with the yeast treatment, and this is reflected in the grading record in a greater percentage of LV's, a thinner olive grade, and lesser percentages of VL's, ML's and KV's, heavy and dark grades. Reduced to current prices, the difference in favor of the yeast amounts to 29 cents a pound. The current schedule of prices for Shade tobacco is listed on page 359 of this bulletin.

The small case lots fall into two groups, those which had 15 days in the small cases and 3 weeks in the bulk, and those which remained in the small case for 80 days. Somewhat different results were obtained from the two lots. While neither procedure resulted in as completely fermented tobacco as a straight bulk treatment, the water treatments were much more poorly fermented. In the absence of added yeast, the tobacco remaining in the small case was still raw, while the treated lots were apparently quite well fermented. A summary of average values for these lots is shown in Table 44.

The results on the tobacco transferred to the bulk, indicate that the lower concentration of bakers' yeast and the water treatment produced tobacco of about equal value, while the other treatments were poorer. Much more marked differences are to be found in the tobacco remaining in the small case. Here all the yeast treatments were superior to water by amounts varying from 30 to 46 cents a pound. The appearance on the bench was notably different, the water-treated tobacco being woody and not too uniform in color. The .83 percent bakers' yeast had a large percentage of light, high value leaves. The 1.48 percent bakers' yeast was light and uniform and only a little poorer than the other yeast treatment. The highest percentages of dark, heavy leaves, and the lowest of light, thin leaves was found with the water treatment.

TABLE 44. AVERAGE VALUES OF SMALL CASE LOTS

Treatment	Price per pound
In Bulk November 8	
Water	$1.767
.83% bakers' yeast	1.775
1.48% bakers' yeast	1.611
In case to January 10	
Water	1.642
.83% bakers' yeast	2.103
1.48% bakers' yeast	1.938

Discussion of results. The greatly different conditions under which the two series of experiments were conducted render close comparisons difficult. Temperature differences in bulks were more responsive to differences in moisture content of the tobacco than to yeast treatments. The comparative absence of "gum" on Shade tobacco made comparisons of that factor impossible. On the upper pickings, the yeast seemed to make the leaves thinner and more pliable, indicating a greater degree of fermentation. Except for the experiment on the 1½ picking, treatment with yeast produced lighter and more uniform colors. A treatment which will produce colors sufficiently lighter and more uniform, and so permit the leaves to go in a higher value grade, has considerable promise to the Shade industry.

The behavior of the tobacco which remained in the small cases throughout was quite similar to that displayed by Havana Seed. It is significant that the highest values obtained in the entire series were from the yeast treatments in small cases. The lower temperature levels prevailing in small cases undoubtedly aided the production of lighter colors and suggest the possibility of case fermentation of Shade tobacco continued for longer periods than is customary in the bulks.

The ability of autolyzed yeast to produce temperatures equal to or exceeding those produced by live yeast, and its further ability to induce fermentative changes almost equal to a similar concentration of bakers' yeast raises the question of the survival of yeast cells in contact with tobacco. Samples of fermented tobacco from the earlier Shade runs were sent as soon as available to the Fleischmann Laboratories and cultured. They found no living yeasts present on any of this tobacco, either the treated or the untreated. Control tests with yeast added to dilute tobacco decoctions gave a normal growth on malt plates. They conclude as follows: "It is therefore obvious that even the yeast added to this tobacco had died before it reached the laboratory". Only in its lesser ability to lighten colors does the autolyzed yeast differ in behavior from bakers' yeast.

It is desired to point out that irradiated yeasts, yeast extracts and yeasts in other forms or stages or conditions might also be utilized in tobacco fermentations.

Summary and Conclusions

A discussion of the technique and practice followed in the fermentation of Connecticut cigar-leaf types is given.

The present knowledge concerning fermentation is summarized.

Results of a study of the application of suspensions of bakers' yeast to Havana Seed and Connecticut Shade are presented. The following conclusions seem justified.

With Havana Seed tobacco fermented in small cases in a constant temperature and humidity chamber:

1. Temperature gains were greater with all yeast treatments than with water. Aeration greatly prolonged the period of high temperature gains.

2. Carbon dioxide production was at a very high rate in all treatments, reaching 1200 mgs. per hour. The amount produced was sufficient to account for most of the dry weight loss.

3. No loss of ammonia was detected at any time.

4. A slight decrease in acidity of the tobacco occurred during fermentation.

5. All yeast treatments produced tobacco which seemed more completely fermented, as judged by appearance and smoking qualities.

6. The use of moisture contents above 30 percent water was detrimental.

With Shade-grown tobacco fermented in bulks:

1. Temperature gains did not consistently favor either the yeast treated or the check tobacco. Small differences in moisture content were a more significant factor in determining the rate and extent of temperature rise.

2. Grading records of sample lots indicated gains of 10 cents and 29 cents due to yeast treatment in two experiments, and no difference in the third case.

3. Lighter and more uniform colors and thinner and more pliable leaves were found with yeast treatments.

With Shade-grown tobacco fermented in small cases:

1. Temperature gains were enhanced by yeast treatments.

2. Similar results to those observed with Havana Seed were obtained with reference to degree of fermentation, lightness and uniformity of colors. Price differences favored yeast treatments by amounts varying from 30 to 46 cents a pound.

3. Tobacco transferred from small cases to a bulk failed to show benefits from yeast applications.

The coöperation of Standard Brands, Inc., in defraying part of the costs of the experiments, and the counsel of Dr. R. E. Lee, Dr. Charles N. Frey, Dr. R. O. Bengis, Mr. George W. Kirby and Mr. Homer C. Bennett is gratefully acknowledged. The technical assistance of Fleischmann Laboratories, Inc., and the hearty coöperation of the Gershel-Kaffenburgh Tobacco Company were also most valuable.

REPORT ON THE INSECT INVESTIGATIONS FOR THE 1937 SEASON

A. W. MORRILL, JR.,[1] AND D. S. LACROIX[2]

In 1936 coöperative investigations on the control of the insect pests of tobacco in the Connecticut River Valley were commenced by the Connecticut Agricultural Experiment Station and the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture[3]. These investigations were continued during the season of 1937.

Tests with insecticides were continued for the control of the potato flea beetle, *Epitrix cucumeris* Harr., on tobacco and the tobacco thrips, *Frankliniella fusca* (Hinds). Some preliminary experiments on the control of wireworms were carried out also. In addition to the experimental work, a survey of the abundance of tobacco insects in the Connecticut River Valley was made. Late in the season a series of field observations for obtaining data on the economic importance of the principal tobacco pests on sun-grown tobacco was completed.

Experiments for the Control of the Potato Flea Beetle on Tobacco

These experiments included tests against the flea beetle with the following insecticides:

1. Cubé dust containing 1 percent of rotenone, using sterilized tobacco dust as the diluent.
2. Cubé dust containing 1 percent of rotenone, using a diluent consisting of 75 percent sterilized tobacco dust and 25 percent neutral tobacco-colored clay.
3. Dust consisting of barium fluosilicate, 8 parts, and sterilized tobacco dust, 2 parts.
4. Dust consisting of barium fluosilicate, 8 parts, and cubé root powder containing about 5 percent of rotenone, 2 parts.

The four dust mixtures were applied in two shade tents, and each was applied on two plots one-eighth acre in size. An equal number of plots one-eighth acre in size were left untreated in the shade tents for data on the infestation prevailing when no treatments were applied.

Seven applications of each insecticide were made between June 4 and July 16 at intervals of 7 days. The rates of application were 6, 8, and 10 pounds per acre, depending upon the size of the plants. The dosage of 10 pounds per acre was used for the last two applications in July when the tobacco was nearing maturity.

Good plant protection was obtained from the application of each of the insecticides listed above. The average of sample counts of insects and damaged leaves showed that none of the dusts was significantly better than the others, but there was a highly significant difference between all the treated plots and the untreated checks. Plots treated with the dusts showed an average of 4.4 percent damage whereas untreated check plots

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[3] Morrill, A. W., Jr., and D. S. Lacroix. Experiments on Control of Tobacco Insects in 1936. Conn. Agr. Expt. Sta. Bul. 391: 84-98. 1937.

showed 24.3 percent damage. During the period of applications, counts were made on 25 plants in each plot. The counts included all living potato flea beetles. At harvest time all leaves from these 25 plants were harvested and carefully examined for insect injury. In Figure 67 is shown graphically the percentage of damage in the treated and in the untreated plots as determined by the examination of leaves from the 25 sample plants. The ratio of the plants sampled was 25: 1,500 plants.

Although good plant protection was obtained with each of the dust treatments applied in 1937, those dusts containing barium fluosilicate in some instances left a white residue on the tobacco leaves. Such discoloration is objectionable on leaves of cigar-wrapper tobacco.

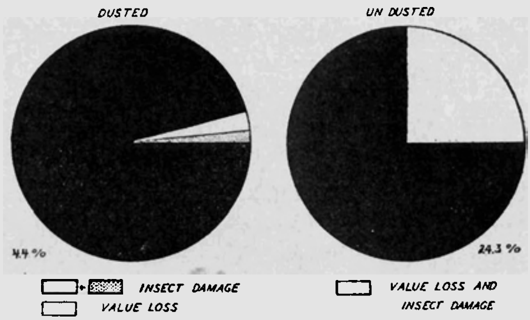

FIGURE 67. Graph showing the average results of dusting for control of the potato flea beetle in comparison with no treatment, as determined by the examination of samples of tobacco leaves from the treated and untreated plots, Windsor, Conn., 1937.

Source of Flea Beetles in Tobacco Fields

In a small, insect-tight cage one square bent in area, studies were made which showed that the potato flea beetle developed in the soil of tobacco shade tents. It was found, however, that most of the infestation of a field came from the outside. In order to determine this, a count was made of the flea beetles on each plant in this shade tent. These studies showed that although some beetles undoubtedly developed in the soil of the field, the majority of them entered from the edges. Most of these apparently migrated from surrounding potato fields after these were treated with insecticides or fungicides; and owing to the relatively small size of the tent-covered tobacco fields, in comparison with the surrounding area, the invasion of the tobacco was rapid and intense.

Observations on the Attractiveness of the Tobacco Plant to Flea Beetles

For years tobacco growers have noticed that flea beetles exhibit a tendency to congregate in large numbers on one leaf or one plant and are not so attracted to an adjacent plant. Just why they react this way is not easily answered, and since the question is asked repeatedly a preliminary investigation was started this season to determine, if possible, what factors are involved. Preliminary chemical analyses by the agronomist of the Station were made of a limited number of heavily infested leaves and leaves from nearby plants which were not infested. These tests, although not conclusive, indicated that the plants favored by flea beetles contained larger quantities of calcium, which would tend to make the plants both more basic and sweeter.

Experiments for the Control of the Tobacco Thrips

The experiments for the control of this insect in 1937 included tests with the following insecticides:

1. Nicotine sulphate (1 to 400) mixed with black-strap molasses at the rate of 1 to 100 and soap at the rate of 1 to 100.
2. Nicotine sulphate (1 to 400) mixed with Karaya gum, 1 part, nicotine spray, 200 parts.
3. Spray made from cubé root powder containing 1 percent of rotenone, 12 pounds, to 50 gallons of water mixed with a spreader (sulphonated phenyl phenol) at the rate of 1 to 400.
4. Dust made from cubé root powder containing 1 percent of rotenone and applied at the rate of 12 pounds per acre, using the same spreader as in No. 3, at the rate of 1 to 200.

None of these tests produced conclusive results. The best plant protection was provided by the application of the 1 percent rotenone dust containing the spreader at the rate of 1 to 200. The spray, mixed at the rate of 12 pounds of a 1-percent rotenone dust in 50 gallons of water and with the spreader at the rate of 1 to 400, gave the next highest degree of protection. The degree of plant protection was determined by making counts of live thrips at four-day intervals on five plants in each of the one-twentieth-acre experimental plots. The problem of controlling the thrips should receive further investigation.

Wireworm Studies

Wireworms are serious pests of young tobacco plants in the Connecticut River Valley, and at the present time no satisfactory control is available. The principal species involved is *Limonius agonus* (Say). Since only limited investigations of this problem could be made in 1937, the work was confined largely to toxicity studies. The chemicals tested were as follows:

1. Materials to serve as repellents or fumigants, applied to the water used in connection with transplanting tobacco, namely, allyl isothiocyanate, dichloroethyl ether, crotonaldehyde, carbon disulphide emulsion with dissolved naphthalene, carbon disulphide emulsion with dissolved paradichlorobenzene, zinc arsenate, acetylene tetrachloride, cubé root powder, pyrethrum extract, and pyrethrum oleoresinate.
2. A material applied to the soil before setting of tobacco plants, namely, naphthalene.
3. Materials applied to the soil after the tobacco plants are set, namely, methyl bromide, calcium cyanide, carbon disulphide, and chloropicrin.

Tests with the first group of materials added to the setting water indicated that only three were effective against wireworms. These were dichloroethyl ether, carbon disulphide emulsion with dissolved naphthalene, and zinc arsenate. The dichloroethyl ether gave the most promising results. The tests showed, however, that this volatile material burns tobacco plants during warm weather. It showed a long residual repellency to the wireworms in the soil and should receive further investigation.

In the second group only naphthalene was tested. The crude flake material was plowed into the soil at the rate of about 800 pounds per acre. Tobacco plants, set immediately after the soil was treated, showed considerable yellowing but soon recovered and apparently were not stunted otherwise. Samples of the soil in the treated shade tent and in an adjoining untreated check were sifted for wireworms at intervals during the season. The average of all samples showed 1.65 wireworms per cubic foot sample in the untreated plots and 0.47 in the plots treated with naphthalene at the rate of about 800 pounds per acre. These averages were based on the results obtained from sifting 146 samples of soil in the treated area and the same number in the untreated check.

In the third group of materials applied to the soil after the plants were set, unsatisfactory results were obtained in all tests. The calcium cyanide and carbon disulphide were drilled into the soil beside newly set plants in the infested plots at the rate of one-fourth to one-half ounce by weight per plant. The application of these dosages killed both the tobacco plants and the wireworms. Additional experiments must be carried out with this group of materials before conclusions can be drawn. Methyl bromide and chloropicrin proved unsatisfactory in these tests and appear to hold no promise as soil fumigants for the control of wireworms.

Losses Sustained in Sun-grown Tobacco

Near the end of the season a survey was made of insect conditions in a selected group of fields of sun-grown tobacco in the Connecticut River Valley. From two to four fields were examined in each township. Five plants were chosen at random in the center and five in each quarter of the field, and an estimate of the damage done to every leaf on each of these plants was recorded. The leaves were scored separately for insect damage. On the basis of the ratio of leaves damaged to those undamaged, an estimate was made of the total losses sustained from each insect. The average of these estimates is presented in graphical form in Figure 68.

Notes on Abundance of Insects

The eastern field wireworm, *Limonius agonus* (Say), remained abundant well into the summer and necessitated several resettings in some districts.

The potato flea beetle, *Epitrix cucumeris* Harr., was present in large numbers on newly-set plants in June, but the second brood of adults did not appear in the large numbers anticipated. This may have been due to the fact that practically all shade-grown tobacco and many potato fields were repeatedly dusted. A few individuals of the tobacco flea beetle, *E. parvula* (F.), were observed on Havana Seed and Broadleaf plants in several localities.

A few records of the seed-corn maggot, *Hylemyia cilicrura* Rond., feeding on newly-set tobacco were obtained in May and early in June.

Grasshoppers were present in about normal numbers on sun-grown types of tobacco and were collected in many shade fields. The red-legged grasshopper, *Melanoplus femur-rubrum* (De G.) and the Carolina grasshopper, *Dissosteira carolina* (L.), were most numerous.

Thrips, *Frankliniella fusca* (Hinds), were unusually abundant in sections where the soil was dry and sandy, but were not found in heavy, moist soils.

Cutworms, *Euxoa messoria* (Harr.), were important pests in many sections, particularly where no poisoned-bran bait was used at setting time. A few climbing cutworms, *Agrotis c-nigrum* (L.), were observed on Shade tobacco as late as August. The cutworm *Polia legitima* (Grote) caused serious injury during May to seed beds in Windsor Locks.

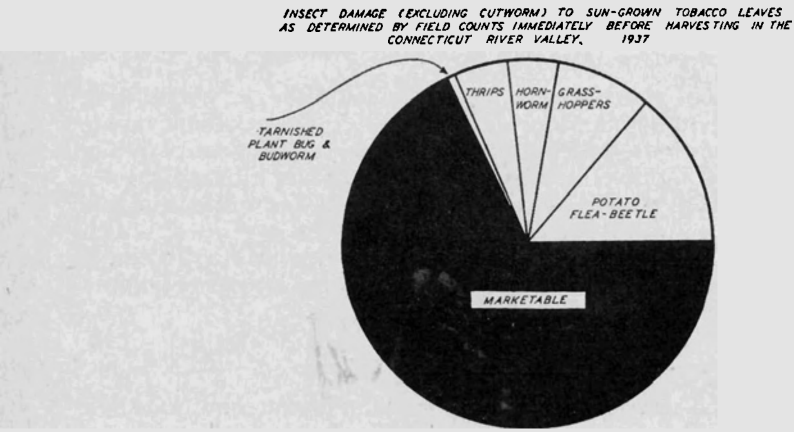

Figure 68. Graph showing the estimated average damage by some of the principal insect pests of sun-grown tobacco, as determined by a series of field examinations made immediately before harvest in the Connecticut River Valley, 1937.

The only tobacco budworms, *Heliothis virescens* (F.), found in the Valley were taken on plants grown in lysimeter pots at the Experiment Station at Windsor and in several fields of late Havana Seed tobacco.

The tarnished plant bug, *Lygus pratensis* (L.), was found occasionally on sun-grown types of tobacco, but no injury which could be traced to this insect was noted.

The crane-fly maggot *Nephrotoma ferruginea* (F.) was found in tobacco soils in small numbers, but injury from this pest was negligible.

On June 30 a small infestation of root aphids, *Trifidaphis phaseoli* (Pass.), was found on tobacco at Windsor. The infested plants were stunted, and an examination of the root system showed that wireworms had previously attacked them. The root aphids were apparently being transferred by an ant, identified as the cornfield ant, *Lasius niger americanus* Emery.

The hornworms, *Protoparce* spp., were observed on sun-grown tobacco throughout the Valley, but they appeared in relatively small numbers until late in the season. In the earlier part of the summer the tomato worm, *Protoparce sexta* (Johan.), was observed to be more abundant than the tobacco worm, *P. quinquemaculata* (Haw.). In the latter part of the season, however, the tobacco worm became more abundant and caused some damage to fields of late-harvested tobacco. Many individuals of both species of hornworms were collected and found to contain the larvae of the parasite *Apanteles congregatus* (Say), indicating a heavy parasitization of these insects.