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TOBACCO SUBSTATION AT WINDSOR

REPORT FOR 1944

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Connecticut
Agricultural Experiment Station
New Haven

CONTENTS

Tobacco Substation at Windsor

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P. J. Anderson and T. R. Swanback

The twenty-third annual report of the Tobacco Substation at Windsor records the progress of experimental work on tobacco production during the calendar year 1944.

In this, the third war year, the farmers had to contend with just as great, or greater, difficulties as in the preceding year. Labor was scarce, high priced and, frequently, inefficient or inexperienced. Fertilizers, insecticides and fungicides were restricted in supply and kind. Machinery and equipment were deteriorating and few replacements could be obtained. Growers of Havana Seed and Broadleaf estimated the production cost at $500 to $600 an acre. Shade growers counted the cost as high as $1,500.

In order to visualize the effects of war conditions on Connecticut tobacco production, Table 1 and 2 are presented below.

Table 1 shows that there was no increase in total acreage of tobacco harvested during the first two war years but the third showed an increase of 1,300 acres over the pre-war average. This increase was almost entirely in the Shade type. Binder types showed little change in total acreage but there was a tendency to turn from Havana Seed to Broadleaf. From Table 2, it is apparent that the total stocks of Broadleaf are the smallest they have been in 12 years while the Havana Seed stock pile is larger now than it was in the years immediately before the war. As for Shade, despite increased acreage and production, the stocks on hand have remained about the same. This probably reflects the increased substitution of Shade wrappers for Sumatra wrappers, which were formerly used to cover one third to one half of our cigars but which cannot be obtained now.

The last column of Table 2 shows the consumption of cigars in the United States as calculated from the revenue stamps used. This shows a steady increase from 1935 to 1942. The figures after 1942 do not reflect the true consumption picture because 20 per cent or more of all cigars manufactured are now allocated to the armed services and when these are sent abroad they do not require revenue stamps. The figures given are only for that part which remains in this country. The figures for 1944 show a decrease of 10 per cent from 1943. This may be because larger quantities are being sent abroad or, in part, because the manufacturers are not making so many cigars due to shortages of labor and materials. At least, it is well known that smokers are not getting as many cigars as they would like and the figures presented do not reflect the market demand. Many more cigars would be smoked if they could be bought, even at higher prices.

TABLE 1. ACREAGE AND PRODUCTION OF TOBACCO IN THE CONNECTICUT VALLEY FOR THREE WAR YEARS AND A TEN-YEAR PRE-WAR AVERAGE.[1]

Type	Acreage				Production in pounds			
	Average 1932-41	1942	1943	1944	Average 1932-41	1942	1943	(Estimated) 1944
Broadleaf	7,690	6,800	6,600	8,000	11,937,000	10,344,000	11,022,000	13,134,000
Havana Seed	6,860	7,600	6,500	6,600	10,941,000	12,716,000	10,963,000	11,732,000
Shade	6,170	6,100	6,300	7,300	5,941,000	5,644,000	6,324,000	7,682,000
Total	20,720	20,500	19,400	21,900	28,819,000	28,704,000	28,309,000	32,548,000

[1] Data supplied by the New England Crop Reporting Service.

TABLE 2. STOCKS OF TOBACCO ON HAND AND CONSUMPTION OF CIGARS.

Year	Total stocks on July 1, unstemmed basis (1,000 lbs.) Broadleaf	Havana Seed	Shade	Large cigar consumption (Tax paid withdrawals)
1933	39,945	39,410	10,509	
1934	40,144	37,179	9,658	
1935	37,072	31,960	8,371	4,763,884,000
1936	33,895	26,646	7,211	5,182,899,000
1937	34,206	25,684	7,249	5,317,437,000
1938	35,075	27,071	6,746	5,138,743,000
1939	29,374	23,878	6,114	5,311,392,000
1940	28,530	24,828	9,279	5,567,584,402
1941	26,795	25,324	7,864	5,959,846,293
1942	28,504	31,311	7,523	6,206,539,537
1943	23,845	30,205	7,358	5,228,312,882
1944	22,805	27,001	7,731	3,940,620,502[1]

[1] For ten months.

Altogether, the outlook for a strong demand for cigar leaf in 1945 is favorable. Broadleaf appears to be in the best position.

After an all-summer "freeze" on sale of the 1944 tobacco, the OPA lifted it on December 18 and announced ceiling prices of 40 cents in the bundle for the binder types and 49 cents on sorted Broadleaf, while Shade was the same as the preceding year. Practically all crops were sold immediately after the "freeze" order was lifted.

Although weather conditions were not very favorable in 1944, in general, the crop was much better than anticipated. Table 3 shows that the total rainfall for May, June, July and August was only a little over one half of the normal, —less than for any year since weather data have been recorded at the Tobacco Station. Some towns in

TABLE 3. DISTRIBUTION OF RAINFALL IN INCHES AT THE TOBACCO SUBSTATION, WINDSOR, 1944.

		By 10-day periods	By months	Average for preceding 22 years
	1-10	.08		
May	11-20	...	1.93	3.39
	21-31	1.85		
	1-10	.10		
June	11-20	1.80	3.68	3.88
	21-30	1.78		
	1-10	.13		
July	11-20	.58	1.30	3.59
	21-31	.59		
	1-10	.56		
August	11-20	1.14	1.92	3.90
	21-31	.22		
Total (4 Months)			8.83	14.76

the tobacco section were more fortunate than Windsor and had more rain but, as a whole, rainfall was inadequate in the tobacco area.

Damage from hail storms was extensive in 1944, not by one or two severe storms but by an unusual number of small, local storms. Hail damage was recorded on June 24, July 1, 4, 8, 11, 15, 16, 27 and 30, August 4, 5, 14 and 17 and September 2 and 5. These storms damaged about 6,600 acres of binder tobacco but only about 890 acres were totally lost. About one half of the acreage was insured against hail loss. Damage to Shade tobacco was small because the cloth protected it from lighter hail storms. About 25 acres of Shade tobacco were destroyed by hail.

On September 14 a hurricane from the South swept across Connecticut. Fortunately, most of the tobacco had been harvested before that date. Tobacco still in the field was so badly wind-whipped that it was a total loss. Shade cloth was torn and ripped from wires (see Fig. 1). A considerable number of curing sheds were blown over but the tobacco in many of them although damaged, was saved. Loss to the Shade industry was over a million dollars.

Dr. S. B. LeCompte, Plant Psysiologist, resigned on July 1.

Most of the old projects of the Station were continued in 1944. An experiment to determine the comparative value of plowing vs. harrowing the land was started on a two acre plot. Another new pro-

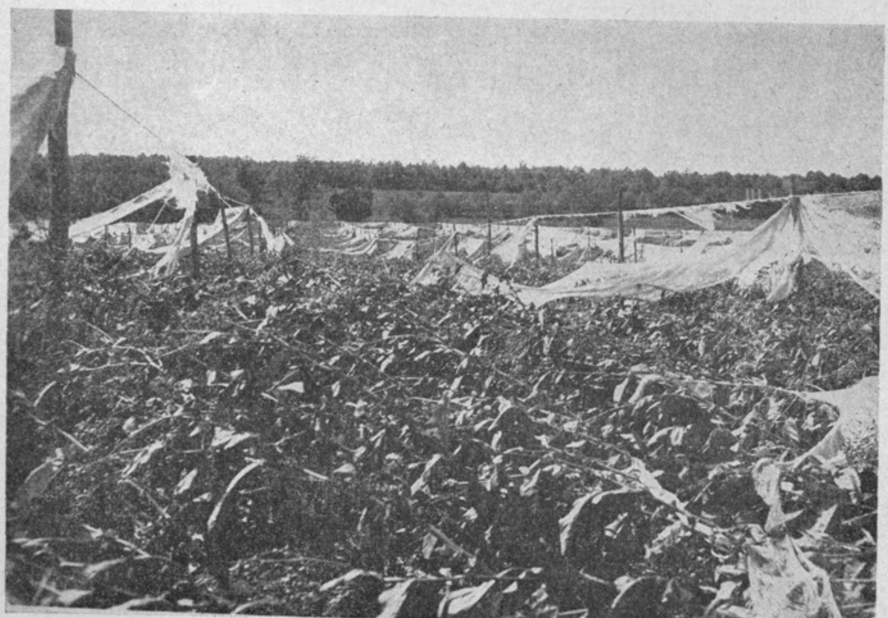

FIGURE 1. Shade field after the hurricane of September 14.

ject this year is a field test of the value of ammonium nitrate as a substitute for other nitrogen sources in the fertilizer mixture.

BAND APPLICATION OF TOBACCO FERTILIZER

The time-honored method of fertilizing the tobacco crop of New England is to distribute the mixture evenly over the field after the land has been plowed and harrowed. It is then mixed with the top soil by harrowing. This gives a uniform distribution of the mixture in the upper six inches or less. A few growers have varied this practice by distributing a small portion in bands where the rows are to be set. Also, addition of a small amount of nitrogen carriers as a "side dressing" after the plants are growing is a common, but not universal, practice.

During the last decade, many agronomists have been experimenting to determine the best location of the fertilizer with respect to the plant. Tests have been made with all sorts of crops in many states and volumes of results have been published. The results show conclusively that no universal rule holds for all crops or even for the same crops under different conditions. Briefly, the best placement depends on (1) the crop, (2) the weather, (3) the soil and (4) the amount and composition of the fertilizer mixture. Probably the simplest way to find out which method is best for a particular crop is to test it accurately under controlled conditions in a given locality. At Windsor, we wished to find out whether row (band) application of fertilizer would produce better quality and higher yields of tobacco, or would permit reduction in the quantity of fertilizer needed or the labor involved. Accordingly, five years ago we began the set of field tests described here.

Plot Lay-out and Experimental Methods

The plots were located on a two-acre field on the Station farm at Windsor. The land, Merrimac Sandy Loam, appears level and uniform, although its productivity varied in previous vegetable trials. Possible effects of these earlier crops or fertilizer treatments were minimized by laying out the tobacco plots at right angles to the preceding long, narrow vegetable plots. The field was first divided into four one-half acre blocks. Each block in turn was divided into 12 plots, measuring 12 feet wide and 150 feet long, and planted with four rows of tobacco. Every treatment was applied on one plot in each of the four blocks, randomizing the arrangement in each block.[1] The early band applications representing three treatments were technically unsuccessful and have been omitted in analyzing the data. Aside from the fertilizer treatment, all cultural operations on the field were uniform throughout the year.

On six plots in each block, the fertilizer was broadcast and harrowed in the usual way. On three others, the fertilizer was deposited

[1] We are indebted to Dr. C. I. Bliss, Biometrician of the Station for advice on plot arrangement and for statistical analysis of the data.

in bands on either side of the row, four inches from the plant stalk and about four inches deep. The fertilizer flowed into the band furrows during setting from a hopper attached to a regular Bemis setter with a feed apron actuated from the axle. The rate of application was regulated by actual trial before starting on the plots.

It has long been the practice of tobacco growers to broadcast the fertilizer a week or more in advance of the transplanting date. To determine the effect of time of application, the fertilizer was applied to half of the broadcast plots a week or two before setting and to the other half at the time of setting. A similar comparison was attempted for the band applications but it proved impossible to set the plants accurately in relation to an earlier band application of fertilizer. This resulted in the loss of many plants from fertilizer "burn", so that the plots with early band applications have been omitted here. The timing of the fertilizer application was a second goal of the experiment.

An advantage claimed for band over broadcast application is that a smaller amount of fertilizer will produce the same results. To answer this, three levels of fertilizer were used. The standard acre application of 2,500 pounds of an 8-4-8 mixture was reduced by one-eighth on a third of the plots and by one-fourth on another third, giving rates of 2,500, 2,188 and 1,875 pounds to the acre. Thus, of the nine plots in each block, six received broadcast and three, band, applications, three of the broadcast plots were fertilized before planting and the others at the time of planting, the three plots for each type of application being fertilized at three different rates.

At time of harvesting, the end plants and the two outer rows of each plot were discarded to eliminate any border effect. Plants which were distinctly not normal, undeveloped "set-overs" and diseased or broken over plants, were discarded. The number of plants available in each plot for measuring the result of treatment varied considerably. They averaged 136, 130, 123 and 108 plants per plot in the years 1941 to 1944, respectively. Both the yield and the grade index for each plot were first adjusted by covariance for fluctuations in the number of plants. Then the adjusted yields were corrected to the equivalent of pounds per acre of 9,000 plants. After the tobacco was cured, it was sorted into the customary grades for Havana Seed tobacco and weighed. The grade index was calculated from the percentage of each grade and length of leaf found in each lot.[1]

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[1] Grade index measures the *relative* value of a lot of tobacco computed from the percentage weight of each grade of leaves in the lot and the relative values of these grades. Assuming that the light wrapper is the perfect leaf of Havana Seed tobacco, it is assigned a value of 1.00. The other grades are assigned values in the same proportion to 1.00 as their market value bore to the price of the light wrapper when this system was established. Here medium wrappers have a value of 0.60; long seconds (19 inches or more), 0.60; short seconds (15 and 17 inches), 0.30; long darks, 0.30; dark stemming (short darks of 15 and 17 inches), 0.20; fillers and brokes, 0.10. The values of these grades have fluctuated during the years that we have used this system of grading but, in order to average results over a period of years, the same system has been retained. To obtain the grade index figure, the percentage of each grade in a lot of tobacco is multiplied by the relative values noted above, the products are added and the sum is divided by 100.

TABLE 4. YIELD AND GRADE INDEX FOR EACH PLOT AFTER INDEPENDENT ADJUSTMENT FOR DIFFERENCES IN THE NUMBER OF PLANTS.

Time and placement of fertilizer	Pounds of fertilizer per acre	Estimated yield in pounds per acre					Estimated grade index					Crop Index
		1941	1942	1943	1944	Mean	1941	1942	1943	1944	Mean	
Early Broadcast	1875	2053	1827	1968	1679	1888	.463	.367	.426	.370	.368	695
		1999	1694	1975	1661		.391	.197	.400	.287		
		1999	1549	2128	2048		.402	.323	.396	.381		
		2276	1535	1901	1923		.442	.258	.385	.404		
	2188	2224	1707	2036	2020	1982	.417	.356	.390	.392	.394	782
		1890	1815	2012	2088		.380	.367	.404	.452		
		2249	1757	2207	2242		.418	.418	.405	.454		
		2112	1465	2060	1834		.386	.308	.368	.393		
	2500	2254	1622	1901	2039	1910	.371	.360	.415	.418	.397	758
		2016	1765	1464	1886		.447	.358	.416	.456		
		1897	1663	1976	2172		.346	.363	.386	.424		
		2288	1686	2048	1880		.422	.357	.385	.429		
Late Broadcast	1875	2188	1663	1865	1878	1933	.447	.359	.391	.302	.395	764
		2132	1634	2066	1926		.393	.362	.410	.390		
		2230	1744	2012	1862		.435	.393	.418	.406		
		2166	1521	1976	2061		.422	.296	.425	.477		
	2188	2177	1953	1908	1752	1955	.469	.396	.430	.434	.410	801
		1914	1622	1865	1732		.406	.306	.397	.395		
		2173	1880	2225	2012		.408	.394	.412	.408		
		2367	1643	2018	2034		.439	.389	.428	.441		
	2500	2129	1804	1816	1703	2034	.506	.354	.442	.286	.418	851
		2270	1951	2066	2101		.421	.452	.419	.446		
		2199	1682	2316	2295		.417	.375	.417	.468		
		2328	1700	1949	2237		.446	.376	.424	.445		
Late Row	1875	2047	1941	1683	1624	1912	.470	.500	.418	.392	.426	815
		1960	1874	1987	1767		.391	.508	.440	.376		
		2255	1783	1920	1990		.426	.432	.419	.346		
		2150	1686	1975	1948		.455	.396	.393	.454		
	2188	2080	1789	1908	1901	1951	.424	.534	.505	.345	.434	847
		2067	1888	1926	1842		.388	.516	.441	.412		
		2326	1879	2134	2029		.442	.491	.446	.401		
		1959	1736	1924	1824		.408	.404	.441	.348		
	2500	2270[1]	1906	2048	2234	2113	.484[1]	.523	.458	.330	.446	942
		2185	1804	2109	2026		.451	.481	.443	.384		
		2293	1997	2206	2284		.461	.475	.426	.418		
		2300	1951	2072	2121		.446	.469	.462	.419		

[1] Missing value replaced by statistical calculation.

Results

This experiment has been repeated on the same plots for five years. In the first year of the test (1940), the carry-over effect of an earlier experiment on the same land increased the variability, so that the data for 1940 have been omitted here. The yields and grading for the other four years are presented in Table 4, adjusted to a uniform stand as noted above. These data have been analyzed statistically with the results summarized in Table 5. The variance ratios (F) for the grade indices have been based upon the so-called "reduced variances" and measure the effect of each treatment factor independently of yield. In terms of both the four-year plot totals and the average trend over the four-year period, a higher grade index was associated with a larger yield. Apart from treatment, the grade index increased 0.014 for each improvement in yield of 100 pounds per acre.

TABLE 5. ANALYSIS OF VARIANCE COMPUTED FROM THE DATA IN TABLE 4. THE GRADE INDEX RESULTS HAVE BEEN CORRECTED FOR THE EFFECT OF YIELD BY COVARIANCE AND REPRESENT REDUCED MEAN SQUARES.

	Degrees of freedom	Variance ration (F) and error variance for: Yield	Grade Index
From 4-year plot totals			
Between blocks	3	5.88[2]	0.85
Broadcast: Early vs. late	1	2.66	2.80
Late: Row vs. broadcast	1	0.39	8.67[2]
Average effect of quantity of fertilizer	1	14.02[2]	0.78
Variability in effect of quantity of fertilizer	5	1.89	0.48
Effect of yield upon grade index	1		4.96[2]
Variance for error	24[1]	19,942	0.001716
From trends in plot results over 4 years			
Broadcast: Early vs. late	1	1.34	0.99
Late: Row vs. broadcast	1	0.04	10.03[2]
Average effect of quantity of fertilizer	1	2.82	0.16
Variability in effect of quantity of fertilizer	5	0.80	2.61
Effect of yield upon grade index	1		10.06[2]
Variance for error	24[1]	13,936	0.000714
From variability about trends in plot results over 4 years			
Late: Row vs. broadcast	2	3.48[2]	21.74[2]
All other effects of treatment	14	1.08	1.64
Effect of yield upon grade index	1		.00
Variance for error	46[1]	12,247	0.00984

[1] Degrees of freedom for grade index diminished by 1.
[2] Statistically significant at $P<0.01$ except for 2 smallest F's where $P<0.05$.

Fertilizer injury. Root burn from too high a concentration of fertilizer adjacent to the plants was a factor which limited the value of the band applications. It was of less importance in the first years of the experiment, but, in the extremely dry year of 1944, it caused the loss of more than twice as many plants on the band application plots as on the broadcast sections, necessitating a great deal of restocking. Many of the undeveloped "set-overs" were discarded at harvest so that 10 per cent fewer plants were taken for data in the banded than in the broadcast plots. Apparently, the placing of so heavy a dose of fertilizer four inches from the plants may cause serious root injury at least in a dry year. This danger is of first importance in weighing the advantages or disadvantages of the two placement practices, and is not fully reflected in the data which exclude the worst "set-overs".

Influence of the time of application of fertilizer. "Late" applications of fertilizer were made immediately before or at the time of setting the plants. On the broadcast plots designated as "early", a period of one to two weeks elapsed between putting the fertilizer in the soil and the setting of the plants. This corresponded to the usual practice of growers. Results from the first four years but without the present adjustment for number of plants were presented in an earlier report[1], to which the reader is referred. The results of another year are now available and have been included in Table 4 with those from 1941-1943, inclusive, for an over-all study. The average yield was 47.0 pounds to the acre greater for the late than for the early broadcast application, while the average grade index improved by 0.0212, a larger increase than that expected from the gain in yield. Neither alone was statistically significant (Table 5), although both were in the same direction. The total increase in relative crop value of 8.1 per cent was not enough larger than the experimental error to consider the advantage in late application of fertilizer as established ($P = 0.075$).

We can conclude that there was no evidence favoring the usual practice of applying the fertilizer early, and there may be some gain in applying it when the plants are set, perhaps through the prevention of early leaching.

Band application vs. broadcast distribution. Comparing the late broadcast with the late row application plots in Table 4, we find very little difference in the average yield for five years—1,974 pounds for broadcast and 1,992 pounds for row. The difference in grade index, however, is greater and statistically significant (Table 5)—.408 for broadcast compared with .435 for row—making a difference of about 7.7 per cent in the relative crop value. It is apparent that the band application of fertilizer gave a better return than the broadcast method. This was expressed in improved grading rather than in increased yield. An adequate explanation of why one method of fertilizer application should give a better grading than another is not apparent. Students of this problem agree that band application results in less fixation of certain plant foods than in the case of broadcasting, thus less of the plant's energy and resources are exhausted in foraging for and absorbing nutrients.

[1] Conn. Sta. Bul. 478:100-103. 1943.

Influence of rate of application. In Table 6, the yields and grade indices are averaged for the four years according to the quantity of fertilizer applied. With each increase in quantity of fertilizer, there was a corresponding increase in yield and grade index. The picture was about the same whether the application was early or late, broadcast or rows, as shown by the lack of significance of the variability in the effect of quantity of fertilizer (Table 5). A similar response to increasing the application of fertilizer has been observed in previous experiments at this Station as published in our reports. In the present investigation, we are more interested in seeing whether a smaller quantity applied at the side of the rows gives results equal to a standard quantity applied broadcast. The crop indices for the late applications in Table 4 indicate that such is the case. As measured by the crop index, the broadcast application of 2,500 pounds of fertilizer gave about the same return as the application in bands of 2,143 pounds or six-sevenths as much fertilizer. This indicates that by using the band method, the grower could reduce appreciably the fertilizer needed.

Summary. We may summarize the conclusions from the five year test:

1. Applying the fertilizer to the soil one or two weeks before setting the plants does not increase the yield or improve the grading. It may just as well be applied at the convenience of the grower up to the date of setting the plants.

2. Band application of the fertilizer increases the grading but not the yield.

3. When the fertilizer is applied in bands, the amount may be reduced below the requirement for a broadcast application without impairing the cash value of the crop.

TABLE 6. QUANTITY OF FERTILIZER.
AVERAGE YIELD AND GRADE INDEX FOR FOUR YEARS.

Fertilizer (pounds per) acre	Yield	Grade index
1,875	1,911	.397
2,188	1,963	.413
2,500	2,019	.420

4. During a dry season there is danger of root injury from a too strong fertilizer solution in the soil if the fertilizer bands are within four inches of the row. Root-burned plants either die or start slowly, necessitate restocking and result in uneven stands. Root injury could probably be reduced by placing the fertilizer bands farther away from the plants but this has not been tested.

THE IRRIGATION EXPERIMENT OF 1944

The rainfall for the summer of 1944 was the lowest we have had in Windsor since records were started here 23 years ago. From this standpoint, it was an ideal year for irrigation experiments. On the test plots, non-irrigated tobacco not only wilted and sun-burned but was quite noticeably stunted. The benefits from irrigation were therefore spectacular this year.

The field. The field selected for the irrigation test is sandy with coarse, sandy subsoil and, therefore, quickly shows the effects of dry weather. It is no worse, however, than hundreds of other tobacco acres in the Valley and, if a grower practiced irrigation at all, he would be most likely to add water to this type of field. The whole lot has a uniform gentle slope and, therefore, is adapted to the method of irrigation used. Each treatment was replicated eight times and there were six check (non-irrigated) plots. This one-acre field was fertilized at a rate of 2,500 pounds of a standard 8-4-8 tobacco fertilizer. Havana Seed was planted May 31. All of the tobacco was tended uniformly, harvested on August 10, cured, and then weighed and sorted into commercial grades. The grade indices[1] were computed from the sorting data.

FIGURE 2. Concentrated nitrate solution is siphoned into the irrigation stream.

[1] See page 270.

Change in method. Irrigation experiments have been carried on every dry year since 1930. Beginning with 1936, they have included plots on which nitrate of soda was added to the irrigation water to compensate for the loss of nitrogen by leaching. Until 1943, the nitrate crystals were distributed by hand in the water as it stood between the rows. This is a rather crude method and, if one is not very careful, may result in uneven distribution of the nitrate. An easier and more accurate method was adopted in 1943 and continued in 1944. The nitrate in solution was introduced at the point where the water leaves the fire hose and starts to run down between the rows. A large carboy containing a concentrated solution of one pound of nitrate of soda to one gallon of water was supported on a movable trestle above the entering stream. From the carboy the solution was siphoned through a rubber tube fitted with a pinch cock which can be adjusted beforehand to deliver the proper amount according to the rate of flow of the water. In 1943 and 1944 this was adjusted to 200 pounds of nitrate of soda to the acre. In order to see whether the concentration of nitrate was uniform at all points as the water flowed down the furrow, analyses were made at four different points in each of several rows. These showed no significant change in strength as the water flowed down. Eight plots received water alone; eight plots, water with added nitrate; six plots, neither water nor nitrate.

Water was applied at a rate of one and one-half to two inches on July 12, July 22 and August 1. No nitrate was added to any plot at the time of the first irrigation because tests showed the nitrate in the soil to be very high at that time. For each of the two later treatments, nitrate of soda was added at the rate of 200 pounds to the acre.

Differences in appearance of the tobacco on the plots were observed a few hours after the first watering and became more pronounced as the dry summer wore on.

The non-irrigated tobacco was short, dark, wilted badly and had many sun burned leaves. On the irrigated plots, the tobacco was larger, more luxuriant and did not wilt. At first, all irrigated plots looked alike but, by August 1, the nitrated plots were darker green, while those which had been irrigated with water alone took on a paler color.

Observations on the cured tobacco in the warehouse showed:

1. *Non-irrigated plots* had short leaves of poor elasticity and color and no quality. Moreover, many of the leaves were yellow and lifeless, typical symptoms of nitrogen starvation. In none of our previous tests had we observed these starvation symptoms in the check plots. Since there was an abundance of nutrients in the soil of these plots, we may assume that either the concentration was so extreme that the roots could not absorb the nitrogen or that the soil was too dry to permit normal nitrification.

FIGURE 3. Effect of irrigation and nitrate. At left, two rows not irrigated. Two rows at right irrigated with nitrate water.

2. *Plots irrigated without nitrate* had larger leaves but many were yellow and lifeless, a condition that we have always found when tobacco was irrigated more than once without addition of nitrate. This results from actual depletion of nitrogen in the soil, as shown by our analyses of soil and leaves in 1936. In other years, when the drouth was not too severe, damage from too much water was often greater than the loss from drouth alone.

3. *Irrigated and nitrated plots* had leaves of the best size, color and quality and there were no yellow leaves. On some of the plots the color was too dark and the veins too prominent, indicating too much nitrogen for this season. A lighter application of nitrate at the second and third irrigation would probably have been better.

The yield and grading records of these plots are shown in Table 8. These data show an increase of 200 pounds to the acre when water alone was used. Another 200 pounds was added to the crop when nitrate was put in the water. The grade index also rose proportionately in the same order. The relative crop value was almost doubled by water and nitrate.

TABLE 7. YIELD AND GRADING RECORDS OF IRRIGATION PLOTS. CROP OF 1944.

Treatment	Yield pounds per acre		Grade index		Crop index	Relative crop value
	Plot	Av.	Plot	Av.		
	1340		.216			
	2110		.347			
Neither irrigated nor nitrated	1101	1526	.179	.255	389.13	100
	1796		.306			
	1366		.229			
	1443		.256			
	1505		.290			
	2057		.369			
	1472		.193			
Irrigated only	1842	1726	.358	.297	512.62	131.73
	1997		.361			
	1553		.241			
	1959		.349			
	1422		.217			
	1821		.328			
	2411		.408			
	1629		.361			
Irrigated and nitrated	2025	1990	.376	.381	758.19	194.83
	2105		.425			
	2192		.446			
	1956		.378			
	1784		.323			

This is the greatest increase we have ever had in the irrigation experiments. Such large benefits could be anticipated only in years of extreme drouth such as 1944.

TOBACCO IRRIGATION EXPERIMENTS DURING FIFTEEN YEARS

In the last fifteen years there have been seven summers during which the tobacco crop in Windsor suffered from drouth. The Station farm differs little from hundreds of other tobacco farms in the Valley either in sandiness of soil or in rainfall. Thus, growers may expect that one out of every two or three years will be a drouth year.

In view of the high acre value of the crop, one might wonder why so few farmers in the Valley practice irrigation. Probably they found many years ago that the mere flooding of a sandy field with water often impaired rather than improved the crop, as our experiments have shown. A second reason may well be that our most valuable type of tobacco, Shade, does not suffer so much from drouth because the cloth conserves water (1) by raising the humidity in the tent and (2) by reducing the wind velocity.

Although we have learned to control most tobacco insects, diseases and fertilizer troubles, the average farmer feels that there is nothing he can do about the weather. It is true that we cannot change the rainfall but we set out 15 years ago to see what could be done about supplementing it. The results of the experiments conducted every drouth year since 1930 have been published from time to time in the annual reports.[1] The reader is referred to these separate reports for discussion of methods and results. It is not our purpose now to review these tests but to state a few general principles of irrigation that they have taught us, to show why the old methods of watering gave disappointing results and how a small change in technique can make irrigation pay every dry year.

The first fact learned was that running water between the tobacco rows whenever they wilt does not usually increase the value of the crop even though it stops the wilting. If we average all the crops shown in Table 8, we find the value of the seven irrigated crops was two per cent less than the non-irrigated. It is true that in extremely dry years like 1944, the non-irrigated tobacco may be so stunted and nearly worthless that pure water will improve it, but we have few years when the drouth is that severe.

Soil and plant analyses showed that the damage from watering was due to leaching of nitrogen from the soil by the stream of water. This depletion is unavoidable with this method of irrigation because it is not practicable to reduce the amount of water used.

In order to maintain the nitrogen supply in the soil, water containing nitrate in solution was used in the later tests. That this kept an adequate supply of nitrogen in the soil was demonstrated by soil and plant analyses and by the value of the crop. The relative crop values given in Table 8 show an average increase (5 years) of 37 per cent by the use of nitrated water in irrigation.

Such are the simple principles of successful irrigation. Now we may consider some of the problems of practical application.

Methods. In these experiments we have used only one method of applying the water. Water is conducted to the higher end or part of the field from a hydrant through two and one-half-inch fire hose and flows down the natural slope in the furrow between the rows. If there is much pitch to the land, it is best to build low dams at intervals in the row, so that the water will stand all along the slope instead of collecting at the lower end. This method was chosen because it is the least expensive, involves the smallest amount of equipment, and has been used most by growers who have practiced any irrigation.

The overhead sprinkling method, whether the apparatus is portable or permanently located, involves much more equipment and labor in setting it up. Growers do not like to dodge around pipes for two or three years in order to use them three weeks. Moreover, they are usually rusted and out of order when needed. The portable whirling sprinkler involves less equipment and has been used successfully by one large tobacco company. The nitrate can be introduced into the water of a sprinkler system but not quite as conveniently as with the surface flow system. The sprinkler system has one advantage in that it gives

[1] Conn. Agr. Exp. Sta. Buls. 391:67-72; 444:264-65; 457:246-47.

TABLE 8. SUMMARY OF SEVEN YEARS OF IRRIGATION TESTS.

Year	Number of irrigations	Nitrate per acre (pounds per application)	Acre yield			Grade index			Crop index			Relative crop value		
			Check	Irrigated	Irrigated and nitrated	Check	Irrigated	Irrigated and nitrated	Check	Irrigated	Irrigated and nitrated	Check	Irrigated	Irrigated and nitrated
1930	3	...	1347	1414	....	.385	.407	...	518.6	575.5	....	100	111.0	....
1934	3	...	1768	1751	....	.335	.246	...	592.3	430.7	....	100	72.7	....
1936	2	100	2114	1937	2152	.336	.346	.445	710.3	670.2	957.6	100	94.3	134.8
1940	2	175	1624	1599	1825	.401	.389	.470	651.2	622.0	857.8	100	95.5	131.7
1941	1	150	1556	1526	1649	.362	.273	.393	563.3	416.6	648.0	100	74.0	115.0
1943	2	200	2081	2175	2213	.395	.412	.418	821.9	896.0	925.0	100	109.0	112.5
1944	3	200	1526	1726	1990	.255	.297	.381	389.0	512.6	758.2	100	131.7	194.8
		Average	1716	1732	1966	.353	.338	.421	606.6	589.1	829.3	100	98.3	137.6

better distribution of the water on the soil surface and, with attention, there need be no leaching.

When and how often? A common fault in irrigating is to wait until it is too late before starting. After the plants are already stunted and are topping out, they are not much benefited. Mere wilting of leaves on a hot afternoon is not a sign that irrigation should start. When they begin to wilt in the morning, do not recover until night, and the experienced grower says they are "standing still", it is time for the first irrigation. Frequency of irrigation will also depend on the weather. In continuous dry, hot weather, it is necessary to repeat once a week but never oftener. Frequently, longer intervals are as good. We have not yet had a season when it was necessary to irrigate more than three times.

How much water? By metering the water, we have found it necessary to apply the equivalent of a rain of one and one-half to two inches at each irrigation. Naturally one irrigates only when the soil is quite dry and, therefore, it absorbs a large amount of water. It is not practical to apply less. With a sprinkler system, one could probably use less water but apply it more often and thus avoid leaching.

How much nitrate? In the experiments of 1934 and 1936, nitrate of calcium was used. In all other tests, nitrate of soda was used. No differences in results were found in comparing the two. We have used quantities varying from 100 to 200 pounds per acre at each application. Since the soil nitrate is usually high in a dry summer, it is rarely necessary to add nitrate at the first application. It is advisable to test the soil between the rows before each application and be guided by these tests in deciding on the quantity of nitrate to add. It should never be over 200 pounds to the acre and frequently this is too much—as in 1944.

Is irrigation practical? According to the data previously cited, the value of the crop can be increased by about one-third through proper irrigation—conservatively, $100 to $200 an acre. Some farms have such fortunate soil water conditions that they rarely suffer from drouth. Manifestly, they should not be irrigated. Fields with rows running down steep grades should not be irrigated. But the majority of tobacco farms have at least some fields which fail to return a profit on dry years. In most cases, these could be profitably irrigated in dry summers. Lack of a suitable source of water would make it difficult on some. Where a community water system is not available, there are usually streams or ponds where a pump can be installed and run by the tractor with which nearly every farm is now equipped. City fire departments usually have condemned fire hose which will not stand high pressure for fire fighting but is excellent for irrigation. It can be bought very reasonably and will last many years. At the Station, we are still using some purchased 15 years ago. Equipment for adding the nitrate consists of a barrel or tub, a few feet of small rubber hose and a pinch cock. Very little labor is used in irrigating and, moreover, during a hot drouth in midsummer, there is little else that the farmer and his help can do about the farm so there should be no labor problem. Extra money outlay for this type of irrigation is thus quite small in proportion to the increased value of a tobacco crop.

RELATIVE VALUE OF PHOSPHATES IN FERTILIZING TOBACCO

T. R. Swanback, H. A. Lunt and P. J. Anderson

Bone phosphates have been the principal sources of phosphorus used in fertilizer mixtures for tobacco in the Connecticut Valley. Because of scarcities of the two most commonly used materials, precipitated bone and steamed bone meal, a search for suitable substitutes was begun in 1940. A preliminary report was made in the Tobacco Substation Report for 1941 (Conn. Sta. Bul. 457: 234-239). The reader is referred to this report for a detailed outline on the experiment.[1] Most of the materials were furnished by the Tennessee Valley Authority.

The effects of the two bone phosphates were compared with those of triple superphosphate, calcium metaphosphate, potassium metaphosphate and potassium calcium metaphosphate. The results were compared with those obtained from check plots which received no special phosphate. A small amount of phosphorus, however, was unavoidably applied to the check plots, because there is no practical way of making a suitable tobacco fertilizer mixture with phosphorous-free materials. The amount added to the checks in this way was about 16 pounds P_2O_5 per acre. All the phosphatic materials listed above furnished 116 pounds P_2O_5 to the acre. The field had been used for vegetable trials for several years before.

Aside from minor variations in the composition of the fertilizer mixtures from year to year, the amounts of nitrogen, potash, calcium and magnesia have been equal for all treatments in the five-year period.

In this period, 1940 and 1941 were favorable years for growing tobacco. The early summer of 1942 was cold and wet, resulting in low yields of reduced quality. The latter part of the 1943 growing season was quite dry. Good yields of excellent quality, however, were produced. In spite of an abnormally dry summer in 1944, yields and grading were satisfactory.

The yields and grade index for the five years are shown in Table 9. The check plots, receiving no special phosphate for five years, produced satisfactory yields. This agrees with earlier results at this Station (Tobacco Station Bul. 5:17-24 and Tobacco Station Bul. 7)

[1] The experiment was started in cooperation with the late Lt. Colonel M. F. Morgan, head of the Soils Department, and was continued with Dr. H. A. Lunt, acting head of the Soils Department, after Dr. Morgan entered military service in 1942.

from which it was concluded that old tobacco soils, in good production, need little or no addition of phosphates.

Annual additions of phosphates modified the yield significantly but had no direct effect upon the grading apart from the general increase in grade index with yield. (Table 10). Results may also be judged from the *crop index* which is the product of mean yield by mean grade index. Since statistical analysis showed a large experimental error in 1940 and one of the metaphosphates was not introduced into the experiment until 1941, the 1940 values were omitted from subsequent analyses. The average relative crop indices for 1941-44, inclusive, reveal three separate groups as follows:

Potassium calcium metaphosphate.....	96.6
Potassium metaphosphate	98.5
No phosphorus	100.0
Precipitated bone	102.3
Steamed bone	103.8
Triple superphosphate	108.0
Calcium metaphosphate	109.6

TABLE 9. YIELD AND GRADE INDEX FOR EACH PLOT AFTER INDEPENDENT ADJUSTMENT FOR DIFFERENCES IN THE NUMBER OF PLANTS.

Source of phosphorus	Estimated yield in pounds per acre					Estimated grade index					Crop index[2]
	1941	1942	1943	1944	Mean	1941	1942	1943	1944	Mean	
	2528	1628	1934	1732		.406	.373	.407	.342		
None	2319	1733	1969	2138	1959	.394	.288	.409	.467	.404	792
P 11	2129	1503	1918	1771		.418	.484	.405	.390		
	2559	1595	1892	1998		.435	.456	.389	.406		
Precipated	2380	1672	1848	1907		.395	.341	.385	.363		
bone	2431	1595	1959	1986	2026	.398	.300	.431	.438	.400	810
P 12	2743	1767	2170	2153		.451	.458	.402	.419		
	1988	1567	2081	2171		.346	.390	.427	.454		
Steamed	2420	1714	1867	1733		.403	.361	.400	.376		
bone	2271	1473	2116	2110	2004	.438	.231	.456	.435	.410	822
P 14	2277	1806	2142	1880		.411	.460	.433	.424		
	2392	1784	1921	2158		.422	.458	.446	.407		
Triple	2416	1700	1889	1825		.414	.427	.405	.388		
super-	2565	1717	1915	2149	2067	.409	.285	.422	.434	.414	855
phosphate	2569	1761	1953	2040		.397	.443	.447	.420		
P 13	2438	1856	2048	2234		.425	.394	.436	.470		
Calcium	2733	1617	1870	2082		.432	.309	.381	.407		
meta-	2499	1675	1844	2224	2084	.428	.218	.416	.415	.416	868
phosphate	2505	1872	2017	2045		.426	.479	.477	.421		
P 15	2482	1792	2065	2026		.478	.506	.449	.418		
Potassium	2008	1614	1915	1605		.429	.396	.419	.382		
meta-	1827	1645	2059	2187	1921	.352	.287	.455	.443	.406	780
phosphate	2378	1761	2072	1995		.447	.497	.353	.427		
P 16	2122	1470	1794	2285		.376	.349	.442	.441		
Potassium	1927	1556	1819	1661		.428	.313	.430	.385		
calcium	1912	1564	2059	2012	1830	.426	.349	.469	.420	.418	765
meta-	1969[1]	1650[1]	1815	1544		.437[1]	.479[1]	.377	.398		
phosphate	1877[1]	1575[1]	2174	2163		.429[1]	.437[1]	.483	.427		
P 17											
"Just significant difference" at P = .05					122						52.3

[1] Missing values replaced by statistical calculation.
[2] Crop index is product of mean yield by mean grade index.

Within groups, yields and relative crop indices differed by less than experimental error. Between groups, differences exceeded the experimental error significantly. (Table 10).

TABLE 10. ANALYSIS OF VARIANCE FROM THE DATA IN TABLE 9. THE RESULTS ON GRADE INDICES HAVE BEEN CORRECTED FOR THE EFFECT OF YIELD AS IN TABLE 5.

	Degrees of freedom	Variance ratio (F) and error variance for: Yield	Grade index
From 4-year plot totals			
Between blocks	3	2.36	12.93[1]
Between treatments	6	4.73[1]	1.77
Between groups	2	11.43[1]	...
Within groups	4	1.37	...
Error for totals	18	26,773	...
From variation between years (within plots)			
Between treatments	18	2.60[1]	0.69
Errors for years x plots	50	17,103	...
Effect of yield	1	...	12.43[1]
Error for all comparisons	67	...	.000958

[1] Statistically significant at $P<0.01$.

In the report for 1941 (see above), it was stated that superphosphate may produce a reddish cast in the colors of the cured leaf. In the 1944 crop, tobacco from only one of the four replicates in the superphosphate treatment had a definite reddish color. The problem of colors is a project in itself and thus not within the scope of this investigation. If there is any possibility, however, that triple superphosphate may interfere in the production of suitable colors, especially in wrapper tobacco, this material will be a second choice.

In recalling the main purpose of the present investigation, namely, to find a suitable substitute for the common bone phosphates, it can be concluded safely that calcium metaphosphate can readily take their place.

Soil Investigations

Soil samples were collected from all the plots in this experiment at the end of the second season (1941) and again after the tests were completed in 1944. Certain chemical and physical analyses were made in search of an explanation for the differences in effectiveness of the various phosphates.

The average values for available phosphorus (Truog) and pH are given in Table 11. In 1941, triple superphosphate and steamed bone provided the highest amount of phosphorus, potassium metaphosphate intermediate, and the others about equally lower values, but these differences are not significant. In 1944, steamed bone was the highest and the checks the lowest, but here again the differences were not significant. Available phosphorus in the 1944 samples determined by two other methods (1 per cent citric acid soluble, and the Wolf method) confirmed, in general, the results by the Truog method. The marked decrease, varying from 40 to 300 ppm, in content of available phosphorus from 1941 to 1944 was largely due, presumably, to fixation. During the three year period, about 75 ppm of phosphorus were added to each plot, except the checks, which received less than 10 ppm. The decrease in pH,[1] averaging about 0.4 pH unit, undoubtedly accounted for some of this fixation—just how much is not known. Analysis of variance of the decreases showed no significant differences between treatments nor between blocks.

Recently Coleman[2] stated that free iron and aluminum contained in the clay fractions of soils are responsible for phosphate fixation. He found that fine clays, containing twice as much of these constituents as coarse clays, fixed twice the amount of phosphate. On this basis, soil colloids would probably carry still more active iron and alumina. The 1944 samples were examined for moisture equivalent, colloids and fine clay (Bouyoucos) (Table 12). The low moisture equivalent values reflect the relatively low moisture-retention properties of this fine sandy loam (Merrimac). While comparison of the means seems to indicate a relationship between phosphorus fixation and colloids or fine clay content, a plotting of single plot values in a scatter diagram shows no correlation whatever. There seems to be more or less direct correlation between fixation and the available phosphorus content in 1941 but not between fixation and available phosphorus in 1944.

Analysis of the 1944 samples for exchangeable potassium and calcium by the Wolf[3] method (Table 13) shows a significantly higher potassium content in the potassium calcium metaphosphate plots and

TABLE 11. AVAILABLE PHOSPHORUS (Truog) AND pH-VALUES OF SOILS FROM PHOSPHORUS PLOTS. AVERAGES OF QUADRUPLICATE PLOTS.

Source of phosphorus	Plot no.	Available phosphorus (ppm) 1941 ppm	1944	pH 1941	1944
None	P11	286	109	5.43	4.94
Precipitated bone	P12	287	121	5.50	4.99
Triple superphosphate	P13	354	138	5.39	4.85
Steamed bone	P14	320	176	5.46	4.77
Calcium metaphosphate	P15	279	125	5.41	4.99
Potassium metaphosphate	P16	307	144	5.40	4.92
Potassium calcium metaphosphate	P17	282[1]	138	5.48	4.94

[1] Average of two plots.

[1] pH determinations were made on air-dried samples. Actual field values would be about 0.4 pH higher. It has long been our experience that air-drying the soil lowers the values about .4 pH unit. This is in line with recent findings of Volk and Bell (Florida Agr. Exp. Sta. Bul. 400, 1944), who report a maximum decrease of .41 and an average of .26 pH unit.

[2] Coleman, Russell. Phosphorus fixation by the coarse and fine clay fractions of kaolinitic and montmorillonitic clays. Soil Science 58:71-77. 1944.

[3] Wolf, Benjamin. Industrial and Engineering Chemistry, Anal. Ed. 15 (4):248-251, 1943.

low values for the potassium metaphosphate plots, with little difference among the remaining plots. Calcium was inclined to be highest in the check and the superphosphate plots and lowest in the potassium calcium metaphosphate and potassium metaphosphate. On the basis of all treatments, however, differences were not significant.

Discussion

Phosphorus, unlike other plant foods, does not leach from the soil, at least not in measurable quantities.[1] Therefore, this element is restricted or lacking in the mobility afforded other plant foods. The latter are subjected to an upward (capillary) movement in dry weather and a more or less downward movement with rainfall, thus supplying the roots with nutrients directly in relation to moisture conditions. Available phosphorus, however, must be present in the root zones in sufficient amounts to meet the need as the roots develop.

A tobacco crop removes less than 25 pounds phosphoric acid (P_2O_5) per acre.[2] Several times this amount (about 120 pounds of P_2O_5 per acre) is needed[3], however, for normal plant growth, in order to maintain the excess required to overcome fixation which is unavoidable under our acid soil conditions for tobacco culture. Also, an excess is needed to maintain a proper balance of nutrients when concentrations of other plant foods increase during periods of low soil moisture content.

In the experiments just reported the original content of available phosphorus in the test field was greatly in excess of crop need as inferred from the results of the 1941 sampling. Hence, differences in

TABLE 12. MOISTURE EQUIVALENTS, TOTAL COLLOIDS AND FINE CLAYS IN SOILS FROM PHOSPHORUS PLOTS; AVERAGE FROM QUADRUPLICATE PLOTS. SAMPLED 1944.

Source of phosphorus	Plot no.	Percentage		
		Moisture equivalent	Total colloids[1]	Fine clay[1] (2 hours)
None	P11	11.17	13.7	7.6
Precipitated bone	P12	10.23	12.6	7.3
Triple superphosphate	P13	10.69	12.8	7.2
Steamed bone	P14	12.41	14.9	7.9
Calcium metaphosphate	P15	10.25	13.7	7.8
Potassium metaphosphate	P16	11.22	14.1	8.1
Potassium calcium metaphosphate	P17	11.57	15.4	8.1

[1] According to Bouyoucos' methods.

yields could not be expected and were not obtained. For some inexplicable reason, however, quality was affected, and the results show the necessity of using certain forms of phosphorus in order to produce high quality tobacco even though the amount of residual phos-

[1] Morgan, M. F. and H. G. M. Jacobson. Conn. Agr. Exp. Sta. Bul. 458, p. 315. 1942.
[2] Swanback, T. R. et al. Conn. Agr. Exp. Sta. Bul. 457:234-239. 1942.
[3] Anderson, P. J. et al. Conn. Agr. Exp. Sta. Bul. 410, p. 401. 1938.

TABLE 13. REPLACEABLE POTASSIUM AND CALCIUM IN SOILS FROM PHOSPHORUS PLOTS; AVERAGE FROM QUADRUPLICATE PLOTS. WOLF METHOD. SAMPLED 1944.

Source of phosphorus	Plot no.	Parts per million	
		Potassium	Calcium
None	P11	180	774
Precipated bone	P12	176	590
Triple superphosphate	P13	168	686
Steamed bone	P14	160	607
Calcium metaphosphate	P15	177	572
Potassium metaphosphate	P16	107	510
Potassium calcium metaphosphate	P17	240	475

phorus in the soil appears to be more than ample for the crop. An attempt to find a correlation between crop index and available phosphorus was unsuccessful. According to Gilligan[1], mobility and availability of superphosphates exceeded that of the metaphosphates. There was no evidence that the relatively low water-solubility of the metaphosphates made them capable of furnishing an adequate supply of available phosphorus over an extended period. Jacob and Ross[2] and others reported by them, have found the metaphosphates about equal to superphosphate so far as yields of various crops are concerned.

It is possible that these meta-forms change into ortho-phosphates in the soil and that di- as well as triphosphates might be formed, depending on the supply of exchangeable bases.

There is some evidence that steamed bone meal, which is mainly a tri-calcium phosphate, is less likely to become fixed. The same is true of potassium calcium metaphosphate, which upon hydrolyzation may split into potassium ortho-phosphate, and tricalcium phosphate. While this is purely speculative, some support is given to it by the fact that our tobacco soils are enriched annually in potash (200 pounds K_2O per acre). In the present experiment, about 1,000 pounds K_2O and about 800 pounds CaO per acre were added uniformly to all plots in the five year period. The higher potassium content of the potassium calcium metaphosphate plots has already been mentioned.

The favorable effect of calcium metaphosphate shown above has been duplicated in the field by many growers who have tried this form of phosphate as a substitute for precipitated bone. Explanation for the difference in effectiveness between calcium metaphosphate and potassium calcium metaphosphate is not easily to be found owing to our incomplete knowledge of their chemical structure and the reactions involved when the materials are incorporated into the soil.

It may safely be concluded that optimum yields of tobacco are produced when there is an ample amount of available phosphorus in the soil, irrespective of source. With respect to quality, however, the results suggest that one source may produce a better grading than another. An explanation for this is still desired.

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[1] Gilligan, G. M. Delaware Agr. Expt. Sta. Bul. 229 (Tech. Bul. 27), 1941.
[2] Jacob, K. D. and Ross, William H. Jour. Agric. Res. 61 (7):539-560, 1940.

Summary

1. Six phosphatic materials were compared in fertilizing Havana seed tobacco in field tests over a five-year period. Precipitated bone, triple superphosphate, steamed bone, calcium metaphosphate, potassium metaphosphate and potassium calcium metaphosphate were the materials tested.

2. Best results, as judged by yield and grading, were obtained from calcium metaphosphate and triple superphosphate.

3. Next in order of effectiveness were precipitated bone and bone meal.

4. Potassium calcium metaphosphate and potassium metaphosphate gave no better results than mixtures without phosphorus carriers.

5. Soil analyses for phosphorus, clay, colloids, water retention and pH failed to offer an adequate explanation for the relative values of these phosphates.

EFFICIENCY OF NITROGEN IN OIL SEED MEALS AND SOME OF THEIR EFFECTS ON SOIL

T. R. Swanback

Nitrogen "went to war", and limited the supply for agricultural needs. It was, therefore, important to use available sources to the best advantage. In this Station's report for 1943, the writer[1] pointed out that castor pomace and soybean oil meal, used on an efficiency-of-nitrogen basis, are fully comparable to cottonseed meal.

The field tests, leading to this conclusion, were continued during the season of 1944. The abnormally dry weather during this period permitted no leaching of nitrogen. From this viewpoint, the season was ideal for observing the effects of the three sources of nitrogen. The results shown in Table 29 indicate clearly that almost identical yields and gradings can be obtained from cottonseed meal, castor pomace and soybean oil meal, when nitrogen is supplied on an efficiency basis. Castor pomace may be used pound for pound as a substitute for cottonseed meal, or 1,600 pounds of soybean meal may be substituted for one ton of cottonseed meal or castor pomace.

While adequate explanations for the different behavior of the three meals were given in the last report, it was also of interest to learn whether these materials varied in their residual effect on the soil. Studies were therefore made on soil reaction, and the supplies of calcium, nitrogen and carbon in the soil.

Soil Investigations[2]

The land on which the experiments were conducted (north corner of Pomeroy tract) is a Merrimac fine sandy loam. Tobacco had been grown on this land for many years previously.

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[1] Swanback, T. R. The relative efficiency of nitrogen in oil seed meals. Conn. Agr. Exp. Sta. Bul. 478:93-100.

[2] The author is indebted to Dr. H. A. Lunt of the Soils Department for analytical data presented herein.

TABLE 14. YIELD AND GRADING RECORDS OF ORGANIC NITROGEN PLOTS. CROP OF 1944.

Amount and source of nitrogen	Plot no.	Yield pounds per acre		Grade index		Average crop index	Relative crop value	5-year average relative crop value
		Plot	Av.	Plot	Av.			
200 lbs. per acre	N11A	1642		.337				
from	N11B	1584	1743	.334	.369	643.17	100	100
Cottonseed meal	N11C	2007		.402				
	N11D	1738		.402				
160 lbs. per acre	N31A	1645		.341				
from	N31B	1679	1739	.343	.368	639.95	99.5	101.5
Castor pomace	N31C	1846		.418				
	N31D	1785		.359				
180 lbs. per acre	N66A	1765		.391				
from	N66B	1721	1730	.398	.389	672.97	104.6	101.8
Soybean oil meal	N66C	1726		.407				
	N66D	1709		.360				

Soil reaction. The pH-value of the soil before the five-year test was begun was 4.60 (on air-dried sample; under field conditions it would be close to pH 5.0). Since this value was considered too low, the equivalent of 200 pounds $CaCO_3$ to the acre (calculated according to Pierre) was added to the fertilizer in the first two years of the test. This did not raise the pH-values sufficiently, however. The average reactions in November, 1941 were: for cottonseed meal plots, pH 4.82; castor pomace, pH 5.04, and soybean oil meal pH 5.01 (air-dried samples).

For each of the last three years, a basic (Pierre) equivalent of 600 pounds $CaCO_3$ was added to the fertilizer. At the termination of the experiments in September, 1944, the average pH-values, in the same order as above, were 4.85, 4.87 and 4.90 (air-dried). It is evident that the three materials do not vary in their effect on soil reaction when nitrogen is applied on an efficiency basis. Pierre values for cottonseed meal, castor pomace and soybean oil meal are 10, 6 and 11, respectively, *i. e.* an addition of 10, 6 and 11 pounds of $CaCO_3$ is required to counteract the acidity produced by 100 pounds of corresponding materials. Thus, nitrogen added on a unit basis from the three sources may vary in its effect on soil reaction.[1]

Calcium. Originally, the soil of the test field contained 156 ppm of replaceable calcium. The lime and fertilizer applied during the five years, equally to all plots, furnished the equivalent of 1,400 pounds of CaO (1,000 parts per million of Ca) per acre. Thus, the total amount of available calcium in the five-year period was 1,156 parts per million, or twice this figure in pounds per acre. At the end of the five-year period (September, 1944), soils from the three treatments,

[1] Conn. Agr. Exp. Sta. Bul. 386:564, and Bul. 306:796.

cottonseed meal, castor pomace, and soybean oil meal, contained 218, 284 and 285 ppm Ca, respectively. The differences between the total supply and residual calcium, amounting to 938 ppm Ca for cottonseed meal, 872 for castor pomace, and 871 for soybean meal treatments, were removed by the crops and (or) leached (below sampling depth, 6 to 7 inches). The average annual withdrawal of this element amounted to 525 pounds CaO per acre for the cottonseed meal treatment, and 487 pounds CaO for each of the other two meals. Since annual yields of tobacco produced by the three meals were about equal in the five-year period, it is suggested that cottonseed meal induces more leaching of calcium than the other two materials.

Nitrogen. A total of 1,000 pounds of nitrogen per acre was supplied in the five-year period from cottonseed meal; 800 and 885 pounds, respectively, were supplied from castor pomace and soybean oil meal. Initial total N-content of the soil was .070 per cent. The soil nitrogen for the three materials, in the order mentioned above, was (average of four plots) .089, .093 and .085 per cent. By simple calculations, we find that the loss of total nitrogen (through leaching and crop removal) amounted to .031 per cent for the cottonseed product, .026 per cent for castor pomace and .035 per cent for soybean meal. The ratio of added nitrogen to nitrogen removal would be 1.61, 1.54, and 1.26 for the materials, in the order mentioned above. Thus, there is a tendency of greater economy in the use of nitrogen from soybean oil meal than in that of the other two meals.

Carbon and carbon nitrogen ratio. Cottonseed meal applied during the five-year period supplied approximately five tons of carbon per acre, castor pomace, four tons, and soybean oil meal, 4.43 tons. In addition, plant residues and cover crops which always followed tobacco in these experiments furnished carbon, presumably in equal amounts on all plots.

The initial carbon content of the soil was estimated to be 1.2 per cent. At the close of the experiments, the average residual content was 1.1, 1.1, and 1.0 per cent, respectively, for the treatments of cottonseed meal, castor pomace and soybean oil meal. Since only the carbon in the fertilizer was varied, it seems logical to assume that this source influenced the final carbon status in the soil. In the cottonseed meal and soybean meal treatments, an average of 0.6 per cent (soil) organic carbon disappeared or was used up in biological processes in the five-year period. Slightly less, or 0.5 per cent, was lost in the castor pomace test.

The proportion of carbon added to lost carbon is .83 to 1 for cottonseed meal, .67 to 1 for soybean oil meal, and .70 to 1 for castor pomace.

It is commonly known that carbon and nitrogen, because of their competition in combinations with oxygen in the soil, always tend to establish an equilibrium. The balance between the two elements is expressed in a C:N ratio. The initial ratio of the soil was 16.9. The ratio is usually narrowed down through continued fertilization and cropping. We find that in the present tests the final C:N ratios are 12.4, 12.0 and 12.0 for cottonseed meal, castor pomace and soybean oil meal, respectively.

From the known fact that, concurrent with oxidation of carbon, nitrogen also is oxidized (nitrified) in a certain proportion, it is indicated that castor pomace and soybean meal would nitrify as rapidly as cottonseed meal. This should serve to correct the common opinion among tobacco growers that nitrogen in castor pomace is more slowly available than that in cottonseed meal.

DISEASES OF TOBACCO IN 1944

P. J. Anderson

Tobacco diseases are rarely serious during dry years. The extremely dry season of 1944 was no exception. Many common tobacco diseases failed to appear at all and, with two or three exceptions, the others were not sufficiently severe to cause appreciable losses. The writer has not made a systematic disease survey of the tobacco region but, in connection with other work, had occasion to inspect hundreds of acres of growing tobacco in all parts of the Valley and is constantly in touch with many growers through whom he would quickly learn of any unusual disease developments.

Moreover, beginning with 1943, the United States Department of Agriculture, Plant Disease Survey, has maintained in this district a plant disease specialist, Dr. Robert C. Cassell, who makes regular inspections of the tobacco crop as well as other crops. This service will keep us in continuous touch with the development of tobacco diseases in the future and should be of considerable value to the industry. The brief notes here recorded are based on Dr. Cassell's published reports and our own observations.

One of the exceptions mentioned above was the early damping off of seedlings in the beds, for a discussion of which the reader is referred to page 293. Aside from this one disease, the seed beds were remarkably healthy. Only a few cases of bed rot (*Pythium aphanidermatum*) were found. Prevalence of clear weather and the generally adopted practice of spraying the beds with Fermate were responsible for the excellent condition of the seed beds.

An encouraging situation this year was the almost total disappearance of mildew, the disease that has caused most worry in seed beds since 1937. Only three affected beds in Connecticut were seen by or reported to the writer. It is too early to predict whether this means that mildew, like wildfire, is on the way out, or whether we may expect a resurgence in later years. At least, spraying of the beds or other precautionary measures should not be discontinued for the present. There is some evidence that the mildew fungus is not able to maintain itself from year to year in this climate and that future outbreaks will depend on the occasional blowing of spores from milder areas of the South. The immediate destruction of any beds found to be infected would be a wise precautionary measure for the Valley as a whole. An organized effort to effect such a program should be considered if mildew becomes troublesome again.

Wildfire, angular leaf spot, sore shin, hollow stalk, Botrytis and Sclerotinia diseases did not appear at all. Pole rot and other curing shed disorders were at a minimum.

Mosaic (calico), which is not affected by the character of the season, occurred in the usual amount on the binder types. Shade tobacco, usually the least affected, showed more mosaic than usual this year.

Black root rot (*Thielaviopsis basicola*) was one of the two diseases that increased in severity in 1944. It caused more damage and was more widespread than in any season for the last 10 to 15 years. This was particularly true of the Shade fields (Broadleaf is naturally less susceptible while many Havana Seed growers plant resistant types on questionable fields). Some Shade fields produced less than half a crop and, in some areas of Shade fields, the growth was so poor that no leaves were harvested. Others made a partial recovery in the later warmer weather and produced a fair crop. On some fields the explanation of the outbreak lay in the more extensive use of stable manure due to shortages of commercial fertilizers in the spring of 1944. The trouble was probably aggravated by use of too much lime in some cases. The rather cool, early growing season was also favorable to the development of root rot.

It has been shown that many factors determine the severity of root rot. The most important conditions that favor root rot are: (1) reduction of acidity of the soil (mostly by liming), (2) use of large amounts of stable manure, and (3) cold temperatures and aeration of the soil. A cold, wet soil that packs easily is a favorable spot for root rot. Cold, wet growing seasons also favor this trouble. Avoidance of these conditions should keep root rot under control.

By a lucky accident, it was learned this year that one of the new Shade varieties (Connecticut 15) is highly resistant to root rot. When a few plants of this variety were planted inadvertently in a badly affected field, they grew to normal size, while the common Shade variety did not make enough growth to be worth harvesting. It should be mentioned here also that the Station long ago developed a resistant Shade type (4R Cuban) which is identical with the commonly planted variety in every respect except for its resistance to disease. This could be profitably used by Shade growers on questionable fields.

CONTROL OF EARLY DAMPING OFF IN SEED BEDS

P. J. Anderson

This trouble was more prevalent in the seed beds in 1944 than in any of the last ten years. Many growers found that shortly after the plants came up in the beds, they began to disappear mysteriously. Every day the stand of plants was thinner. In some beds there were so few plants left that the growers worked up the soil and seeded the beds a second time. The plants are so small at this stage and disappear so quickly that the cause can be determined only by a very close examination of the seedlings. When this was done, it was found that in the majority of the affected beds the trouble was the early damping off disease caused by the parasitic fungus, *Pythium debaryanum.* Twelve years ago the writer made an exhaustive study of this trouble and published the results in the annual report of the Tobacco Experiment Station for 1933 (Conn. Agr. Exp. Sta. Bul. 359:336-354). After testing a considerable number of chemicals, it was found that a formaldehyde dust mixed with the soil just before seeding gave the best control. This dust was made by mixing 15 parts by weight of formaldehyde with 85 parts of ground charcoal or fine dry humus and raking it into the soil at the rate of one and one-half ounces to a square foot.

Although this treatment gave good control of the disease, it has the drawback of being rather laborious to apply and the grower is prone to be discouraged by the number of operations involved in getting together his materials, mixing the dust and then raking it into the soil. In later experiments (not previously published) an attempt was made to find an equally effective method that could be more easily applied.

Simplified Formaldehyde Method. Since the soil of most tobacco seed beds contains a high proportion of humus, it was easy to conclude that the soil itself could be used as the absorbent and diluent, thus eliminating the operation of preparing the formaldehyde dust mixture.

The first tests were made in greenhouse benches with soil taken from moderately infected tobacco seed beds. Formaldehyde was applied on this soil at the rate of one pint to 75 square feet of bed. Since this small amount of solution was difficult to distribute evenly, it was first diluted with eight or 10 times its volume of water and then sprinkled onto the soil while it was being prepared for seeding. The seed was immediately sowed and raked in very lightly. Then it was watered in the usual way. A similar area was treated and seeded in the same way except that formaldehyde was not added. When the plants came up, a moderate amount of damping off developed on the control bed but none on the treated bed. When the plants were an inch high, representative areas a foot square were pulled and counted to see what effect the treatment had on the stand of plants. Results were:

4	square feet	untreated	had 1459	plants
4	"	" treated	" 3297	"

Thus there were more than twice as many plants on the treated area.

The same treatment was also used on a larger scale in the seed beds of one of the Shade plantations with satisfactory results.

Formaldehyde Drench Method. Damping off can be entirely eliminated by a formaldehyde drench method. The best method we have yet found for getting perfect stands of healthy seedlings in the greenhouse is to sow the seed in dry soil in flats; then drench this soil by sub-irrigation with a formaldehyde solution of one teaspoonful in a gallon of water. This not only eliminates damping off but it also stops Pythium root rot (yellow patch) and seems to stimulate the plants to more rapid growth. It also prevents growth of green algae on the surface of the soil.

Unfortunately, sub-irrigation is not a practical operation in a seed bed. Experiments were therefore made to see whether the same beneficial results could be obtained by drenching the soil by sprinkling instead of sub-irrigation.

In the first experiments, the moderately dry soil was first thoroughly drenched with the solution (one teaspoonful to one gallon of water) until it was muddy. Seed was then distributed on the surface and lightly covered with dry soil sifted over it. As a control, other flats were drenched with water instead of formaldehyde solution. Serious damping off developed in the controls but none in the treated flats.

In order to see whether we could eliminate the operation of sifting the dry soil over the seed after distribution, a modified drench method was tried:

The seed was sowed and lightly raked in dry soil. Then the formaldehyde solution was sprinkled over it until it was entirely drenched and muddy. This gave equally good control. Representative areas of equal size were pulled and counted when the plants were an inch high and produced the following:

Untreated	areas	1459	plants
Treated	"	2991	"

A practical objection to this last method was that the seed floated during the drenching and then collected in bunches so that the plants were not uniformly distributed when they came up.

Seed Treatment. Damping off of many kinds of plants may be prevented or minimized by coating the seeds with a fungicidal powder before sowing. If an effective seed dust for tobacco could be found, it would give us the ideal control method because it involves so little time and expense that it would be universally adopted as an insurance measure. Method of treatment is to shake the seed in a closed jar with a small amount of the dust until inspection shows each seed uniformly coated with the dust. Any excess dust may be sifted out but ordinarily this is not necessary.

Twelve years ago, the writer first started experimenting with some of these dusts and reported partial control with red cuprous oxide (cuprocide). In more recent years these experiments have been extended to a longer list of chemicals. The experiments were conducted in the greenhouse during the winter in badly infested soil. Each chemical has been tried four to six different times during the last two years. Dusts tried were Cuprocide, Semesan, Fermate, Thiosan and Arasan. The seedlings were grown under sash in the greenhouse under moist conditions and with thick stands that would favor the development of damping off. Observations were made on the time of appearance and extent of spread of the damping off and finally all plants were pulled and counted.

Without describing the experiments in detail or presenting the supporting data, we can make the following general summary statements:

1. None of the treatments were injurious to the sprouting seeds.

2. Control of damping off was not complete for all tests with any of the dusts. In some series of tests, Arasan or Fermate gave complete control but in later series, the same dusts did not give good control. This inconsistency of results in the different series, which was observed for all the dusts, is not easy to explain.

3. Any treatment was usually, but not always, better than no treatment.

4. The seed treatment almost always delayed the appearance of the trouble even when it did not prevent it.

5. On the whole, best results were obtained with Arasan, Cuprocide and Fermate.

6. A grower who has had trouble with damping off and does not wish to treat the soil with formaldehyde, would do well to treat his seed with any of those three dusts. It does not guarantee full control but minimizes the risk.

The principle of seed treatment is that the chemical makes a protected zone in the immediate vicinity of the coated seed where the fungus cannot enter. When, however, the germinating seedling has extended itself beyond the limits of the protected zone, the fungus is able to attack. This attack may be made by hyphae through the ground or by aerial hyphae which may be seen running from plant to plant in a severe attack. Apparently, none of the dusts produces a sufficiently extended protected zone to prevent these later attacks. Thus the degree of control obtained in a trial may vary according to whether the most severe outbreak occurs at an early or later stage. This possibly explains the inconsistency of results mentioned previously. It also explains the delayed appearance of the disease when seeds are treated.

With the object of extending the zone of protection in some of the tests, the surface of the soil was sprayed with a Fermate solution, in addition to treating the seed with Fermate. This gave somewhat better control of the damping off but was detrimental to the seedlings. The seed germinated as usual but the roots failed to establish themselves as well in the ground so that the little seedlings lay prostrate on the surface or were knocked over by the first sprinkling. An overdose of Fermate at this germination stage is definitely detrimental.

Practical Considerations. Some growers never have trouble with this early damping off. Obviously, it would be wasted effort for them to take any precautionary measures and we do not recommend the use of any measures by the growers in general. Other growers are not so fortunate and frequently they have certain beds that are more subject to damping off than others. Steam sterilization of the soil does not eliminate the trouble. Moreover, we do not know any effective methods which may be started after the seed has germinated and the plants are dying, although spraying with Bordeaux will give some relief. Therefore, it is essential for the grower, who expects trouble to develop, to do something about it when sowing the beds. Of the methods with which we have experimented, the formaldehyde sprinkle method as described above is the most certain and practical. If he does not wish to go to this much trouble he can at least treat the seed with Arasan, Cuprocide or Fermate.