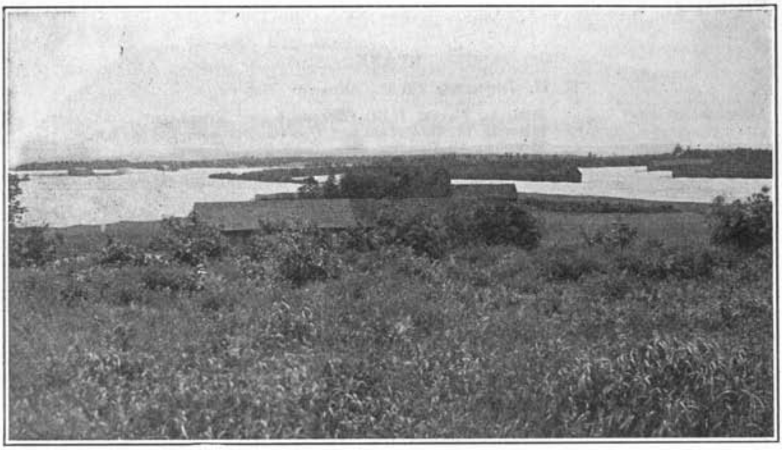
TOBACCO STATION BULLETIN 10 MARCH, 1928

Connecticut Agricultural Experiment Station

New Haven, Connecticut



A THOUSAND ACRES OF SHADE TENT ON WINDSOR PLAINS.

REPORT
OF
TOBACCO STATION
AT WINDSOR

1927

CONNECTICUT AGRICULTURAL EXPERIMENT STATION

OFFICERS AND STAFF

QUINNIPIACK PRESS, INC., NEW HAVEN

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Report of the Tobacco Substation
1927

P. J. Anderson, N. T. Nelson, and T. R. Swanback

Following the custom of previous years this annual report is presented to the tobacco growers of the state to inform them of the progress of experiments which are under way at the Tobacco Substation. Each year old projects are enlarged, new projects are undertaken and more data accumulate. Since a complete report on all experiments would be too lengthy, it has seemed best to confine this one to certain projects which have not been previously discussed or are of particular interest at this time, reserving the others for separate bulletins. Bulletins which are now in preparation and will soon be ready for distribution are:

Topping Havana Seed Tobacco.
Soil Reaction as a Factor in Growing Tobacco.
Priming and Curing Shade Tobacco.

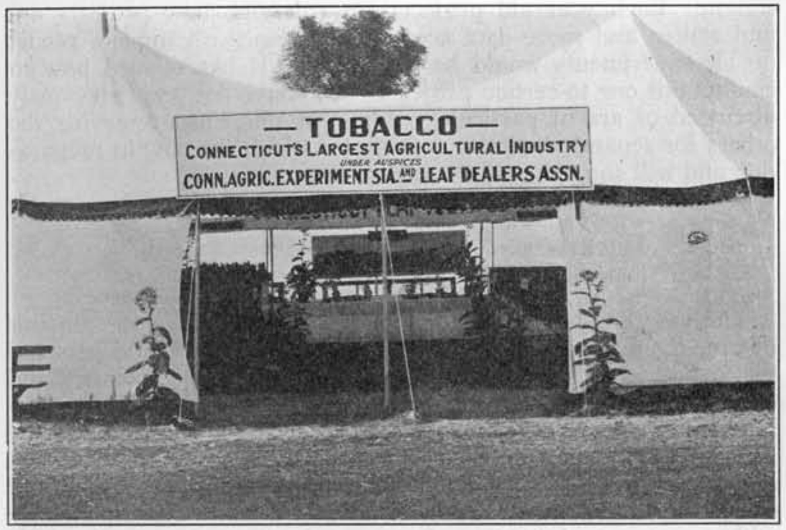
The year has been marked by a steady increase in the amount of time the members of our staff have given to public and personal service work with the tobacco growers. Each year farmers and packers are making more use of the station. Requests for personal conferences regarding fertilizers, methods of curing and the like have more than doubled. A great deal more time has been spent in testing acidity of soils, testing germination of seed and answering calls for personal visits to farms. Correspondence with growers, packers, manufacturers, fertilizer firms and others interested in tobacco has increased correspondingly.

In July the annual field day in cooperation with the New England Tobacco Growers' Association was attended by several hundred growers. In September we staged a tobacco exhibit at the Connecticut State Fair in cooperation with the Connecticut Leaf Dealers' Association. This exhibit was visited by thousands of people during the week and served a useful purpose in acquainting the people of the state with the importance of the tobacco industry and the work of the Tobacco Station.

The increasing volume and importance of this type of work will soon require the entire time of one man. It would be desirable to add such a man to our staff and thus conserve the attention of the present staff for research alone.

INFLUENCE OF SOME FERTILIZER INGREDIENTS ON THE BURN OF TOBACCO

Connecticut tobacco is raised for smoking only. Obviously if it does not burn well, it is of little value. To be sure, there is always a market for low grades which are used for scrap chewing but they command a price so low that the crop is raised at a heavy loss if sold for this purpose. Chewing tobacco is only a by-product of the cigar leaf industry, a utilization of what would otherwise be loss. The first requisite of our tobacco then is that it shall have a good burn. A fine growth, heavy yield and excellent appearance of the cured leaf are of no avail if the tobacco does not burn well.



TOBACCO EXHIBIT AT THE CONNECTICUT STATE FAIR, SEPTEMBER, 1927.

In connection with the fertilizer experiments burn tests have been made to determine what effects the fertilizers applied to the soil have on the burn of the tobacco. These tests were begun with the crop of 1925 and repeated annually, but no previous report on them has been published. It is the purpose of this first report to present and discuss the burn data to date.

FACTORS WHICH INFLUENCE THE BURN

The burn is influenced by a number of other factors besides the fertilizer applied. The burn possessed by a given lot of tobacco

is a resultant of the interaction of a number of these influences and it is rarely possible to predict the effect of each factor except by trial. Some of these factors are:

1. **The locality.** Although cigar tobacco has been grown experimentally all over the United States and in most of the countries of the world, the industry has survived in a few restricted localities only which now supply the world's markets. Attempts to establish new centers of production, with a very few notable exceptions, have been failures; not because tobacco would not grow in other places but because some one or more of the characteristics of burn or quality did not satisfy the smoker. Even within the tobacco sections there are certain localities which produce tobacco of char-

TOBACCO TENTS AT THE CONNECTICUT STATE FAIR.

acteristics distinctive from the tobacco produced in other localities of the same section. To determine the causes of these differences is one of our problems.

2. **The climate.** Temperature, humidity, distribution of rainfall, occurrence of frosts and prevalence of fogs at certain periods all have their influence on burn and quality.

3. **The soil.** Even within small tobacco sections, growers have found by experience that certain types of soil produce tobacco with excellent burn, while others are not suitable. Most tobacco farmers find that certain fields on their farms grow tobacco of better quality than others, consequently they raise it continuously

on one certain field which comes to be known as the "tobacco lot" and may remain the same through several generations.

4. **The season.** It is a well known fact among dealers and manufacturers that crops of certain years are poor "burners" and they purchase as little as possible of the tobacco of that season, while they are eager to "stock-up" with all they can get of the crop of other seasons which are known to have yielded leaf of fine burn. Seasons of insufficient rainfall are likely to give poor burn.

5. **The method of handling.** Differences in methods of cultivation, in time and stage of topping, suckering, and harvesting may influence burn.

6. **The cure.** The rapidity of cure and the temperature and humidity at which this process occurs have been found to influence burn.

7. **Fermentation.** The principal purpose of sweating and resweating tobacco is to improve the burn.

IMPORTANT POINTS IN JUDGING THE BURN

In judging the burn, the following points are taken into consideration:

1. **Fire holding capacity.** This is measured by the length of time during which a leaf or a cigar continues to glow after being ignited. The longer it glows, the better the tobacco—at least, up to a certain optimum.

2. **Color of ash.** The most desirable ash is light gray to white. Muddy gray, dark gray and black ashes are objectionable. Ash color can be judged only on the cigar. The ash of a single leaf held between the hands may be dark gray or black but when the leaf is wrapped on the cigar it frequently gives a gray or white ash. Color of ash is governed by completeness of combustion and, to some extent, by abundance of some calcining agent like lime. When the combustion is not complete, considerable carbon remains and this causes dark color.

3. **Closeness of burn.** This also can be judged only on the cigar. The black band which precedes the red line of glow should be very narrow—not over 1/25th of an inch—and sharp. When it is broad and of indefinite outline it is called "coaling." This is objectionable. Sometimes this is the fault of an improperly matched filler, binder and wrapper. A filler which burns too rapidly is likely to cause "coaling." Coaling is commonly accompanied also by bad aroma and taste and a darker ash color.

4. **Evenness of burn.** The line of ignition should be regular and pass in a straight line around the cigar. Like the preceding, a defect in this respect is quite often due to improper manufacture of the cigar.

5. **Flavor.** Although there is some looseness in the use of this term, we apply it to the gustatory sensation received when the inhaled smoke comes in contact with the tongue and other parts of the mouth. Some apply the term to the taste of the tobacco itself when certain constituents of the head of the cigar go into solution in the mouth. Or it may refer to the combination of the two.

6. **Aroma.** The odor of the smoke is very important in judging the value of tobacco. Certain sections of the world owe their prominence in the tobacco industry entirely to the aroma of the tobacco grown there. Tobacco which does not burn with a pleasing aroma is worthless for smoking purposes.

The preferences of smokers differ so much that there has not been any satisfactory method devised for measuring or evaluating the aroma and flavor. On account of this difficulty and the fact that no marked differences due to fertilizer treatment have been detected in our tests, we have omitted all reference to these two factors in the following discussion.

7. **Coherence of ash.** Coherence of ash refers to its capacity for remaining in compact form for a considerable time after combustion. Coherence is good if the ash of a cigar remains intact for one inch or more after burning. Some split and fall off in large chunks or curl. Some are "flakey" and small particles keep falling away during smoking. Either of these characteristics is undesirable. An exceptionally good ash often will keep the exact form of the cigar until it is two or three inches long without flaking, splitting, crumbling or falling off.

METHODS OF TESTING THE BURN

There are two methods of testing the burn of tobacco. The first method, known as the "strip test", is made by lighting a single leaf while held in the hands. In the second, the "cigar test," the leaves are rolled on a cigar before lighting.

The strip test is most useful in comparing the fire-holding capacity of lots of tobacco. It may also prove the aroma. It cannot be used for determining flavor, ash color, closeness or evenness of burn, or coherence of ash. A good fire-holding capacity, however, as indicated on the strip test, is usually associated with a desirable condition of the other factors mentioned.

The tobacco buyer makes considerable use of the strip test. He stretches the leaf taut between his two hands and then ignites it either with the glowing end of a cigar or with a match. Ignition of the leaf by the burning end of the cigar is the ideal method of making the strip burn test. A match, candle, or Bunsen burner starts a flame which rapidly chars the leaf. A steady spreading line of ignition without flame is the desired condition. In making a large number of tests involved in the comparison of tobacco from different experimental plots, ignition by the lighted cigar is obviously not practicable. We have, therefore, adopted a method which most closely simulates it, *viz.*, ignition from an incandescent electric filament wound in a coil such as one finds in electric cigar lighters. We have used a commercial cigar lighter sold under the name of "Hold-heet", which is supported on a stand like a desk telephone and with a coil so exposed as to be easily touched by the taut leaf. This has been modified to operate either from a foot switch or a hand switch worked by an assistant who is recording. The duration of burn is the number of seconds elapsing between instant of removing leaf from "match" and the last spark of the spreading glow. This is measured either with a stop watch or by counting with the aid of a metronome. We have used the latter method because it permits counting by both operators at once and thus saves time. The leaf is ignited near the midrib in four places uniformly spaced on all leaves and is then held in a vertical position with the fire progressing toward the margin. The position in which the leaf is held is not important, but it is important that it should be the same for all tests of a given series. Sixty seconds has been adopted as the maximum since most leaves will burn from midrib to margin in about that space of time and because sixty seconds on the leaf is a satisfactory burn. Some leaves burn longer but in the interest of time saving, an arbitrary limit had to be set. Even though they burn longer they are recorded as sixty seconds.

It is very essential that all leaves be equally moist. We have accomplished this by keeping all the leaves of the series under test wrapped together in a rubber blanket for some time before the test and removing them only as fast as needed. It is also important that the tobaccos to be compared be equally fermented and aged. Comparison of tobacco tested in the spring with other plots tested in the fall will usually lead to false conclusions.

It is particularly important that the number of tests be large. Individual leaves from the same plot show wide variation in fire-holding capacity. Therefore, figures, to be significant, must be averages of a large number of tests. It is doubtful whether a conclusion based on less than a hundred tests is safe. Tests were made on all of the four principal grades of leaves and on all replications of the same treatment.

The cigar test. In this test the cured fermented leaves are used in making cigars and are then smoked. They may be used (1) as *wrapper alone* on some standard filler and binder, (2) as *wrapper and binder* on a standard filler, or (3) for *entire cigars* (clears). All three have been used in our tests. Since practically all Connecticut tobacco is used for binders and wrappers, the first two would seem to be best. A character such as aroma, however, is not easy to judge if a foreign filler is used. At first thought, the cigar test seems much preferable to the strip test, but errors may easily arise from the improper adjustment of wrapper, binder and filler. The cigar test is essential for comparing ash color and coherence and the closeness and evenness of burn. It may supplement the test of fire-holding capacity but in this respect it cannot measure as fine differences as the strip test.

The test cigars may be smoked in the usual way, or by a mechanical intermittent smoker. The mechanical smoker is more rapid and does not suffer from over indulgence, but it cannot be used for testing taste. Also it seems to change the aroma for the worse. For testing the other characteristics, however, the mechanical smoker is just as accurate as the human one.

Fire-holding capacity is determined by stopping the machine and recording the number of minutes elapsing before the cigar stops burning as determined by absence of smoke on renewal of inhaling.

Ash color is denoted as white, light gray, medium gray, dark gray, black. Sometimes there is a brownish cast to a gray ash and it is termed "muddy." Color charts have not been found very useful because of lack of uniformity in color even on a single cigar. Ash color should not be determined on the end of the cigar but from a median section.

Some Nitrogenous Fertilizer Materials

In previous reports (Tobacco Station Bulletins 5, 6 and 8) the five-year nitrogen experiment (1922-26) has been fully discussed. The object of this old nitrogen series was to compare the effect of certain nitrogen-carriers in the fertilizer mixture, on the yield and quality of tobacco. The comparative yields have been fully tabulated and discussed in previous reports. The quality has been measured by the percentage of grades when sorted and by judgment of experts. Only brief reference has been made previously to the burning capacity of the tobacco. Such tests have now been made on the last two crops of this series.

During the first three years of the experiment no burn records were made with the exception of a small number on the crop of 1923 (Bul. 5, p. 10, 11). The number of tests, however, was entirely too small to warrant conclusions.

When the crops of 1925 and 1926 were sorted, sample "hands" of light wrappers, medium wrappers, darks and seconds were packed in regular cases (250-300 lbs. of tobacco) and fermented in the sweat rooms of commercial warehouses.[1] After the "force sweat" of about six weeks, the cases were removed to the station

[1] The writers are indebted to Mr. John Orr of Windsor Locks and Mr. W. S. Pinney of Suffield for the use of sweat rooms for this purpose.

warehouse where they were allowed to undergo a "natural sweat" during the following summer before burn tests were made in the fall. This procedure necessitates delay of a year after sorting before the test can be made and explains why reports on burn have not been presented previously. Both "strip" tests and "cigar" tests were made.

To make the strip tests, five leaves of each hand were selected and each leaf tested in four places (as previously described under "Methods"). Thus there were 20 individual tests of each grade, there were four grades of each of the triplicate plots making a total of 240 individual tests for the tobacco receiving a given treatment. Repetition on the tobacco of the two years raises the number of individual tests for each treatment to 480. This number should be sufficiently large to make the results significant. The duration of burn, in seconds, for the different treatments and the four grades of each is tabulated below (Table 1).

TABLE 1. OLD NITROGEN SERIES. FIRE HOLDING CAPACITY OF 1925–26 CROPS.
STRIP BURN TESTS

Plot No.	Special source of Nitrogen	Duration of Burn (seconds)										
		Dark		Mediums		Lights		Seconds		Ave. of all grades		Av. of both years
		1925	1926	1925	1926	1925	1926	1925	1926	1925	1926	
N1	1/5 N. in Nitr. soda	35.7	10.6	44.4	16.2	49.1	39.8	43.2	44.0	43.7	27.7	35.4
N2	½ N. in Nitr. soda	32.4	11.3	34.4	14.2	34.2	29.7	38.8	39.9	34.9	23.8	29.4
N3	1/5 N. in Sulf. am.	20.2	8.7	22.6	13.5	30.8	19.0	29.5	22.9	25.8	16.0	20.9
N4	½ N. in Sulf. Am.	14.4	8.2	15.7	9.5	18.1	16.9	14.8	23.1	15.7	14.3	15.0
N5	All N. in Organics	15.4	9.2	16.0	14.7	17.8	21.1	18.2	27.0	16.9	18.0	17.5
N6	½ N. in D.G. Fish	14.0	11.7	25.9	20.3	34.2	31.8	32.0	37.4	26.5	25.3	25.9
N7	½ N. in tankage	36.9	12.1	33.4	14.2	40.1	28.1	46.4	31.3	39.2	21.4	30.3

DISCUSSION OF RESULTS OF STRIP TESTS

Effect of increasing the nitrate of soda. The N1 formula is the standard formula with which to compare all others. Tobacco produced on this formula consistently had the highest burning capacity of all the plots. One-fifth of the nitrogen was from nitrate of soda, the remainder being in cottonseed meal and castor pomace in ratio of 3:1. No sulfate of ammonia was applied to these plots during the five years of the experiment. On the N2 plots, the same fertilizer was applied except that the nitrate of soda was increased to furnish one-half of the nitrogen (100 lbs.). The fire-holding capacity is consistently lower on these N2 plots. During the preceding 3 years of the experiment, however, the N2 plots had a fertilizer containing 260 lbs. of sulfate of ammonia per acre annually. Whether there was any "carry-over" effect of the sulfate of ammonia is not certain. The depression in burn for the second year was not as great as for the first.

Effect of sulfate of ammonia. The fertilizer mixtures used on plots N3 and N4 were identical with those used on N1 and N2 respectively except that in N3 and N4 the mineral nitrogen was in the form of sulfate of ammonia instead of nitrate of soda. N4 had the lowest fire-holding capacity of any of the plots and also had the most sulfate of ammonia applied. N3 also, which had only one-fifth of its nitrogen from sulfate of ammonia, showed a decided depression in fire-holding capacity when compared with either of the nitrate of soda plots. This consistent depression of burn on the sulfate of ammonia plots is the most marked of any of the differences brought out in these tests of the old nitrogen series.

Effect of omitting all mineral carriers of nitrogen. The N5 plots had all their nitrogen in the form of cottonseed meal and castor pomace during 1925 and 1926. During the preceding three years, however, these plots received all their nitrogen in mineral carriers (including 724 lbs. of sulfate of ammonia per acre annually). It is more probable that the low fire-holding capacity which they show was due to the carry-over effect of the previous high sulfate treatment rather than the use of the organics in 1925 and 1926.

Effect of dry ground fish. The treatment of the N6 plots where half of the nitrogen was from fish, has not been changed during the five years of the experiment. The burn in all grades is consistently somewhat lower than for the N1 plots with which it should be compared. Apparently fish also has a depressing effect on burn although not as marked as that shown by sulfate of ammonia.

Tankage. The treatment of the tankage plots also has not been changed during the five years. Although the final average is five seconds below that of the N1 plots the differences were not so consistent nor so large as between the others.

CIGAR TESTS

For cigar tests, an experienced cigar maker used the seconds and light wrappers for each plot (1) as binder and wrapper on a standard filler and (2) as filler, binder and wrapper ("clears"). Some were smoked in the usual way, others by means of the automatic smoking apparatus described above.

Fire holding capacity. With but a few exceptions all cigars easily held fire for five minutes. The longest was nine minutes. The highest fire-holding capacity was possessed by cigars from the N1, N2, and N7 plots, the lowest by N3, 4, 5. In this respect it agreed fairly well with the strip tests.

Ash color. Differences between treatments were more marked in the color of the ash than in any other respect. N1 had the best color, usually light gray with an occasional medium. The N7 cigars were mostly as light as the N1 but threw some darks. N2 was medium gray. The ash of N3, 4, and 5, was unsatisfactory, being mostly dark muddy gray with a few mediums.

Coal band was best on N1, 2, 6, 7, but was broad and inclined to indefinite "coaling" on N3 and 4. Also in evenness, N3 and N4 were the poorest.

Coherence was good for all treatments. There was no flaking, splitting or crumbling in any of them.

The correlation of burn characters is well illustrated by comparison of the N1 burn with N4. N1 possesses the combination of high fire holding capacity, light ash, and a close and even burn. Contrasted with this is N4 with low fire-holding capacity, dark ash, uneven burn with broad coal band. This correlation has prevailed throughout all our tests.

SINGLE SOURCES OF NITROGEN

In another series of plots, started in 1926, four nitrogenous fertilizer materials were compared by using each as the *only* source of nitrogen on one of four plots on another field. The plots were one-fortieth acre in size. All other ingredients of the mixture except the nitrogen carrier were the same. A sufficient ration of potash and phosphoric acid was supplied to avoid any shortage. The four carriers were cottonseed meal, nitrate of soda, sulfate of ammonia and synthetic urea. After the same period of force sweat and natural sweat as previously mentioned for the other tobacco, burn tests were made; twenty tests of each grade. The results are presented in Table 2.

TABLE 2. SINGLE NITROGEN CARRIER SERIES. CROP OF 1926.
STRIP BURN TESTS.

Plot No.	Nitrogen Carrier	Duration of Burn in Seconds.				
		Darks	Mediums	Lights	Seconds	Ave
N11	C. S. Meal	11.5	34.7	39.8	50.0	34.0
N12	Nitr. Soda	13.3	48.2	38.1	48.5	37.0
N13	Sulf. Am.	10.0	14.8	28.4	30.0	20.8
N14	Urea	14.9	29.7	35.5	34.8	29.0

This table shows again the marked depression in the fire-holding capacity resulting from sulfate of ammonia. This is evident in all grades.

The nitrate of soda plot showed no depression but a somewhat better burn than cottonseed alone. Tobacco from the urea plot did not burn quite as well as from the cottonseed plot. Since, however, this was the first year of the series and since the plots were not replicated, it is best not to draw conclusions except from large and consistent differences. The table is included here because it corroborates the conclusion drawn from the old nitrogen series as to the injurious effect of sulfate of ammonia on burn.

ADDITIONAL EVIDENCE ON EFFECT OF SULFATE OF AMMONIA

Additional support for the same conclusion is afforded by results of a third set of experiments in which the effect of acid and alkaline fertilizers on soil reaction and prevalence of black rootrot is under test. The composition of the acid, alkaline, and neutral fertilizer mixtures is as follows:

ACID FERTILIZER (PLOT T1a AND T1b).

Material	Lbs. per Acre	Plant nutrients per acre		
		NH_3	P_2O_5	K_2O
Ammonium sulfate	440	110.0		
Cotton seed meal	1100	90.2	31.9	16.5
Precipitated bone	333		128.1	
Sulfate of potash	367			183.5
Total..........................		200.2	160.0	200.0

ALKALINE FERTILIZER (PLOT T2a AND T2b).

Material	Lbs. per Acre	Plant nutrients per acre		
		NH_3	P_2O_5	K_2O
Nitrate of soda	585	110.0		
Cotton seed meal	1100	90.2	31.9	16.5
Precipitated bone	333		128.1	
Carbonate of pot.	282.3			183.5
Total..........................		200.2	160.0	200.0

General Formula (Plot T3a and T3b).

Material	Lbs. per Acre	Plant nutrients per acre		
		NH_3	P_2O_5	K_2O
Cotton seed meal	1463.4	120.0	42.4	21.9
Castor pomace	588.2	40.0	10.6	5.9
Nitrate of soda	105.5	19.83		
Ammophos (urea in 1927)	103.1	20.17	22.41	
Precipitated bone	220.0		84.6	
Sulfate of potash	172.2			86.1
Carbonate of potash	132.3			86.1
Total....................		200.0	160.5	200.0

These mixtures have been applied annually, starting with 1924, to the same three plots. In addition, one-half of each plot was heavily limed each year.

It will be noted that the acid fertilizer contains a large quantity of sulfate of ammonia while the alkaline fertilizer contains sufficient nitrate of soda to furnish the same amount of nitrogen.

Results of burn tests on the crops of 1925 and 1926 are presented in Table 3.

Table 3. Rootrot Series. Crops of 1925, 1926.
Strip Burn Tests.

Plot No.	Character of Fertilizer	Lime Treatment	Duration of Burn (In Seconds)								All Grades		
			Darks		Mediums		Lights		Seconds		Average		Ave. of 2 yrs.
			1925	1926	1925	1926	1925	1926	1925	1926	1925	1926	
T1	Acid	yes	18.4	.....	.....	12.1	.....	9.7	7.3	8.4	13.7	14.8	14.2
		no	10.8	.....	18.9	15.9	12.3	28.9	14.7	13.9	.....	.....	.....
T2	Alkaline	yes	30.2	.....	37.4	29.8	32.9	25.8	23.1	22.1	35.4	33.2	34.3
		no	29.8	.....	38.7	27.6	43.3	45.1	48.7	48.9	.....	.....	.....
T3	Neutral	yes	37.1	.....	28.6	15.0	12.5	17.8	17.9	22.6	32.5	29.1	30.8
		no	39.4	.....	39.3	30.3	28.7	45.0	39.1	40.2	.....	.....	.....

Here again the burn was reduced to less than one-half of the fire-holding capacity of the other plots when large quantities of sulfate of ammonia were used.

The fact that sulfate of ammonia applied in the fertilizer under these conditions injures the burn, is thus fairly well established but the reason for this effect has not been fully determined. The first explanation that would occur to one is that it increases the sulfur content of the leaf. Garner found sulfates to be injurious to burn.[1] The chemical analyses of tobacco from these plots (p. 45) does show some increase in the sulfur absorbed. The

[1] U. S. D. A. Bur. Pl. Indus. Bul. 105, p. 18. 1907.

analyses show no significant differences in quantity of total nitrogen, nitrate nitrogen or ammonia nitrogen. As will be shown in a later page in this bulletin, sulfate of ammonia has in every case made the soil more acid. It is conceivable that the acid condition is indirectly the cause of poor burn since it causes changes in the solubility of certain soil elements and affects the nutrition of the tobacco plants.

Sulfate of ammonia is not used very extensively for a tobacco fertilizer but assumes importance for two reasons: (1) it has been used as a cheap source of nitrogen in some mixed goods where the manufacturer is not required to reveal the constituents of the mixture and (2) it is being used by some growers with the object of making the land more acid where rootrot has become prevalent. It may be anticipated in either case, its use will be attended by some impairment of burn.

UREA

The urea series was begun in 1925 with six plots on Field IX. Two plots received the standard formula which contains no urea and in which all the nitrogen is in cottonseed meal, castor pomace and nitrate of soda. Two other plots received the same mixture except that one-half of the nitrogen was from urea. On the last two plots, *all* the nitrogen of the formula was in urea. Except for the quantity of urea, all the fertilizer formulas were the same.

Burn tests were made on the samples of the 1925 crop in the spring before they had a chance to go through the natural summer sweat. This is reflected in the low burn capacity as compared with that of the 1926 crop. Tests of the latter were made after the summer sweat. The tests of both years are presented in Table 4.

Table 4. Urea Series. Crop of 1925–26.
Strip Burn Tests.

Plot No.	Quantity of Urea	Duration of Burn (Seconds).										
		Darks		Mediums		Lights		Seconds		All grades		Both years
		1925	1926	1925	1926	1925	1926	1925	1926	1925	1926	
N1	No urea	13.9	9.3	15.2	21.1	11.9	40.0	22.5	33.0	15.9	25.8	20.9
N8	½ N. in urea	18.8	8.3	18.6	17.5	24.8	33.3	22.9	36.1	21.3	24.0	22.7
N9	All N in urea	10.7	11.3	19.6	22.5	19.2	26.9	17.9	37.4	17.0	24.5	20.8

Each figure in the extreme right hand column is the average of 320 individual burn tests. A study of this table does not show any significant differences in burn corresponding to the different quantities of urea used.

"Cigar tests" were made on tobacco from all the urea plots and from the two adjacent checks. There were no significant differences in the fire-holding capacity, evenness or closeness of burn, nor in coherence of ash. In the color of ash, however, the cigars from the urea plots were somewhat superior to the check plots, being mostly very light gray to white. There was no tendency to flaking in any of them. No explanation of this whiteness of the urea cigars is apparent.

Potash Salts

Experimental field plots for the purpose of comparing different carriers of potash have been grown on the station farm since 1923. The results of the tests are recorded in Bulletins 5, 6, and 8, of the Tobacco Station. There are four series of these, located on different parts of the farm.

Double sulfate of potash-magnesia. The first series consists of a block of six plots which were begun in 1923 for the purpose of comparing high grade sulfate of potash with double sulfate of potash-magnesia. The two K1 plots were fertilized with the standard ration which has all the mineral potash in the form of high grade sulfate; the K2 plots had an equal amount of potash in form of double manure salts while the K3 plots had the same amount of potash divided equally from the two sources. No changes in location of plots have been made during the five years of the experiment. Burn tests were made on the crops of 1925 and 1926. Results of the strip burn tests are presented in Table 5.

Table 5. Double Manure Salts *vs.* High Grade Sulfate As Source of Potash. Strip Burn Tests On Crops of 1925, 1926.

Plot No.	Source of Potash	Duration of Burn in Seconds. Darks 1925	Darks 1926	Mediums 1925	Mediums 1926	Lights 1925	Lights 1926	Seconds 1925	Seconds 1926	All grades 1925	All grades 1926	Two year Av.
K1	H. Grade Sulfate	36.4	14.9	25.8	16.4	52.9	36.7	36.1	44.0	37.8	28.0	32.9
K2	Double Manure Salts	23.4	10.6	25.9	16.8	36.4	30.1	28.7	41.4	28.6	24.7	26.7
K3	One half from each	25.7	15.4	24.2	18.3	48.9	33.6	39.5	32.7	34.6	25.0	29.8

Each of the figures in the right hand column is an average of 320 tests. A study of this table shows a small but very consistent drop in the fire-holding capacity through the use of the double salt to replace high grade sulfate. When a mixture of the two was used, the fire-holding capacity was exactly intermediate between the others. The constancy of these differences leads us to conclude that the use of sulfate of potash-magnesia is detrimental to the burn of tobacco. Since no chemical analyses of the tobacco from these plots has yet been made we are not in a position to offer an explanation of this effect. The first explanation which would occur to one is that it was due to an increase either in the magnesia or the sulfate content of the leaf.

Muriate. The injurious effect of muriate of potash has been demonstrated experimentally in various tobacco sections but in the Connecticut Valley no data on this point are on record previous to the experiments described in our report for 1926. This experiment was continued for two years. Burn tests as compared with adjacent check plots where the fertilizer was identical except for the use of sulfate instead of muriate are recorded in Table 6.

Table 6. Muriate *vs.* Sulfate of Potash. Strip Burn Tests of Crops of 1925 and 1926

Plot No.	Source of Potash	Duration of Burn in Seconds Darks 1925	Darks 1926	Mediums 1925	Mediums 1926	Lights 1925	Lights 1926	Seconds 1925	Seconds 1926	All grades 1925	All grades 1926	Average of two years
K6	Muriate	3.6	4.2	5.6	6.7	5.6	4.9	4.6	8.6	4.9	6.1	5.5
K1	Sulfate	35.7	10.6	29.1	16.2	49.1	39.8	43.2	44.0	43.1	27.7	35.4

The results are so overwhelmingly adverse for muriate that there could be no question as to its ruinous effect on burn when used to supply 172 lbs. of potash per acre (about 150 lbs. chlorine). On another part of the same field, plots, where 53 lbs. of chlorine are applied annually, are included in some experiments in cooperation with the United States Department of Agriculture. Mr. H. F. Murwin, in charge, found that this smaller amount was also very deleterious to the burn.

Carbonate and Nitrate of Potash. This set of ten plots on Field V was started in 1925 with the object of comparing carbonate, nitrate and sulfate of potash. Plots were in duplicate in 1925 and 1926 but the experiment enlarged in 1927 to make five replications of each treatment. Burn tests were made on the crops of 1925 and 1926 and are recorded in Table 7.

TABLE 7. CARBONATE, NITRATE AND SULFATE OF POTASH.
STRIP BURN TESTS ON CROPS OF 1925 AND 1926.

Source of Potash	Duration of Burn (Seconds): Darks 1925	Darks 1926	Mediums 1925	Mediums 1926	Lights 1925	Lights 1926	Seconds 1925	Seconds 1926	All Grades 1925	All Grades 1926	Ave. of two years
Sulfate	34.0	27.9	30.8	41.5	46.4	54.6	32.1	52.9	35.8	44.2	40.0
Carbonate	41.5	22.8	40.7	54.5	50.4	59.1	47.4	58.8	45.0	48.8	46.9
2/3 Nitrate 1/3 carbonate	27.2	16.7	51.3	39.4	44.2	54.7	49.8	54.9	43.1	41.4	42.3
½ carbonate ½ sulfate	40.2	19.1	25.3	49.1	44.7	51.7	41.8	48.3	38.0	42.3	40.2
1/3 sulfate 1/3 carbonate 1/3 nitrate	44.6	26.5	43.3	50.6	38.8	57.9	45.0	47.7	42.9	45.2	44.1

The differences in fire-holding capacity of the different plots are small. Of the three carriers, carbonate ranks first, nitrate second, and sulfate third. A combination of the three carriers, however, gave almost as good results as carbonate.

QUANTITY OF PHOSPHORUS

On the phosphorus series, four different quantities of phosphoric acid per acre were applied annually for five years. The four plots were in triplicate. During the fourth and fifth years, the only special carrier of phosphorus was precipitated bone. During the preceding three years a mixture of precipitated bone and superphosphate was used on the P1 plots. The amount of phosphoric acid applied per acre is given in Table 8. The 53 lbs. in the P2 formula were in the cottonseed meal and castor pomace of the formula. There were no special phosphorus carriers. Burn tests were made on the crops of the fourth and fifth year and are presented in the same table. Each figure in the right hand column is the average of 480 tests.

TABLE 8. PHOSPHORUS SERIES.
STRIP BURN TESTS. CROPS OF 1925 AND 1926.

Plot No.	Lbs. P_2O_5 per acre	Duration of Burn Seconds: Darks 1925	Darks 1926	Mediums 1925	Mediums 1926	Light 1925	Light 1926	Seconds 1925	Seconds 1926	All Grade 1925	All Grade 1926	Two Year Avrg.
P2	53	26.0	12.5	26.7	20.7	39.4	30.3	53.9	37.2	36.5	25.2	30.9
P3	100	31.9	16.1	31.1	19.2	37.8	31.3	44.8	38.6	36.4	26.3	31.4
P1	160	19.6	8.4	19.7	14.0	25.5	34.1	28.8	34.0	23.4	22.6	23.0
P4	200	21.6	8.8	26.6	18.9	26.9	25.4	34.5	34.9	27.4	22.0	24.7

It is apparent from these tests that the two plots which received the smaller quantity of phosphorus produced tobacco with the highest fire-holding capacity. Those two which received the heavy applications of phosphorus show a consistent depression in fire-holding capacity. These results lead us to believe that heavy applications of phosphorus to old tobacco land may affect to some extent the fire-holding capacity of the tobacco and should be avoided. In view of the fact that chemical analyses fail to show greater absorption of phosphorus by tobacco on the high phosphorus plots it is not easy to explain this effect.

For a full discussion of the phosphorus experiment, the reader is referred to Tobacco Station Bulletin 7.

When "cigar tests" were made, there were no differences apparent in fire-holding capacity or ash characters.

LIME

Heavily limed plots on three different fields afford an opportunity to test the effect of lime on burn.

Lime series on Station Field VIII. Beginning with 1922 these plots were limed heavily each year. With the last application in spring of 1925 they had received five tons of hydrated lime per acre, and the reaction of the soil was somewhat above 7.0 pH. In Table 9 the burn of the tobacco from these plots is compared with the check plots of the urea series on one side and with the check plots of the manure and cover crop plots on the other. These checks had the same fertilizer treatment as Field VIII and were immediately adjacent to it but were never limed.

TABLE 9. LIME PLOTS.
STRIP BURN TESTS.

Plot No.	Lime Treatment	Duration of Burn in Seconds: Darks 1925	Darks 1926	Mediums 1925	Mediums 1926	Lights 1925	Lights 1926	Seconds 1925	Seconds 1926	Avrg.
THIELAVIA SERIES 1925–1926										
T1, 2, 3a	Lime	28.5	.....	33.0	18.9	22.7	17.8	16.1	17.7	22.1
T1, 2, 3b	No lime	26.7	.....	32.3	24.6	28.1	39.7	34.2	34.3	31.4
LIME SERIES ON FIELD VIII. 1926.										
L	Lime		22.5		27.8		26.1		20.7	22.5
C3, 5, 14	No lime		15.8		29.0		37.8		38.5	30.3
N1	No lime		9.3		21.1		40.0		33.0	25.8
LIME SERIES ON POQUONOCK FIELD 1926.										
4H, 14A	Lime		20.9		20.1		12.1		10.6	15.9
6A, 14B 15A	No Lime		26.8		39.2		37.1		42.7	36.4

The results show that the tobacco from the checks on either side of the limed plots burned longer than the limed tobacco.

Thielavia series. On this series, which has been mentioned previously in connection with the sulfate of ammonia tests, one half of each of three plots was limed annually at a rate of one ton hydrated lime per acre. Tests on the crops of 1925 and 1926 are recorded in Table 9. Here again there is a distinct depression in fire-holding capacity from the heavy use of lime.

Poquonock series. In some field experiments on brown rootrot at Poquonock, two plots were limed annually at same rate as the Thielavia plots beginning in 1925. Tests on the tobacco from these and from adjacent unlimed plots are included in Table 9 and show that here again there was a distinct lowering of the fire-holding capacity from lime.

From the results of these three independent series of tests it is apparent that lime applied in large quantity reduces the fire-holding capacity as measured by the strip test.

Cigar tests. Cigars were made from the lime series of 1925 but not from the other series. These were compared with the checks of the urea series and manure series. The lime-treated tobacco gave the most perfect burn of any of the cigars from the crop of 1925. The ash color was mostly pure white or at most a very light gray. The coal band was extremely narrow and even. There was a slight tendency to flaking of the ash but it was not objectionable. The fire-holding capacity was also the best of any of the cigars, this being the only lot which would hold fire for ten minutes. This is not easy to explain in view of the injurious effect which the lime had in the strip burn tests of tobacco from the same plots.

Summary

1. Sulfate of ammonia seriously lowered the fire-holding capacity both when tested by the strip test and when the cigar test was used. Dark muddy ash, uneven burn and coaling also characterized the cigar test.

2. Large quantities of dry ground fish in the mixture also lowered the fire-holding capacity but not so much as the sulfate of ammonia.

3. Tankage had no pronounced effect.

4. Results with nitrate of soda were not entirely conclusive but did not indicate serious, if any, impairment of burn.

5. Urea did not affect the fire-holding capacity but increased the whiteness of ash.

6. Large quantities of phosphorus lowered fire-holding capacity on strip test but made no difference in the cigar test.

7. Muriate of potash almost destroys the fire-holding capacity.

8. Double sulfate of potash-magnesia lowered the fire-holding capacity when compared with high grade sulfate.

9. Comparing nitrate, carbonate and sulfate of potash, the differences in fire-holding capacity were not large but two years' results ranked carbonate first, nitrate second, and sulfate third. Ash characters were in the same order.

10. Lime in large amount reduced the fire-holding capacity when tested on the leaf. On the cigar, however, the fire-holding capacity was good. From the standpoint of whiteness of ash, closeness and evenness of burn, the cigars from the lime plots ranked highest.

CHEMICAL ANALYSES OF TOBACCO FROM THE NITROGEN PLOTS

*E. M. Bailey and P. J. Anderson**

The analytical data reported here were obtained upon tobacco grown upon a series of experimental plots referred to in this, and in previous publications, as the "old nitrogen series". Many data are already available upon the composition of tobacco leaf grown under various conditions, particularly with varying applications of nitrogenous and other fertilizers, but because of the rather complete history of these plots as regards fertilizer applications for a number of years past, it was felt that analyses of the leaf, in addition to their present interest, would be of value for reference in future work. The chief purpose of these analyses is to show what differences, if any, in leaf composition might be found where nitrogen was supplied in equal amounts but in varying forms. Then too, since the tobaccos from these plots have shown decided differences in leaf quality, burn for example, it was thought that analyses might show certain correlations between composition and burning quality which would, at least, be suggestive. No doubt many factors are involved in the explanation of satisfactory or unsatisfactory burning capacity, and the difficulties of postulating such qualities in terms of chemical composition of leaf are recognized. Interpretations based upon the composition of the entire leaf may be further complicated due to the unequal distribution of certain constituents between midrib and the remainder of the leaf. These and other considerations probably led to the so-called "synthetic" method of approaching the problem of burn by which tobacco is

* With the collaboration of Messrs. Fisher, Nolan and Mathis to whom credit for the analytical work involved is due.

directly treated with various chemicals and the resultant effects upon burning quality noted.

The analyses herein reported are of the leaf as a whole. Sample hands were taken from each plot and each of the four grades when the tobacco was sorted. These hands were fermented and aged as already described in the discussion of burn tests. It was not thought necessary to analyze all of the four grades of each plot. The two most distinct grades were therefore selected, *viz.,* dark wrappers and light wrappers. The dark wrappers are the heavier leaves from the tops of the plants. The grade which is called "lights" in these analyses was not always of sufficiently good quality for that grade; in some cases the long seconds were substituted, particularly in the crop of 1926, but the position on the plant is in all cases the same, i.e., well toward the bottom but above the sand leaves and short seconds.

Methods of Analysis

The moist leaves as received were air-dried and the air-dry material analyzed. Woody butts of leaves were removed but the midribs were left intact. The air-dry material was ground to pass a 1/25 in. sieve and the ground material preserved in tightly stoppered containers. The methods of analysis employed were those as described in Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists,[1] but the following additional comments may be made.

Nitrogen. Total nitrogen was determined by the Kjeldahl method modified to include the nitrogen of nitrates. Nitrate nitrogen was determined by the reduced iron method, distilling with magnesium oxide, and making a correction for the nitrogen due to the action of sulphuric acid upon organic material.[2] Nicotine nitrogen was calculated from nicotine as determined by the silicotungstic acid method. The determination of nitrogen in ammonium salts by the usual method of distillation with magnesium oxide gives results which are not reliable as evaluations of ammoniacal nitrogen because of the interference of nicotine which distills over under the conditions imposed by the method. In order to determine the effect of nicotine upon the distribution of nitrogen as determined by the usual methods, solutions of ammonium sulphate, nitrate of soda and nicotine citrate of definite concentrations were prepared and determinations of total nitrogen, ammoniacal nitrogen and nitrate nitrogen made. The results obtained are summarized as follows:

[1] Chapter IV, pg. 39 et seq.
[2] Jour. Assoc. Offi. Agr. Chemists. 11, 32, 1928.

Influence of Nicotine On Nitrogen Distribution

Material		Total Nitrogen gm.	Nitrogen In Ammonia gm.	Nitrogen In Nitrate gm.
Ammonium sulphate	present, calc.	0.0080	0.0080	0.0000
	found	0.0080	0.0081	0.0002
Sodium nitrate	present, calc.	0.0144	0.0000	0.0144
	found	0.0146	0.0000	0.0140
Nicotine citrate	present, calc.	0.0061	0.0000	0.0000
	found	0.0063	0.0020	−0.0006
Ammon. sulph.+ Sodium nitrate	present, calc.	0.0224	0.0080	0.0144
	found	0.0224	0.0080	0.0135
Ammon. sulph+ Nicotine citr.	present calc.	0.0141	0.0080	0.0000
	found	0.0140	0.0098	−0.0002
Sodium nitrate+ Nicotine sulph.	present, calc.	0.0205	0.0000	0.0144
	found	0.0200	0.0020	0.0135
Ammon. sulph.+ Sodium nitrate+ Nicotine citrate	present, calc.	0.0285	0.0080	0.0144
	found	0.0281	0.0098	0.0133

Aliquots were taken so that the amounts of the several materials approximate percentages of the magnitude found in our analyses of tobacco. It is evident from these results that total nitrogen and nitrate nitrogen are accurately evaluated in mixtures of these three substances, but that results for nitrogen in ammonium salts are too high due to the presence of nicotine. Under the conditions of uniform technique, which was the same as employed in the analyses of tobacco reported here, ammoniacal nitrogen is enhanced by about 0.2 per cent due to nicotine. Under other conditions (longer distillation for example), the error due to nicotine may be increased. In the determination of nitrate nitrogen by the method here employed the value for "ammoniacal" nitrogen is involved as a corrective factor, but however imperfect this factor may be as an expression of ammonia it does not vitiate the evaluation of nitrate nitrogen. Nicotine was determined by distilling with sodium hydroxide and precipitating nicotine in the distillate by means of silicotungstic acid.

Sulphur was determined by the tentative magnesium nitrate method. Sulphate sulphur was determined by digesting the tobacco with 1 per cent hydrochloric acid at room temperature for three hours in a shaking machine and precipitating sulphate in the filtered solution with barium chloride, also at room temperature. Sulphate sulphur was calculated from the barium sulphate obtained.[1]

Summaries of Analytical Data

Complete analyses were made on both the dark and light leaves of the 21 plots of the 1925 crop. The data from triplicate plots which received the same fertilizer treatment were averaged and are presented in Table 10. The significant differences in the nitrogen fertilizer treatments are noted in the column headings of this table.[2]

Supplementing Table 10 is Table 11, which gives results obtained on the 1926 crop from the same plots as are represented for the previous year. These data are to check or to amplify certain points of particular interest suggested by the results obtained on the 1925 crop.

It should be noted that in the selection of leaves for the 1926 series (Table 11), seconds were used in most cases instead of lights. As seconds are lower down on the stalk than the lights the differences in composition shown in certain instances must be interpreted with this reservation in mind.

And finally in order to facilitate comparisons of several groups with reference to separate constituents, or groups of constituents, the data are rearranged and summarized for that purpose in the series of tables beginning with Table 12a.

[1] Ohio Agr. Exp. Station, Bull. 285, 1915.
[2] Conn. Agr. Exp. Station, Tobacco Station Bull. 6, 1926, gives a complete statement of fertilizer mixtures used.

Table 10. Complete Analyses of Samples From the Crop of 1925 (Averages of Triplicates, Moisture-free Basis).

	N 1 Plots 1/5 N. in Nitr. Soda			N 2 Plots ½ N. in Nitr. Soda			N 3 Plots 1/5 N. in Sulf. Am.			N 4 Plots ½ N. in Sulf. Am.			N 5 Plots All N. in Organics			N 6 Plots ½ N. in Fish			N 7 Plots ½ N. in Tankage		
	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Ash, total	25.77	28.01	26.89	23.32	27.55	25.44	25.74	29.32	27.53	25.49	27.00	26.25	24.37	26.80	25.59	24.83	27.39	26.14	24.58	27.62	26.10
Sand + SiO_2, sol.	1.82	1.27	1.55	1.02	1.60	1.31	1.15	1.62	1.39	0.96	1.30	1.13	1.00	1.40	1.20	1.00	1.32	1.16	1.08	1.38	1.23
Fe_2O_3 + Al_2O_3	0.19	0.17	0.18	0.19	0.25	0.22	0.18	0.22	0.20	0.21	0.21	0.21	0.17	0.21	0.19	0.27	0.23	0.25	0.20	0.24	0.22
CaO	5.85	6.53	6.19	5.41	6.69	6.05	5.76	6.70	6.23	6.42	7.71	7.07	6.42	7.57	7.00	6.26	7.23	6.75	6.14	7.23	6.69
MgO	0.98	0.99	0.99	0.75	0.73	0.74	0.78	0.79	0.79	0.84	0.89	0.87	0.81	0.78	0.80	0.81	0.83	0.82	0.99	0.93	0.96
Mn_3O_4	0.07	0.05	0.06	0.05	0.06	0.06	0.16	0.23	0.20	0.17	0.22	0.20	0.22	0.31	0.27	0.09	0.11	0.10	0.09	0.10	0.10
K_2O	7.91	8.28	8.10	7.24	8.63	7.94	8.26	9.40	8.83	7.85	8.15	8.00	7.60	8.13	7.87	7.52	8.54	8.03	7.75	8.64	8.20
P_2O_5	0.85	0.70	0.78	0.75	0.69	0.72	0.83	0.83	0.83	0.87	0.75	0.81	0.78	0.73	0.76	0.68	0.62	0.65	0.80	0.64	0.72
S, total	0.75	0.68	0.72	0.74	0.74	0.74	0.84	0.84	0.84	0.97	0.90	0.94	0.79	0.81	0.80	0.74	0.70	0.72	0.75	0.70	0.73
S in ash	0.66	0.63	0.65	....	....	0.69	....	....	0.78	....	....	0.85	0.76	0.72	0.74	....	....	0.67	....	....	0.61
Cl	0.44	0.37	0.41	0.51	0.46	0.49	0.57	0.48	0.53	0.46	0.34	0.40	0.46	0.34	0.40	0.60	0.57	0.59	0.76	0.60	0.68
N. total	4.74	3.92	4.33	4.54	3.88	4.21	4.78	3.94	4.36	4.87	4.05	4.46	4.90	4.25	4.58	4.70	3.91	4.30	4.76	3.87	4.32
N. as ammon.	0.82	0.49	0.66	1.00	0.51	0.76	0.85	0.46	0.66	0.90	0.53	0.72	0.82	0.54	0.68	0.82	0.50	0.66	0.81	0.49	0.65
N. as nitrate	1.02	1.28	1.15	0.93	1.30	1.11	0.98	1.30	1.14	1.01	1.33	1.17	1.07	1.48	1.27	1.07	1.36	1.22	0.92	1.32	1.12
Nicotine	3.10	2.26	2.68	3.01	2.23	2.62	2.91	1.84	2.38	3.08	2.28	2.68	2.74	2.11	2.43	3.04	2.12	2.58	3.18	2.29	2.74
N. in nicotine	0.54	0.39	0.47	0.52	0.39	0.46	0.50	0.32	0.41	0.53	0.39	0.46	0.47	0.36	0.42	0.52	0.36	0.44	0.55	0.39	0.47

TABLE 11. ANALYSES OF SAMPLES FROM THE CROP OF 1926
(AVERAGES OF TRIPLICATES, MOISTURE-FREE BASIS)

	N 1 Plots 1/5 N. in Nitr. Soda			N 2 Plots ½N. in Nitr. Soda			N 3 Plots 1/5 N. in Sulf. Am.			N 4 Plots ½ N. in Sulf. Am.			N 5 Plots All N. in Organics			N 6 Plots ½ N. in Fish			N 7 Plots ½ N. in Tankage		
	Dark	Seconds	All	Dark	Seconds	All	Dark	Seconds	All	Dark	Seconds	All	Dark	Seconds	All	Dark	Seconds	All	Dark	Seconds	All
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Ash, total	24.83	27.36	26.08	24.08	29.13	26.61	24.45	28.79	26.62	25.30	28.19	26.75	25.18	28.31	26.74	25.40	29.26	27.33	24.99	29.03	27.01
Al_2O_3	0.05	0.09	0.07	0.04	0.08	0.06	0.08	0.14	0.11	0.08	0.11	0.09	0.08	0.13	0.10	0.07	0.06	0.07	0.04	0.04	0.04
Mn_3O_4	0.16	0.14	0.15	0.14	0.13	0.14	0.28	0.29	0.29	0.35	0.39	0.37	0.38	0.36	0.37	0.17	0.18	0.18	0.16	0.19	0.18
S, total	0.79	0.73	0.76	0.84	0.66	0.75	1.08	0.84	0.96	1.04	0.89	0.96	0.95	0.75	0.85	0.87	0.76	0.82	0.79	0.69	0.74
S, as sulphate	0.75	0.66	0.71	0.69	0.56	0.62	0.96	0.79	0.88	0.98	0.75	0.86	0.80	0.62	0.71	0.75	0.62	0.69	0.67	0.55	0.61
S, organic	0.04	0.07	0.05	0.15	0.10	0.13	0.12	0.05	0.08	0.06	0.14	0.10	0.15	0.13	0.14	0.12	0.14	0.13	0.12	0.14	0.13
N, total	5.56	4.49	5.03	5.57	4.12	4.85	5.74	4.14	4.94	5.59	4.44	5.01	5.68	4.39	5.04	5.58	4.38	4.98	5.70	4.13	4.92
N, as ammon.	1.25	0.75	1.00	1.26	0.58	0.92	1.37	0.55	0.96	1.26	0.61	0.94	1.16	0.57	0.87	1.20	0.54	0.87	1.19	0.58	0.92
N, as nitrate	1.11	1.26	1.19	1.03	1.27	1.15	0.93	1.15	1.03	0.94	1.19	1.06	1.18	1.41	1.30	1.20	1.34	1.27	1.13	1.23	1.18

DISCUSSION OF ANALYTICAL DATA

Total ash. Sand and soluble silica. These constituents for the several plots are summarized in Table 12a. Total ash is higher in the light leaves than in the dark, as would be expected since the light leaves contain considerably more of both calcium and potash than is found in leaves higher up on the stalk. In the 1926 crop it appears that the ash of the dark leaves is nearly the same as that of the corresponding leaves of the previous crop; but the seconds (lower on the stalk than lights), are somewhat higher in ash, on the average, than the leaves immediately above (lights), of the year before. The differences between the several plots with respect to ash are not great enough to be of significance.

TABLE 12a. COMPARISON OF GROUPS BY CONSTITUENTS.
(AVERAGES, MOISTURE-FREE BASIS).

Plots	Total Ash						Sand and Soluble Silica, SiO_2		
	1925 Crop			1926 Crop			1925 Crop		
	Dark	Light	All	Dark	Second	All	Dark	Light	All
	%	%	%	%	%	%	%	%	%
N1	25.77	28.01	26.89	24.83	27.36	26.08	1.82	1.27	1.55
N2	23.32	27.55	25.44	24.08	29.13	26.61	1.02	1.60	1.31
N3	25.74	29.32	27.53	24.45	28.79	26.62	1.15	1.62	1.39
N4	25.49	27.00	26.25	25.30	28.19	26.75	0.96	1.30	1.13
N5	24.37	26.80	25.59	25.18	28.31	26.74	1.00	1.40	1.20
N6	24.83	27.39	26.14	25.40	29.26	27.33	1.00	1.32	1.16
N7	24.58	27.62	26.10	24.99	29.03	27.01	1.08	1.38	1.23
Maximum	25.77	29.32	27.53	25.40	29.26	27.33	1.82	1.62	1.55
Minimum	23.32	27.00	25.44	24.08	27.36	26.08	0.96	1.27	1.13
Average	24.87	27.67	26.28	24.89	28.58	26.73	1.15	1.41	1.28

Sand and soluble silica are a little higher in light leaves as shown by the averages and, generally by the separate plots. The differences are not striking but they are in the expected direction. If the results for total ash be corrected for sand and soluble silica the differences in ash already noted remain of about the same magnitude and in the same direction.

Iron and aluminum, and **manganese.** The results for these constituents are summarized in Table 12b. In the 1925 crop, iron and aluminum were determined together and there are practically no differences either between dark leaves and light or between the several plots. In the crop of the succeeding year, aluminum was determined separately. Considering the magnitude of the values involved, the differences are not very striking; but plots 3, 4 and 5 as a group are higher in aluminum than the others. The soil of these three plots was relatively more acid than that of the other plots.

TABLE 12b. COMPARISON OF GROUPS BY CONSTITUENTS.
(AVERAGES, MOISTURE-FREE BASIS).

Plots	Iron and Aluminum $Fe_2O_3 + Al_2O_3$ 1925 Crop			Aluminum Al_2O_3 1926 Crop			Manganese Mn_3O_4 1925 Crop			Manganese Mn_3O_4 1926 Crop		
	Dark	Light	All	Dark	Second	All	Dark	Light	All	Dark	Second	All
	%	%	%	%	%	%	%	%	%	%	%	%
N1	0.19	0.17	0.18	0.05	0.09	0.07	0.07	0.05	0.06	0.16	0.14	0.15
N2	0.19	0.25	0.22	0.04	0.08	0.06	0.05	0.06	0.06	0.14	0.13	0.14
N3	0.18	0.22	0.20	0.08	0.14	0.11	0.16	0.23	0.20	0.28	0.29	0.29
N4	0.21	0.21	0.19	0.08	0.11	0.09	0.17	0.22	0.20	0.35	0.39	0.37
N5	0.17	0.21	0.19	0.08	0.13	0.10	0.22	0.31	0.27	0.38	0.36	0.37
N6	0.27	0.23	0.25	0.07	0.06	0.07	0.09	0.11	0.10	0.17	0.18	0.18
N7	0.20[1]	0.24	0.22	0.04	0.04	0.04	0.09	0.10	0.10	0.16	0.19	0.18
Maximum	0.27	0.25	0.25	0.08	0.14	0.11	0.22	0.31	0.27	0.38	0.39	0.37
Minimum	0.17	0.17	0.18	0.04	0.04	0.04	0.05	0.05	0.06	0.14	0.13	0.14
Average	0.20	0.22	0.22	0.06	0.10	0.08	0.12	0.15	0.14	0.23	0.24	0.24

1 Single analysis.

There are no conspicuous differences in manganese content between the dark leaves and light leaves or dark leaves and seconds of the two years. Between plots however it is seen that 3, 4 and 5 are decidedly higher than the other plots in both years. The leaves of these plots showed the poorest burning qualities in both series of tests for the two years. To what extent, if any, manganese contributes to this result remains to be determined, but the association of the two features is of more than passing interest. So far as shown by these analyses manganese is the only element, with the exception of sulphur, (and possibly aluminum) which shows any distinct correlation with burning quality.

Calcium and Magnesium. The results for these elements are summarized in Table 12c. Light leaves are noticably higher in calcium than the dark leaves, but as regards magnesium, there are no differences, either between the leaves of the same plot or between the various plots.

TABLE 12c. COMPARISON OF GROUPS BY CONSTITUENTS.
(AVERAGES, MOISTURE-FREE BASIS).

Plots	Calcium (CaO) 1925 Crop			Magnesium (MgO) 1925 Crop		
	Dark	Light	All	Dark	Light	All
	%	%	%	%	%	%
N1	5.85	6.83	6.19	0.98	0.99	0.99
N2	5.41	6.69	6.05	0.75	0.73	0.74
N3	5.76	6.70	6.23	0.78	0.79	0.79
N4	6.42	7.71	7.07	0.84	0.89	0.87
N5	6.42	7.57	7.00	0.81	0.78	0.80
N6	6.26	7.23	6.75	0.81	0.83	0.82
N7	6.14	7.23	6.69	0.99	0.93	0.96
Maximum	6.42	7.71	7.07	0.99	0.99	0.99
Minimum	5.41	6.69	6.05	0.75	0.73	0.74
Average	6.04	7.14	6.57	0.85	0.85	0.85

Although no special carriers of magnesia were used in the fertilizer mixtures applied to these plots, they received annually about 15 lbs. in cottonseed meal and castor pomace. Since there was no indication of "sand drown" on these plots during 1925 and 1926, we may conclude that this quantity is sufficient for the needs of the crop. Immediately adjacent to these plots are others where the effect of different quantities of fertilizer magnesia are being tested by Dr. W. W. Garner of the United States Department of Agriculture. He has kindly furnished the following magnesia analyses of 1925 tobacco from these plots:

Quantity of Magnesium (Lbs. MgO per acre) in fertilizer		Percent magnesium (MgO), in leaves
	W. W. G. PLOTS	
0		0.28
30		1.40
60		2.07
	OUR PLOTS	
15		0.85

These figures show that increases in fertilizer magnesia are reflected in the magnesia content of the leaves. The plots which received no magnesia had leaves showing typical sand drown.

Phosphoric acid, Potash and Chlorine. The results are summarized in Table 12d. The different fertilizer treatments received by the several plots are not reflected in any conspicuous degree by the phosphoric acid content of the leaves of the various plots. Dark leaves are slightly higher in phosphorus than the light leaves, which agrees with analyses from the adjacent phosphorus plots.[1]

[1] Conn. Exp. Sta., Tobacco Station Bull. 8, p. 14.

Considering the rôle of this element in protein synthesis its greater abundance in leaves nearest the growing point is to be expected.

TABLE 12d. COMPARISON OF GROUPS BY CONSTITUENTS.
(AVERAGES, MOISTURE-FREE BASIS).

Plots	Phosphoric acid (P_2O_5) 1925 Crop			Potash (K_2O) 1925 Crop			Chlorine (Cl) 1925 Crop		
	Dark	Light	All	Dark	Light	All	Dark	Light	All
	%	%	%	%	%	%	%	%	%
N1	0.85	0.70	0.78	7.91	8.28	8.10	0.44	0.37	0.41
N2	0.75	0.69	0.72	7.24	8.63	7.94	0.51	0.46	0.49
N3	0.83	0.83	0.83	8.26	9.40	8.83	0.57	0.48	0.53
N4	0.87	0.75	0.81	7.85	8.15	8.00	0.46	0.34	0.40
N5	0.78	0.73	0.76	7.60	8.13	7.87	0.46	0.34	0.40
N6	0.68	0.62	0.65	7.52	8.54	8.03	0.60	0.57	0.59
N7	0.80	0.64	0.72	7.75	8.64	8.20	0.76	0.60	0.68
Maximum	0.87	0.83	0.83	8.26	9.40	8.83	0.76	0.60	0.68
Minimum	0.68	0.62	0.65	7.24	8.13	7.87	0.44	0.34	0.40
Average	0.79	0.71	0.75	7.73	8.54	8.13	0.54	0.45	0.50

Potash is consistently more abundant in the lower leaves, an observation in accord with Jenkins' results on the crop of 1896. Between plots the differences are not notable save for the fact that plot 3 shows the maximum both in dark and in light leaves.

Chlorine was a little higher in the dark leaves than in the light, but the quantity is also quite small and not very variable for the different plots. The highest percentage is in the N7, (tankage) plots, the next highest in the fish plots (N6). Both of these materials contain some chlorine. It is possible that the higher percentage of chlorine in N7 explains why the burn is not quite so good as for N1.

Sulphur. Determinations of this element are summarized in Table 12e. The quantity of sulphur which the several plots have received through fertilizer applications in the past five years has varied widely. The largest amounts of sulphur have been introduced through the applications of ammonium sulphate (60% SO_3), but dry ground fish (5% SO_3), acid phosphate (25% SO_3), and sulphate of potash (46% SO_3), have also added considerable amounts of sulphur.

TABLE 12e. COMPARISON OF GROUPS BY CONSTITUENTS.
(AVERAGES, MOISTURE-FREE BASIS).

Group	Total Sulphur (S) 1925 Crop			Total Sulphur (S) 1926 Crop			Sulphur (S) in Ash 1925 Crop			Ratio Sulphur in Ash to Total Sulphur 1925 Crop	Sulphate Sulphur 1926 Crop			Organic Sulphur (Total S-Sulph. S.) 1926 Crop		
	Dark	Light	All	Dark	Second	All	Dark	Light	All	All	Dark	Second	All	Dark	Second	All
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
N1	0.75	0.68	0.72[1]	0.79	0.73	0.76	0.66	0.63	0.65[1]	0.90	0.75	0.66	0.71	0.04	0.07	0.05
N2	0.74	0.74	0.74[1]	0.84	0.66	0.75	.....	.....	0.69[2]	0.93	0.69	0.56	0.63	0.15	0.10	0.13
N3	0.84	0.84	0.84[1]	1.08	0.84	0.96	.....	.....	0.78[2]	0.93	0.96	0.79	0.88	0.12	0.05	0.08
N4	0.97	0.90	0.94[1]	1.04	0.89	0.96	.....	.....	0.85[2]	0.90	0.98	0.74	0.86	0.06	0.14	0.10
N5	0.79	0.81	0.80[1]	0.95	0.75	0.85	0.76	0.72	0.74[1]	0.93	0.80	0.62	0.71	0.15	0.13	0.14
N6	0.74	0.70	0.72[1]	0.87	0.76	0.82	.....	.....	0.67[2]	0.93	0.75	0.62	0.69	0.12	0.14	0.13
N7	0.75	0.70	0.73[1]	0.79	0.69	0.74	.....	.....	0.61[2]	0.84	0.67	0.55	0.61	0.12	0.14	0.13
Maximum	0.97	0.90	0.94	1.08	0.89	0.96	.....	.....	0.85	0.93	0.98	0.79	0.88	0.15	0.14	0.14
Minimum	0.74	0.68	0.72	0.79	0.66	0.74	.....	.....	0.61	0.84	0.67	0.55	0.61	0.04	0.05	0.05
Average	0.79	0.78	0.78	0.91	0.76	0.83	.....	.....	0.71	0.91	0.80	0.65	0.73	0.11	0.11	0.11

[1] Checked by analysis of a composite sample for the group.
[2] Determined on a composite sample for the group.

The following summary shows (1) the quantities of sulphur (as SO_3), applied to the several plots in the fertilizer, (2) the quantities of sulphur (as SO_3), found in the tobacco leaves of the 1925 crop, (3) the percentage of sulphate (SO_3), in the ash of the leaves, and (4) the average burn for the several plots.

TABLE 13. CORRELATION OF SULFUR IN FERTILIZERS AND IN TOBACCO CROP.

Plot	Pounds of SO_3 applied in fertilizer						SO_3 in ash of tobacco 1925	Pounds SO_3 per acre, in crop of 1925	Average burn, seconds. Crops of 1925 and 1926
	1922	1923	1924	1925	1926	total	%		
N1	226	226	226	76	76	830	1.63	33.29	35.4
N2	399	399	399	94	94	1385	1.73	34.75	29.4
N3	610	610	610	172	172	2071	1.95	39.32	20.9
N4	237	237	237	335	335	1381	2.13	42.97	15.0
N5	504	504	504	73	73	1661	1.85	39.41	17.5
N6	286	286	286	153	153	1164	1.68	35.32	25.9
N7	215	215	215	104	104	853	1.53	31.38	30.3

There appears to be an inverse correlation between the amount of sulphur applied to the soil and the burning capacity of the leaf produced thereon. The three plots which have been notable for poor burn (as well as poor quality) are N3, N4 and N5. These are the plots which have received the largest applications of sulphate in the fertilizer and which show the highest percentages of sulphate in the ash of the leaves. The plot which had the poorest burn (N4), received the heaviest application of sulphur in 1925 and 1926. Plots N3 and N5 also produced leaves of poor burning capacity. These plots received relatively light applications of sulphur in 1925 but heavy applications in the preceding years the effects of which were probably carried over. In general, it appears that substantial increases in applications of sulphate-containing fertilizers are followed by increased absorption of sulphur in the tobacco plant. This is in accord with the observations of Jenkins[1] in the Poquonock experiments of 1896; however, he found somewhat greater increases than are shown by the results recorded here. Patterson[2] also found increased absorption of sulphur by tobacco following increases of sulphur in fertilizer applications. In the Poquonock experiments, tobacco from the high sulphur plots was very poor in fire-holding capacity.

The evidence presented here is not conclusive proof that the increased sulphur content of the leaf is the cause of the poor burning quality observed, but the correlation suggests it as a probable cause or a contributing factor. The detrimental effects of chlorine are not conspicuous in the amounts shown by these analyses.

[1] Conn. Exp. Sta. Report. 1896.
[2] Agr. Sci. 8. 329. 1894.

The sulphur retained in the ash constitutes about 90 per cent of the total sulphur and is nearly identical in amount with that obtained by extracting the leaf with dilute hydrochloric acid and which is designated as sulphate sulphur.

Nitrogen and **Nicotine.** The original purpose of this series of tobacco plots was to compare the effects of different nitrogenous fertilizers upon the composition and character of the tobaccos grown thereon as regards nitrogen distribution in the leaf. These analytical results are summarized in Table 12f.

TABLE 12f. COMPARISON OF GROUPS BY CONSTITUENTS. (AVERAGES, MOISTURE-FREE BASIS).

Plot.	Total Nitrogen			"Ammonia" Nitrogen			Nitrate nitrogen			Nicotine, nitrogen, calc. from nicotine.			Nicotine		
	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All	Dark	Light	All
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
							1925	Crop							
N1	4.74	3.92	4.33	0.82	0.49	0.66	1.02	1.28	1.15	0.54	0.39	0.47	3.10	2.26	2.68
N2	4.54	3.88	4.21	1.00	0.51	0.76	0.93	1.30	1.11	0.52	0.39	0.46	3.01	2.23	2.62
N3	4.78	3.94	4.36	0.85	0.46	0.66	0.98	1.30	1.14	0.50	0.32	0.41	2.91	1.84	2.38
N4	4.87	4.05	4.46	0.90	0.53	0.72	1.01	1.33	1.17	0.53	0.39	0.46	3.08	2.28	2.68
N5	4.90	4.25	4.58	0.82	0.54	0.68	1.07	1.48	1.27	0.47	0.36	0.42	2.74	2.11	2.43
N6	4.70	3.91	4.30	0.82	0.50	0.66	1.07	1.36	1.22	0.52	0.36	0.44	3.04	2.12	2.58
N7	4.76	3.87	4.32	0.81	0.49	0.65	0.92	1.31	1.12	0.55	0.39	0.47	3.18	2.29	2.74
Maximum	4.90	4.25	4.58	1.00	0.54	0.76	1.07	1.48	1.27	0.55	0.39	0.47	3.18	2.29	2.74
Minimum	4.54	3.87	4.21	0.81	0.46	0.65	0.92	1.28	1.12	0.47	0.32	0.42	2.74	1.84	2.38
Average	4.76	3.97	4.36	0.86	0.50	0.68	1.00	1.34	1.17	0.52	0.37	0.45	3.01	2.16	2.59
							1926	Crop[1]							
N1	5.56	4.49	5.03	1.35	0.75	1.00	1.11	1.26	1.19	...	...	...	...	...	...
N2	5.57	4.12	4.85	1.26	0.58	0.92	1.03	1.27	1.15	...	...	...	...	...	...
N3	5.74	4.14	4.94	1.37	0.55	0.96	0.93	1.15	1.03	...	...	...	...	...	...
N4	5.59	4.44	5.01	1.26	0.61	0.94	0.94	1.19	1.06	...	...	...	...	...	...
N5	5.68	4.39	5.04	1.16	0.57	0.87	1.18	1.41	1.30	...	...	...	...	...	...
N6	5.58	4.38	4.98	1.20	0.54	0.87	1.20	1.34	1.27	...	...	...	...	...	...
N7	5.70	4.13	4.92	1.19	0.58	0.92	1.13	1.23	1.18	...	...	...	...	...	...
Maximum	5.74	4.49	5.04	1.37	0.75	1.00	1.20	1.41	1.30	...	...	...	...	...	...
Minimum	5.56	4.12	4.85	1.16	0.54	0.87	0.93	1.15	1.03	...	...	...	...	...	...
Average	5.63	4.30	4.91	1.24	0.60	0.93	1.07	1.26	1.17	0.64	0.40	0.52	3.70	2.34	3.02

[1] Seconds used instead of light in 1926 series.

It will be noted that total nitrogen is invariably higher in the dark leaves than in the light leaves or in the seconds. This might be expected since the dark leaves are nearer the growing point where the protein content of the cells is highest in all plants. It would be expected also that nicotine would be most abundant in the upper leaves and the results show that such is the case. The same is true for the alkaloidal content of the leaves of other species of plants, tea for example, the old leaves of which are practically devoid of caffeine.

That nitrate nitrogen is more abundant in the lower leaves is shown by the results obtained on the crops of both years. Jenkins[1] found somewhat more nitrates in the long wrapper (upper) leaves as reported in 1896 but the reverse was true according to certain results reported earlier.[2] Total nitrogen is higher in the 1926 crop but nitrate nitrogen is about the same for both years.

The partition of nitrogen evaluated as "ammonia" nitrogen must be interpreted with the reservations already mentioned in the discussion of methods. It will be noted that this value parallels the nicotine content with respect both as to the distribution between dark and light leaves and as to the increases observed in the 1926 crop. While there is no doubt that nicotine enhances the "ammonia" value there is still evidence of ammonia in considerable amounts. Young[3] however, concludes that the tobaccos which he examined contained little, if any, ammonia.

Comparing the individual plots there seem to be no significant quantitative differences. We may conclude from this that none of the nitrogenous fertilizers used had any marked differential influence on the quantity of nitrogen absorbed by the plants. When 200 pounds of ammonia per acre are applied, whether it be in the form of cottonseed meal, castor pomace, nitrate of soda, sulphate of ammonia, fish or of tankage, substantially the same amount of nitrogen is found in the leaf.

[1] Conn. Exp. Sta. Report 1896. p. 326.
[2] Conn. Exp. Sta. Report 1892, p. 29.
[3] Analyst. 52, 15. 1927.

Tobacco in 1896 and in 1925

A comparison of the experimental crop of tobacco in 1896 with the crop of 1925 on the basis of constituents in the moisture-free crude ash is given in the following summary:

Table 14. Composition of Tobacco Crop of 1925 Compared With That of 1896

	1896 Long Wrapper		1896 Short Wrapper		1925	
	range	avg.	range	avg.	range	avg.
Sand and SiO_2	7.5—12.9	11.0	18.0—27.0	23.4	4.3— 5.7	4.9
Iron and Al.	0.8— 1.4	1.1	1.1— 1.7	1.4	0.7— 1.0	0.8
Lime, CaO	14.5—25.1	20.1	10.0—22.0	17.6	22.7—27.3	25.0
Magnesia, MgO	2.3—11.0[1]	6.8[2]	2.5—12.3[5]	6.6[6]	2.9— 3.7	3.2
Potash, K_2O	24.9—35.7	29.7	20.0—30.0	24.1	30.1—32.1	31.0
P_2O_5	2.0— 3.1	2.2	1.1— 2.1	1.6	2.5— 3.1	2.9
SO_3	2.5— 7.7[3]	4.1	1.4— 6.6[7]	3.0	3.5— 4.8	4.1
Cl	0.4— 8.5[4]	1.7	0.3— 5.9[8]	1.0	1.3— 2.6	1.9

[1] Omitting one result, 2.3—8.9
[2] " " " average is 6.3
[3] " " " 2.5—6.0
[4] " " " 0.4—1.5
[5] " " " 2.5—8.9
[6] " " " average is 6.0
[7] " " " 1.4—4.7
[8] " " " 0.3—0.7

It appears that certain constituents varied more widely in the 1896 crop than in the recent one. The higher content of sand and silica simply means that the leaves in that year were not so free from adhering dirt. The sum of the calcium and magnesium is substantially the same in both years and there are no conspicuous differences in other items so far as shown in the above comparison. There seems to be no basis for the opinion, not infrequently held by growers, that the tobacco plant today is absorbing from the soil a ration of nutrients which is radically different from that of 30 years ago.

Summary

Comparing the effects of fertilizer formulas in which cottonseed meal, castor pomace, nitrate of soda, sulfate of ammonia, dry ground fish and tankage were used in the combinations previously described, we find that:

1. Different sources of fertilizer nitrogen have not substantially affected the quantity of total nitrogen, "ammonia" nitrogen, nitrate nitrogen or nicotine in the leaf, nor the ratios between them.

2. The percentages of total nitrogen, of "ammonia" nitrogen and of nicotine are invariably higher in the upper than in the lower leaves. Nitrate is more abundant in the lower leaves.

3. The different fertilizer treatments have not affected appreciably the percentages of total ash, soluble silica, iron, calcium, magnesium, phosphorous or potash in the leaf.

4. Increased percentages of manganese, sulfur, and, to a less degree, alumina in the leaves were found in those plots treated with sulfate of ammonia. This is correlated with a more acid soil reaction and a poorer burn of the tobacco.

5. The lower leaves of the plants (seconds and lights) have higher percentages of total (crude) ash, potash and calcium than the upper leaves.

6. The upper leaves (darks) have higher percentages of phosphorus, nitrogen, and chlorine than the lower leaves.

THE EFFECT OF SOME NITROGENOUS FERTILIZERS ON SOIL REACTION

M. F. Morgan and P. J. Anderson

Considerable attention has been focused during recent years on the importance of keeping a proper degree of soil acidity for the growing of tobacco. Some soils are so acid that the growth is stunted, others are not acid enough and consequently the crop suffers from rootrot.

It is common knowledge that lime and wood-ashes are the principle agents responsible for neutralizing the acidity of the soil and thus bringing about a condition favorable to rootrot. Concerning the effect of the other materials which are applied so generously and continuously to tobacco fields as fertilizers, there is little information at hand. Since the long continued use of a certain material, by changing reaction always in one direction, may have a potent influence for good or evil, it would be desirable to ascertain the tendency of each of our common fertilizer ingredients.

The fertilizer experiments which are in progress on the tobacco station farm offer an excellent opportunity for determining some of these effects. Each plot is treated annually with the same fertilizer throughout a period of years. Soil samples are taken periodically, tested, and kept on file for future study. Location of plots is the same from year to year.

The present discussion will be confined to the nitrogen ingredients, reserving the others for future reports. Our most extensive field experiment on nitrogen sources is the series of 21 plots on Field I known in our previous reports as the "Old Nitrogen Series". This experiment was conducted for five years, 1922-26, and the results fully reported in Tobacco Station Bulletins 5, 7, and 8. No mention of soil reaction, however, was made in these previous reports.

The plots were in triplicate and different nitrogen carriers were used on the different plots but the actual amount of nitrogen, phosphoric acid and potash applied annually was the same on each during the five years. No soil samples were taken when the experiment was begun in 1922 but since the land is fairly uniform and previous treatment had been the same, it is safe to assume that the reaction of all plots was approximately the same originally. The first set of soil samples was taken in May, 1925, the second set in May, 1927. All samples were taken before plowing in spring. All determinations were by potentiometer. The treatment of these 21 plots is described in Bulletins 5 and 6 of the Tobacco Station. The results of the tests are presented in Table 15.

TABLE 15. OLD NITROGEN SERIES ON FIELD I.
Carriers of nitrogen and reaction of soils in 1925 and 1927.

Plot No.	Lbs. of ammonia carrier 1922–24	Reaction May 1925	Lbs. of ammonia carrier 1925–26	Reaction May 1927
N1 N1* N1**	2100 C. S. Meal 800 Cast. Pomace 200 Nitr. Soda	4.73 4.60 4.66	1463 C. S. Meal 588 Cast. Pomace 212 Nitr. Soda	4.70 4.54 4.64
Ave.		4.66		4.63
N2 N2* N2**	1270 C. S. Meal 410 Cast. Pomace. 365 Nitr. Soda 260 Sulf. Am.	4.63 4.55 4.58	915 C. S. Meal 368 Cast. Pomace 531 Nitr. Soda	4.88 4.70 4.70
Ave.		4.59		4.76
N3 N3* N3**	550 Sulf. Am. 676 Nitr. Soda	4.54 4.46 4.53	1463 C. S. Meal 588 Cast. Pomace 160 Sulf. Am.	4.35 4.25 4.32
Ave.		4.51		4.31
N4 N4* N4**	1270 C. S. Meal 410 Cast. Pomace 265 Sulf. Am. 435 Nitr. Soda	4.55 4.55 4.57	915 C. S. Meal 367 Cast. Pomace 400 Sulf. Am.	4.31 4.40 4.18
Ave.		4.56		4.26
N5 N5* N5**	724 Sulf. Am. 552 Nitr. Potash	4.20 4.26 4.35	1829 C. S. Meal 735 Cast. Pomace	4.26 4.44 4.25
Ave.		4.27		4.32
N6 N6* N6**	1150 C. S. Meal 1250 H. G. Fish 200 Nitr. Soda	4.40 4.33 4.57	731 C. S. Meal 294 Cast. Pomace 958 H. G. Fish 106 Nitr. Soda	4.37 4.51 4.62
Ave.		4.50		4.50
N7 N7* N7**	1150 C. S. Meal 1359 Tankage 200 Nitr. Soda	4.46 4.47 4.40	731 C. S. Meal 294 Cast. Pomace 769 Tankage 80 Nitr. Soda	4.47 4.54 4.65
Ave.		4.44		4.55

These tests furnish data from which we can judge the effect of the following sources of nitrogen:

1. Sulfate of ammonia.
2. Nitrate of soda.
3. A 3 to 1 combination of cottonseed meal and castor pomace.
4. Dry ground fish.
5. Tankage.

The evidence on each of these may be discussed separately:

Sulfate of ammonia. The N5 plots received the heaviest sulfate of ammonia application of any of the plots during the first three years. At the end of that time they were the most acid of all the plots. During the last two years the N4 plots were the ones to which the heavy dose of sulfate was applied. Correspondingly, they were the most acid at the end of the two years. Even 160 lbs. of sulfate on the N3 plots caused a decided drop in reaction when it was not counterbalanced by nitrate of soda during the last two years. The acidifying tendency of sulfate of ammonia can be traced on every plot where it was used.

Nitrate of soda. The effect of this material is best observed on the N2 plots. These plots were more acid than the N1 plots at the end of the first three years but during the last two years they received heavy applications of nitrate of soda without any counterbalancing sulfate of ammonia. As a result, the raction at the end of five years was the least acid of any of the plots. This same influence of nitrate of soda may be observed also, but to a less degree, on the other plots where smaller quantities of it were used.

Combination of cottonseed meal and castor pomace. This seems to have no appreciable effect on the reaction of the soil as may be seen during the last two years of the N5 plots.

Fish. Comparing the N1 plots with the N5 plots there seems to have been a slight acidifying tendency from the use of fish. This is mild as compared with the effect of sulfate of ammonia.

Tankage seems to have had the same tendency as fish but the results are not very conclusive. The changes in reaction both from fish and from tankage have been too small to warrant a conclusion that they have any *pronounced* tendency to change the soil reaction.

Further data on the effect of some nitrogenous substances on the reaction of the soil were furnished by the set of experiments described on page 60 in which four different nitrogen carriers were compared when each was used as the *only* source of nitrogen. These were *cottonseed meal, nitrate of soda, sulfate of ammonia* and *urea.* This experiment was started in 1926 on uniform soil. The soil was tested one year later and again in December, 1927. The reactions determined are presented below:

TABLE 16. SOIL REACTIONS (pH) ON SINGLE SOURCE OF NITROGEN PLOTS

Carrier	Reaction	
	May 3, 1927	December 1, 1927
Cottonseed meal	5.21	5.85
Nitrate of Soda	5.42	6.12
Sulfate of Ammonia	4.99	5.35
Urea	5.03	5.58

The fact that all reactions are higher in December than in May is due to seasonal variation. It will be noted that at each test the nitrate of soda plot had the highest reaction and the sulfate of ammonia had the lowest. This corroborates our conclusion from the old nitrogen series that nitrate of soda makes the land less acid and sulfate of ammonia makes it more acid. There is no indication that cottonseed meal has any effect on the reaction.

Urea seems to have made the soil somewhat more acid.

In other experiments at New Haven, urea was used as the source of nitrogen in combination with other treatments. During the first month after application these soils showed a noticeable tendency toward decreasing the acidity, probably due to the rapid formation of ammonia. After this period, and throughout the season, plots treated with urea were consistently about .2 pH more acid than corresponding plots without urea in all cases where no lime was used. This was on a soil having a reaction of 4.9 pH prior to treatment. The only explanation for this phenomenon that occurs to us is the theory that in the nitrification of the ammonia formed from the urea, there is a removal of basic material from the soil.

SUMMARY

1. Sulfate of ammonia has had the strongest influence in changing the soil reaction. It has consistently made the soil more acid.

2. Nitrate of soda has just as consistently made it less acid but its influence in this direction is not quite so marked as the influence of sulfate toward acidity.

3. Cottonseed meal has not made any appreciable change in reaction.

4. Dry ground fish and tankage have had a very slight tendency to make the soil more acid.

5. Urea produces a slightly more acid condition after the initial period of rapid ammonia formation is concluded.

These results are in accord with those of experiments at other stations. The investigations by Hartwell and others at the Rhode Island station are particularly illuminating. These have been

fully discussed by Burgess.[1] His findings not only confirm ours on sulfate of ammonia, nitrate of soda, fish and tankage but he also adds results on two other sources of nitrogen which are sometimes used in tobacco mixtures, *viz.*, hoof meal and horn meal. These also seem to have a slight acid tendency like tankage and fish.

Two other mineral sources of ammonia which are coming to be used more frequently in tobacco mixtures are *nitrate of potash* and *nitrate of lime*. We have had only one year's experience with nitrate of lime. When the soil was tested and compared with the check plots at the end of the year, there was no appreciable difference. Plots which have been treated with nitrate of potash for three years at the rate of 267 lbs. per acre (43% K_2O) show no significant change in reaction during that time.[2]

SYNTHETIC UREA AS A SOURCE OF NITROGEN

The purpose of this experiment was to see whether synthetic urea can be used to replace, partly or entirely, the organic ammoniates in the fertilizer mixture.[3] During the third year, the six plots were in the same place on Field IX and the fertilizer mixture was identical with that applied during the preceding years except that the quantity of magnesia in all mixtures was equalized by use of magnesium carbonate in place of double sulfate of potash-magnesia which was previously used. This change was made in order to eliminate differences in sulfur content of the three formulas.

The two N1 plots had all the nitrogen in cottonseed meal, castor pomace and nitrate of soda. Standard formula, *no urea.*

On the N8 plots, *one-half* of the nitrogen was from urea, with the other half from cottonseed meal and castor pomace.

On the N9 plots, *all* of the nitrogen was supplied in urea.

The fertilizer was applied on May 20 and the field set to Havana Seed plants on May 28.

During the growing season, no differences in growth as between the various treatments were observed. There was still a poor spot in the center of the field as mentioned in reports of previous years[4] but this affected several of the plots and apparently had no relation to fertilizer treatment. The plants from this area were excluded

[1] Bulletin 189, Rh. Island Exp. Station, 1922.

[2] After this bulletin had gone to press the very recent work of Pierre (Jour. Am. Soc. Agron. **20**: 254) came to our attention. His investigations substantiate the results herein reported, and his paper attempts detailed theoretical explanations of the changes in soil reaction produced by various nitrogenous fertilizers.

[3] Tobacco Station Bul. 8, p. 33 for a complete discussion of this experiment during the first two years.

[4] Tobacco Bul. 6, p. 14.

at harvesting. On account of the unfavorable season the crop was light. All plots were harvested on August 5 and sorted in the station sorting shop in December. During the sorting it was noted that the tobacco from the three south plots was somewhat dead and yellow and therefore contained a considerable percentage of "brokes" as indicated in Table 17. The three north replicates, however, produced tobacco of good quality. This difference between the south three and the north three plots has been apparent throughout the three years of this experiment as may be seen by reference to yields in Table 18. The differences have been consistently about 200 lbs. per acre in favor of the north tier of plots. This inequality is apparently due to soil differences in the field and bears no relation to fertilizer treatment.

The yields, sorting records and grade indices* for 1927 are presented in Table 17. A summary of the three years' experiment is shown in Table 18.

The latter table shows that the average yield during the three years is so nearly the same (less than half of 1% difference) that the differences are not significant. The grade index for the standard formula and for the ½ urea formula is also practically the same but there is a drop of about .02 when urea was the only source of nitrogen.

These results strengthen the tentative opinion stated in our report for 1926 that urea may be advantageously used to furnish a part, probably up to one-half, of the nitrogen of the fertilizer formula.

Further experiments in which urea was used as the only source of nitrogen are discussed on p. 60.

* *The Grade Index.* In comparing the quality of tobacco grown on different plots it is very difficult to keep in mind the percentage of six to eight commercial grades of tobacco from one plot and compare with a like number from another. To simplify these comparisons a grade index was devised. The grade index is a single number expressing the quality of *all* the tobacco grown on a particular plot. It is based on the percentage of carefully assorted commercial grades and the relative price value of the different grades. Although market prices vary from year to year, it was found after consultation with experienced dealers, that the ratios of prices between the different grades are fairly constant. These adopted price relationships for the different grades are as follows:

(L)	Light wrappers..........	1.00	(LD)	Long darks (19" up)...	.30
(M)	Medium wrappers.......	.60	(DS)	Dark stemming (17")..	.20
(LS)	Long sec. (19" up).......	.60	(F)	Fillers................	.10
(SS)	Short seconds (15" and 17")................	.30	(Br)	Brokes................	.10

The grade index of any plot is obtained by multiplying the percentage of each grade by the price in the above schedule and adding the products.

TABLE 17. UREA SERIES. YIELDS AND GRADINGS FOR CROP OF 1927.

Plot No.	Nitrogen Treatment	Acre Yield		Percentage of Grades								Grade Index	
		Plot	Ave.	L	M	LS	SS	LD	DS	F	Br	Plot	Ave
N1-5	No urea	1060	....	3	4	21	6	33	7	11	15	.337	....
N1-6		1296	1178	9	10	17	9	34	9	10	2	.411	.374 ....
N8	½ N from urea	1053	....	5	4	21	8	27	14	11	10	.354	
N8-1		1441	1247	11	19	13	7	37	2	7	4	.446	.400
N9	All N from urea	1060	....	3	5	14	6	35	8	4	25	.312	
N9-1		1223	1142	12	12	14	8	32	10	9	3	.428	.370

TABLE 18. UREA SERIES. YIELDS AND GRADE INDICES FOR THREE YEARS.

Plot No.	Nitrogen Treatment	Yield per acre				Grade Index			
		1925	1926	1927	Ave of 6	1925	1926	1927	Ave of 6
N1-5	No urea	1364	1501	1060	....	.268	492	.337	....
N1-6		1561	1711	1296	1416	.411	473	.411	.399 ....
N8	½N in urea	1356	1488	1053	....	.325	.545	.354	....
N8-1		1597	1695	1441	1422	.303	.405	.446	.396 ....
N9	All N in urea	1347	1622	1060	....	.257	.489	.312	....
N9-1		1465	1810	1223	1421	.352	.445	.428	.381 ....

FRACTIONAL APPLICATION SERIES

Many growers believe that they obtain better results by broadcasting only a part of the fertilizer mixture before setting and applying the remainder as a side dressing to the growing plants. The side dressing may also be divided and applied at two or three times. The usual time is just before hoeing in order to get the fertilizer well distributed about the plants. There is great diversity of opinion among growers as to the benefits of such a practice and in regard to time of making later applications and as regards materials to be used. Some use the same mixture for both broadcasting and side dressing. More often, however, only the quickly available nitrogen carriers are used for the side dressings. This practice is based on the assumption that nitrogen which is applied early may leach away and the plants will suffer from shortage unless some quickly available form is applied later. The potash and phosphorus on the other hand do not leach appreciably.

Field tests were begun at the experiment station in 1923 to compare these two methods. From the results of the experiment of the first three years, described in Bulletins 5 and 6, it was concluded that nothing was gained either in yield or quality by fractional application. In those experiments, however, the mixture applied at each time was of the same composition. Beginning with 1926 a new series was started which differed from the first series in two ways: (1) the six plots were located on extremely leachy soil and (2) only the nitrogen carriers were reserved for side dressings. The composition of the fertilizer for each application was as follows:

Carrier	Pounds per acre			
	Broadcast before setting	1st side dressing	2nd side dressing	Total
C. S. Meal	463.4	600	400	1463.4
Cast. Pomace	1323.5	...	...	1323.5
Nitr. Soda	35.5	35	35	105.5
Ammo. Phos	33.1	35	35	103.1
Ppt. bone	185.4	...	...	185.4
Sulf. potash	164.8	...	...	164.8
Carb. potash	126.8	...	...	126.8

This formula supplies 250 lbs. ammonia, 160 lbs. phosphoric acid and 200 lbs. potash. The three fractional plots were on different parts of the field but each was immediately adjacent to a check plot where the same mixture was used but all at one time as a broadcast application.

The season of 1926 was very dry. No differences in growth as between the two fertilizer methods were observed. The yield records of these plots are included in Table 19. The season of 1927 was just the opposite, being very wet and theoretically should have been very favorably for the fractional plots.

The broadcast application of fertilizers in 1927 was made on May 20. The field was set on June 7. The stand was uniform and the growth was good throughout the season but no marked differences resulting between the two methods of fertilizing were observed in the field.

The second application of fertilizer was made on June 20 and the third on June 30.

All plots were harvested on August 11; thus the tobacco was in the field just 64 days. It was stripped in September and sorted in station shop in December.

TABLE 19. FRACTIONAL APPLICATION SERIES, 1926 AND 1927.

Plot No.	Treatment	Yield per acre		Percentage of grades, 1927								Grade Index 1927
		1927	1926	L	M	LS	SS	LD	DS	F	B	
F 6	Fractional	1148	1300	9	6	15	11	29	9	17	4	.375
C 5	Broadcast	1221	1426	11	8	18	14	27	8	11	3	.419
F 6-1	Fractional	1211	1550	15	7	15	10	33	2	13	5	.433
C 5-1	Broadcast	1291	1612	20	15	9	10	29	3	11	3	.481
F5-1	Fractional	1413	1603	21	16	9	6	33	2	10	3	.494
C3-1	Broadcast	1343	1618	13	11	15	9	34	2	12	4	.435
Ave. of fractional		1257	1484	15	10	13	9	32	4	13	4	.434
Ave. of broadcast		1288	1552	14	11	14	11	30	4	11	3	.445

The sorting and yield records are presented in Table 19. In each case the fractional plot is compared with broadcast plot immediately adjacent.

These data show that the tobacco on the fractional plot had a higher yield or better grading record only in one of the three comparisons. The averages in both methods of measuring are somewhat adverse to fractional applications.

Yield records for the dry year 1926 are included in the above table. They show the same adverse effect of fractional application. Quality records were not made for 1926.

These results are in accord with those from our previous tests, in that they show no advantage to be gained by making several applications as compared with a single original application of the same quantity and kind of fertilizer.

In 1927 another series of fractional application plots was started in which nitrate of lime was used as the only source of nitrogen in comparison with a single broadcast application of castor pomace. The broadcast mixtures were spread on the plots on May 21 and the fractionals were made June 15 and July 8. The schedule of fertilizer applications are given in Table 20.

TABLE 20. GIVING DATE OF APPLYING FERTILIZERS IN FRACTIONAL NITRATE OF LIME PLOTS. TOBACCO SET, MAY 26, 1927.

Plot No.	Source of Ammonia	Broadcast applications (May 21)			Fractional Applications Ammonia		Total NH_3
		NH_3	P_2O_5	K_2O	June 15	July 8	
N19	None	0	80	200	0	0	0
N20	Nitrate of lime	9	80	200	18	36	63
N21	Nitrate of lime	18	80	200	36	72	126
N22	Nitrate of lime	36	80	200	72	108	216
N23	Nitrate of lime	72	80	200	144	...	216
N24	Castor pomace	216	80	200	none	none	216

Observable differences in effects of these treatments on the growth and appearance of the tobacco were apparent as early as the middle of June. Symptoms of yellowing and smaller growth were found on all of the nitrate of lime plots. In contrast, the tobacco grown on the castor pomace plot was larger and of a deeper healthier green color. On June 25 the noticable differences between the nitrate of lime plots were more of size than color. The size of the plants was almost in proportion to the amount of ammonia applied. This condition prevailed until harvest on August 7.

The effects of these treatments on the yield and quality are given in Table 21.

TABLE 21. SORTING RECORDS, YIELDS, AND GRADE INDEX OF FRACTIONAL APPLICATIONS OF NITRATE OF LIME *Versus* A SINGLE BROADCAST APPLICATION OF CASTOR POMACE, 1927.

Plot No.	Lbs. NH_3 per acre.	Percentage of grades D	S	B	F	Grade index	Yield per acre
N19	0	7	3	29	61	.112	602
N20	63	30	27	22	21	.228	827
N21	126	32	31	22	15	.250	1028
N22	216	33	32	19	16	.295	1102
N23	216	35	35	14	16	.316	1125
N24	216	32	40	14	14	.328	1135

These results indicate a serious decrease in yield and quality when the total ammonia applied per acre is reduced below 126 pounds. Considerably better quality and yield were obtained when this was raised to 216 pounds. Similar results may be anticipated the first year, particularly if the rainfall of the season is above normal. The low yields due to nitrogen deficiency in the soil also are correlated with poor quality.

Where high yields are desired there seems to be no evidence in favor of fractional application. These results also support the general idea that to most crops nitrogen should be applied early, although there was no serious falling off in quality by a late, heavy application (July 8) on plot N22 as compared with N23.

SINGLE SOURCES OF NITROGEN

An experiment to determine the effect of single sources of nitrogen was begun on four plots in 1926. Nutrients were supplied to all at the rate of approximately 200 lbs. ammonia, 160 lbs. phosphoric acid and 200 lbs. potash per acre, the only difference in the four plots being in the carrier of nitrogen. The materials compared were nitrate of soda, sulfate of ammonia, urea and cotton-

seed meal. In 1927, castor pomace and nitrate of lime plots were added to the test. All of these plots were located on fairly light leachy soils.

No striking differences in field growth were noted in the dry season of 1926, except that the nitrate of soda plot seemed much better than the cottonseed meal plot. In 1927, an exceptionally wet season, certain abnormal symptoms of growth on the nitrate of soda plot were evident three or four weeks after transplanting. These symptoms were yellowing due to insufficient nitrogen and also a chlorotic condition diagnosed as magnesia hunger. As the season progressed, nitrogen deficiency apparently was the limiting factor causing yellow stunted growth, and masking the magnesia hunger symptoms. At harvest, magnesia hunger was very severe on the sulfate of ammonia plot. The cottonseed and castor pomace plots had no magnesium chlorosis and the urea plot had only a slight amount on a small percentage of the plants. These three plots (cottonseed meal, castor pomace, urea) maintained a healthy green color throughout the season.

The tobacco grown on sulfate of ammonia apparently had sufficient nitrogen (as indicated by yields) and had a dark green color on all the leaves not affected by magnesium chlorosis. The reason for the severity of this trouble on this plot in contrast to the urea plot is difficult to explain. There is a possibility of the soluble magnesia in the soil combining with the sulfate radical in excess and forming magnesium sulfate, a highly soluble salt, which later was leached from the surface soil by the heavy rains. The urea, however, did not supply any sulfate to cause this effect. Enough magnesia was supplied in cottonseed meal or castor pomace to fulfill the requirements of the plant, and chlorosis did not occur on these plots. It seems, therefore, that the response of a plant to particular nitrogenous fertilizers may depend largely on the seasonal factors of rainfall and temperature.

The sorting records of these plots are given in Table 22.

TABLE 22. SORTING RECORDS OF TOBACCO GROWN ON SINGLE SOURCES OF NITROGEN.

1926–1927

Plot No.	Material	Percentage of Grades D		S		L		M		F		B	
		1926	1927	1926	1927	1926	1927	1926	1927	1926	1927	1926	1927
N11	C.S. Meal	45	40	24	33	5	0	2	0	20	13	4	14
N12	Nitr. Soda	47	20	26	5	6	0	4	0	16	55	1	20
N13	Sulf. Amm.	50	35	29	42	5	0	3	0	10	11	3	12
N14	Urea	46	40	26	33	7	3	4	5	14	13	3	14
N22	Nitr. Lime	..	33	..	32	..	0	..	0	..	16	..	19
N23	Nitr. Lime	..	35	..	45	..	0	..	0	..	16	..	14
N24	Cast. pom.	..	32	..	40	..	0	..	0	..	14	..	14

The sorting records indicated that good quality tobacco was produced by cottonseed meal and castor pomace. Nitrate of soda had a tendency to produce harsh, dry, non-elastic, yellow tobacco. Tobacco grown on urea was of fair to good quality, while sulfate of ammonia produced coarse, veiny (white and prominent veins), dark, heavy tobacco in all grades. The *yield* was highly satisfactory when sulfate of ammonia was the nitrogen source. It gave the highest yields of the substances tried. Nitrate of lime was much more satisfactory than nitrate of soda, but it must be remembered that this has been tried only for one year.

A summary of the results of these trials is given in Table 23.

TABLE 23. SUMMARY TABLE OF YIELDS AND GRADE INDEX. 1926–1927.

Plot No.	Material	Yield per acre			Grade Index		
		1926	1927	Ave.	1926	1927	Ave.
N11	C. S. Meal	1228	1131	1179	.288	.297	.292
N12	Nitr. Soda	1440	688	1064	.353	.130	.241
N13	Sulf. Amm.	1482	1386	1432	.370	.333	.351
N14	Urea	1350	1166	1258	.375	.350	.362
N22	Nitr. Lime	....	1102	....	....	.295	....
N23	Nitr. Lime	....	1125	....	....	.316	....
N24	Castor pomace	....	1135	....	....	.328	....

MANURE AS A SUPPLEMENT TO COMMERCIAL FERTILIZER

In the early days of tobacco growing in New England, manure was the only fertilizer used. It produced large yields of excellent[1] quality tobacco for many years previous to the advent of commercial fertilizers. When the farmers began to expand the acreage, there was not enough manure to adequately cover the land. This condition lead to the importation of manure from New York and other large cities, a practice which is still continued to some extent, but the diminishing supply and increasing cost are rapidly bringing this era to a close. From the day when commercial fertilizers began to supplant manure there has been a continuous controversy as to the relative merits of the two. It is now generally agreed that it is impracticable, in this section, to grow tobacco on manure *alone* but there is no unanimity on the question of whether it is best to use commercial fertilizer *alone* or to supplement it with manure. A half century or argument by growers, packers, and manufacturers, pro and con, supported by thousands

[1] Standards of quality in cigar leaf tobacco have probably changed, so what is remembered as "excellent" might not be accepted as such today.

of individuals' examples has not settled the dispute. When on the other hand, we turn to controlled experimental data from the Agricultural stations we find the results just as inconclusive. Thirty years ago Goessman[1] in Massachusetts and Jenkins[2] in Connecticut carried on manure experiments for several years but both hesitated to draw any conclusions from the data collected. More recently Jones[3] in Massachusetts started a more comprehensive experiment with manure. His results up to the present indicate some benefits from the addition of manure. No other manure experiments on New England tobacco have been published. It is surprising that there have been no more scientific attempts to solve so old and so important a question in tobacco growing, although the complexity of the problem is recognized.

To be sure, the problem is becoming of less importance because the supply of purchasable manure may become so scarce and costly within the next decade or two that none will be purchased. Nevertheless there will always be a limited supply produced on tobacco farms and the question to be decided is whether this could be used most advantageously to supplement the commercial fertilizer on the tobacco lot or whether it could be better used for other crops.

In an effort to determine more accurately the supplementary value of manure, the following experiment was begun in the fall of 1925 and two years' results are now available. It is planned to continue this experiment for a minimum period of five years. Since manure is known to have a long-continued after effect, it is too early to draw conclusions. The data of the first two years must be considered as merely indicative. Annual or biennial reports on this experiment will be published as data are available.

It is the common belief of tobacco growers that the benefits of manure are more pronounced on sandy, "leachy" land where it functions in retaining moisture and plant food. In conformity with this belief, a coarse sandy knoll was selected for the experiment. The crop has always been light on this field because it suffered from lack of water during dry years and the nitrogen leached away during rainy years.

Eight 1/20th acre plots are included in the experiment, four of which are treated annually with manure. Each manure plot has an adjacent plot which is not covered with manure but in every

[1] Goessman, C. A. Field experiments with tobacco in Massachusetts. Mass. Agr. Exp. Sta. Rpt. 10 (1898): 128-132. 1899.

[2] Jenkins, E. H. Experiments in growing tobacco with different fertilizer. Conn. Agr. Exp. Sta. Rpt. 20 (1896): 302-321. 1897.

[3] Jones, J. P. Report of progress in tobacco investigations. Mass. Agr. Exp. Sta. Circular 74: 4 1927.

other way is treated just like it. Two of the manure plots receive stable manure, the other two receive artificial, or so-called "Adco" manure.[1]

The stable manure is spread on the land during the fall and remains on top of the ground until the following spring when it is plowed under. Twenty loads per acre are applied to one of the plots and forty loads to the other. The adco manure is applied in the spring at the rate of some thirty loads per acre.

The following fertilizer mixture was applied alike to *all* plots from 10 days to two weeks before setting.

Carrier	Lbs. per acre	Nutrients per acre		
		NH_3	P_2O_5	K_2O
C. S. Meal	1463.4	120.00	42.40	21.95
Cast. Pomace	1323.5	90.00	23.80	13.24
Nitr. Soda	105.5	19.83	....	....
Ammophos	103.1	20.17	22.41	....
Ppt. Bone	185.4	....	71.39	....
Sulf. Potash	164.8	....	....	82.41
Carb. Potash	126.8	....	....	82.40
Total..............	3472.5	250.00	160.00	200.00

Although the same amount of plant food was applied in 1927, the composition of the mixture was altered slightly as follows:

Carrier	Lbs. per acre	NH_3	P_2O_5	K_2O
C. S. Meal	1463.4	120.00	42.40	21.95
Cast. Pomace	1323.5	90.00	23.80	13.24
Nitrate of Lime	105.5	19.83	....	....
Urea	36	20.17	....	....
Sulf. Potash	164.8	....	....	82.41
Carb. Potash	126.8	....	....	82.40
Total..............	3220.0	250.00	66.20	200.00

[1] *Preparation of Adco manure.* This is made in our case from grass and weeds by treating them with Adco reagent. After the grass was cut and partially dried, a stack was begun by making a layer about one foot high after tramping and watering until thoroughly saturated. A layer of the dry reagent was then spread over the top, then another layer of grass made in the same way as above and covered with the reagent. This was continued until there were six layers. Somewhat over a ton of grass and 150 lbs. of the reagent were used. The stack developed considerable heat at first and had to be watered frequently and turned several times. Other organic materials such as leaves, straw, corn stalks, etc., could be used but were not available for this experiment. The stacks were made in July but were not spread on the plots until the following spring, at which time they had the appearance and consistency of a rotted manure pile.

During 1926 no differences in growth were observed in the field. The season was very dry, resulting in small growth and poor quality on all of this part of the field.

The yield and sorting data for the eight plots are recorded in Table 24.

TABLE 24. MANURE PLOTS, 1926.

Plot No.	Treatment	Yield per A.	Percentage of grades								Grade index
			L	M	LS	SS	LD	DS	F	B	
M1	40 loads stable manure per A	1404	7	6	6	17	35	14	13	2	.338
C3	No manure	1279	8	2	1	17	25	24	19	4	.295
M1-1	20 loads stable manure per A.	1489	8	10	15	12	35	5	12	3	.396
C3-1	No manure	1618	8	10	12	8	39	3	12	8	.379
M2	Adco manure	1379	8	6	6	13	23	24	17	3	.328
C14	No manure	1285	4	3	12	15	26	12	16	12	.305
M2-1	Adco manure	1281	4	4	9	17	21	21	18	6	.298
C14-1	No manure	(1)..	6	3	3	16	13	32	23	4	.274
Ave. of stable manure		1447	..	..	..	..	..	..	..	..	.367
Ave. of checks		1449	..	..	..	..	..	..	..	..	.337
Ave. of Adco Manure		1380	..	..	..	..	..	..	..	..	.313
Ave. of check		....	..	..	..	..	..	..	..	..	.289

(1) Yield record lost.

In this table the record of the adjacent control plot follows that of each manure plot. Comparing each in turn with its control, the results, even for the first year in an unfavorable season show some advantage from the use of manure. The yield is higher in all but one comparison. The grade index is higher for the manure treatment in each of the four comparisons.

The larger yields on the M1-1 and C3-1 plots are accounted for by location on somewhat less sandy land than the others. The yield on plot M1-1 may have been affected by shading from the station building immediately adjacent.

The season of 1927 was the reverse of 1926. There was entirely too much rain, resulting in low yield but the quality of the tobacco was much better.

During the growing season there was apparent a small difference in size, in favor of all the manured plots as compared with checks. The yield and sorting data as presented in Table 25 show that this difference was real since in every case the yield was higher on the manured plots. Also the grade index was higher in three out of the four comparisons. The exception was on the M1-1 plot which is on somewhat heavier land and since the percentage of darks was higher here than on any other plots, the reason for the lower index is apparent.

Since these four comparisons were located on different parts of the field and since these differed in physical character and apparently in natural productiveness, it is not possible to make a direct comparison of stable manure with artificial manure. By comparing each with its own control however it is apparent that both kinds of manure used as a supplement, have been about equally efficient in increasing the yield and improving the quality of the tobacco both in a dry year and a wet year.

TABLE 25. MANURE AND CHECK PLOTS. YIELD AND SORTING RECORDS. CROP OF 1927

Plot No.	Manure Treatment	Yield per acre	Percentage of Grades								Grade index
			L	M	LS	SS	LD	DS	Fil	BR	
M 1	Stable Manure	1375	19	16	8	6	37	3	9	2	.480
C 3	No Manure	1062	7	5	14	10	31	5	16	11	.344
C 5	No Manure	1221	11	8	18	14	27	8	11	3	.419
M 1-1	Stable Manure	1402	7	13	12	10	40	3	11	4	.391
C 3-1	No Manure	1343	13	11	15	9	34	2	12	4	.435
C 5-1	No Manure	1291	20	15	9	10	29	3	11	3	.481
M 2	Adco Manure	1259	16	12	8	8	40	2	11	3	.442
C 14	No Manure	1161	4	7	17	9	36	4	17	6	.350
M2-1	Adco Manure	1300	22	13	5	9	37	2	11	1	.482
C 14-1	No Manure	1217	6	9	15	7	38	4	17	4	.368
Ave. of Stable Manure		1389	13	15	10	8	39	3	10	3	.436
Ave. of Checks		1232	13	10	14	11	30	4	12	5	.419
Ave. of Adco Manure		1280	19	13	7	9	39	2	11	2	.462
Ave. of Checks		1189	5	8	16	8	37	4	17	5	.359

ORGANIC MATTER IN TOBACCO SOILS

M. F. Morgan

Tobacco growers in the Connecticut valley, growing tobacco on the same fields for many years, are frequently concerned with the possibility of a depletion in the organic matter in their soils, and the consequent undesirable condition which is known to accompany such deficiency.

The average tobacco soil ranges in texture from a light loam through the intermediate grades of fine sandy loam, sandy loam, loamy sand to the coarse sand upon which much of the shade tobacco is grown. These light-textured soils are usually accepted as holding a relatively low amount of organic matter, unless the soil is of a very poorly drained type. Along the Atlantic seaboard, sandy soils are often seriously deficient in organic content. The barren sandy areas in New Jersey frequently contain less than one-half percent of organic matter in the surface soil. Sandy loam soils of the South Atlantic states rarely exceed one percent organic

matter, and the average is probably near .6 percent. Even the best agricultural practices in this region fail to build up the organic content to any considerable extent.

The average soil of the United States has been estimated by Waksman[1] to contain about 2 percent organic matter. Black clay loam soils of the Illinois prairie contain from 6 to 8 percent organic matter. The highly fertile and very heavy textured soils of the Red River valley in Manitoba frequently contain from 10 to 15 percent organic matter.

During the past year, a study has been made of the organic matter in Connecticut tobacco soils in order to ascertain the approximate level of organic content in average tobacco soils and whether or not the system of tobacco culture usually practised in this region has a tendency toward depletion in the supply of organic matter in the soil.

Results of analyses of many samples of surface soil from Connecticut fields of various types of soil and under different agricultural management show the following results:

	No. Soils included in study*	Average percent organic matter in surface soil
Upland loam and fine sandy loam soils under dairy farm rotations, chiefly cropped to corn and grass hay	41	4.27
Well drained upland loam and fine sandy loam soils in permanent pasture	29	4.39
Sandy loam and fine sandy loam soils in tobacco	70	3.18
Very sandy tobacco soils	31	2.53

* Only well drained soils were included in this study.

It is evident that the amount of organic matter in all Connecticut soils is much higher than that of similar soils in states farther south along the Atlantic seaboard. An explanation of this fact is to be found in the difference in climate. With the same amount of rainfall, the organic content of the soil increases with decreasing temperature. This is in accord with well known physical laws, since the greater the temperature, the more rapid are the processes which produce destruction of organic matter in the soil.

As compared to the somewhat heavier upland soils, the tobacco soils are significantly lower in organic content. Within the tobacco district, the excessively sandy soils are more deficient in organic matter.

Investigators in the prairie region have found that there is a rapid decline in organic matter during the first few years after the

[1] Waksman, S. A. 1927. Principles of soil microbiology. 897 pp., Baltimore: Williams and Wilkins Co.

virgin soil is put under the plow. The heavy textured soils of Nebraska were found by Alway[1] to lose as much as one percent per year of their original organic content during the first thirty years of cultivation. Russell[2] and Shutt[3] both concluded that this loss becomes less with increasing periods of time. Such soils, although still very high in organic matter, have been depleted to the point where serious ill effects are to be observed.

On the other hand, the results of culture on the organic content of the soil in older agricultural regions and with somewhat different climate have frequently shown no ill effects. In the famous Broadbalk field plots at Rothamsted, wheat has been grown continuously since 1852 on Plot 8 without any organic fertilizers or manure, on commercial fertilizers alone, maintaining the yield at a consistently high level during the entire period, and with no evidences of decline. White[4] reports that applications of a mineral fertilizer containing only phosphorus and potassium has maintained the organic content of the soil during 40 years of a grain rotation. Bear and Salter[5] found that on a plot with a complete fertilizer containing only minerals, and with the removal of 117,910 lbs. of produce in 15 years, there was 3.04 percent organic matter in the soil at the end of the period, while a plot with no fertilizer, from which was taken only 40,960 lbs. of produce, showed only 2.14 percent organic matter. Bear[6] states that "soil organic matter is largely a by-product of those farming practices which result in large crop yields."

In order to throw light on the possibilities of depletion of organic matter in soils under continuous tobacco culture, two methods of study were followed.

The first of these was a comparison of the organic content of the plots of the nitrogen series at Windsor, on Merrimac sandy loam soil, sampled in the springs of 1925 and 1927. Results of the analyses are shown in Table 26.

[1] Alway, F. J. 1909. Changes in the composition of the Loess soil of Nebraska caused by cultivation. Neb. Agr. Exp. Sta. Bull. 111.

[2] Russel, J. C. 1927. Organic matter requirements of soils under various conditions. Jour. Amer. Soc. Agron. 19: 380.

[3] Schutt, F. T. 1925. The influence of grain growing on the nitrogen and organic matter content of the western prairie soils of Canada. Jour. Agr. Sci. 15: 162.

[4] White, J. W. 1927. Soil organic matter and manurial treatment. Jour. Amer. Soc. Agron. 19: 389.

[5] Bear, F. E., and Salter, R. M. 1916. The residual effects of fertilizers. W. Va. Agr. Exp. Sta. Bull. 160.

[6] Bear, F. E. 1924. Soil Management. 255 pp., New York: J. Wiley and Sons.

TABLE 26. ORGANIC MATTER IN SOIL FROM NITROGEN SERIES.

Plot No.	Nitrogen treatment	Percent organic matter 1925	1927
1	1/5 N in nitr. soda	2.53	3.24
2	½ N in nitr. soda	2.48	2.52
3	1/5 N in sulf. am.	2.60	2.38
4	½ N in sulf. am.	2.76	2.72
5	All N in organics	2.98	2.79
6	½ N in fish	3.02	3.10
7	½ N in tankage	2.28	2.72
1*	1/5 N in nitr. soda	2.86	2.93
2*	½ N in nitr. soda	3.29	2.95
3*	1/5 N in sulf. am.	3.69	3.41
4*	½ N in sulf. am.	3.38	3.55
5*	All N in organics	3.24	3.50
6*	½ N in fish	3.21	3.12
7*	½ N in tankage	3.67	3.41
1**	1/5 N in nitr. soda	3.46	3.17
2**	½ N in nitr. soda	2.91	2.91
3**	1/5 N in sulf. am.	2.81	2.95
4**	½ N in sulf. am.	3.08	3.29
5**	All N in organics	3.15	3.21
6**	½ N in fish	2.83	3.31
7**	½ N in tankage	3.71	3.45

SUMMARY AVERAGE OF ALL PLOTS TREATED ALIKE.

Plot No.	Nitrogen treatment	Percent organic matter 1925	1927	Change 1925–27
1	1/5 N in nitr. soda	2.95	3.12	+.17
2	½ N in nitr. soda	2.89	2.80	—.09
3	1/5 N in sulf. am.	3.06	2.91	—.15
4	½ N in sulf. am.	3.07	3.18	+.11
5	All N. in organics	3.12	3.16	+.04
6	½ N in fish	3.30	3.18	—.12
7	½ N in tankage	3.22	3.19	—.03

It is obvious from inspection of the data that neither in 1925, after three years of various treatments of different combinations of organic and mineral forms of nitrogen, or in 1927, after five years such treatment, has there been any appreciable effect upon the amount of organic matter in the soil. It is also seen that between 1925 and 1927 there was no consistent change in the amount of organic matter on the various plots.

One must realize that the time elapsing between sampling in this study may easily be too short for the slight changes that occur to be revealed in the analysis. Hence it was thought that a comparison between tobacco fields which have been cropped for various periods might show evidences of depletion in the older fields if any tendency toward diminishing organic content actually exists. Samples from one hundred and thirty fields were analyzed for organic matter. (In this and other similar analyses, organic matter was calculated from the amount of inorganic carbon by using the factor 1.724.)

The results are reported in Table 27 according to both character of soil and time in tobacco.

TABLE 27. ORGANIC MATTER IN TOBACCO SOILS.

	Percent organic matter		
	Lowest	Highest	Average
Sandy loams and fine sandy loams			
21 soils 0 to 6 years in tobacco	2.10	4.89	3.16
26 soils 7 to 20 years in tobacco	2.24	5.45	3.18
27 soils over 20 years in tobacco	2.24	5.14	3.20
Very sandy soils			
16 soils 0 to 6 years in tobacco	1.98	4.17	2.82
15 soils over 6 years in tobacco	1.41	3.21	2.24
Loams and very fine sandy loams			
6 soils 0 to 6 years in tobacco	2.12	3.69	3.13
8 soils 7 to 20 years in tobacco	2.31	4.52	3.49
10 soils over 20 years in tobacco	2.22	3.78	2.80
Soils of all types			
43 soils 0 to 6 years in tobacco	1.98	4.89	3.03
44 soils 6 to 20 years in tobacco	1.41	5.45	3.03
43 soils over 20 years in tobacco	2.22	5.14	3.06

With sandy loam and fine sandy loam soils there appears to be no appreciable difference either in range or average amount of organic matter in the soil, regardless of the length of time the field has been cultivated for tobacco. These textures include the most typical tobacco soils. The amount of organic matter would seem to be sufficient to provide satisfactory conditions in soils of this character.

The very sandy soils (containing less than 20 percent silt and clay) show evidences of decrease in organic content with the longer periods of cropping. There was an insufficient number of fields in tobacco for over twenty years to justify their separation into a group.

The small number of the loams and very fine sandy loams in each time class is probably insufficient to show any definite correlation, but it was deemed advisable to separate them from the lighter textured soils.

A tabulation of all the soils shows that 43 fields in tobacco over twenty years show almost exactly the same average amount of organic matter in the soil as the same number of fields in tobacco for less than seven years, in nearly all cases after a long period of practical non-use for agricultural purposes. Many of the fields in the latter group were direct from woodland.

Since there is no significant decrease or increase in the organic content of soils under tobacco culture of the type ordinarily practised in Connecticut, except in the case of the excessively sandy soils, the decomposition of organic matter must be constantly offset by organic matter returning to the soil. No figures are available to show the annual decomposition of organic matter in tobacco soils, but some estimate can be made from the amount entering the soil. The fertilizer used in the tobacco district of the Connecticut Valley usually contains about 2,000 lbs. of organic material as cottonseed meal, castor pomace, fish, etc. If the tobacco stalks are returned, about 1,000 lbs. of organic matter is thus contributed. Roots and other crop residues furnish perhaps 500 lbs. of organic matter on an airdry basis. Thus the annual amount of organic matter added to the soil under continuous tobacco cropping without cover crop or manure is approximately 3,500 lbs. This is as much organic matter as would be contained in from 8 to 9 tons of ordinary manure. When cover crops or manure are used, the return of organic matter to the soil is correspondingly greater, but practise in respect to their use is so variable that it is difficult to estimate the average conditions.

The decomposition of the annual increment of organic matter entering the soil is probably quite rapid. DeTurk[1] in studies of the cumulative effect of crop residues on the Illinois fertility plots found that non-legume residues decompose rapidly when incorporated in well drained soils and that decomposition of this material was at least eighty percent.

Cottonseed meal, a highly nitrogenous, organic material, is readily decomposed in the process of liberation of its nitrogen. Its decay furnishes an important source of energy to the micro-organisms of the soil.

From the above, it appears reasonable to assume that most of the annual decomposition of organic matter is from recent crop residues, organic fertilizers and manure. The small, undecomposed residue from these sources is about equal to the amount slowly decomposing from the relatively inert organic matter which has remained in the soil in a well-humified condition for a long period.

Excessively sandy soils, under cultivation, provide optimum conditions for loss of more of the organic matter of this older type, in addition to a fairly complete decomposition of recent crop residues and manures. Thus it is more difficult to maintain the organic matter of such soils at their original level.

[1] DeTurk, E. E. 1927. Organic matter supplied in crop residues. Jour. Amer. Soc. Agron. 19: 369.

PROGRESS REPORT ON THE COVER CROP EXPERIMENTS

The problem of a winter cover crop for tobacco soils was discussed in some detail in our report for 1925.[1] Evidence was submitted to show that the timothy cover crop—which is the most commonly used one in Connecticut—is of questionable value for this purpose. Considerable evidence has accumulated since that time both in Connecticut and in other states to show that although it serves the purpose of preventing blowing and washing of the soil, timothy also has a depressing effect on the succeeding crop of tobacco. It is conceivable that there may be some fields and some conditions where this injurious influence has not operated and this explains why some growers believe their crop is benefited. Since such conditions have obviously not been present wherever controlled experiments were conducted, it seems likely that there are many fields which are injured by timothy cover crops. The evil effect is correlated with the root malady which has received the name of *"brown rootrot"* but since we know so little about this disease, we are not warranted in concluding that *all* cover crops will have the same depressing effect. The purpose of the experiments which were started at the Windsor station in the fall of 1925 was to see whether there are other crops which can serve all the useful purposes desired but without the bad after-effect of timothy.

The crops selected for test were timothy, rye, redtop, vetch, alfalfa, barley, spring wheat and oats. The first three are nonleguminous crops which live over winter, the second are examples of legumes, the last three are crops which make a large growth during the fall but die during the winter. Use of the latter three does not involve the practice of plowing under a green crop, the plants being dead and dry in the spring.

The land selected for this experiment is on Fields V and VII of the station farm and is the lightest and most sandy soil on the farm. It is believed that such soil would be most likely to show any benefits derived from cover crops. This land is not entirely uniform since it slopes in several directions from the top of a knoll and some plots are thus on somewhat more productive land. An effort was made, however, to distribute the check plots in such a way as to overcome this inequality.

The cover crops were sowed just as soon as the tobacco was harvested; August 29 in 1925, August 25 in 1926, and August 17 in 1927. All made a good growth before winter; the wheat, barley and oats were about a foot high before they were killed by freezing and made a dense mat of tops which effectually prevented blowing or washing of the land. The land was not inoculated with

[1] Conn. Agr. Station, Tobacco Bul. 6, 1926, p. 55.

bacteria for the legumes during the first year and as a result, nodules were not abundant on the roots. It was inoculated the second year and there has been an abundance of nodules since that time. The crops were plowed under on May 6 (Field VII) and May 13 (Field V) in 1926 and on April 30 in 1927.

The fertilizer mixture applied to all plots is the same as described under the manure experiments (page 64). There are 22 one-twentieth acre plots in this experiment. Each cover crop is on duplicate plots. The time of setting, harvesting, stripping and sorting is the same as described under the manure experiments.

During the very dry year of 1926, the growth on all of these plots was poor and the quality of the cured crop so unsatisfactory that it was not sorted. The yields only are presented in Table 28.

The season of 1927 on the other hand was very wet and therefore favorable to growth on this light, well-drained land. The tobacco was of good quality but of low yield. Some of the plots showed evidences of starvation before harvesting on August 4-7. Differences in growth, however, were not marked during the summer.

The tobacco from all the plots was sorted in December and was in good condition.

The yield and grading records are presented in Table 28. On account of the soil inequalities previously mentioned it will be necessary to discuss the results for each cover crop separately.

TABLE 28. COVER CROP SERIES YIELD FOR 1926–27. SORTING RECORDS FOR 1927.

Plot No.	Cover crop	Yield per A		Percentage of Grades, 1927								Grade index 1927
		1926	1927	L	M	LS	SS	LD	DS	F	B	
C6	Timothy	1373	1203	17	10	14	6	29	7	14	3	.450
C6–1	Timothy	1666	1278	15	12	12	9	33	4	12	3	.443
C7	Barley	1430	1296	19	14	10	8	31	3	13	2	.472
C7–1	Barley	1507	1357	12	11	16	6	37	2	14	2	.436
C8	Rye	1455	1387	21	13	7	8	37	2	11	2	.480
C8–1	Rye	1717	1404	21	17	7	6	32	3	11	3	.488
C9	Oats	1678	1356	15	14	14	6	36	2	11	2	.461
C9–1	Oats	1621	1371	18	11	14	8	36	2	10	2	.478
C10	Vetch	1642	1430	7	9	16	7	44	2	13	2	.392
C10–1	Vetch	1479	1399	11	12	16	6	39	2	12	2	.434
C3	Check	1279	1062	7	5	14	10	31	5	16	11	.344
C5	Check	1426	1221	11	8	18	14	27	8	11	3	.419
C3–1	Check	1618	1343	13	11	15	9	34	2	12	4	.435
C5–1	Check	1612	1291	20	15	9	10	29	3	11	3	.481
C12	Alfalfa	1243	1198	13	15	9	9	39	2	11	2	.435
C12–1	Alfalfa	1191	1238	12	13	13	8	37	2	14	1	.430
C13	Redtop	1104	1212	10	14	8	10	38	3	15	2	.399
C13–1	Redtop	1174	1240	16	16	9	5	37	2	13	2	.455
C15	Wheat	1364	1261	6	9	15	11	39	3	14	3	.377
C15–1	Wheat	1137	1210	17	14	7	7	36	4	13	2	.448
C14	Check	1285	1161	4	7	17	9	36	4	17	6	.350
C14–1	Check	....	1217	6	9	15	7	38	4	17	4	.368

ALFALFA, REDTOP, AND WHEAT

These six plots along with the two adjacent check plots (C14 and C14-1) were on Field V and cannot be compared directly with the other cover crop plots. They must be compared with their own checks.

The average yield of the check plots was 1,189 lbs. per acre as compared with 1,218 for alfalfa, 1,226 for redtop, and 1,236 for wheat. Thus all show a small increase due to the cover crop in the wet year of 1927. During the extremely dry year 1926, however, the check plots showed a slight advantage over the cover crop plots. Since, however, the entire crop was very poor on this field in 1926 we are inclined to attach more weight to the 1927 results than to those of the previous year.

From a study of the yield records, sorting records and condition notes (many of the leaves tended to be yellow and dead) it would seem that all of these plots, being on a light leachy soil, suffered somewhat from shortage of nitrogen or overripeness but that the effect was most pronounced on the plots without cover crops. This resulted particularly in a lower quality but also in a somewhat reduced yield.

TIMOTHY, RYE, OATS, BARLEY, AND VETCH

These plots were on Field VII and must be compared with the checks C3, C5, C3-1, C5-1. Since the field is not of uniform fertility it is probably best to compare in each case with the *nearest* check rather than with an average of all checks. We may analize the results for each of these cover crops:

Timothy. Since the timothy plots were immediately adjacent to the C5 check plots they should be compared with these two rather than with other check plots.

C5	Check	yielded 1426 lbs. in 1926 and 1221 in 1927.
C6	Timothy	yielded 1373 lbs. in 1926 and 1203 in 1927.
C5-1	Check	yielded 1612 lbs. in 1926 and 1291 in 1927.
C6-1	Timothy	yielded 1666 lbs. in 1926 and 1278 in 1927.

Since in three comparisons out of four, the check plots yielded more than the timothy plots we may conclude that timothy has at least not increased the yield during the first two years but has had a somewhat depressing effect. The average grade index was about the same for check and timothy plots in 1927. No quality records were made in 1926.

Barley. These plots also should be compared with the C5 plots which were nearest.

C-5	(Check)	yielded 1426 lbs. in 1926 and 1221 in 1927.
C7	(Barley)	yielded 1430 lbs. in 1926 and 1296 in 1927.
C7-1	(Barley)	yielded 1507 lbs. in 1926 and 1357 in 1927.

The yields in 1926 are contradictory but the results in 1927 are decidedly in favor of the cover crop.

Rye. The rye plots were nearest the C3-1 check and should be compared with it. Both in yield and in quality, these plots exceeded the check in 1927. In 1926 one exceeded the check while the other was not quite as good. Altogether, the results are in favor of using a rye cover crop.

Oats. In every comparison both years, the yield on the oats plots was larger than any of the check plots. The grade index in 1927 was also somewhat higher for the oats plot. These results are uniformly favorable to the use of an oats cover crop.

Vetch. The yield on these two plots was the highest of any of the field in 1927 and 3rd highest in 1926 but the color of the tobacco was dark and greenish with a high percentage of dark grades resulting in a low grade index.

For the conditions of the experiment and for 1927 only, we may say that:

1. All the cover crops with the exception of timothy increased the yield.
2. The grade index was higher on all of them with the exception of vetch which seems to have caused the tobacco to be heavier and darker.
3. Oats, barley, rye and wheat gave the best results.

TOBACCO MOSAIC[1]

G. P. Clinton and Florence A. McCormick

While Jenkins, in his History of Connecticut Agriculture, states that the Indians cultivated tobacco and that prior to 1801 more than ten tons were grown yearly in this state, we have been unable to find even a casual reference to the mosaic disease occurring here prior to 1898. It was in the Station's Report (pp. 242-60) for that year that Sturgis, then Botanist, published the first scientific discussion of the trouble in the United States, although several

[1] The year 1927 was marked by an unusually severe outbreak of the mosaic disease (calico). In view of the great interest which has thus been aroused, and to answer as far as possible the many questions which we have had, it semed wise to include this discussion in the present report.

European investigators had been writing about it for a few years previously.

In 1900 Loew (U. S. Dep. Agr. Rep. 65: 24-27) in his "Physiological Studies of Connecticut Leaf Tobacco" also had a short discussion of this trouble, while Woods (U. S. Bur. Pl. Ind. Bull. 18) in 1902 made the first general treatise on the disease in this county. Allard, after a preliminary article in 1912, published his investigations and observations (U. S. Dep. of Agr. Bull. 40), part of which were conducted in this state, in 1914. Chapman, working at the Massachusetts Station, published a preliminary article in the report of that Station in 1913 and an extended report in 1917. Thus most of the early work on the disease in this country, except that by Selby, recorded in the Ohio Station Bulletin 156 in 1904, centered in or referred to the tobacco grown in the Connecticut Valley.

The senior writer first began his studies of tobacco mosaic in the summer of 1906 when his attention was called to a serious outbreak of the trouble at Portland, Conn. The results of his several years' study were published in the Report of this Station (pp. 357-424) for 1914. About five years ago he again, with the junior author, took up the study of this disease in the hope of throwing further light upon its causal agent. No printed report of these later investigations has yet been published; the results however, have been informally discussed in scientific meetings and some of them are mentioned in this article.

EFFECT ON HOST

We shall not take much space in describing the effect of this disease on the tobacco plant since the tobacco growers of the state are all more or less acquainted with the disease. It might be well, however, to state that at first it was generally known here as "Calico". Such restricted terms as "frenching", "brindle", "mongrel", and "grey top" have been somewhat in use. Frenching has also been used to apply to "strap" leaf plants even when mosaic was not present.

The chief characteristics of mosaic are manifested in the leaves, as shown by irregular areas of lighter or yellow-green color mixed with the normal green tissues. This gives a mottled or mosaic effect. Sometimes, however, a narrow band of tissue along the veins is of a deeper green color. Other cases show the yellow-green areas almost white. This mottling is due to the destruction of the chlorophyll, or green coloring matter, in these areas and as a result the surrounding tissue grows faster, often giving a puckered effect to the leaf. In some cases the leaves are more or less distorted, extreme cases being the "strap" leaves.

In general the mosaic leaves and plants are slightly smaller than the healthy ones but if mosaic of a serious kind occurs in the very young plants extreme dwarfing or malformation may occur. Besides this decrease in yield mosaic leaves, because of their more brittle nature, and their susceptibility to sun scorch are less valuable for cigar making and any considerable amount of mosaic in a crop is likely to reduce its value on this account. Some growers therefore refuse to harvest mosaic plants.

Calicoed plants are especially susceptible to sun scorch, when sunny, hot days suddenly follow a damp or rainy period. In such cases large irregular areas of the calicoed leaves are killed and turn a reddish-brown color known as "rust" usually called "red rust" to distinguish it from other leaf spots that occur in non-calicoed leaves. Billings in his book, "Tobacco, its Culture, Manufacture and Use", published in Hartford in 1875, recognized this trouble under the terms "Brown Rust" or "Firing", though he made no statement concerning calico which no doubt often existed as a contributory trouble.

CAUSE?

Since Sturgis' original article in 1898, much has been learned concerning mosaic of tobacco, and especially since 1914 concerning mosaic troubles in general. In fact in recent years mosaic diseases have been written about and discussed at botanical meetings perhaps more than any other one subject. They have now been recorded for a great variety of plants, and recently experimenters have begun to describe different types of mosaic on the same plant.

Yet, despite the increased knowledge along various lines, we are still ignorant of the exact causal agent of mosaic for any of these plants. Of course various theories, suggestions and beliefs have been brought forth but as yet none of these have been backed by sufficient evidence to gain general support. Some of these were made by the earliest investigators, and some by the more recent ones. The writers have tried to gain evidence to support belief in any of them, without prejudice to a particular one, but have to admit that so far they have failed.

Without going into detail the following may be named as some of the suggestions as to causal agent of mosaic that have been advanced: (1) An Ordinary Bacterium; (2) Enzymes; (3) A Toxin; (4) A Vital Fluid; (5) Environment; (6) An Ultra-microscopic Bacterium; (7) Bacteriophage; (8) Foreign Plant Protoplasm; (9) A Slime Mold; (10) A Protozoan; (11) A Chytridiaceous Fungus; (12) Mitochondria or Elaioplasts of Other Plants; (13) A Filterable Virus. Most of these names are difficult enough to make the origin obscure to the layman, even if they represented the true causal agent.

Without defining what the active principal of a "virus" is, the phrase "filterable virus" is now generally applied to the liquid from diseased tissues which after passing through a fine earthen filter still retains the "infective principal" that will produce the disease in healthy tissues when inoculated into them under favorable conditions. Such is the case with the liquid squeezed from mosaic tobacco tissues, so investigators are agreed in calling it a "filterable virus" but as to its real nature we are still in doubt.

We do know, however, from Duggar's work (Ann. Mo. Bot. Gard. **8**: 354) that the infective principal that passes through these filters is so small that the particles are less than one thirty-third of a micron in diameter. As a micron is one twenty-five thousandth of an inch in length, these particles are much smaller than the smallest of known living things. For instance a round bacterium one micron in diameter is comparatively small for bacteria, the smallest of known living organisms, and yet it would take over thirty-seven thousand of these infective particles (if round) of the mosaic virus to make one of these round bacteria. This seems too small for them to be living organisms.

Again, so far, no one has been able to multiply these infective particles of virus outside of living plant tissues. There is no doubt that they are recreated or multiplied within mosaic plant tissues, however, since one can go on infecting healthy plants from previously infected mosaic plants through countless generations, even if one starts with a very diluted and small amount of mosaic juice on the first plant.

KNOWN FACTS OF MOSAIC

While we cannot yet properly classify the causal agent, we still have learned much about it and its relation to its hosts. For example, the senior writer was the first to prove that tobacco mosaic juice could produce mosaic diseases on other hosts when, in 1907, he infected tomato plants with it. Since then investigators have claimed to have infected a great variety of plants with it or *vice versa*. More recently, however, some are claiming that different hosts have different mosaics in many cases, while others describe several distinct virus, if not mosaic, diseases for both tobacco and potato. Our experience has been that, for a number of plants belonging to the same family as the tobacco such as tomato, pepper, ground cherry and petunia, infection from mosaic tobacco juice, through finger inoculation, is usually successful but with plants outside this nightshade family, even though in nature they sometimes developed mosaic troubles, similar inoculations with mosaic tobacco juice usually or always fail.

It has long been known that infection of tobacco plants could take place by getting mosaic juice on one's fingers and then rubbing healthy plants with them. Later Allard found that lice also could inoculate plants when traveling from mosaic to healthy ones. In ordinary seasons we believe that field infection of tobacco plants in this state takes place largely by "fingering" but the past

season, in which mosaic was so prominent, was very favorable for the development of lice on all kinds of plants and especially so on tobacco, and they apparently were an important factor in the unusual amount of mosaic tobacco.

It has been found that the mosaic virus lives over in certain perennial plants and that weeds of this nature are a source of infection for cultivated annual crops in their vicinity through lice migration, etc. We noticed this was the case in several fields of cucurbits that showed unusual mosaic infection last year.

We have learned that the "virus" is not carried in the seed of mosaic tobacco so that this is not a source of infection, which is very important to know. Likewise experience has shown that the virus does not live, at least to any great extent, in the soil over winter, since a field badly infected with mosaic one year is just as likely to be free from it the next as an entirely new field, with other conditions for the two exactly the same. We have not proven, on the other hand, that an occasional plant in a field may not have become infected from protected mosaic tobacco refuse in the soil.

We do know, however, that old tobacco refuse that has been kept dry in warehouses, barns, etc., is a decided menace in producing the disease if used in connection with young growing plants. Dried mosaic leaves kept in the herbarium as specimens for 18 to 24 years have been used by the writers to produce mosaic in healthy plants. Likewise liquid from fresh mosaic leaves, partially preserved, has produced the disease after 18 years. Valleau and Johnson of Kentucky (Phytopath. **17**: 517) have also shown that chewers of "natural leaf" tobacco can finger and spit the disease into seed beds, but such infection is not so likely to occur in this state.

While the "virus" of the disease is so easily destroyed by the moist winter conditions or by short exposure to moist heat below the boiling point, it is still very resistant to certain chemical substances at even longer exposures, such as, various strengths of alcohol, ether, toluol, corrosive sublimate, hydrogen peroxide, etc.

It was early learned that the mosaic virus injures only the young growing leaves. This means that when a growing plant is infected the mature leaves show no indications of the injury and only the upper younger growing ones become mottled; also that any sucker or sprout growth later on also becomes mottled. This is important because in the general handling of a tobacco field throughout the season, if there is only a fair amount of mosaic present at the beginning, by the end of the season most of the plants have become infected, and this shows either in the subsequent growth of leaves, sprouts or suckers. As the latest growth is never harvested, the injury to the crop, however, is not greatly increased by its presence if the marketable leaves have escaped injury.

While the mature leaves of a tobacco plant at the time of its infection will show no indication of mosaic to the naked eye, we do know that in time the virus of the disease may run down into them and the juice from their tissues is just as effective in producing the disease as that from the evidently mottled leaves above. So the macroscopic appearance of these leaves is not a sufficient test of their ability to produce mosaic infection. However, we have a microscopic test that is reliable. It will also usually detect mosaic in infected plants before visible signs appear and in some cases of slow development of mottling a long time before. This test is the presence of "plate crystals" in the cells of the infected tissues, especially in the plant hairs where they are readily detected, as these crystals are never seen in healthy tobacco.

A normally growing tobacco plant inoculated with the mosaic virus will show indications of the disease through mottling of the young leaves in 7 to 14 days after inoculation. On the other hand if the conditions of temperature, moisture or food supply are such that the plant is at a stand still or is making very slow growth, the appearance of the disease is quite apt to be delayed proportionately. We are even of the opinion that with these unfavorable conditions for plant growth, infection does not always, or at least not so readily, take place, so that we can see here the possibility of favorable and unfavorable weather conditions influencing the amount of mosaic that develops in the tobacco fields. We reach this conclusion also partly from our work with greenhouse plants under these variable conditions.

Once a tobacco plant becomes visibly infected with mosaic it rarely if ever outgrows it. There may be rare cases where the new leaves do not show the mosaic mottling but the mosaic ones, even if the mottling fades out, will still be a source of infection. Johnson of Wisconsin (Phytopath. 11: 452) has shown that there is an optimum (28°-30° C.) and a maximum (about 36° C.) temperature for the appearance of mosaic tissue in the tobacco leaves and that when the plant is grown above the maximum, mosaic fails to appear in the new growth, thus showing at least arrested development. However, these were controlled greenhouse experiments and just how applicable they are in explaining the effect of heat in field plants growing under constantly varying temperatures is not certain. However, we think we may assume that temperatures above 36° C. are unfavorable for the development of mosaic in field tobacco.

It takes some time after the virus is inoculated into a leaf before it becomes general throughout the plant. It moves upward in the stem toward the young growing leaves faster than it does downward into the lower mature leaves. If a single leaf is inoculated it takes some hours to move through the leaf into the stem. The length of time apparently varies according to the part and age of the leaf inoculated and how fast the plant is growing. Under ordinarily favorable conditions, a mature leaf has remained on the plant after inoculation for four days without the virus reaching the stalk and becoming a source of general infection, while a very young inoculated leaf has produced general infection after the second day.

PREVENTIVE MEASURES

With the preceding facts in mind, based also partly on practical experience, the following precautionary measures are advocated. As there is no known cure for mosaic, all treatments are preventive rather than remedial. In the first place the seed bed is the most important factor. Let mosaic get only a fair start in a seed bed and the chances are that there will be injurious outbreaks in the field. It is often hard to detect mosaic in the seed bed, because the plants are young when pulled and do not always show it even when present. The seed bed, however, should be carefully watched and if any mosaic or suspicious plants are seen these with the surrounding plants should be pulled up without touching the other plants. As mosaic is killed by moist heat, steam sterilization of seed beds for other purposes no doubt helps to keep the trouble down. If the trouble shows in the beds with no apparent reason, it may be desirable to make new beds.

The following negative precautions should also be followed with seed beds: (1) Do not make the beds on land that was in tobacco the previous year, as some of the tobacco refuse may harbor enough of the virus to infect a plant or two which will favor spread of the trouble by handling or by lice to other plants. (2) Do not use tobacco stalks, tobacco water or tobacco refuse of any kind on the beds for any purpose, as this is liable to bring in serious trouble if the mosaic virus is present in it. (3) Do not allow the men to chew "raw" tobacco while tending the beds. In weeding, pulling, etc., do not handle the plants more than is necessary, and see that the hands are kept clean by an occasional washing with soap and water. (4) An outbreak of lice, of course, should never be allowed in the seed bed.

In the field the most critical time is the transplanting. Men in setting the plants very often get their hands deeply stained with tobacco juice and if any of this happens to be from a calicoed plant they are very likely to infect a number of the plants they set out. The preventive measure of course is to handle the plants so that the juice gets on the fingers no more than is necessary and to occasionally wash the hands. Removal of infected weeds early in the season may help some. In "worming" and "suckering", especially early in the season, care should be used not to touch the calico plants. A survey of the field may be made soon after the plants start to grow and all mosaic plants removed while they are still young. Later removal is of doubtful value.

While it will be a great satisfaction to finally know the exact cause of mosaic tobacco, it is doubtful that when this is definitely determined we will be much better off than at present as to preventive measures for its control, and probably it will bring no positive curative treatments.