Bulletin 311 January, 1930

TOBACCO SUBSTATION AT WINDSOR

REPORT FOR 1929

P. J. ANDERSON, T. R. SWANBACK, O. E. STREET
AND OTHERS

Connecticut
Agricultural Experiment Station
New Haven

ERRATUM

The figure showing the structure formula of nicotine on page 235 and similar figure for nicoteine on page 237 should be transposed.

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CONNECTICUT AGRICULTURAL EXPERIMENT STATION

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY, NEW HAVEN, CONN.

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REPORT OF THE TOBACCO SUBSTATION FOR 1929[1]

The tobacco season of 1929 was marked, first, by exceptionally low rainfall during the growing period and, second, by the most destructive single hail storm in the history of the valley.

Rainfall for the critical months of June and July, and the less critical August, for 1929, as compared with the average of the last half century, was:

	June	July	August
Rainfall in 1929	1.67	.98	4.87
Average rainfall for 57 years	3.09	4.36	4.39

More than half of the August rainfall was during the hailstorm of August 1. Thus, both the amount of rainfall and its distribution were unfavorable to production of a good crop of tobacco. The most noticeable effects of this dry season on the quality were more prominent veins and heavier leaves. The actual yield of the crop in pounds to the acre was therefore greater than would have been anticipated from a field inspection.

After the destructive hail, State Commissioner of Agriculture Buckingham made a farm to farm survey, from which we quote the following figures on the extent of the damage:

The total tobacco loss due to hail was more than $2,359,000 on the 715 farms which furnished complete information. Of this $391,000 was shade-grown tobacco, $1,750,000 was Broadleaf and $218,000 was Havana Seed (Table 1).

TABLE 1. TOBACCO HAIL DAMAGE BY VARIETIES

Variety	Acres affected	Amount of damage
Broadleaf	6,613	$1,749,840
Shade-grown	2,438	391,282
Havana Seed	1,045	218,354

In the case of shade-grown tobacco, the first picking and part of the second had been finished before the storm, so that the most valuable part of the crop was saved. It is estimated that, on farms within the hail area, 16 percent of the total value of the shade-grown crop was lost.

Broadleaf and Havana Seed tobacco suffered much more severely, with losses of 88 per cent and 70 per cent, respectively, of the total value of the crop. The proportion of the loss covered by insurance was so small as to be almost negligible.

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[1] For bibliographical purposes all material should be credited to P. J. Anderson, T. R. Swanback and O. E. Street, unless otherwise indicated.

The storm ranged over ten towns, but the greatest devastation fell in South Windsor and East Hartford.

TABLE 2. TOBACCO HAIL DAMAGE BY TOWNS

Town	Amount of damage
South Windsor	$907,000
East Hartford	658,000
Windsor	163,000
Glastonbury	153,000
Manchester	111,000
Bloomfield	89,000
East Windsor	86,000
Simsbury	79,000
Vernon	70,000
Ellington	43,000

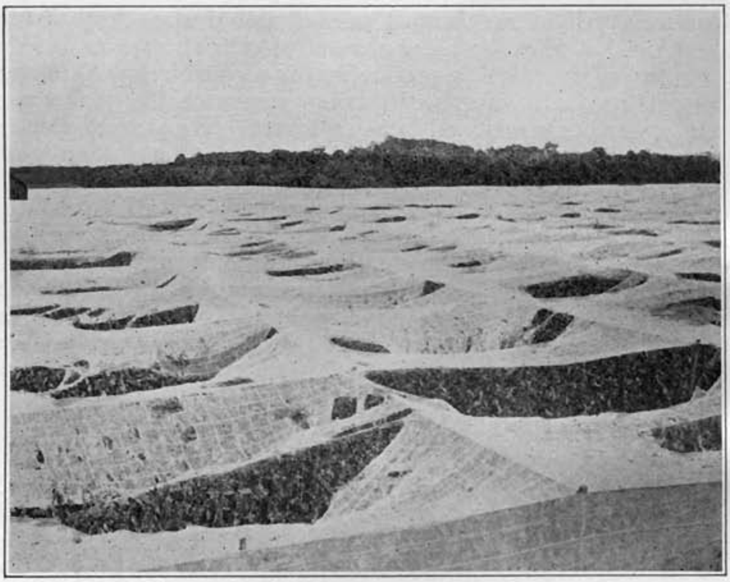

FIGURE 5. This was a promising shade field before the hail storm.

A summary by towns of the figures made public by Commissioner Buckingham appears in Table 3.

Tobacco on all the experimental plots at Windsor was completely destroyed. All data for the year on these plots is confined to observations on growth before August 1. On the shade tobacco, however, the first three primings, 11 leaves, had been harvested and they furnished valuable information for the experiments on selection and breeding.

TABLE 3. HAIL LOSS BY TOWNS AND VARIETIES

Town	No. farms affected	Shade-grown Per cent damage	Shade-grown Loss (dollars)	Broadleaf Per cent damage	Broadleaf Loss (dollars)	Havana seed Per cent damage	Havana seed Loss (dollars)
Bloomfield	24	10	51,000	100	3,000	71	24,569
East Hartford ...	163	37	120,852	94	503,279	100	34,500
East Windsor ...	36	15	14,250	54	70,501	45	1,350
Ellington	15	10	17,500	47	17,343	60	8,100
Glastonbury	96	0	0	64	142,997	54	10,187
Manchester	63	0	0	90	93,524	96	16,128
Simsbury	35	8	51,460	70	2,100	51	25,298
South Windsor ..	235	75	52,500	97	854,975	0	0
Vernon	25	15	22,500	96	43,776	100	4,800
Windsor	90	13	51,220	56	18,345	68	93,432
Total	782	16	391,282	88	1,749,840	70	218,364

FIGURE 6. What the hail storm did to a good crop of Havana Seed tobacco.

One addition has been made to the scientific staff of the tobacco station. O. E. Street was appointed physiologist of the station July 1. He is engaged in biochemical investigations, in which his major study is the development of colors during the curing process.

Mention should be made here of the excellent tobacco research by members of the experiment station staff outside of the tobacco substation, and by the Connecticut Agricultural College staff:

Dr. E. M. Bailey and others of the analytical chemistry department made the numerous chemical analyses of tobacco which have been published in our reports. Their fertilizer analyses are also of inestimable value to the growers.

Dr. H. B. Vickery and Dr. G. W. Pucher have reported important progress in investigations of the nitrogenous constituents of the tobacco leaf and their transformation during the curing process.

M. F. Morgan and other members of the soils department have made notable contributions in their soil and nutrition studies on tobacco in the last five years.

Professor Davis and Professor Hendrickson of the college economics department are conducting an investigation of the economics of tobacco production and more recently Professor

FIGURE 7. Shade tobacco tent on the experiment station farm after the hail storm.

Boyd of the same department has begun a thorough study of the marketing problems of the tobacco industry.

The extension department has again contributed the part-time services of J. S. Owens in conducting curing demonstrations. There is, however, need for more extension work among the tobacco farmers.

The most important addition to the physical equipment of the tobacco substation during the year is an extensive system of lysimeters installed by the soils department. This affords means to study and measure plant food elements lost by leaching. The lysimeters have been in operation since June 1 and they are

FIGURE 8. Broadleaf after the hail storm.

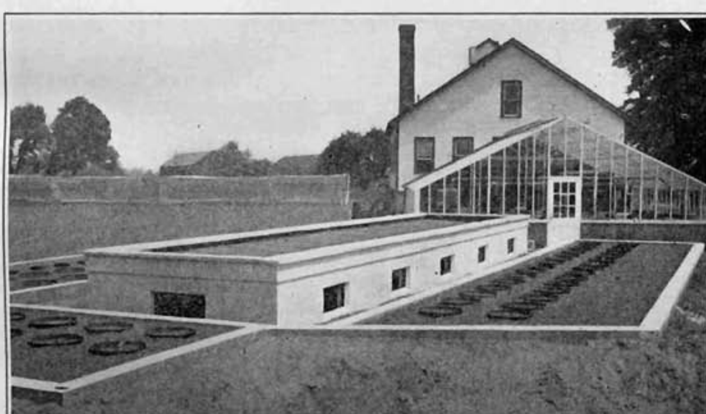

FIGURE 9. Exterior view of the lysimeters.

yielding interesting information which will be published in later reports. Illustrations are printed in Figures 9 and 10.

Other improvements are a garage and the addition of an adjacent acre for experiments.

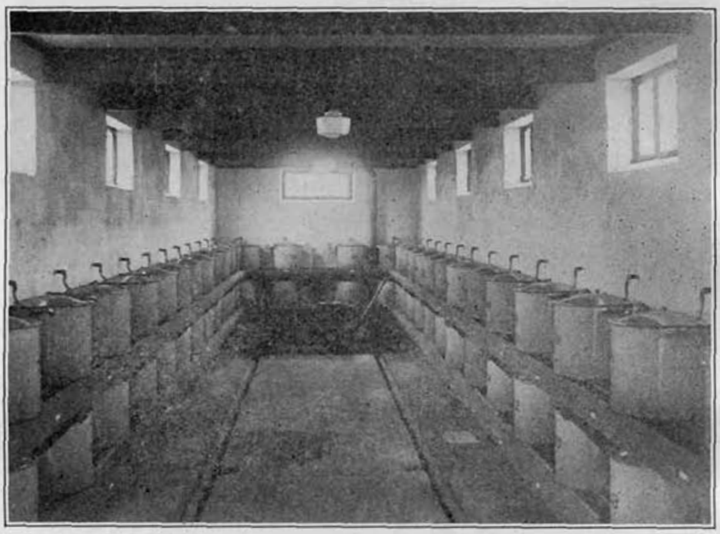

FIGURE 10. Interior of lysimeter pit.

Despite the loss of considerable data on the fertilizer and cover crop plots through the storm, the year has been one of steady improvement and of progress in a number of lines of investigation, the most important of which are summarized in this report.

POTASH FERTILIZER EXPERIMENTS

Some observations and previously unrecorded data on the potash experiments in progress at the tobacco substation have accumulated since our last report.

QUANTITATIVE SERIES

Field growth. A comparison during the 1929 growing season of the plots which had received 300 pounds, 200 pounds or 100 pounds of potash to the acre showed no marked differences in growth. However, on those plots to which no potash had been applied, except for 28 pounds to the acre in the organic fertilizer material, growth was noticeably smaller and leaves were less luxuriant. These plots never showed any acute symptoms of potash hunger, but on hot days they could be picked out readily from the others, because of their wilted and flagging leaves, a symptom which has been observed in previous seasons on the no-potash plots.

Effect of quantity of potash on fire holding capacity of the leaves. Samples of four grades of leaves from the plots of 1928 were force-sweated and aged until September, 1929, when strip burn tests were made in the usual manner, as described in previous reports. Results of these tests on the old series (third year of the experiment) are presented in Table 4 and a summary of the first three years is given in Table 5.

TABLE 4. OLD QUANTITATIVE POTASH SERIES ON FIELD V. STRIP BURN TESTS FOR CROP OF 1928

Quantity of K_2O applied	Plot No.	Duration of burn (seconds) Darks	Mediums	Lights	Seconds	Average for Plot	Treatment
None	K11	15	..	..	19	17	21
	K11-1	24	..	..	26	25	
100 lbs. to acre	K12	48	39	44	49	45	41
	K12-1	43	38	34	30	36	
200 lbs. to acre	K9	50	47	53	53	51	51
	K9-1	44	54	55	47	50	

TABLE 5. SUMMARY OF THREE YEARS RESULTS ON THE ABOVE PLOTS

Quantity of potash	Average burn for crop of 1926	1927	1928	All
None	39	36	21	32
100 lbs. to acre	40	57	41	46
200 lbs. to acre	45	56	51	51

These data show that the fire holding capacity grows less every year on the no-potash plots. For the first year, the decline was hardly noticeable; it was very apparent for the second year and still more so the third. On the plots which had 100 pounds K_2O to the acre, there was no ill effect on the fire holding capacity the first *two* years, but a decided drop in the third. The burn has been maintained throughout on the 200 pounds plots. In making these tests, it was observed that the ash on the no-potash plots was whiter than on the others. This was probably due to the increase of calcium and magnesium in the leaf when the potash content was reduced.

Similar burn tests were then made on tobacco from the more recent series of potash plots on Field I. Results of these tests (second year) are presented in Table 6. The fertilizer treatment

TABLE 6. NEW QUANTITATIVE POTASH SERIES ON FIELD I. STRIP BURN TEST FOR CROP OF 1928

Quantity of K_2O to acre	Plot No.	Duration of burn (seconds) for					
		Darks	Mediums	Lights	Seconds	Average for Plot	Average for Treatment
None	K11-2	34	37	44	45	40	37
	K11-3	34	45	33	38	38	
	K11-4	39	49	44	45	44	
	K11-5	14	32	21	32	27	
100 lbs.	K12-2	50	40	47	43	45	52
	K12-3	54	59	53	58	56	
	K12-4	53	54	57	56	55	
200 lbs.	K9-2	55	54	58	54	55	52
	K9-3	56	54	56	52	54	
	K9-4	55	56	59	53	56	
	K9-5	34	49	55	52	48	
	K9-6	43	58	59	56	54	
	K9-7	53	53	48	49	51	
	K9-8	26	44	48	55	43	
300 lbs.	K13	35	48	50	49	46	51
	K13-1	41	40	56	46	46	
	K13-2	44	52	57	51	51	
	K13-3	55	57	58	58	57	
	K13-4	55	48	53	59	54	

of these plots is a replication of that on the older quantitative series previously mentioned, but with the addition of five plots on which 300 pounds potash to the acre were applied. As far as fire holding capacity is concerned, the results for the first two years duplicate those of the older series. That is, on the no-potash plots there is a slight decline in fire holding capacity the first year and a much more decided drop the second year. The other plots show no impairment in this respect during the first two years. Raising the rate of application to 300 pounds an acre has had no effect on the burn. Neither has this excessive quantity of potash produced any beneficial influence on the yield or quality of the crop, as was mentioned in our report for 1928.

Influence of quantity of fertilizer potash on chemical composition of the leaves. Sample hands of two grades (darks and seconds) from the first and second crops of the older quantitative series were analyzed by the department of chemistry to see to what extent an increased amount of fertilizer potash would influence the potash absorption of the leaf. These analyses are presented in Table 7. Since previous analyses at this station and elsewhere have shown that the quantity of other mineral bases in the leaf may also be affected by the amount of potash, calcium and magnesium were also determined.

TABLE 7. INFLUENCE OF QUANTITY OF FERTILIZER POTASH ON POTASH, LIME AND MAGNESIA IN THE LEAF

Amount of K_2O to acre in fertilizer	Plot No.	Grade	Percentage of Potash (K_2O) 1926	Ave.	Potash (K_2O) 1927	Ave.	Lime (CaO) 1927	Ave.	Magnesia (MgO) 1927	Ave.
None (except 28 lbs. in organics)	K11	D	6.96	**7.00**	5.46	**5.46**	5.33	**5.74**	0.85	**0.94**
	K11	S	7.03		4.71		7.02		1.09	
	K11-1	D			6.00		4.28		0.78	
	K11-1	S			5.67		6.33		1.03	
100 lbs. total	K12	D	7.20	**7.27**	7.19	**7.00**	4.25	**5.18**	0.69	**0.82**
	K12	S	7.33		7.18		6.00		0.93	
	K12-1	D			7.06		4.42		0.74	
	K12-1	S			6.58		6.04		0.92	
200 lbs. total	K9	D	7.97	**8.15**	7.69	**7.64**				
	K9	S	8.32		7.97					
	K9-1	D			7.81					
	K9-1	S			7.10					

From a study of this table we may conclude that:

1. *The percentage of potash in the leaf is materially affected by the quantity applied in the fertilizer—even though this soil contains an enormous natural reserve of potash.*

2. *The deficiency of potash in the leaf from the no-potash plots becomes more pronounced during the second year than the first.*

3. *One hundred pounds of potash to the acre in the fertilizer result in a deposit of less potash in the leaves than 200 pounds to the acre, but the deficiency during the second year is not more pronounced than during the first year.*

4. *Decrease in potash is accompanied by increase in both calcium and magnesium in the leaf. That is, the smaller the percentage of potash, the greater the percentage of calcium and magnesium (always one or both).*

In the 1927 "no-potash" samples the potash: calcium ratio was approximately 1: 1. All previous analyses of tobacco from plots on the station farm have shown a ratio in which the potash figure was greater than 1.

5. *There is a general relation between fire holding capacity, as measured by the strip test, and the ratio of potash on the one side to calcium and magnesium on the other. The wider the ratio, in favor of potash, the longer the burn.*

There is, however, a danger of placing too much emphasis on this point. In the first place, it has been shown that in high-lime tobacco, the burn on the cigar is much better than the strip test would indicate, not only in duration but also in closeness of burn, aroma and taste. In the second place, too much potash may cause a dark charred ash, while an increase in calcium or magnesium will make the ash white and more porous. The optimum ratio of these mineral bases in cigar leaf tobacco has not yet been fully established.

COMPARISON OF CARRIERS

In 1929, potash from five different carriers was compared. They were sulfate, nitrate, carbonate, tobacco stems, cottonhull ash, and various combinations of these. As far as could be judged in the field, no significant differences in the tobacco raised on these could be observed.

Effect of different carriers on fire holding capacity. Strip burn tests were made on the fermented samples of the 1928 crop in the same manner as mentioned above for the quantitative series. Results of the tests on the old qualitative series are presented in Table 8 and the average results for four years in Table 9. The differences in fire holding capacity are small. It may be significant, however, that during each of the four years the duration of burn for the carbonate plots has been somewhat the highest. Also, with one exception, the shortest burn has been on the sulfate plots.

TABLE 8. OLD QUALITATIVE SERIES ON FIELD V. STRIP BURN TEST FOR CROP OF 1928

Carrier	Plot No.	Duration of burn (seconds) for: Darks	Mediums	Lights	Seconds	Average for: Plot	Treatment
Sulfate	K1-2	51	50	49	47	49	46
	K1-3	42	47	39	48	44	
Carbonate	K5	52	58	60	56	57	56
	K5-1	56	53	58	..	54	
Nitrate ⅔	K7	59	54	53	56	56	54
Carbonate ⅓	K7-1	53	50	54	58	54	
Sulfate ½	K8	57	44	59	54	54	53
Carbonate ½	K8-1	53	47	53	56	52	
Sulfate ⅓ ...... Carbonate ⅓ ... Nitrate ⅓	K9	50	47	53	53	51	51
	K9-1	44	54	55	47	50	

TABLE 9. OLD QUALITATIVE POTASH SERIES ON FIELD V. SUMMARY OF STRIP BURN TESTS FOR FOUR YEARS

Carrier	Plots	Average duration of burn in— 1925	1926	1927	1928	All four
Sulfate	K1-2 K1-3	36	44	53	48	45
Carbonate	K5 K5-1	45	49	56	55	51
Nitrate ⅔ ...... Carbonate ⅓	K7 K7-1	43	41	53	54	48
Sulfate ½ ...... Carbonate ½	K8 K8-1	38	42	55	53	47
Sulfate ⅓ .... Carbonate ⅓ .... Nitrate ⅓	K9 K9-1	43	45	55	51	49

Results of the tests on the more recent series of potash plots on Field I, presented in Table 10, are similar to those of the older

TABLE 10. NEW QUALITATIVE POTASH SERIES ON FIELD I. STRIP BURN TESTS FOR CROP OF 1928

Source of Potash	Plot No.	Duration of burn (seconds) for Darks	Mediums	Lights	Seconds	Average for Plot	Treatment
Sulfate	K1-4	33	45	54	56	47	51
	K1-5	38	44	..	49	44	
	K1-6	36	54	58	51	50	
	K1-7	40	..	..	46	43	
	K1-8	50	59	56	60	56	
	K1-9	60	56	59	57	58	
Carbonate	K5-2	58	..	60	54	57	54
	K5-3	45	59	59	60	56	
	K5-4	45	45	57	54	50	
Nitrate ⅔ ...... Carbonate ⅓	K7-2	53	52	49	49	51	52
	K7-3	38	56	57	57	52	
	K7-4	51	52	..	..	52	
Sulfate ½ ...... Carbonate ½	K8-2	27	48	55	52	46	49
	K8-3	33	34	52	56	44	
	K8-4	50	58	60	59	57	
Sulfate ⅓ ...... Carbonate ⅓ .... Nitrate ⅓	K9-2	55	54	58	54	55	52
	K9-3	56	54	56	52	54	
	K9-4	55	56	59	53	56	
	K9-5	34	49	55	52	48	
	K9-6	43	58	59	56	54	
	K9-7	53	53	48	49	51	
	K9-8	26	44	48	55	43	
Stems	K14	54	51	54	52	53	53
	K14-1	47	51	..	55	51	
	K14-2	54	57	51	56	54	

series. Again carbonate is at the top, but the differences in fire holding capacity between the treatments seem too small to be of much significance. Three plots which received all their potash in stems were included in this series. The fire holding capacity on these was as good as the others.

Summing up all the information we have obtained up to date on fire holding capacity as measured by the strip test, we may say that the differences produced by use of sulfate, carbonate, nitrate or tobacco stems or various combinations of the above are very small; possibly too small to be of consequence, if any one of the potash carriers is preferable from the standpoint of price, convenience in mixing, or the like.

Effect of different potash carriers on chemical composition of tobacco. Two questions occur as to the effect of different potash carriers on the composition of tobacco: First, does the leaf absorb more potash from one carrier than from another? Second, is the percentage of sulfur in the leaf increased when sulfate is used in the fertilizer? Samples of darks and seconds from the fermented crop of 1927 were analyzed by the chemistry department for sulfur and potash. As far as the amount of potash absorbed is concerned, these data, presented in Table 11, show that the differences are very small and not constant. There is no indication that tobacco will actually take up more potash from one carrier than from another.

TABLE 11. OLD QUALITATIVE POTASH SERIES. PERCENTAGE OF POTASH AND SULFUR IN CROPS OF 1926-1927

Source of potash	Plot No.	Grade	Percentage (air dry basis) of Total sulfur (S) Crop of 1927	Total sulfur (S) 1927 Ave.	Total sulfur (S) 1926 Ave.	Sulfate (S) 1927	Sulfate (S) 1927 Ave.	Organic Sulfur 1927	Potash (K_2O) 1927	Potash (K_2O) 1927 Ave.	Potash (K_2O) 1926 Ave.
Sulfate	K1-2	D	0.50	0.49	0.57	0.36	0.36	.14	7.27	7.83	8.49
	K1-2	S	0.43			0.29		.14	7.53		
	K1-3	D	0.56			0.42		.14	8.13		
	K1-3	S	0.48			0.37		.11	8.40		
Carbonate ..	K5	D	0.43	0.42	0.46	0.28	0.28	.15	7.16	7.60	8.13
	K5	S	0.38			0.24		.14	7.65		
	K5-1	D	0.44			0.31		.13	7.82		
	K5-1	S	0.42			0.29		.13	7.76		
Nitr. ⅔ .... Carb. ⅓	K7	D	0.45	0.43	0.43	0.31	0.29	.14	7.36	7.80	8.50
	K7	S	0.41			0.28		.13	7.85		
	K7-1	D	0.47			0.32		.15	7.98		
	K7-1	S	0.39			0.26		.13	8.02		
Sulf. ½ .... Carb. ½	K8	D	0.47	0.46	0.52	0.32	0.33	.15	7.69	7.82	8.13
	K8	S	0.44			0.31		.13	7.67		
	K8-1	D	0.51			0.38		.13	7.85		
	K8-1	S	0.42			0.29		.13	8.08		
Sulf. ⅓ .... Carb. ⅓ ... Nitr. ⅓	K9	D	0.44	0.45	0.54	0.31	0.32	.13	7.69	7.64	8.15
	K9	S	0.41			0.29		.12	7.97		
	K9-1	D	0.51			0.36		.15	7.81		
	K9-1	S	0.46			0.33		.13	7.10		

The data on sulfur, however, are of more interest and importance. Sulfur occurs in two forms in the tobacco leaf. In the organic form it is a necessary constituent of the protoplasm. In the inorganic form it occurs as sulfate, probably combined mostly with potash as a base. In this latter form it is objectionable since it reduces the amount of potash which is free to combine with organic acids—it is only in the latter combination that potash promotes burn. It is therefore important to reduce as much as possible the inorganic or sulfate form. A study of the table shows first of all that the quantity of organic sulfur is remarkably constant (about .13 per cent of the dry weight of the leaf) and does not vary with the source of fertilizer potash. But the sulfate sulfur shows considerable variation, depending on the amount of this element which was applied in the fertilizer. Comparing for example the carbonate plots of 1927 with the sulfate plots of the same year, the sulfate sulfur was increased about one-third by application of sulfate of potash in the fertilizer. In other words, any sulfur which is added in the fertilizer will appear only as increased sulfate in the leaf. It is unnecessary in the development of the plant and calls for additional potash in order to keep up the burn. Although a certain small amount (.13 per cent) of sulfur is necessary to the growth of tobacco, there is no need to apply any extra sulfur in the fertilizer, since the plant will always be able to satisfy its needs from the soil sulfur or the sulfur which is unavoidably added in the organics of the fertilizer mixture.

The somewhat reduced fire holding capacity which has been found in the sulfate plots, as compared with the carbonate, is probably due to this small increase in sulfate sulfur. From the standpoint of good combustion it is probably fortunate that the ability of the tobacco plant to absorb increased quantities of sulfur is very limited. None of the analyses which have been made on Connecticut Valley tobacco show a sulfur content as high as one per cent while most of them come close to .5 per cent. In this respect, sulfur is in sharp contrast to chlorine, which the plant may absorb in large amounts, following rather regularly the quantity which has been applied to the soil.[1] Phosphorus, the third mineral acid element of the plant, acts more like sulfur. In fact, phosphorus is even more constant and it is difficult to change the percentage which occurs in the leaf, no matter how much is applied to the soil.

Jenkins, according to the report of the experiment station for 1896, page 328, found much greater differences in sulfur content between the tobacco grown with sulfate of potash and that grown

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[1] In some recent Kentucky experiments (Kentucky Agricultural Experiment Station Report. **41**:17) the chlorine content of tobacco was raised from .048 per cent in unfertilized tobacco to 6.5 per cent in tobacco where 800 pounds KCl to the acre were used in the fertilizer.

with carbonate. The percentage of sulfur in the ash of the first was two to four times as much as that in the latter. This was accompanied by similar differences in fire holding capacity. Ames and Boltz (Ohio Agricultural Experiment Station Bulletin 285, page 187) also found both total sulfur and sulfate sulfur increased in the leaf when sulfate of potash was used. The same was true when other carriers of sulfur, such as superphosphate and sulfate of ammonia, were used.

Concerning increase in the sulfur content of Burley tobacco from increased application of sulfate of potash, we quote from the 1928 report of the Kentucky experiment station, page 17, "The percentage of sulfur in the tobacco increased with increasing applications of potassium sulfate, but at a much lower rate than in the case of chlorine, the range being from .4 per cent in the unfertilized tobacco to 1.187 per cent in tobacco fertilized with 800 pounds per acre of potassium sulfate."

From the consensus of data from all available sources, both in the Connecticut Valley and elsewhere, the following principles with regard to sulfur for tobacco may be regarded as thoroughly established.

1. *From a growth standpoint, the addition of sulfur in the fertilizer mixture is unnecessary.*
2. *Applications of sulfates to the soil increase the percentages of sulfates which will appear in the leaves.*
3. *Sulfates in the leaf are injurious to the burn.*

In view of these facts it is best to avoid in the fertilizer all materials containing considerable percentages of sulfur unless there should be some very distinct advantage from some other standpoint in using them.

Effect of potash carriers on soil reaction. This subject was discussed in some detail in the report for 1928. There remains to be added only the results on the fifth year of the series. This

TABLE 12. REACTION OF POTASH PLOTS IN 1929

Source of potash	Plot No.	Reaction of soil 1925 May 20	1929 May 20	June 20	July 2	July 20	August 20
Sulfate	K1-2	6.02	5.91	5.00	5.12	5.43	5.92
	K1-3	5.09	5.06	4.25	4.32	4.96	4.76
Carbonate ..	K5	5.53	5.56	4.83	4.80	4.98	5.23
	K5-1	5.21	5.11	4.50	4.39	5.12	4.96
Nitr. ⅔	K7	5.31	5.13	4.43	4.55	4.92	5.17
Carb. ⅓	K7-1	5.30	5.15	4.18	4.35	4.49	4.56
Sulf. ½	K8	5.26	5.32	4.50	4.60	4.92	4.93
Carb. ½	K8-1	5.10	5.30	4.25	4.42	4.76	4.73
Sulf. ⅓ .... Carb. ⅓ .... Nitr. ⅓	K9	5.05	5.21	4.73	4.71	5.21	5.07
	K9-1	5.05	5.18	4.32	4.30	4.76	4.83

year it was thought best to determine reaction, not only immediately before and after removal of the crop, but also at several times in the growing season. The results for 1929 are presented in Table 12.

The samples of 1925 were taken before the experiment was started, immediately before application of fertilizer. The corresponding May samples for 1929 were also taken before application of fertilizers, four years after the first series of samples. Comparing these two columns it appears that the various treatments of the four intervening years have had little effect on the soil reaction.

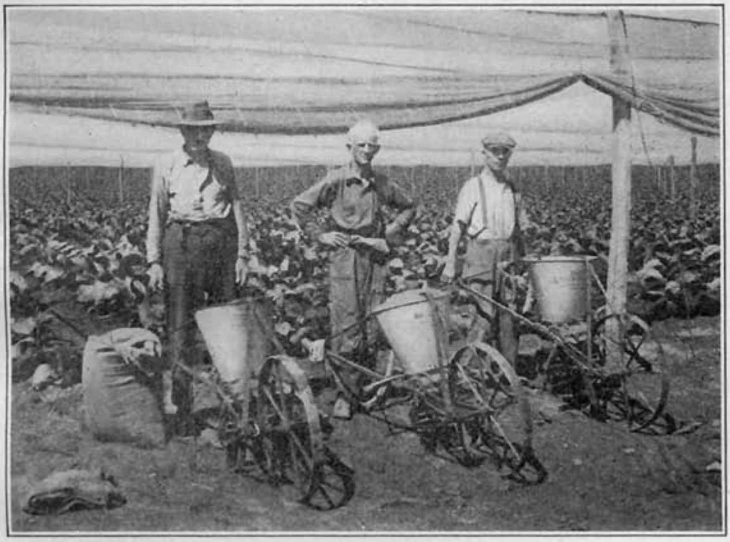

FIGURE 11. Side dressing the growing crop with wheelbarrow fertilizer sowers.

It will be noticed that during the remainder of the summer, all the plots were unusually acid, a condition which was not confined to these plots but was general throughout the state. The very dry summer following two years of heavy rainfall probably had some influence here. There was considerable variation in reaction up and down during the summer but no consistent tendency of any one treatment to make the soil more acid or less acid than the others.

We are justified in concluding, therefore, from all the results obtained through this five-year test that when sulfate, carbonate, nitrate or various combinations of them are used to supply 200 pounds of potash an acre, none of them will produce any significant change in reaction of a soil of this type.

THE USE OF MANURE AS A SUPPLEMENT TO COMMERCIAL FERTILIZER

In previous reports of this station,[1] field tests on the value of manure when used *in addition to* the regular application of commercial fertilizer have been described. Yield and sorting records for the first three years of the experiment show that in general there has been an improvement, both in yield and percentage of better grades, from the use of either stable manure or artificial (adco) manure on our sandy soil. The improvement was greater during the wet years of 1927 and 1928, but was only slight in the comparatively dry year of 1926, the first year of the experiment.

The extremely dry season of 1929 presented an opportunity for observing the effect of annual applications of manure on growth during that type of a season, even though yield and sorting data were prevented by the hail storm. On all the manure plots, both stable and adco, the plants were badly stunted in growth and the leaves were dark green and curled under at the edges. In fact, these were the poorest plots on the farm and their strong contrast to the adjacent plots made them easy to pick out by the many observers who passed judgment. The tobacco would have been hardly worth harvesting, even if the hail had not destroyed it.

Various explanations might be advanced for this result, but at any rate it is certain that under the dry conditions of this test on a sandy soil, the accumulated organic matter did not serve to retain the water, a property frequently ascribed to it, for the use of the crop. On the plants, the symptoms were those of drought rather than of nitrogen starvation.

Different results were obtained in an experiment with shade tobacco on the S. F. Holcomb farm in West Granby. Here a heavy application of cow manure was made to alternating bents in the shade tent. On the manured bents the tobacco became taller and had a more luxuriant growth. Growth in the other bents was below the average and unsatisfactory. This was a new field, the second year in tobacco, which had been used many years for general crops. The available phosphorus was relatively low in the soil, 26 pounds phosphorus to the acre. These conditions may account for the results. In this case the commercial fertilizer was reduced to 850 pounds an acre, instead of 2300, where the manure was applied.

Despite the unfavorable results which were obtained on the station farm during the past year, other results and the experience of many growers lead us to believe that the moderate use of manure to supplement the commercial fertilizer is a good practice

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[1] Tob. Sta. Bull. 10, 62. Conn. Agr. Exp. Sta. Bull. 299, 192.

wherever manure is available on the farms. Its purchase from outside sources at the high prices now commonly asked, however, is economically questionable. The shade tobacco grower may possibly be able to compensate himself for the added cost, but not the stalk grower. Manure contains a supply of all the elements which the growing plant needs, both the major three and the rarer elements. It may therefore supply a need which may be overlooked in preparing a concentrated chemical mixture. In this respect it is similar to tobacco stems. Some growers use stems and manure on alternate years and this practice seems to be sound.

When manure is used, the quantity of plant food supplied in the commercial mixture may be reduced, but not pound for pound, that is, a pound of plant food in manure does not seem to be as effective as a pound of the same element in a commercial mixture. Just how far this reduction may be carried is a matter for each grower to determine for his own type of soil. Certainly it is not economical to disregard entirely, as some do, the plant food which is added in manure.

It is generally conceded that manure alone will not produce the best results.[1] On the other hand, it is true that many fine crops of tobacco are being produced annually with no manure. Manure may be frequently beneficial, but it is not essential to the production of good tobacco.

EFFECT OF MANURE ON SOIL ACIDITY

In order to determine what effect annual applications of manure may have on the reaction of the soil, samples from the manure plots and adjacent unmanured plots on the station farm were tested at three different times. The first of these was taken in

TABLE 13. EFFECT OF MANURE ON ACIDITY OF THE SOIL

	pH reaction on—					
	May 8, 1929		July 3, 1929		October 15, 1929	
Kind of manure	Manure	Check	Manure	Check	Manure	Check
Stable, 20 loads	5.60	5.27	5.00	4.75	5.57	5.27
Stable, 40 loads	5.85	5.33	5.24	4.90	5.64	5.53
Adco, 30 loads	5.59 5.50	5.25 5.30	5.15 5.30	4.63 4.60	5.77 5.90	5.24 5.03

the spring before plowing the land, one during the growing season when the crop was about half grown, and the third in the late fall of the fourth year of the test, before application of manure for the next year.

[1] This opinion has been confirmed recently by experiments in Pennsylvania. See Pa. Bull. 240, 1929. The same conclusion was expressed by Jenkins after his experiments in Poquonock more than 30 years ago. Report of Conn. Agr. Exp. Sta. for 1897, 250.

Results of the tests presented in Table 13 show that manure has invariably made the soil less acid. Since this is true for all the different times of the year, it is obvious that this is a permanent effect and not transitory. Since black rootrot is favored by an alkaline reaction of the soil, it is possible that this change in reaction may at least partly account for the greater prevalence of

FIGURE 12. The second hoeing.

this disease in fields which have been heavily manured. The greater abundance of organic matter in the soil is probably also a contributing factor.

EFFECT OF MANURE ON THE BURN

Samples of the crop of 1928, taken from the center rows of each of the plots, were tested for fire holding capacity after sweating thoroughly and aging for a year. Results of these strip tests, presented in Table 14, indicate a slightly better burn for the manure plots. The differences, however, may be too small to be significant. Burn on all plots was so good that it is not easy to make any sharp distinction between tobacco grown with and without manure. At least we are safe in concluding that no impairment has resulted from the use of manure. These results agree rather closely with those of the Poquonock experiments of Jenkins, 1893-96. In three of the four years of that experiment, the fire holding capacity of the leaves from the manure plots was above the average of all the plots. In the fourth year it was somewhat below average (report for 1897, page 242).

In experiments in Ohio, Ames and Boltz (Ohio station Bulletin 285, 1915) also rated highly the burning qualities of tobacco from the manure plots. It has been found both in Connecticut and Ohio that tobacco from those plots contains an increased percentage of chlorine, but this does not seem to have affected adversely the fire holding capacity.

TABLE 14. MANURE SERIES OF 1928. STRIP BURN TESTS ON SWEATED SAMPLES

Carrier	Plot No.	Duration of burn (seconds) Darks	Mediums	Lights	Seconds	Average for Plot	Average for Treatment
Stable, 40 loads ..	M1	58	53	47	53	53	56
Stable, 20 loads ..	M1-1	59	59	59	57	58	
Adco, 30 loads ...	M2	59	57	55	60	58	58
	M2-1	58	54	59	59	58	
No manure	C3	58	54	54	57	56	53
	C3-1	58	57	49	50	54	
	C5	56	..	..	57	56	
	C5-1	51	52	54	53	53	
	C14	46	41	54	51	48	
	C14-1	44	50	51	55	50	

HYPER HUMUS

T. R. Swanback

Hyper Humus is a processed swamp peat residue, black and granular, consisting of decayed vegetation of past ages, which is marketed by the Hyper Humus Company of Newton, N. J. It is 80 per cent organic matter and has been used to advantage as a soil amendment for growing various crops which are benefited by increased organic matter in the soil. Since it seemed possible that tobacco also might be benefited by more organic matter in the sandy soils where it is commonly grown, some experiments with it have been made at this station. The results are here reported.

GREENHOUSE EXPERIMENTS

Greenhouse tests were made first in an attempt to determine what quantity of Hyper Humus might be applied most profitably. For this test, four-gallon crocks were filled with common sand and Hyper Humus in the following proportions, each treatment being in duplicate:

1. No Hyper Humus added
2. 12.5% " " by volume
3. 25% " " " "
4. 25% " " " "
5. 50% " " " "

The material was well mixed with the sand, together with 0.25 gm. $CaCO_3$ for each crock.

A nutrient solution was added to the crocks, except for number 3. It had the following composition:

Urea	30 cc of 1% solution
Sodium acid phosphate	24 cc " " "
Potassium carbonate	40 cc " " "
Magnesium sulphate	40 cc " " "
Traces of boron and iron.	

Enough water was added to obtain suitable moisture. One plant was set in each and allowed to grow for about 75 days before harvesting. Weight of the plants when harvested is given in Table 15.

TABLE 15. RELATIVE GREEN WEIGHTS OF TOBACCO PLANTS IN GREENHOUSE TESTS

Treatment and number	Green weight of 2 plants, ounces	Rel. weights of the total plant	Remarks
1. No Hyper Humus	3.88	1.00	
2. 12.5% " "	5.26	1.37	
3. 25% " "	4.88	1.26	No nutrients added
4. 25% " "	6.00	1.52	
5. 50% " "	8.38	2.16	

From this table it is evident that the 12.5 per cent treatment did nearly as well as the 25 per cent and was fully as good as treatment three, where no nutrients were added, but which also had 25 per cent Hyper Humus. The increased yield where Hyper Humus alone was added shows that the material either contains some available plant nutrients or may have increased the availability of those present. The benefit is more evident in the treatment with 50 per cent Hyper Humus, chemical treatment being the same as the check.

In a second test an attempt was made to determine the humus requirements for optimum growth, by using quantities of the material at closer intervals than in previous tests.

Pure silica sand, practically free from organic matter, was used in duplicate and percentages of Hyper Humus were 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 by volume. To each of the two-gallon crocks, two liters of the following nutrient solution was added.

Ammonium nitrate	0.200 gms.
Calcium nitrate	1.000 "
Di-potassium hydrogen phosphate	2.400 "
Magnesium sulfate	1.000 "
Ferric citrate	0.005 "
Traces of boron and manganese	
Water	1,000 "

One plant of Havana Seed tobacco was set in each crock. After a few weeks it was found that up to 21 per cent, each increase of Hyper Humus gave a corresponding increase in size of plants. They were harvested after two months. Dry weights at this time are given in Table 16.

From this experiment it appears that when pure silica sand is used, the quantity of Hyper Humus required for optimum growth lies around 21 per cent by volume, which would correspond to about 4.9 per cent of organic matter by weight.

Finally, a test was made to determine the ability of Hyper Humus to prevent or reduce leaching. Twelve two-gallon crocks were filled to a height of two inches with pure silica sand, on top of which was placed a two-inch layer of Hyper Humus. The crocks were then filled up with a mixture of common sand and station soil from a plot that had had no fertilizer treatment for a number of years, in the proportion of one to two.

Six crocks, for comparison, had a four-inch layer of silica sand at the bottom *without* a layer of Hyper Humus and were filled up with the sand-soil mixture. Nutrients were added in a dry form at the rate to the acre of:

200 lbs. nitrogen			455 lbs. potassium nitrate
160 " phosphoric acid	derived from		300 " urea
200 " potash			667 " sodium biphosphate

The nutrients were thoroughly mixed into the soil and then the crocks were watered. One plant of Havana Seed tobacco was set in each crock. The plants developed about equally well in the two series. When they reached the budding stage, they were cut down in order to prevent the roots from penetrating the bottom layer

TABLE 16. DRY WEIGHTS OF TOBACCO PLANTS GROWN IN PURE SAND + VARYING QUANTITIES OF HYPER HUMUS

Per cent Hyper Humus by volume	Approximate per cent of Hyper Humus by weights	Ounces: Whole plant, average of 2 plants	Ounces: Leaves: Leaves	Ounces: Leaves: Average of 2 plants
0	0.0	1.35	0.45 0.40	0.43
3	0.7	2.50	0.50 0.60	0.55
6	1.4	3.30	0.70 0.55	0.63
9	2.1	3.25	0.55 0.75	0.65
12	2.8	3.25	0.70 0.75	0.73
15	3.5	3.45	0.70 0.80	0.75
18	4.2	3.00	0.70 0.75	0.73
21	4.9	4.20	0.80 0.85	0.83
24	5.6	4.20	0.75 0.80	0.80
27	6.3	3.85	0.85 0.75	0.80
30	7.0	3.80	0.80 0.85	0.83

of silica sand, which was not to be depleted in nutrients through absorption by the plants. Soil and Hyper Humus were removed from the crocks and the remaining silica sand was well mixed, so as to obtain composite samples from the twelve humus treated pots, as well as from the checks. On these samples, Mr. Jacobson of the soils department determined the content of nitrogen, phosphorus and potash.

The results are given below:

	Per cent N	ppm NO_3	ppm P	ppm K
Check (no Hyper Humus)	.0139	21.7	15	44.22
Hyper Humus treated	.0187	20.8	15	41.41

It should be kept in mind that the volume of silica sand in the check pots was twice as large as that of the treatment. On this account the figures for the treatment would be cut approximately in half. The results of this test would thus indicate that Hyper Humus to an extent of 50 per cent decreases leaching of nutrients.

In another experiment, the quantity of silica sand at the bottom was equal for all treatments. Into two of them was placed a two-inch layer of Hyper Humus alone, two other crocks had a six-inch layer of soil added and the third pair had a layer of humus and a layer of soil on top of the silica sand. An equal portion of a nitrate of soda solution was poured on the crocks containing soil. Thereafter equal amounts of water were poured on all the crocks, a procedure which was repeated a few times. Samples from the silica sand were taken, as in previous experiment, and content of nitrates was determined. The results are listed below:

	Crock 1	Crock 2
Hyper Humus alone	37.2 ppm	20.4 ppm
Soil alone	1136 "	1107 "
Hyper Humus + soil	673 "	569 "

If the amount of nitrate present in the humus be subtracted from the nitrate content of the humus + soil treatment, it is apparent that the Hyper Humus was able to check about fifty per cent of the leaching, which is in agreement with the conclusion reached above.

FIELD EXPERIMENTS

In 1927, plots of one-eightieth of an acre were laid out in two series, Series I on Field VII and Series II on Field VI, each including four different quantities of Hyper Humus applied to the soil, 10, 20, 30 and 40 tons to the acre. The material was spread on the plots in April and thoroughly harrowed into the soil, which also received commercial fertilizer, equally for all plots, at a rate of 250 pounds ammonia, 100 pounds phosphoric acid and 200 pounds potash to the acre. Plants on all were set early in June. During the growing season the growth in general was better on the treated plots than on plots not treated with Hyper Humus.

The tobacco was harvested early in August. Curing of the crops was very good for Series I, while some of the tobacco was damaged in the curing of the second series. Table 17 gives the sorting records for the Hyper Humus experiment of 1927.

TABLE 17. HYPER HUMUS PLOTS. SORTING RECORD FOR 1927 CROP

	Tons Hyper Humus to acre	Yield of leaves, lbs. to acre	Percentage of grades L	M	LS	SS	LD	DS	F	B	Grade index
Series I	None	1062	7	5	14	10	31	6	16	11	.346
" "	10	1197	16	8	19	7	30	1	10	9	.454
" "	20	1121	10	6	21	6	31	4	12	10	.403
" "	30	1145	19	9	15	6	31	1	13	6	.466
" "	40	1227	16	7	21	7	30	2	11	6	.460
Series II	None	1296	9	8	15	5	47	3	11	2	.403
" "	10	1387	5	4	20	4	36	7	14	10	.352
" "	20	1296	4	6	15	7	33	14	15	6	.335
" "	20	1397	7	4	19	5	40	2	14	9	.370
" "	30	1441	8	7	15	4	43	2	13	8	.378
" "	40	1208		4	14	7	32	10	16	17	.284

The tobacco in Series I was all rated as of good quality. Yield figures and grade indexes indicate that there were no appreciable differences in results between the varying quantities of Hyper Humus, although in general the treatments all show better results than the check plots. From the results above the following summary is made:

Average yields without Hyper Humus ..	1179 lbs. to acre	
" " with Hyper Humus	1269 " " "	
" grade without Hyper Humus..	.375	
" " with Hyper Humus	.389	

The tests were continued in 1928. In the fall of 1927 the treated plots received the same amounts of Hyper Humus as were applied in the spring of the same year. Although the crop in the field looked rather promising, the sorting records of the cured tobacco have a very poor showing, as may be learned from Table 18.

TABLE 18. SORTING RECORDS OF HYPER HUMUS. CROP OF 1928

	Total Hyper Humus to acre	Acre yield Plot	Acre yield Ave.	Percentage of grades L	M	LS	SS	LD	DS	F	Grade index Plot	Grade index Ave.
Series I	None	880		1	..	14	20	18	25	22	.280	
" "	10	986		..	..	..	33	32	14	21	.244	
" "	20	908					34	27	15	24	.237	
" "	30[1]											
" "	40	1080		4		13	27	24	17	15	.320	
Series II	None	1305	1199	4	9	33	10	27	5	12	.425	.350
" "	None	1093		7	4	20	13	33	8	15	.275	
" "	10	926				23	16	20	17	24	.302	
" "	20	1051	1036	3		15	22	28	11	21	.313	.347
" "	20	1020		3	5	29	7	31	7	18	.380	
" "	30	1312				24	9	42	11	14	.333	
" "	40	1175		3	2	13	26	24	15	17	.317	

Neither the yields nor the grade indexes, with two exceptions, were improved by the treatments. A summary of the results will plainly show the slight differences:

Average yield without Hyper Humus	1039 lbs. to acre
" " with Hyper Humus	1049 " " "
" grade index without Hyper Humus ..	.315
" " " with Hyper Humus	.312

It may be mentioned that adjacent to the Hyper Humus plots in Series I was a manure plot which yielded 1069 pounds to the acre with a grade index of .319. Comparing this result with the best result in Series I, it is apparent that this treatment, now amounting to 80 tons of Hyper Humus to the acre, gave results similar to the same application of manure. This raises the question whether Hyper Humus will stand in competition with manure, economically or otherwise, in field culture of tobacco.

[1] Excluded because of error in stripping.

BURN TESTS

Burn tests were made on sweated samples of tobacco from the Hyper Humus series of the 1928 crop. The technique of these is described in previous bulletins of this station.

The results, recorded in Table 19, show that Hyper Humus in most cases had lowered the fire holding capacity, as judged by the strip test. A possible explanation to this may be the fact that Hyper Humus, contrary to ordinary peat, contains considerable lime, since it is produced from an old lake basin with calcareous sedimentation.

TABIE 19. HYPER HUMUS SERIES FOR 1928. STRIP BURN TEST ON SWEATED SAMPLES

Tons Hyper Humus to acre	Duration of burn (seconds) Darks	Mediums	Lights	Seconds	Average
None	58	54	54	57	56
20	43			53	48
40	53			59	56
60	57			54	56
80	55		50	42	49
None	56	45	60	58	55
None	56	56	52	54	55
20	29			32	31
40		33	34		34
40	25		18	30	24
60	58			52	55
80	48	22	23	22	29

SUMMARY OF SERIES I AND II

20 tons of Hyper Humus	40 sec.
40 " " " "	43 "
60 " " " "	56 "
80 " " " "	39 "
Average of checks (no Hyper Humus)	56 "
" " Hyper Humus treatments	45 "

SEED BED EXPERIMENTS

Inquiry from several growers on the use of Hyper Humus for tobacco seed beds led us to undertake a test with this material on two of the station seed beds, each measuring about three and one-third square rods or 880 square feet.

In October, 1928, one ton of Hyper Humus was harrowed into each of the beds. For comparison, a third received about one ton of well decomposed horse manure. Each bed received one bag of castor pomace which was harrowed in together with the humus and the manure. The following spring it was observed that *the growth* of tobacco plants was equally good in the two treatments. Also the *soil temperature* remained the same in both.

In *pulling the plants,* it was noticed that fully as big a lump of soil stuck to the roots from humus treated beds as from the manured one. One year's result would probably not justify any recommendations but the test seems to permit the use of Hyper Humus as a substitute for manure in seed beds, especially where the latter is not readily available.

DISCUSSION OF RESULTS

It is evident from the greenhouse experiments that addition of Hyper Humus up to a certain extent has benefited the growth of tobacco, while in the field tests the results are only slightly in favor of the material. An important difference in the experiments

FIGURE 13. Application of poison bait for killing cut worms.

is that in the greenhouse tests the humus was added to sand practically free from organic matter, while in the field the treatments were merely an addition to the organic matter already present. Ordinarily the tobacco soils in the Connecticut Valley contain from three to five per cent organic matter[1] and increasing the content in the fields where it is lower than this would probably be beneficial. Appleman,[2] investigating the effect of organic matter on soils, found that an early crop of potatoes came up sooner than did the potatoes in the control rows. This investigator also noted that the content of CO_2 increased in the treated rows up to 0.24 per cent, as compared with 0.058 per cent in the

[1] Conn. Tob. Substation Bull. 10, 66-71, 1927.
[2] C. O. Appleman: Percentage of Carbon Dioxide in Soil Air, Soil Science, 1927, XXIV, 241-245.

non-treated ones. The carbonic acid present in the soil would probably serve as a solvent for less available nutrients.

In order to observe to what extent organic matter had increased in the humus-treated plots, samples were taken six months after the second application from the various treatments, as well as from the checks. The content of organic matter was determined by Mr. Jacobson of the soils department. Results are given below:

Average content of organic matter from check plots	3.45%
" " " " " " application of 20 ton H-H	3.67%
" " " " " " " " 40 " "	4.10%
" " " " " " " " 60 " "	4.63%
" " " " " " " " 80 " "	4.63%

Up to 60 tons to the acre there was a steady increase in organic matter, while further applications did not increase the content correspondingly.

In general, the addition of Hyper Humus has caused little improvement in yield. Carbonaceous material, that is, not fully decomposed plant residues, present in a soil requires for its decomposition a certain amount of nitrogen. Investigators[3] have found a distinct relation between the carbon and nitrogen contents of soils. That is, the carbon-nitrogen ratio will remain constant. Therefore, where Hyper Humus is used as a soil amendment, care should be taken to supply sufficient nitrogen to permit the biological changes in the soil, as well as the nutrition of the plants grown thereon.

Finally, it should be mentioned that the soil reaction had not changed through the addition of the various quantities of humus. Determinations were made in July, 1929, with the following results:

Checks (No H-H)	4.90 pH
20 tons H-H	4.90 "
40 " "	4.93 "
60 " "	4.85 "
80 " "	4.83 "

[3] Sievers, F. J., and Holtz, H. F. The Significance of Nitrogen in Soil Organic Matter Relationships. Wash. Agr. Exp. Sta. Bull. 206, 1926.

CHEMICAL COMPOSITION OF A POOR BURNING TOBACCO CROP COMPARED WITH A GOOD BURNING CROP

E. M. Bailey and P. J. Anderson

It is well known to leaf dealers and manufacturers that crops of certain years do not burn well, while those of other years are distinguished by their excellent burning qualities. This difference has also been observed in the burn tests which have been made on the crops of the different years at the experiment station. The crop of 1924 had an extremely low fire holding capacity, coaled badly on the cigar and had a bitter taste. The crop of 1927, in contrast, had an unusually long fire holding capacity and good burning qualities on the cigar. In our report for 1928, it was pointed out that the fire holding capacity of our crops has shown a general correlation with the rainfall of the season during which they were grown. Thus the poor burning crop of 1924 was grown in an extremely dry season and the good burning crop of 1927 during a season of high rainfall. This same correlation between rainfall and burn has been observed in Pennsylvania by Haley, Nassett and Olson.[1]

There are two ways in which a season might affect the leaf; it might change its chemical composition, or it might change the mechanical structure of the leaf. In order to see how the season affects the chemical composition, tobacco from the two contrasting crops of 1924 and 1927 was analyzed by the analytical chemistry department. Samples were taken from plots which had the same fertilizer treatment for the two years, as well as during the intervening years. This included six plots of the old potash series and six plots from the lime series. Two grades, darks, D, and seconds, S, were selected for analyses. Some of the samples from the 1924 crop were not available because they had been used up in previous tests.

Results of the analyses are presented in Table 20.

This table shows that there were considerable and consistent differences in content of potash, chlorine, nitrogen and calcium and smaller differences in magnesium and phosphorus.

Potash. During the wet year the potash content was consistently higher, in the old potash series, than during the dry year. In the lime series, however, the potash content had been greatly reduced by yearly applications of lime. Morgan, Anderson and Dorsey[2] have shown that this reduction in potash content con-

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[1] Plant Physiology, 1928, III, 185-197.
[2] Conn. Agr. Exp. Sta. Bull. 306, 1929.

sistently follows application of lime and also on these same plots the fire holding capacity was correspondingly reduced. Haley, Nassett and Olson found that the potash content of tobacco leaves is higher during seasons of heavy rainfall. In view of the well known influence of potash in promoting burn, it seems likely that this was a contributing factor in making the 1927 crop burn better than the 1924 crop.

Chlorine. In the dry year crop of 1924, the chlorine content of the leaves was from two to ten times as great as in the 1927 crop. Perhaps no one element is more deleterious to burn than chlorine. It is therefore probable that this was a second contributing factor to the poor burn of the 1924 crop. Since chlorine salts are very readily leached from the soil, it is to be expected that during the wet year, any chlorine which was in the fertilizer would be quickly carried away, while during the dry year the chlorine salts would be absorbed by the roots of the plants.

Calcium. This element was consistently higher in the 1924 crop. According to the explanation offered by Haley, Nassett and Olson, calcium in the soil complex is replaced by potassium when potash salts are applied in fertilizer. This results in the accumulation of calcium salts in the surface soil. Heavy rains leach them down, but in a dry season they remain and are absorbed by the tobacco roots, which results in a more abundant deposit of calcium salts in the leaves.

In previous articles we have presented abundant data to show the retarding influence of lime on the fire holding capacity of tobacco as measured by the strip test. This apparently has been due to magnesium rather than calcium. Calcium salts are not known to improve the fire holding capacity, but on the other hand, there is little conclusive evidence that they hinder it.

Magnesium. Only the plots K1, K1-1, K3, T1b and T2b give us a true comparison of the magnesia content in dry and wet years. These show that more magnesia was deposited in the leaves in a dry year. The explanation of this is probably the same as for calcium. Plots K2 and K2-1 received annual applications of sulfate of potash magnesia and the high magnesia content of the later year may be due to accumulation of that element through the intervening years. Plots T1a and T2a and T3a received yearly application of magnesia in limestone and as a result the 1927 crop showed the highest percentage of magnesia of any of the samples tested. Comparison of these figures with the K2, K2-1 figures for the same year shows that dolomitic limestone is more effective than double manure salts in introducing magnesia into the leaves wherever such a result is desired.

In previous reports we have shown that magnesia has a decided influence in reducing the fire holding capacity of tobacco. Garner also finds that all magnesium salts are injurious to burn. Like the calcium salts, however, they make the ash white.

The greater abundance of magnesium in the leaf during a dry year is probably another contributing factor to poor burn.

Nitrogen. The most striking contrast shown by the analyses is in the nitrogen content. In every comparison without exception nitrogen is higher in the tobacco of the dry year. This applies not only to total nitrogen but also to every form of nitrogen. All the forms of nitrogen, with the exception of nitrates, are considered injurious to burn of tobacco. Any beneficial influence of the small amount of nitrate was probably more than counterbalanced by the quantity of the other nitrogenous compounds. The higher nicotine content may account for the bitter taste of the 1924 crop and the greater abundance of albuminous compounds for its poor aroma. The high nitrogen content of the leaf in a dry year is probably due to accumulation of nitrates in the surface soil—without leaching—and to retarded growth which prevents proper dilution in the plant.

Phosphorus. Phosphoric acid content was consistently higher in the dry year. The explanation is not obvious. Phosphates are injurious to fire holding capacity.

Sulfur. Total sulfur was also somewhat higher in the dry year. The apparent exceptions shown in the tobacco from plots K2 and K2-1 are due to the larger quantity of sulfur supplied yearly to these plots in double manure salts. The same differences in sulfur content were shown in the crop of 1926[1] on these plots. The injurious effect of sulfur on burn is discussed in another section of this report.

Manganese was consistently higher in the dry year. The apparent exceptions in plot T1b are due to the heavy annual applications of sulfate of ammonia to this plot. This made the soil more acid. It has been shown in previous reports of this station that a more acid soil results in increased manganese in the leaf. This same fact probably explains the increase of manganese during the dry year of 1924 in the other plots, that is, the soil is naturally more acid during a dry year. No data are available on the effect of increased manganese on the burn.

Silica, iron and alumina were all consistently more abundant in the leaves in the wet year. All three are probably inert as far as burn is concerned.

ALKALINITY OF THE WATER SOLUBLE ASH[2]

As long ago as 1870, Schloesing[3] showed that there is in general a direct relation between the alkalinity of the water soluble constituents of a tobacco ash and its fire holding capacity. Alkalinity

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[1] Conn. Agr. Exp. Sta. Bull. 299, 157.

[2] Determined according to Methods of Analysis, Asso. Off. Agr. Chemists, Edition 1925, page 180, sections 9, 12 and 13. Two grams of material used.

[3] Schloesing, Th. Uber die Verbrennlichkeit des Tobaks. Journ. F. prak chemie, LXXXI, 143-150.

TABLE 20. COMPOSITION OF CROP OF 1924 (POOR BURN) COMPARED WITH CROP OF 1927 (GOOD BURN), MOISTURE FREE BASIS

Plot	Grade	Treatment		Total ash 1924	Total ash 1927	SiO_2 1924	SiO_2 1927	Fe_2O_3 + Al_2O_3 1924	Fe_2O_3 + Al_2O_3 1927	CaO 1924	CaO 1927	MgO 1924	MgO 1927	Mn_3O_4 1924	Mn_3O_4 1927	K_2O 1924	K_2O 1927	P_2O_5 1924	P_2O_5 1927
		Potash Series																	
K1	D	All K in H. G. sulfate		26.18	25.33	2.45	3.65	0.42	0.43	5.16	4.47	1.35	0.58	0.16	0.10	8.08	8.00	1.01	0.78
K1	S				31.40		5.50		0.76		5.59		0.75		0.15		9.26		0.72
K2	D	All K in double manure salts		25.76	25.84	2.46	3.84	0.33	0.49	4.86	3.88	1.44	1.22	0.16	0.12	7.80	8.43	0.99	0.76
K2	S			28.23	30.84	3.36	6.63	0.40	0.89	5.63	4.42	1.63	1.71	0.16	0.16	7.97	8.84	0.87	0.65
K3	D	Half and half		26.46	26.41	3.02	4.51	0.31	0.45	5.03	4.17	1.36	0.99	0.11	0.09	7.93	8.00	0.92	0.84
K3	S				31.58		7.85		0.88		4.96		1.20		0.13		8.39		0.68
K1-1	D	All K in H. G. sulfate		26.41	24.97	2.86	3.53	0.38	0.35	5.17	4.08	1.36	1.04	0.16	0.06	7.88	8.31	1.05	0.79
K1-1	S				32.26		8.07		0.87		4.91		0.87		0.13		8.81		0.64
K2-1	D	All K in double manure salts		25.68	26.73	2.76	4.28	0.37	0.47	4.98	3.99	1.31	1.81	0.13	0.12	7.48	8.24	0.92	0.74
K2-1	S			28.87	32.33	3.90	8.37	0.39	0.98	5.91	4.55	1.60	1.62	0.14	0.11	7.83	8.33	0.76	0.60
K3-1	D	Half and half			25.39		3.77		0.38		4.23		1.09		0.05		7.89		0.76
K3-1	S				30.66		7.40		0.73		5.23		1.43		0.08		7.59		0.54
		Lime Series																	
T1a	D	Acid fertilizer	With lime	25.78	23.81	2.27	5.48	0.24	0.48	6.17	4.30	1.12	2.93	0.08	tr.	6.81	4.66	0.97	0.60
T1a	S				28.17		9.12		0.83		4.65		3.91		tr.		3.89		0.58
T1b	D		Without lime	26.01	25.08	3.72	3.84	0.38	0.39	4.53	4.96	1.15	0.76	0.15	0.24	7.66	7.04	1.02	0.77
T1b	S			28.15	29.67	3.89	7.16	0.40	0.81	6.15	5.73	1.21	0.78	0.13	0.34	7.08	7.01	0.96	0.71
T2a	D	Alkaline fertilizer	With lime	25.46	22.85	2.65	3.90	0.22	0.24	5.87	4.21	1.08	2.35	0.02	0.00	6.82	5.51	0.89	0.61
T2a	S				28.05		7.12		0.41		4.91		2.73		0.00		5.62		0.48
T2b	D		Without lime	25.29	24.28	2.52	3.66	0.33	0.52	5.77	4.76	1.06	0.70	0.04	0.02	6.90	7.11	0.96	0.68
T2b	S				30.60		8.62		0.96		4.96		0.66		0.02		7.32		0.58
T3a	D	Neutral fertilizer	With lime		22.01		3.17		0.18		4.19		3.21		tr.		5.03		0.53
T3a	S			29.39	25.73	3.99	6.60	0.38	0.41	7.87	4.49	1.33	4.23	0.02	0.00	5.99	4.24	0.62	0.42
T3b	D		Without lime		23.57		3.23		0.31		4.57		0.94		0.02		6.88		0.67
T3b	S				30.26		8.97		1.02		5.62		1.22		0.03		5.96		0.40

TABLE 20. COMPOSITION OF CROP OF 1924 (POOR BURN) COMPARED WITH CROP OF 1927 (GOOD BURN), MOISTURE FREE BASIS (Continued)

Plot	Grade	Treatment		Cl		S (total)		N (total)		N (as NH_3)		N (as NO_3)		N in (nicotine)		Nicotine		Alkalinity of water soluble ash	
				1924	1927	1924	1927	1924	1927	1924	1927	1924	1927	1924	1927	1924	1927	1924	1927
		Potash Series																	
K1	D	All K in H. G. sulfate		0.61	0.43	0.86	0.73	4.79	4.00	0.47	0.24	0.62	0.37	0.37	0.29	2.17	1.69	94.8	108.0
K1	S				0.37		0.76		3.09		0.06		0.62		0.15		0.86		129.8
K2	D	All K in double manure salts		0.54	0.27	0.93	0.86	4.64	3.82	0.45	0.19	0.36	0.13	0.39	0.29	2.23	1.69	91.0	109.0
K2	S			0.50	0.18	0.79	0.83	5.10	3.05	0.34	0.13	0.62	0.52	0.38	0.17	2.19	0.97	100.0	124.5
K3	D	Half and half		0.59	0.21	0.82	0.79	4.65	3.67	0.43	0.15	0.39	0.17	0.41	0.20	2.40	1.17	90.5	111.0
K3	S				0.15		0.73		2.70		0.08		0.39		0.12		0.67		125.4
K1-1	D	All K in H. G. sulfate		0.65	0.26	0.83	0.76	4.70	3.75	0.52	0.24	0.84	0.17	0.43	0.36	2.46	2.09	91.0	114.3
K1-1	S				0.15		0.68		2.45		0.09		0.21		0.17		0.98		137.0
K2-1	D	All K in double manure salts		0.53	0.27	0.89	0.96	4.55	3.47	0.45	0.19	0.52	0.35	0.45	0.27	2.58	1.54	89.5	105.5
K2-1	S			0.44	0.14	0.74	0.82	3.76	2.44	0.31	0.13	0.77	0.30	0.35	0.16	2.00	0.91	102.0	115.5
K3-1	D	Half and half			0.25		0.79		3.73		0.30		0.26		0.38		2.20		108.5
K3-1	S				0.15		0.59		2.37		0.13		0.22		0.20		1.18		116.5
		Lime Series																	
T1a	D	Acid fertilizer	With lime	0.48	0.04	0.74	0.58	5.10	2.67	0.56	0.25	0.52	0.00	0.48	0.41	2.80	2.37		
T1a	S				0.04		0.55		2.18		0.21		0.00		0.35		2.02		
T1b	D		Without lime	0.51	0.09	1.03	0.78	5.37	3.74	0.63	0.27	0.83	0.26	0.40	0.36	2.34	2.06		
T1b	S			0.41	0.04	0.79	0.69	4.47	2.80	0.45	0.15	0.75	0.13	0.39	0.23	2.24	1.34		
T2a	D	Alkaline fertilizer	With lime	0.50	0.04	0.51	0.45	4.78	2.76	0.49	0.24	0.64	0.00	0.45	0.35	2.62	2.00		
T2a	S				0.09		0.45		2.08		0.09		0.00		0.23		1.34		
T2b	D		Without lime	0.47	0.28	0.54	0.47	4.89	3.38	0.52	0.26	0.62	0.09	0.49	0.39	2.82	2.27		
T2b	S				0.42		0.42		2.36		0.13		0.13		0.25		1.47		
T3a	D	Neutral fertilizer	With lime		0.04		0.37		2.83		0.28		0.04		0.43		2.46		
T3a	S			0.47	0.22	0.42	0.34	3.81	1.97	0.30	0.22	0.86	0.00	0.47	0.35	2.71	2.03		
T3b	D		Without lime		0.04		0.53		3.34		0.26		0.09		0.39		2.24		
T3b	S				0.04		0.39		2.09		0.17		0.00		0.24		1.41		

of the ash solution is due almost entirely to the carbonate of potash which it contains; that is, the more carbonate, the more alkaline the solution. The leaf does not contain carbonate of potash, but when it is burned, potash salts of the organic acids, malate, citrate, and others in the leaf, are oxidized to carbonate. The inorganic potash salts, sulfate, chloride and phosphate, are not changed. Hence the alkalinity of the ash solution is a measure of the quantity of organic potash salts which the leaf contains, and, as has been frequently pointed out, the more organic potash salts, the better the burn.

In the good burning crop of 1927, the increased percentage of potash and reduced percentage of sulfate, chlorine and phosphate would indicate that more of the potash was combined with the organic acids than in the poor burning crop of 1924. In order to see whether this relationship is further indicated by the alkalinity of the water soluble ash, and to determine the parallelism between this factor and the fire holding capacity of the leaf, the analyses recorded in the last two columns of Table 20 were made.

These figures show that in every case the results are as would be anticipated; that is, the alkalinity of the good burning 1927 crop is uniformly much higher than that of the poor burning crop of 1924. Also it is of interest to note that the alkalinity of the seconds, usually the best burning leaves, is in every case higher than that of the darks from the same plot.

Alkalinity of the soluble ash thus appears in this comparison to be a good index to fire holding capacity.

CHEMICAL INVESTIGATIONS OF TOBACCO[1]

By Hubert Bradford Vickery and George W. Pucher

In spite of the great economic importance of the tobacco plant, there is not available sufficient accurate information on the nature of the various chemical compounds that are present in the green leaf or the changes which they undergo during the curing and fermentation processes. The identification of these compounds and a study of the reactions by which they are formed and in which they play a part is of fundamental importance for the understanding of the metabolism of the plant and may lead to improved methods for the production and use of the tobacco plant.

Although a plant tissue contains a complex mixture of substances, it is possible to classify these substances into groups the members of which have certain common characteristics. For practical reasons we have selected as our first point of attack the large and complex group of compounds that contain nitrogen.

The nitrogenous compounds of the tobacco plant may be divided, as a matter of convenience, into those that are soluble in hot water and those that are insoluble. It is this first group of compounds upon which our experimental work is being concentrated at the present time. This fraction contains volatile and non-volatile bases, nitrates, amides and amino acids, purines, and probably many other substances of less well-known types. As a first step in the elaborate series of operations that must be carried out before any single substance can be isolated and identified, accurate methods of chemical analysis must be developed so that the various details of the manipulations may be followed quantitatively. The analysis of tobacco extracts presents such unusual difficulties that new or considerably modified methods, even for the determination of the most commonly occurring nitrogenous substances, must be devised.

The presence of nicotine, a base almost as volatile as ammonia, in tobacco extracts has made it necessary to develop a special technique for the determination of ammonia nitrogen and of amide nitrogen. The methods hitherto used are elaborate and tedious, involving uncertain corrections for the nicotine present. Our method takes advantage of a curious property of permutit, a synthetic silicate, which, at the proper reaction, undergoes selective

[1] The chemical investigations of tobacco herein described were carried out as part of a general project under the title "Cell Chemistry," by the Department of Biochemistry of the Connecticut Agricultural Experiment Station, New Haven, Conn. The Department has enjoyed the benefit of close coöperation from the Tobacco Substation. The expenses were shared by the Connecticut Agricultural Experiment Station and the Carnegie Institution of Washington, D. C.

quantitative base exchange with ammonia in the presence of other volatile bases such as nicotine and trimethylamine, thereby removing the ammonia from the solution. The ammonia so taken up may be quantitatively released by adjusting the reaction and then estimated colorimetrically by Nessler's solution. The figures thus obtained represent the actual ammonia content of the extracts analyzed and corrections for nicotine or other amines are not required. The presence of nicotine and ammonia has also made it advisable to develop a modification of the Jones method for the determination of nitrates that are usually present in the extract. This modification enables us to determine the nitrate content of tobacco with considerable accuracy.

The presence of nitrates in tobacco plant extracts makes it necessary to employ special methods for the determination of total nitrogen in them. We have confirmed the observations of Ranker (1)[1] that the well-known and widely used salicylic acid-zinc method, when applied to aqueous extracts, gives inaccurate results and this observation has compelled us to develop a method that can be applied to aqueous solutions. The results of this investigation are being prepared for publication at the present time.

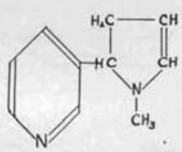
It may also be mentioned here that evidence has been accumulated which indicates that the determination of peptide nitrogen by the methods generally used may be erroneous when tobacco samples containing large quantities of nitrates are analyzed.

Each method of analysis must be studied in detail in order to ascertain whether the data obtained have significant value when the method is applied to tobacco extracts.

THE BASES OF TOBACCO EXTRACTS.

a. NICOTINE.

Nicotine is the chief volatile alkaloid of the tobacco plant.



Structure formula of nicotine.

This substance has received a great deal of attention from tobacco investigators. Nevertheless, in spite of a vast accumulation of data, there is still no real explanation of the source of niçotine in the plant nor more than speculation concerning its function.

[1] Numbers in parentheses refer to bibliography on page 245.

The amount of nicotine present in the tobacco leaf varies over a wide range depending upon the age, species and method of cultivation. The relationship between the age of the plant and its content of nicotine is extremely interesting. Thus it has been shown by Smirnov (2) that nicotine constantly increases during the life period of the plant. This investigator believes that nicotine represents a passive substance in the metabolism and that the quantity present may serve as an index of the age of the plant.

Pictet (3, 4) has suggested that nicotine may be formed during the growth of the plant from decomposition of the complex nitrogenous constituents, such as protein, nucleic acids, chlorophyll, etc., in the tissues. Mothes (5), however, has taken exception to this view and advanced experimental evidence to show that nicotine is not derived from the breakdown of protein. This investigator concluded that: 1. Nicotine is not a reserve material for nitrogen metabolism. 2. Nicotine synthesis takes place where there is active growth and is influenced neither by light nor by the introduction of outside sources of nitrogen. 3. The quantity of nicotine synthesized is not proportional to the size of the leaves. 4. There is no relationship between the amount of protein and the amount of nicotine synthesized.

Garner (6) has suggested that nicotine is present in the tobacco leaf in two forms, the one combined with organic acids of the leaf and the other free, or very loosely combined. The "free" nicotine has been correlated with the flavor of tobacco, a high proportion being, in part at least, responsible for the harsh and disagreeable taste sometimes observed. In view of this the determination of the proportion of "free" nicotine may be of importance in judging the quality of tobacco.

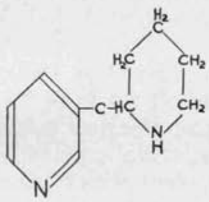
Nicotine is an organic base and can combine with one or with two equivalents of acid. The extent to which combination takes place varies with the hydrogen ion concentration of the solution. The hydrogen ion concentration of an extract of tobacco depends upon the relative proportions of the soluble basic and acidic substances derived from the leaf: the extent of hydrolysis of the salts of nicotine contained in such an extract will determine the fraction of the total nicotine which is present as "free" nicotine. The well-known equation

$$\mathrm{pH} = \mathrm{pK} + \log \frac{[\text{free base}]}{[\text{salt of base}]}$$

shows that the degree of hydrolysis, represented by the last term, depends only on the reaction of the solution and the dissociation constant of the base. Once the magnitude of the dissociation constant of nicotine has been determined, a curve can be constructed from which the proportion of the nicotine present in the "free" form in a sample of tobacco can be read directly at the point corresponding to the hydrogen ion concentration of an aqueous extract of the sample. The dissociation constants of nicotine have therefore been determined (7) and a curve showing the relation between the degree of hydrolysis and the hydrogen ion concentration has been constructed. This curve permits an accurate and simple evaluation of the "free" nicotine of tobacco samples, since a determination of the hydrogen ion concentration only is required. This is most conveniently accomplished by the quinhydrone electrode.

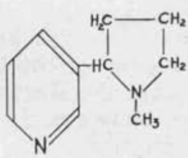
b. ALKALOIDS OTHER THAN NICOTINE IN TOBACCO EXTRACTS.

Pictet and Rotschy (8) first demonstrated that there are a number of bases that possess properties allied to those of nicotine present in tobacco extracts. Of these, nicotimine, a liquid isomeric with nicotine, is volatile with steam. The formula proposed by Pictet and Rotschy represents this substance as 2-piperidyl-3 pyridine. The correctness of this formula was not, however, conclusively proved.



Nicotimine.

Two other bases isolated by Pictet and Rotschy were not volatile with steam. Nicoteine, a liquid, was assigned a formula

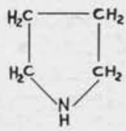


Nicoteine.

which represents a reduced form of nicotine. Nicotelline was isolated as a crystalline solid. No structure has been assigned to it.

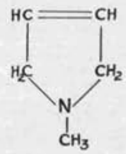
Noga (9) some years ago described two substances isolated from tobacco as new alkaloids to which he gave the names isonicoteine and nicotoine. The experimental evidence for the existence of these substances is not entirely convincing.

In addition to the alkaloids that have been mentioned, Pictet and Court (4) isolated from cured tobacco small amounts of the simple nitrogenous bases, pyrrolidine,



Pyrrolidine.

and N-methyl pyrroline.



N-methyl Pyrroline

These substances were considered by Pictet as probable precursors of nicotine and the related alkaloids of the tobacco plant.

The alkaloids and simpler bases of tobacco are of great interest to the plant physiologist. No exhaustive investigation of the metabolic changes in the plant which give rise to their formation has ever been published, although the problem is of much importance.

It is clear from this discussion of the work of Pictet that a steam distillate obtained from an alkaline extract of tobacco may contain other substances in addition to nicotine. One, at least, of these substances is an alkaloid that behaves in a manner similar to nicotine, that is, it forms an insoluble silicotungstate and picrate and is difficult to separate from this substance. It is evident, therefore, that existing methods for the determination of nicotine in tobacco are not exact, since the silicotungstate precipitate prepared in the usual way inevitably contains any other volatile alkaloid similar in structure to nicotine. The "nicotine" determination on the steam distillate of a tobacco sample therefore gives values that represent the sum of the nicotine and the other volatile base or bases that are precipitated by silicotungstic acid. Inasmuch as the other volatile bases make up only a small part of the whole, the complexity of the precipitate is not of great significance in practical work, but this fact must be recognized in any detailed study of the chemistry of the tobacco plant.

A rough idea of the amount of the substances other than nicotine that are precipitated by silicotungstic acid from the steam volatile fraction of extracts of cured tobacco leaves was secured from the following data. A steam distillate that contained 63.0 gm. of nicotine as determined by silicotungstic acid precipitation was subjected to a careful examination by fractional crystallization of the picrates of the alkaloids. The equivalent of 58.0 gm. of nicotine was obtained as picrate and 4.1 gm. of other alkaloids, likewise as picrates, were found. Thus at least 6.5 per cent of the "nicotine" indicated by the silicotungstic acid method actually represents volatile bases other than nicotine. These are minimum values since losses occurred in the manipulations.

From the bases other than nicotine, 0.6 gm. of a base was isolated that reacted with nitrous acid and with benzoyl chloride in the manner described by Pictet and Rotschy for nicotimine. This material gave a beautifully crystalline dipicrate much more soluble than nicotine dipicrate and quite different from it in appearance. The decomposition point was 179.5-180.5° C. (uncorr.), whereas nicotine dipicrate decomposes at 218-220° C. (uncorr.). Pictet described his preparation as an oily picrate that melted at 163°C. Our preparation, perhaps due to its greater degree of purity, had a higher melting point. In the crude form it yielded an oily picrate with a melting point around 170-175°C. The nitrogen content of the pure picrate was 18.29 per cent, while the nitrogen calculated for nicotine dipicrate was 18.06 per cent. The substance is therefore isomeric with nicotine.

C. THE ABSENCE OF NICOTINE IN MATURED TOBACCO SEEDS

In order to gain some insight into the formation of nicotine in the plant, a quantitative comparison of the nicotine content of ungerminated and germinated tobacco seed was carried out. This study was undertaken to establish definitely the presence or absence of volatile bases of a complexity comparable to that of nicotine in matured tobacco seed and also to discover whether seeds germinated entirely without outside sources of food were capable of producing nicotine.

In regard to the occurrence of nicotine in tobacco seed, the literature is at considerable variance. Thus Scurti and Perciabasco (10), Paris (11), Bernardini (12), Chaze (13), and Ilyin (14) maintain that there is no nicotine in tobacco seed. On the other hand, Albo (15), Ciamician and Ravenna (16), and Klein and Herndlhofer (17) claim to have demonstrated the presence of this alkaloid in the seed. None of the investigators who have claimed that nicotine is present in tobacco seed have attempted to isolate this substance and thus conclusively establish their contention.

Little information regarding the amounts of nicotine present in very young tobacco plants has been published and, as far as we have found, no one has reported the isolation of this alkaloid from such material. Chuard and Mellet (18) reported no nicotine in 20 day old plants, while in plants at 50 days the leaves contained

0.33 per cent and the roots 0.15 per cent. Chaze (13) demonstrated the presence of nicotine in 1 mm. plants by a histochemical technique with Bouchart's reagent. Paris also states that germinating seed contains a small quantity of nicotine.

a. *Experiment 1.* 20 gm. finely ground seed of Cuban shade tobacco were suspended in water, an excess of sodium hydroxide was added and the material was distilled with steam into N/10 hydrochloric acid until 2 liters of distillate had been collected. The distillate was concentrated at a reaction of pH 4.0 *in vacuo* to a volume of 50 cc. On the addition of silicotungstic acid no precipitate was formed.

b. *Experiment 2.* 100 gm. of seed of Connecticut Havana tobacco were extracted three times with boiling water. The extract was concentrated *in vacuo* to a volume of 200 cc. and 100 cc. of this extract (50 gm. seed) were distilled at alkaline reaction with steam into acid and the distillate was concentrated to 50 cc. On the addition of silicotungstic acid no precipitate was obtained. Several other experiments on different batches of seed were carried out with similar negative results.

According to Rasmussen (19) silicotungstic acid will give a detectable precipitate with nicotine in a dilution of 1 : 300,000. Since, in Experiment 2, a distillate from 50 gm. of seed gave no precipitate with silicotungstic acid, it may be concluded that matured tobacco seed contains only undetectable traces of nicotine, confirming the recent experimental work of Ilyin. This investigator found that immature seeds contain some nicotine (substances precipitable with silicotungstic acid) which progressively diminishes until complete disappearance at full maturity. This observation probably explains the conflicting views in the literature on the occurrence of nicotine in tobacco seeds, since some of the investigators may have been dealing with mixtures of immature and mature seeds.

d. THE ISOLATION OF NICOTINE FROM 9-11 DAY GERMINATED TOBACCO SEED

Preparation of Material. Seed of Cuban shade tobacco which showed 90 per cent germination and contained no nicotine was germinated in the dark on blotters for from 9-11 days until a growth of about 2-3 cm. was obtained. The seedlings were then removed from the blotters and, after weighing, were transferred immediately to a closed vessel containing chloroform. The material was held in an atmosphere of chloroform for 2-3 hours and then spread out on shallow pans and dried overnight at 60-70° C. The dry material could be separated by means of sieves into two parts. The separation was not perfect, but two fractions were obtained, one of which contained the greater part of the cotyledon and hypocotyl, and the other chiefly the seed coats and ungerminated seeds.

Preparation of Extracts. Samples of these two fractions and also of the original seed each weighing 100 gm. were extracted three times by boiling with ten times their weight of distilled water. The aqueous extracts were concentrated *in vacuo* and made to a definite volume for subsequent analyses. They are referred to in what follows as the hypocotyl-cotyledon extract, the seed coat extract, and the seed extract.

Isolation of Nicotine from the Hypocotyl-Cotyledon Extract. 100 cc. of the water extract of the cotyledons and hypocotyls, equivalent to 19 gm. dry substance, were concentrated *in vacuo* to a thick sirup after the addition of 5 cc. 2N hydrochloric acid. The sirup, after the addition of an excess of sodium hydroxide, was distilled with steam, with the constant addition of a little butyl alcohol to prevent foaming, into an excess of hydrochloric acid until about 1000 cc. of aqueous distillate had been collected. The distillate was concentrated *in vacuo* to 25 cc., was made alkaline with sodium hydroxide and extracted with ether. After *cautious* evaporation of the ether 30 mg. of a light yellow oil with the characteristic odor of crude nicotine remained. The oil was dissolved in 5-10 cc. of water and poured into 25 cc. of a saturated aqueous solution of picric acid. A voluminous yellow precipitate immediately formed and 50-60 cc. of boiling water were required to effect its complete solution. When the solution was cooled characteristic needles of nicotine dipicrate separated. These were filtered off, washed with water and alcohol and dried. The crystals sintered at 218° and decomposed at 220-221° C. After recrystallization from water the decomposition point was raised to 224-225° C., and a mixture of this material with a sample of pure nicotine dipicrate showed no depression of the decomposition point.

It is therefore clear that nicotine is present in the sprouts and cotyledons of tobacco seed after only 9-11 days of germination. It is also evident that nicotine can be synthesized by the plant from the reserve of food material in the seed at a very early stage of growth and, unless one is prepared to admit that atmospheric nitrogen enters into the reaction, that outside sources of nitrogen are not called upon at this stage for the synthesis. These experiments strikingly confirm the work of Mothes (5), who found that nicotine synthesis takes place during the early growth of the plant.

NITROGEN DISTRIBUTION IN GERMINATED AND UNGERMINATED SEED

In view of the demonstration that nicotine is synthesized by the germinating plant from its own reserve of food material it was interesting to investigate the distribution of the nicotine nitrogen as well as the other forms of nitrogen in the extracts of the germinated and ungerminated seed. These data are presented here in detail since only a limited number of analyses of tobacco seed before and during the early stages of germination are recorded in the literature. Paris (10) records an incomplete analysis of mature tobacco seeds. Ilyin (14), whose paper was received during the preparation of this bulletin, presents analyses of some of the nitrogenous constituents of three types of oriental tobacco seed. Ilyin also studied the distribution of nitrogen in

TABLE 21. ANALYSIS OF UNGERMINATED AND GERMINATED SEED IN PER CENT OF DRY WEIGHT

	Ungerminated seed	Ungerminated oriental tobacco seed[1] Ilyin (14)	Germinated seed — Seed coat	Germinated seed — Cotyledons Hypocotyls	Germinated oriental tobacco seed[1] Ilyin (14)
	%	%	%	%	%
Total Insoluble Solids	**80.40**	....	**88.51**	**77.80**	....
Insoluble inorganic	1.32	....	2.64	2.21	....
Insoluble organic	79.08	....	85.87	75.59	....
Total Soluble Solids	**19.60**	....	**11.49**	**22.20**	....
Soluble inorganic	2.59	....	1.32	3.35	....
Soluble organic	17.01	....	10.17	18.85	....
Reducing substances (as glucose)	0.00	....	2.60	8.09	....
Total Nitrogen	**4.06**	**4.02**	**3.96**	**5.56**	**4.78**
Insoluble nitrogen (chiefly protein)	3.46	3.87	3.39	4.15	3.94
Soluble Nitrogen	**0.60**	0.15	**0.57**	**1.41**	0.84
Ammonia nitrogen	0.02	....	0.06	0.13	0.13
Nitrate nitrogen	0.03	....	0.00	0.00	....
Amide nitrogen	0.06	....	0.04	0.10	0.27
Nicotine nitrogen	0.00	0.001	0.01	0.05	0.05
Unknown volatile base nitrogen	0.01	....	0.03	0.04	....
α amino nitrogen	0.09	....	0.15	0.43	0.43
Peptide nitrogen	0.13	....	0.04	0.02	....
Other nitrogen (unknown forms)	0.26	....	0.24	0.64	....
Basic nitrogen	0.11	....	0.06	0.20	....
Non-basic nitrogen	0.29	....	0.29	0.64	....
Reaction of Extract (pH)	**6.72**	....	**5.82**	**5.23**	....

these seeds at germination intervals of 5-15 days. However, no similar data have been recorded, as far as we are aware, on the type of tobacco seed used in these investigations. For comparative purposes the averages of the figures obtained by Ilyin are appended to the data presented in Tables 21 and 22. Our analyses were performed on the three extracts whose preparation has already been described. Duplicate determinations were made in all cases by the following methods:

Total nitrogen—Kjeldahl.

Ammonia nitrogen—Colorimetric with permutit, see Vickery and Pucher (20).

Nitrate nitrogen—Modification of Jones method, see Vickery and Pucher (21).
Amide nitrogen—Method, see Vickery and Pucher (20).
Nicotine—Silicotungstic acid method (22).
Unknown volatile bases—Total volatile base nitrogen by titration minus nicotine nitrogen minus ammonia nitrogen.
α amino nitrogen—Van Slyke method (23).
Peptide nitrogen—Hydrolysis of extract with 8N sulphuric acid and determination of increase of α amino nitrogen by Van Slyke method.
Basic nitrogen—Nitrogen in phosphotungstic acid precipitate of hydrolyzed extract according to Osborne and Harris (24).
pH—Quinhydrone electrode.

Table 21 presents the data obtained upon germinated and ungerminated seeds calculated to per cent of the dry material.

TABLE 22. DISTRIBUTION OF THE NITROGEN IN UNGERMINATED AND GERMINATED SEED

	Total soluble nitrogen			Total soluble and insoluble nitrogen		
		Germinated seed			Germinated seed	
	Ungerminated seed	Seed coat	Cotyledons Hypocotyls	Ungerminated seed	Seed coat	Cotyledons Hypocotyls
	%	%	%	%	%	%
Ammonia nitrogen	3.33	10.53	9.22	0.49	1.52	2.34
Nitrate nitrogen	5.00	0.00	0.00	0.74	0.00	0.00
Amide nitrogen	10.00	7.02	7.08	1.48	1.01	1.80
Nicotine nitrogen	0.00	1.76	3.54	0.00	0.25	0.90
Unknown volatile base nitrogen	1.67	5.27	2.84	0.25	0.76	0.72
α amino nitrogen	15.00	26.30	30.5	2.22	3.78	7.73
Peptide nitrogen	21.7	7.02	1.42	3.20	1.01	0.36
Other nitrogen (unknown forms)	43.3	42.1	45.4	6.41	6.06	11.51
Total soluble nitrogen				14.79	14.39	25.36
Insoluble nitrogen (chiefly protein)				85.21	85.61	74.64
Basic nitrogen	18.3	10.5	14.2	2.71	1.52	3.60
Non-basic nitrogen	48.4	50.8	45.4	7.15	7.33	11.51

It will be observed that the aqueous extract of ungerminated seed is less acid than that from the germinated material.

In Table 22, the proportions of the different forms of nitrogen have been recalculated as percentages of the total soluble nitrogen and of the total nitrogen respectively. These figures show that about 3.5 per cent of the soluble nitrogen, equivalent to 0.90 per cent of the total nitrogen of the cotyledons and hypocotyls, and about 1.8 per cent of the soluble nitrogen, equivalent to 0.25 per cent of the total nitrogen of the seed coat, is nicotine. These

[1] Average of 10-11 day germination in the dark.

figures agree in order of magnitude with those of Ilyin, who obtained about 1 per cent of the total nitrogen as nicotine at the same period of germination. During the germination, as would be expected, there is a marked increase in total soluble nitrogen, but the data indicate that the ungerminated seed is relatively higher in amide nitrogen than the germinated material. The nitrate present in seed disappears during germination.

The cotyledons and hypocotyls contained 8 per cent of reducing sugar, as estimated by the Benedict method. Glucosazone equivalent to 3.3 per cent of sugar expressed as glucose was obtained by direct isolation. Thus only about 41 per cent of the total reducing substances are represented by glucose (or fructose). The remaining reducing substances may consist of other carbohydrates or of substances of unknown nature.

THE OCCURRENCE OF NITRATE NITROGEN IN TOBACCO

It is stated in the literature that tobacco contains nitrate. The quantities generally reported are, however, small. In the course of our work certain samples of tobacco were encountered which

TABLE 23. VARIATIONS IN NITRATE CONTENT OF GREEN TOBACCO GROWN UNDER DIFFERENT CONDITIONS

	$\frac{\text{Nitrate N}}{\text{Total N}}$	$\frac{\text{Nitrate N}}{\text{Total soluble N}}$	$\frac{\text{Nitrate N}}{\text{Dry weight}}$
	%	%	%
No. 1 Nitrogen starved	0.0[1]	0.0	0.00
No. 2 KNO_3 fertilizer	14.7	45.0	0.72
No. 3 Organic fertilizer	23.2	53.0	1.19

contained unusually high proportions of nitrate. In view of this a brief study was made of some of the factors that contribute to the high nitrate content of tobacco. Experiments were also conducted with the object of demonstrating conclusively that the substance which is estimated as nitrate by indirect methods actually is this substance.

The data reported in Table 23 show the extremes of the variation in the nitrate content of the tobacco samples we investigated. These samples were grown in the hothouse and differed only in the type and quantity of nitrogenous fertilizer received. The plants in Experiment 1 received no fertilizer; they were dwarfed and the leaves were yellow in color. In Experiment 2 the plants received daily as much potassium nitrate solution as they would endure. Growth was abundant and the plants were normal in appearance. The plants in Experiment 3 received their nitrogen in the organic form from castor pomace and cotton seed meal. Here also normal growth was obtained. Aqueous extracts of the leaves of all of these plants were prepared and analyzed.

[1] Negative diphenylamine reaction.

These data indicate that the nitrate nitrogen may vary from zero to 23 per cent of the total nitrogen or from zero to 50 per cent of the total soluble nitrogen of the plant. From samples 2 and 3 nitron nitrate equivalent in amount to more than 90 per cent of the indicated nitrate content was isolated in the crystalline form.

Wide variations in the proportions of nitrate nitrogen may also occur in tobacco plants grown under field conditions. The data in Table 24 represent analyses of dried cured samples of 1927 field crops grown on plots with different sources of nitrogenous fertilizers.

TABLE 24. VARIATIONS IN NITRATE CONTENT OF CURED TOBACCO GROWN UNDER DIFFERENT CONDITIONS

	$\frac{\text{Nitrate N}}{\text{Total N}}$	$\frac{\text{Nitrate N}}{\text{Dry weight}}$
	%	%
No fertilizer	3.54	0.113
Sodium nitrate	3.54	0.093
Castor pomace	4.92	0.121
Calcium nitrate	7.64	0.213
Cotton seed meal	9.27	0.296
Urea	16.21	0.598
Ammonium sulphate	19.48	0.779

The nature of the fertilizer employed exerts considerable influence upon the proportion of nitrate in the cured tobacco. The low values obtained with sodium nitrate fertilization are unquestionably due to the fact that 1927 was a very rainy season and soluble salts, such as sodium nitrate, were leached from the soil before maximum storage in the plant could take place. The highest values were obtained with ammonium sulphate. This material is not readily leached out of the soil and consequently the plants had a continuous available source of nitrogen. It is evident from both Table 23 and 24 that the nitrate nitrogen found in tobacco may vary over a wide range, depending upon the rainfall during the growing season as well as upon the type of nitrogenous fertilization employed.

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FIELD EXPERIMENTS ON BROWN ROOTROT[1]

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During the seasons of 1925, 26, 27 and 28, field experiments on brown rootrot were conducted on a badly infected acre of tobacco land on the farm of T. F. Connor of Poquonock. No previous report of these experiments has been made. Although, in general, the results only confirm those which have been obtained in other sections, notably Massachusetts and Wisconsin, nevertheless it seems worth while to publish them as confirmatory evidence and also for the information of Connecticut growers who may not have access to publications from other states on this subject.

OCCURRENCE AND SYMPTOMS

Brown rootrot occurs wherever tobacco is grown in New England, as well as in at least the majority of the tobacco growing sections of America. The disease is not new. Within the last fifteen years experiment station workers have studied and applied this new name to a stunted and uneven condition of tobacco crops which were planted on sod land or after certain other crops which appear to have an adverse effect on a following tobacco crop. That such an after effect existed has been known for generations.

The most readily observed symptom of the trouble above ground in the field is stunted growth. In the majority of instances the field is not affected throughout, but only in patches of irregular sizes and shape. This gives the field a non-uniform appearance. In places the tobacco appears normal in size, while in others it hangs back and appears to stop growing altogether. During hot days, plants in affected spots wilt more quickly. Affected plants do not die, but look unhealthy and stunted. From the symptoms above ground, a case of brown rootrot cannot be distinguished from black rootrot or various troubles caused by unfavorable soil conditions.

The only certain diagnostic character of the disease is the presence of dead roots of a brown color, the number of which depends on how severely the crop is affected. Roots of all sizes may be attacked. With the continuous dying of its roots the plant is stimulated to the production of an abnormally larger number

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of smaller roots which also continue to die, resulting in the production of a brush-like tuft of brown roots at the bottom of the stalk. Roots above the brush are likely to be larger and not so much affected. When the roots are washed and examined closely, it will be found that in the early stages of infection, a root will show brown dead areas or lesions, while the remaining portions of the root may be still white and healthy.

These root symptoms are the only ones by which the disease can be identified and when it is recalled that the natural color of any dead tobacco root almost irrespective of the agent which killed it, is brown, it is easy to understand why there has been so much uncertainty in its diagnosis and so much confusion and diversity of opinion as to its cause.

CAUSE

Various causes of brown rootrot have been suggested and most of them supported by a certain amount of evidence. A review of the evidence for and against each would add nothing to the present discussion and will therefore not be attempted. This much is, however, certain:

1. It has not been shown that any organism, parasitic or saprophytic, is the cause.
2. There is abundant evidence that a preceding crop may cause it. But there is no considerable uniformity of opinion as to how the preceding crop operates to produce such a result.
3. Certain fertilizers, soil amendments or toxins have been shown to produce brown dead roots on tobacco plants under certain conditions, but it is not at all sure that this is the same trouble which is commonly observed in the field. In fact it is not at all certain that there is one single cause of brown rootrot. There may be a number of agents, any one of which may produce brown rootrot under the right conditions.
4. All soils do not react alike to the same causal agents, that is, on some soils it seems to be possible to produce a perfectly normal crop on sod land, while in adjacent fields the results may be failure. The same difference may be seen in spots of the same field, even where previous treatment of the whole field was the same.

PLAN AND PURPOSE OF THE EXPERIMENT

The field experiments at Poquonock were undertaken with the object of determining further the effect of preceding crops and of other cultural practices on the development and on the prevention of brown rootrot. Specifically the questions for which an answer was sought were:

1. *Do certain preceding crops cause rootrot? Will the omission of these crops cure the trouble?*
2. *What effect has manure on rootrot?*
3. *What is the effect of lime?*
4. *Will fallowing be a benefit to affected land?*
5. *Will an acid fertilizer have any effect on rootrot?*
6. *Is the disease affected by the time of plowing the land?*
7. *Can it be cured by sterilization of the soil?*

The field was divided into one twentieth acre plots. All treatments were in duplicate and the figures presented in the tables

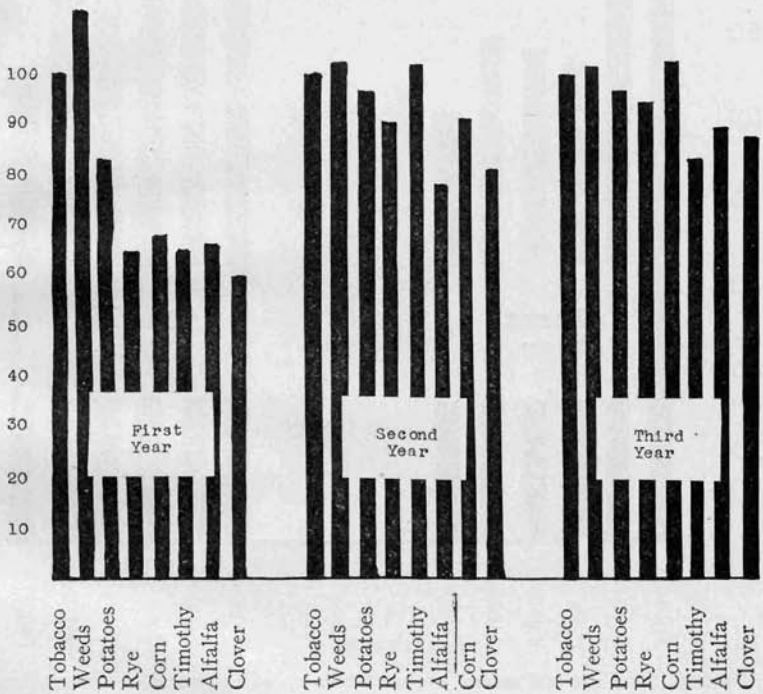

FIGURE 14. First, second and third crops of tobacco after one year of rotation crop (tobacco after tobacco = 100).

below represent the average yield of the two, calculated to an acre basis. Although the tobacco was sorted and percentages of grades recorded, they are not presented here, because in this investigation we are dealing more with yield than with quality. Results were judged first on the basis of yield and secondly from examination of roots for the symptoms of disease.

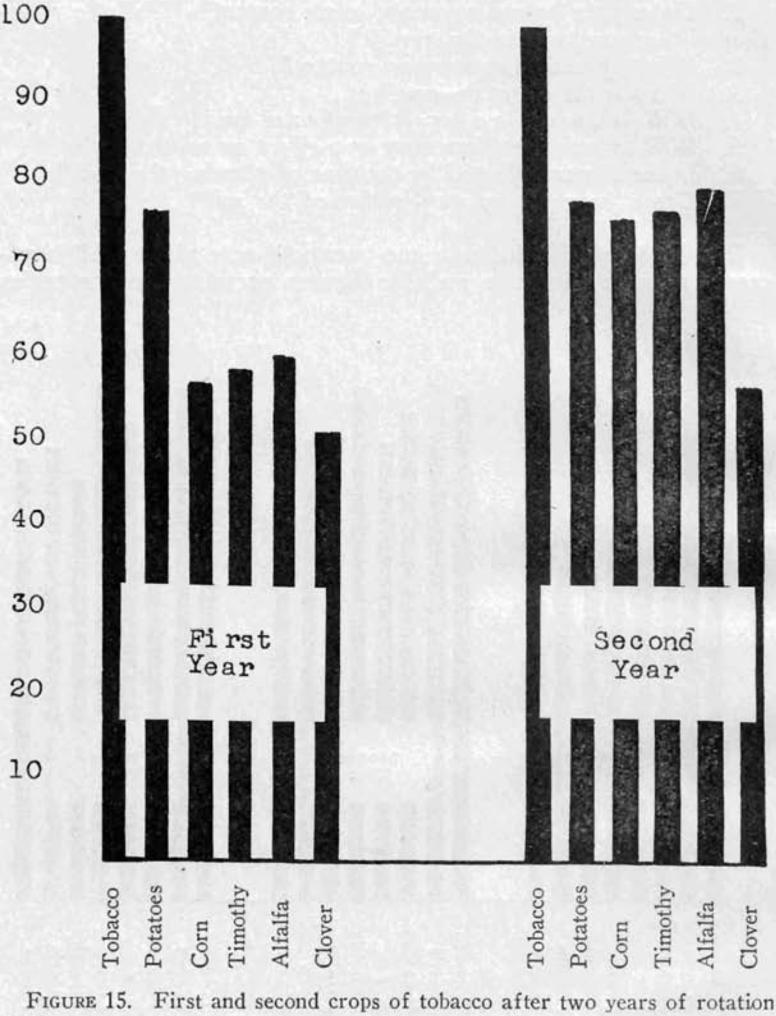

FIGURE 15. First and second crops of tobacco after two years of rotation crop.

EFFECT OF PRECEDING CROPS

In 1925 the following crops were grown on duplicate plots:

1. Potatoes.
2. Corn.
3. Timothy.
4. Alfalfa (with nurse crop of oats).
5. Clover (with nurse crop of oats).

6. Rye. This crop had been grown in 1924 but was not harvested. Old straw rotted on ground in 1925 and self seeded.
7. Weeds. Plowed, then left to grow up in natural weed vegetation during 1925.

In 1926 one-half of each plot was set to tobacco, and the alternating crop repeated on the other half.

In 1927 and 1928 tobacco was raised on all plots.

This arrangement afforded an opportunity to measure the result of either one year or two years of each crop and also to get the after effects during the next two years. Yields under these different conditions are shown in Tables 25 and 26 and graphically in Figures 14 and 15.

TABLE 25. YIELD OF FIRST, SECOND AND THIRD CROPS OF TOBACCO AFTER ONE YEAR OF OTHER CROPS

Preceding crop	Pounds to acre First crop 1926	Second crop 1927	Third crop 1928
Tobacco	1181	1110	1167
Timothy	765	860	974
Corn	798	1146	1198
Alfalfa and oat	787	1017	1050
Clover and oat	709	915	1031
Potatoes	979	1071	1133
Rye	765	1013	1111
Weeds	1327	1138	1179

TABLE 26. YIELD OF FIRST AND SECOND CROPS OF TOBACCO AFTER TWO YEARS OF OTHER CROPS

Preceding crop	Pounds to acre First year 1927	Second year 1928
Tobacco	1110	1167
Timothy	665	891
Corn	628	885
Alfalfa and oats	669	932
Clover and oats	561	767
Potatoes	852	893

A study of these tables shows that the yield is materially reduced when tobacco follows the other crops, the reduction in yield being somewhat greater when following two years of the preceding crop. The forage crops, timothy, alfalfa, clover and corn are particularly injurious. Potatoes cause less reduction than the forage crops. Plowing under a crop of rye straw from the second preceding year has had the same injurious effect as the forage crops. The best results were obtained by abandoning the field to natural weed growth for a year.

Decided recovery was observed in the second tobacco crop after the forage crop, complete recovery in the case of corn. This recovery was more pronounced during the third year but was not yet complete for all of them.

Roots from each plot were washed and examined for disease immediately after harvest each year. When the root condition of the different plots was tabulated and compared with the yields, there was found to be a fairly constant relation, which was, the more severe the root lesions, the smaller the yield. From this, it is safe to conclude that the low yields are due to brown rootrot and that the weight of cured tobacco is a measure of the percentage of infection on the roots.

CONTINUOUS TOBACCO

The first year of this experiment, 1925, was a good growing season and yields on adjacent fields were high, yet, on the check plots of this field the average yield to the acre was only 860 pounds and the roots were found to be badly diseased. The increased yields of the following years (Table 25) and the root examinations show that there was a decided recovery when tobacco was grown continuously on the same plots. There may be an objection that the yields of 1926, '27 and '28 on all the plots were too low for profitable tobacco growing. This was largely due, however, to unfavorable weather conditions. On account of excessive rainfall, the crops of 1927 and 1928 were unusually light throughout this section. A severe hail storm in 1927 further reduced the yield of that year. This field was set to tobacco again in 1929 and although no yield records were taken, observations indicated that the crop on the whole was about normal.

These results agree with those obtained in other states, showing that the continuous growing of tobacco on the same land reduces brown rootrot damage.

FALL PLOWING

Two plots were plowed in the fall and only disked in the spring. Two others were plowed in both fall and spring. Yields on these plots were as follows:

	1926	1927
Plowed only in fall	1181	1103
Plowed fall and spring	1181	1117

These figures do not indicate that plowing in both fall and spring produces any better results than fall plowing only.

MANURE

Two plots had an application of manure at the rate of 20 tons to the acre in the spring of 1925, 1926 and 1927. This was in addition to the regular application of commercial fertilizer. Yields on these plots as compared with no manure plots were:

	1925	1926	1927	1928
Manure	1219	1361	1247	1191
No manure	860	1181	1110	1167

Observations in the field during the first years of the experiment showed marked improvement in growth where manure was added. The yields for the four years were higher than on the unmanured plots. The fact that one of the manure plots was on a corner of the field which was not so badly affected with rootrot may have accounted for some of this difference. Nevertheless it was evident throughout the series that manure was beneficial on this land.

ACID FERTILIZER

On two of the plots a special fertilizer mixture, designed to give the soil a more acid reaction, was used instead of the regular mixture which was applied to the other plots. This mixture differed from the regular formula in having more than half of its nitrogen from sulfate of ammonia and was composed as follows:

1100 lbs. cottonseed meal
440 lbs. sulfate of ammonia
315 lbs. double superphosphate
367 lbs. sulfate of potash

Yield on these plots as compared with those where the general fertilizer was used were:

	1925	1926	1927	1928
Acid fertilizer	931	1248	824	918
Neutral fertilizer	860	1181	1110	1167

Apparently there was a slight improvement during the first two years, but it was followed in the succeeding two by a serious decline. Last year these plots showed the symptoms of manganese poisoning. This is characteristic of a soil which is too acid for tobacco. Since root examinations during the last years showed that these plants were practically free from root lesions, it is safe to conclude that the reduced yield was due to the very acid soil rather than to rootrot. When the series was started in 1925, this soil tested 4.91 pH. In the fall of 1927 the acid plots tested 3.81, much more acid than any other plot on the field.

We may conclude then that although an acid fertilizer may have a strong effect in eliminating brown rootrot, yet the injury from the increased acidity may be more disastrous than that from rootrot.

LIME

Two of the plots were limed at the rate of one ton to the acre of air slaked lime in 1925, 1926 and 1927. Yields on these plots as compared with the unlimed plots were:

	1925	1926	1927	1928
Limed	958	1316	1262	1246
Not limed	860	1181	1110	1167

Starting with a reaction around 5.0 pH at the beginning of the experiment, the limed plots had reached a reaction of 6.7 pH, in the fall of 1927, much more alkaline than any of the other plots. Such a reaction is usually favorable to *black* rootrot, but this disease never became prevalent on this field. The yield data indicate that there has been considerable benefit from the use of lime on this particular field.

FALLOW

When the first crop of this experiment was set in 1925, two plots were left without any plants. No fertilizer was applied, but they were plowed, harrowed and cultivated throughout the season, just as the plots which had tobacco on them.

In the next three years, they were fertilized and set to tobacco. Yields for these years were:

	1925	1926	1927	1928
Fallowed	....	1170	1169	1197
Not fallowed	860	1181	1110	1167

These data show that fallowing has caused recovery to about the same degree as the continuous growing of tobacco, that is, the yield of the first crop after one year of tobacco was approximately the same as after one year of fallow. Examination of the roots showed reduction in severity of infection at about the same rate as the increase in yield.

STERILIZING THE SOIL

In 1925, two plots were sterilized with steam—the ordinary steam pan method used on tobacco beds, and two others were sterilized with formaldehyde diluted one part in 25 of water and applied at the rate of one quart a square foot of soil. Yields on these plots for four years were:

	1925	1926	1927	1928
Not sterilized	860	1181	1110	1167
Sterilized with formaldehyde	1125	1283	1161	1211
Steam sterilized	1575	1530	1181	1214

Steaming the soil almost doubled the yield the first year. Root examination at the close of the season showed that the disease had been completely eliminated by this treatment. Steaming was not repeated the following years, but the benefit the second year was nearly as large as the first year and improvement was apparent in the field even in the third and fourth.

Formaldehyde greatly increased the yield the first year, but it was not as effective as steam. After the second year, the effects of the two were about the same.

A third method of sterilizing the soil was tried in a small way. Soil from the worst affected plots was spread in a thin layer on a board floor to dry and aerate for two weeks. A like amount of soil from the same plots was kept in moist condition. Both soils were then put into separate pots and one tobacco plant was grown in each of eight pots. The plants in the aerated soil grew much more rapidly than the others, which were stunted. At the end of six weeks, the former weighed approximately ten times as much as the latter. Root examination showed that aeration had eliminated the disease from the soil.

Because of the expense, these methods of sterilizing the soil will probably never be practical in the field in a large way, but they may be useful on small spots. They are of considerable interest for the information they may furnish as to the nature of the disease.

SUMMARY

The type of brown rootrot which was present in this field is closely associated with the previous cropping system.

It becomes most severe when tobacco follows the forage crops, timothy, corn, rye, alfalfa or clover.

Potatoes are less injurious in this respect than the forage crops.

With continuous tobacco culture, injury is reduced to a very low amount.

Fallowing without fertilization has the same effect as continuous tobacco.

Abandoning the land to the natural weed growth for a year was more beneficial than either continuous tobacco cropping or fallowing.

Addition of stable manure increased the yield on this field.

Annual applications of lime were beneficial.

Use of an acid fertilizer reduced the disease on the roots, but did not increase yield, because the soil became too acid for good growth.

The disease can be completely eliminated by steaming the soil or thoroughly aerating it. Sterilizing by formaldehyde is less beneficial than the other methods.

Time of plowing the land as practiced in this experiment had no effect on the severity of the disease.

RECOMMENDATIONS

On the basis of these experiments, supplemented by results of experiments in other sections, we recommend the following to the tobacco grower who has trouble with brown rootrot:

1. *Do not attempt to rotate tobacco with other crops. Avoid particularly the forage crops. Do not use timothy cover crops on land which shows a tendency toward brown rootrot.*

2. *Continuous tobacco culture is better than trying to "rest" the land by growing other crops. If there is opportunity to rest the land, let it grow up to the natural weed vegetation for a year or longer.*

BLACK ROOTROT RESISTANT SHADE TOBACCO

John G. Wolf

Black rootrot of tobacco, caused by the fungus *Thielavia basicola* Zopf, has inflicted heavy loss on growers of shade tobacco. The disease prevents the normal growth of plants and thus reduces the yield, even on soil which has all the necessary plant nutrients.

Much of the so-called "running out of tobacco soils" is due to rootrot. When such crops as tobacco are grown year after year on the same land, the soil may eventually become infested with disease organisms and so be unsuitable for further growing of that crop.

The problem, then, is to produce a tobacco plant that will mature normally, season after season, on the same field. With this object in view the writer has carried out his investigations at the tobacco substation the last three seasons.

In the last quarter of a century, a great many disease-resistant crop plants have been developed. Among them are wilt-resistant cowpeas, wilt-resistant sea island cotton, alfalfa resistant to leaf spot, cabbage resistant to yellows, rust-resistant wheat, spinach resistant to yellows, rust-resistant asparagus, watermelon resistant to anthracnose, and smut resistant corn.

In tobacco, black rootrot-resistant strains have been found in the White Burley type, Wisconsin Havana Seed and Pennsylvania Broadleaf. No degree of resistance has ever been found in any strain of Connecticut shade tobacco.

In almost every instance, the first plant selections for resistance were made in fields where the crop was practically a failure, except for a few plants, possibly naturally immune, which stood above the others and seemed perfectly normal. Using these apparently resistant plants as a starting basis, eliminating all possible crossing by selfing, and using rigorous row selections for several generations, strains have been developed with the desired inheritance and a high probability of breeding true. Especially is this true with tobacco, which is normally self-fertilized.

Hugo De Vries, a Dutch botanist, described the appearance of new characters which were departures from normal. These he called "mutations." This change may be in only one visible feature, such as form of leaf, color of flower, or height of plant. They occurred in such a way that they could not be due to Mendelian segregation and many were proved to be actual germinal changes.

Author's Acknowledgment. The writer acknowledges his appreciation and indebtedness for helpful suggestions and criticisms of Dr. Paul J. Anderson, pathologist-in-charge of the tobacco substation, and to Dr. Donald F. Jones, geneticist of the experiment station.

In self-fertilized species, these occurrences are extremely rare, but when found they may be assumed to be mutations and to have the potential ability to breed true. In cross-fertilized plants there is a greater chance to select desirable combinations of disease resistant factors.

It is well to note that a normally resistant plant in a certain locality may be a failure in some other geographical center, which is probably due to higher specialization of fungi to the host. Also, it is often difficult to obtain a uniformly "infected" soil for experimentation. In our investigation, at the J. Ford Ransom lot in Windsor, only about one-half of the area in use was found to be badly infected with rootrot.

FIGURE 16. Field of Cuban shade tobacco showing the desirable uniformity of stand when no rootrot is present.

SYMPTOMS OF BLACK ROOTROT

This disease is prevalent in all the tobacco growing sections of the northern states and in Europe. Its presence in the tobacco field first becomes known to the farmer when he notices that the plants in certain parts of his lot lag behind the rest of the field. Some may stop growing completely. On hot days the affected plants wilt and the leaves flag. When the plants are pulled, many of the lateral roots are seen to be rotted off. The diseased portions of the roots are dark brown to black, instead of white, as a healthy root should be. On smaller roots the lesions go completely through and the root drops off, but on larger laterals the lesions appear as black, rough enlargements, while the center of the root may still be healthy. Loss of the roots has a direct connection with the flagging leaves, since the reduced root system is unable to supply enough water to equal the volume which is transpired by the leaves on a hot day.

Soils particularly conducive to rootrot are those which are heavy and cold, apt to be water-logged, those which are nearly neutral in reaction, usually due to liming, and those which have been manured heavily.

IMPORTANCE OF BLACK ROOTROT TO THE SHADE INDUSTRY

Shade tobacco is more susceptible to black rootrot than either of the other two types of tobacco grown in Connecticut. Although it is well known to all shade growers that thousands of acres of shade land have "run out" since this type has been grown on it, it is not so well appreciated that most of this "running out" is due to increase in prevalence of the black rootrot fungus in the soil. When the reduced yield makes it no longer profitable, this land must be abandoned for a time and the poles and wire transferred to other land. This transfer, the added expense of leasing or purchasing new land, the necessity of operating at a distance from home and frequently from convenient sheds, all must be computed in the bill which the grower pays to rootrot. If it were possible to calculate in dollars the loss the growers have sustained from these operations and from the reduced yields, the figure would be in millions. Suffice it to say that it is the most serious disease problem with which the shade grower must contend.

ORIGIN OF THE 4R RESISTANT STRAIN

Since resistant mutations have been found in other types of tobacco, it was not unreasonable to believe that one would be found sometime in the Cuban Shade type. Although many fields had been carefully searched for years, no indication of resistance was found until 1927. In July of that year it was discovered on the badly diseased part of a shade field, owned by Mr. Ransom, that a few strong luxuriant plants grew twice the height of the sickly little ones about them. They had sturdy stalks in contrast with the "pipe stem" stalks of the other plants. These large plants were not grouped in one place, but were scattered singly over more than half an acre. This part of the field had suffered from rootrot several years before 1927. When some of the *little* plants were now dug up they showed a badly rotted root system, characteristic of black rootrot.

Close examination and testing of the soil at the base of the few large normal plants failed to show any difference between this and the soil in the rest of the field. In leaf shape and other growth characteristics, these plants were like the normal plants from the unaffected part of the field. There was therefore no reason to suspect that these plants were a different type of tobacco, accidentally introduced, or that they were affected by any soil differences. They could only be a mutation or a hybrid from some previous crossing.

Inquiry revealed that the seed was the same as the owner had been using for several years. It was originally from the same strain as that grown by the other shade growers, the Hazelwood type, brought from Cuba by William Hazelwood in 1903, and selected for uniformity for a number of years by J. B. Stewart and co-workers. Mr. Stewart states that the seed which he finally distributed and is now universally grown in the valley is the progeny of a single plant which they selected. Therefore it does not seem likely that these plants could have come from segregation in a hybrid population.

Although the diseased plants "spindled up" taller in the latter part of the season, they *never* produced leaves of any commercial value and were always much inferior to the mutants in size. The seed heads of 18 of the larger plants were bagged to prevent any accidental crossing. The progeny of this seed was subsequently designated as the "4R strain" (abbreviation for Ransom Rootrot Resistant) to distinguish it from the ordinary shade tobacco.

After the seed had been harvested, the root systems of the bagged plants and of neighboring *small* plants were washed and examined. The root system of the susceptible plants was badly diseased, most of the lower roots being mere stubs. The best roots were at the top and had developed after the bottom ones had been rotted away. The root system of each of the 18 healthy was several times as large as the others and was characterized by strong long laterals *at the bottom*. There were lesions of black rootrot, however, even on these roots, but not nearly so numerous as on the susceptible plants and the injury was small. Apparently we had here, not immunity, but a high degree of resistance, or, possibly, it might be called increased root vigor.

FURTHER TESTING OF THE 4R STRAIN IN 1928

This rootrot infested field, where the first selections were made, was kindly made available by Mr. Ransom to continue the selections under an environment favorable to development of the disease.

The selfed seed, obtained from the selected plants of 1927, were sown in 1928, the progeny of each plant being kept separate. In the bed no variation could be discerned between the resistant and the ordinary Cuban seedlings, both being vigorous and normal.

Late in May, these plants were set in the Ransom lot and also in an uninfested shade field on the station farm in order to observe the quality of the product under normal conditions. The regular Cuban was used as a check in both fields.

Early in the growing season, it was noticeable that many rows showed considerable vigor and some resistance when compared with the checks. Unfortunately for the experiment, this was a poor rootrot year, for the plants brought to the laboratory in July showed but little infestation, while the check rows had slightly more. Later observations taken on field growth showed the resistant rows to be far superior to the checks, in vigor and general growth.

About the middle of July, the best plants from the best rows

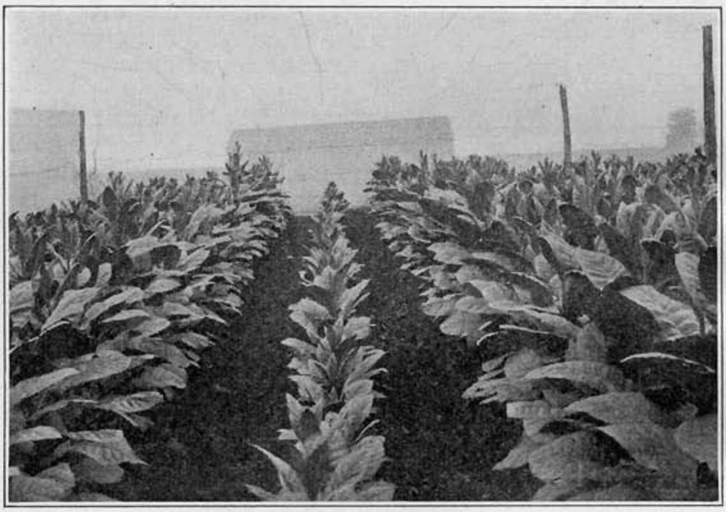

FIGURE 17. Row of common Cuban between rows of 4R Cuban. All set the same day.

were selected with the assistance of two experienced shade growers, Mr. Ransom and Mr. Stewart. The object of this selection was to choose plants having ideal Cuban characteristics, leaves of good texture, proper size and shape, with a goodly number of marketable leaves and generally showing good commercial possibilities. These were properly tagged and selfed by bagging.

The plants set in the station tent afforded an opportunity for comparing the quality and the tobacco was followed through to the grading tables. These leaves showed no significant difference in quality as compared with the regular Cuban. Apparently, then, the selections must be made mostly on the basis of apparent resistance. Soil samples taken on the field showed about the same reaction as the preceding year. The root systems when dug up and carefully examined showed those of the resistant plants to be larger, yet having a few lesions of black rootrot. Since two rows had shown most promise during the season, twenty of the best plants from these two were selected for seed with which to continue the tests for 1929.

CONTINUATION IN 1929

Seed of each of these 1928 selected plants was sown separately and one row each was set in the Ransom field early in June, 1929.

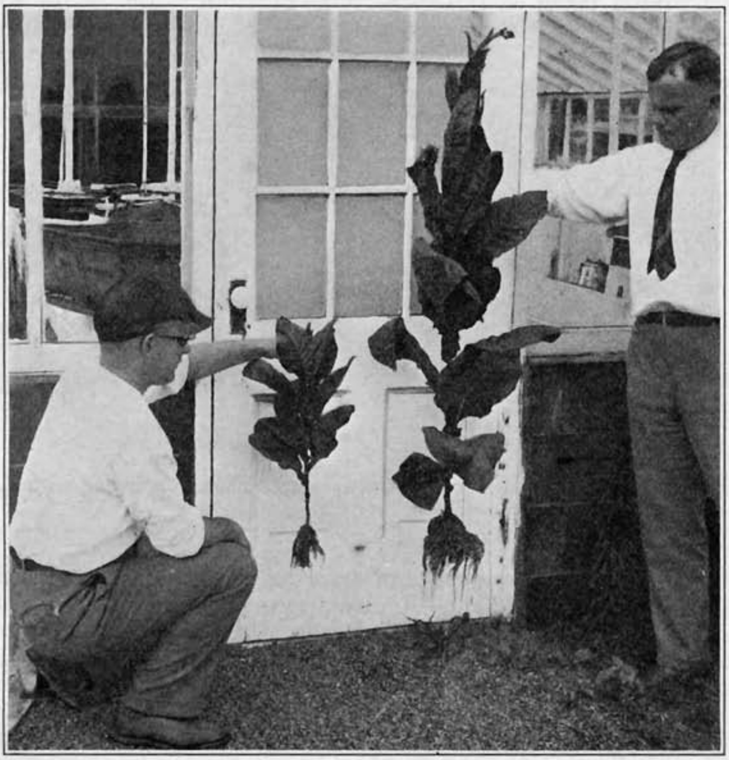

FIGURE 18. Resistant Cuban plant (4R) on right compared with common Cuban on left.

As before, ordinary Cuban was used for a check. As early as July 10, it was noticed that the check rows seemed stunted or were rather slow in starting and many rootrot lesions had developed, while the 4R strain was exceedingly vigorous and examination showed little, if any, rootrot infection.

One of the interesting facts of 1928 and 1929 was the uniformity of the plants in each of the resistant rows, which shows a definite mutational characteristic. As before, some rows seemed superior to others and showed considerable promise. This was evident on the left side of the field, where the rootrot infection had always been severe. On the right this variation was not so pronounced.

On July 16 the resistant rows far outstripped the check rows of the regular Cuban. This difference between the resistant and susceptible Cuban plants is shown in Figures 17 and 18 from photographs taken on this date. One hundred plants on the susceptible row at this time averaged 41 inches in height, in contrast

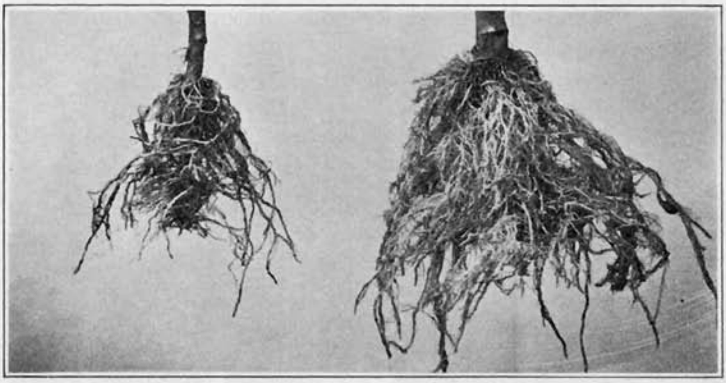

FIGURE 19. Root system of 4R Cuban plant (right) compared with that of common Cuban.

with 67 inches as the average of an equal number on the adjacent 4R row. On July 22 the 4R plants stood 24 inches higher than those on the check rows on the left side, where the rootrot infestation had been the worst. At this time, the resistant plants at the right, less infested part, also were taller and superior in every way to the normal check rows. The first priming of a resistant and an adjacent susceptible row was taken for measurements after curing and sweating. From these the following measurements were taken at time of sorting:

	Susceptible Cuban	Resistant 4R4
Average length of leaf	10 inches	14 inches
Average width of leaf	5 "	8 "
Weight of first picking (to acre)	175 lbs.	340 lbs.

The 4R leaves were of good size, shape and quality. The leaves of the susceptible Cuban were short, narrow, pointed and practically none was considered to be of commercial value. Also none of the leaves above the first picking became large enough to be of any value.

In early fall, the roots were dug and examined. The root systems of the resistant plants were large, white in color, had many strong laterals and were comparatively free of rootrot lesions. On the check, they were smaller, with stubs due to rotting off and with an abundance of lesions.

Late in July the best rows were selected and the best plants selfed by bagging. On the first of August the severe hail storm hit the section, but sufficient seed to continue this strain was saved.

SUMMARY

1. A strain of Cuban shade tobacco highly resistant to rootrot, but not differing in other respects from ordinary shade tobacco, has been isolated and tested for two years in this field.

2. The strain at this time is fairly uniform, which shows it to be a mutation and not a hybrid.

3. Resistance to disease is often not absolute and the extent of infection is greatly influenced by environmental conditions. It is therefore desirable that the 4R strain be tested on other fields, The station will be glad to furnish a limited amount of this seed for trial to growers who have infested fields.

SEASONAL FLUCTUATIONS IN SOIL REACTION

T. R. Swanback and M. F. Morgan

Soil acidity, as measured in terms of pH values, has become of such great interest to tobacco growers that soil tests are being made at frequent intervals on a great many tobacco fields. A considerable amount of confusion has arisen because carefully selected soil samples of the same field frequently show pronounced variation in reaction when collected at different dates. Is this phenomenon to be ascribed to errors in sampling or in method of measurement of pH values, or does the pH of the soil actually change from time to time?

Other investigators have noted seasonal changes in the acidity of certain plots where soil conditions and methods of testing were carefully controlled. Kelley[1] found variations in pH in the same plot which amounted to 1.0 pH during the year. During the summer, with a prolonged drouth, there was a continual increase in acidity, while fall rains produced a decrease. With the coming of winter, pH values showed a slight increase in acidity when the soil became frozen, while in the spring the soil returned to a normal reaction. Baver,[2] studying changes in acidity from day to day during the summer, observed that two unlimed plots became progressively acid through the season from May to September and concluded that there is a constant increase in acidity from spring to fall, with a return to approximately the original acidity the following spring. He ascribed this seasonal trend either to the dehydration of colloids by drying of the soil, or to the accumulation of soluble salts during the summer.

During the past three seasons data on periodic variations in the acidity of certain plots at Windsor show that tobacco soils of the Connecticut valley may also show a similar seasonal change in pH.

SINGLE NITROGEN SOURCE PLOTS AT WINDSOR

A set of plots at Windsor, where the effect of different carriers of nitrogen is studied, has also been used to observe the soil reaction during the various seasons. Four plots were laid out in the spring of 1926: cottonseed meal, nitrate of soda, urea and sulfate of ammonia. Three were added to this series in the spring of 1929: castor pomace, linseed meal and dry ground fish.

Reactions were determined before fertilizers were applied in 1926 and 1927, and from December of that year up to date nearly every month.

The graphs in Figure 20 show that the reaction varies consider-

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[1] Soil Science, 16, 46-47.
[2] Soil Science, 23, 403-407.

ably during the year. The heavy line, representing reactions on the cottonseed meal plot, probably expresses approximately the seasonal fluctuations in pH values which may occur in an ordinary tobacco soil. The differences between the summer months and other seasons may range from one-half to more than a unit pH.

Figure 20 also shows clearly the extremely acid condition which is produced by sulfate of ammonia, as compared to the tendency of nitrate of soda, while urea and the organic fertilizers are intermediate in their effects.

SEASONAL TRENDS IN CONCRETE-WALLED SOIL PLOTS AT NEW HAVEN

Since the spring of 1927, the soil reaction of forty-eight small concrete-walled soil plots has been determined at frequent intervals. Various combinations of lime, nitrogen, phosphorus and potassium have been applied from time to time in experiments with vegetable crops. Urea has been the sole source of nitrogen.

On all treatments there was an increase in acidity during the summer of 1927. Marked fluctuations occurred, since the rainfall was irregularly distributed. There was a decrease in acidity in the fall, with a slight increase in the winter period. In 1928 there was no significant increase in acidity during a summer of heavy and well distributed rainfall. Fall and winter brought slightly more acid conditions. The spring of 1929 brought a return to conditions similar to previous years, while the very dry summer showed high acidity, which decreased after heavy August rains, and increased considerably during the dry period of early autumn. The acidity was still higher than normal in December, 1929, although it showed a gradual rise in pH values (decreasing acidity).

Treatments including nitrogen showed increasing acidity during the months following their application, to a much more marked degree. The following figures, compiled from thirty-four successive dates during the period May, 1927 to December, 1929, show that the nitrogen treatment is a very important factor in accentuating these periodic fluctuations:

Treatment	Mean pH	Average departure from mean pH	Maximum pH	Minimum pH
None	4.95	.15	5.39	4.51
PK	5.07	.13	5.40	4.61
NPK	4.81	.29	5.48	4.15

NITRATE CONTENT OF THE SOIL AS A FACTOR IN SEASONAL FLUCTUATIONS

The lysimeter experiments with different sources of nitrogen on various soils have provided some data as to seasonal change in pH on soils which were also studied weekly as to nitrate nitrogen content of soil in the period from June 1 to November 22, 1929.

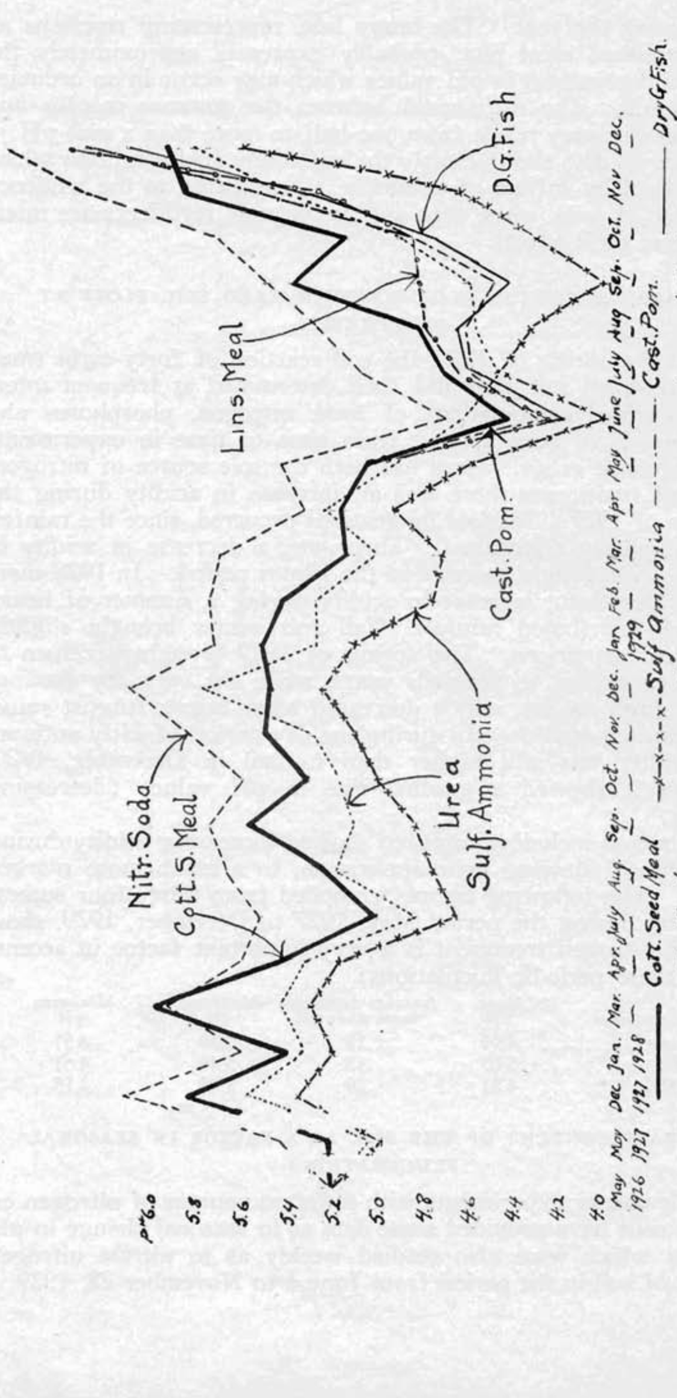

FIGURE 20. Curves of seasonal fluctuations in soil reaction on field plots at Windsor.

Four different soils were used. A fertilizer containing only the mineral elements was compared with added rates of application of nitrate of soda, sulfate of ammonia, urea and cottonseed meal,

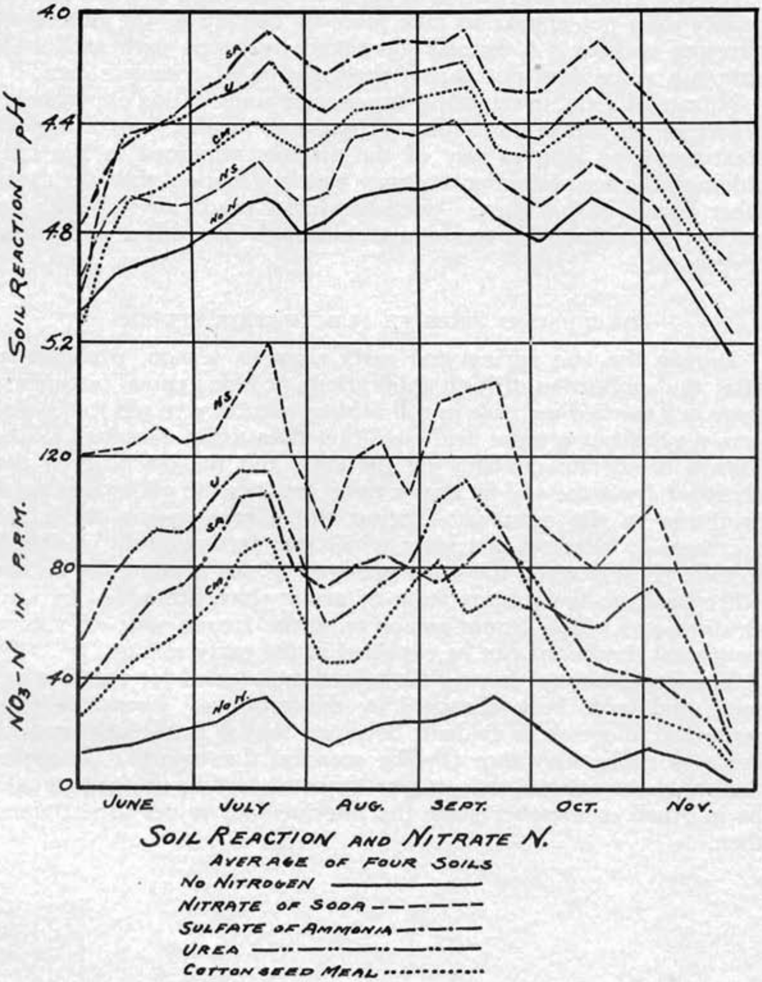

FIGURE 21.

at rates of application equivalent to 200 pounds of nitrogen to the acre, on each of the soils. The soil, in small cylinders, was kept fallow during the season.

Figure 21 shows the fluctuations in nitrate nitrogen and pH from week to week for the average values of the four soils. (It is to be noted that the pH is plotted upside down so that if an increased nitrate content is accompanied by increased acidity, the corresponding decreased pH will show as a rise in the curve.)

A good general correlation is apparent, although the decrease in acidity does not appear to take place as quickly as the decreased nitrogen content. A similar agreement is noted with each soil, although space does not permit presentation of complete data.

Nitrate of soda, in the heavy application used in this experiment, produced an increased acidity (compared to the "no nitrogen" treatment), as long as any of the nitrates remained in the soil, although the acid-forming tendency was less marked than the three other forms of nitrogen. Urea produced practically as high an acidity as sulfate of ammonia, although its effect was less permanent.

CONCLUSIONS FROM PH FLUCTUATION STUDIES

During the late spring and early summer season, particularly after the application of high applications of nitrogenous fertilizers, there is a marked increase in soil acidity (decrease in pH). A dry season produces a more acid condition than a wet season. Withdrawal of nitrate nitrogen by the crop and the leaching of the fertilizer from the soil by heavy rains restores the pH to a normal condition in the autumn. During the winter season there are decreases or increases in acidity, which may be due on the one hand to mild periods when the frost goes out of the ground, or, on the other hand, to the accumulation of acids which are added by rain or snow and which cannot escape from the frozen soil. A return to normal conditions can be expected in the early spring.

The importance of having the tobacco soil tested for reaction has more and more been observed by the growers. From the data presented above, it is evident, however, that it is of equal importance to make allowance for the seasonal fluctuations. It seems reasonable to assume that proper times of testing the soils would be in April or October since the intermediate values are attained then.

DAMPING OFF OF YOUNG SEEDLINGS

In unsterilized plant beds in the station greenhouse, young seedlings almost as soon as they could be seen, began to die off and disappear. This continued until the few plants left were more than an inch high. They died off in bunches, particularly where the stand was thickest. This same trouble appears always to be present in the greenhouse and has been observed in seed beds else-

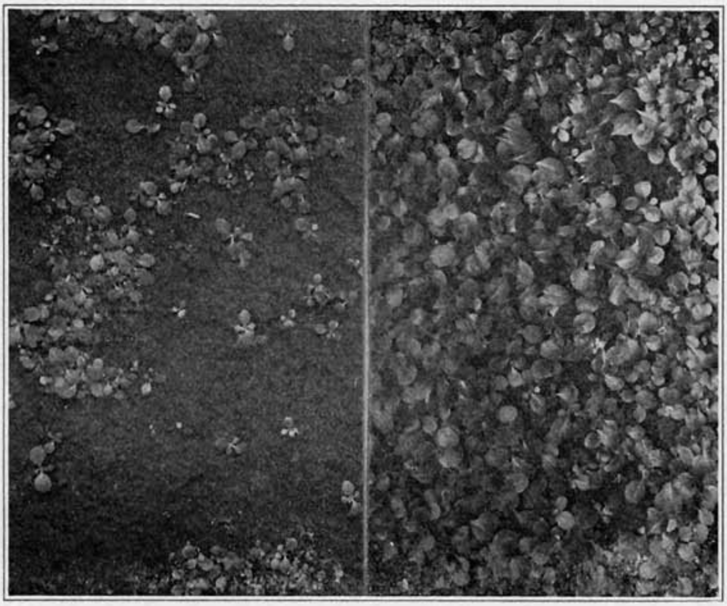

FIGURE 22. Sterilized and unsterilized plant beds. Bed to the right was soaked with 1% acetic acid.

where. It is not known just how prevalent and destructive it is among the tobacco plantations of the state, because no comprehensive survey has been made, but troubles which appear to be the same are common every year.

A close examination of the young plants shows that the stalk is attacked at the base between the soil and the first leaves. This part of the stalk shrivels to a string, then the plant topples over and dies on the ground. The affected part of the stem may remain green for a long time or may turn brown. Under damp conditions the top of the plant remains alive for some time after the stem is rotted through, but finally all parts of the plant become slimy and rotten.

When the dead plants are examined under the microscope, they are found to be completely permeated with the mycelium of a fungus, Pythium. This fungus lives in the soil, but is able to attack and live on the seedlings only in their very young stages.

In order to see whether this condition could be prevented by sterilization, two new beds were started with the same soil. The soil of one was saturated with a one per cent solution of acetic acid and was seeded about three weeks later. The other was seeded at the same time without sterilization. The plants all came

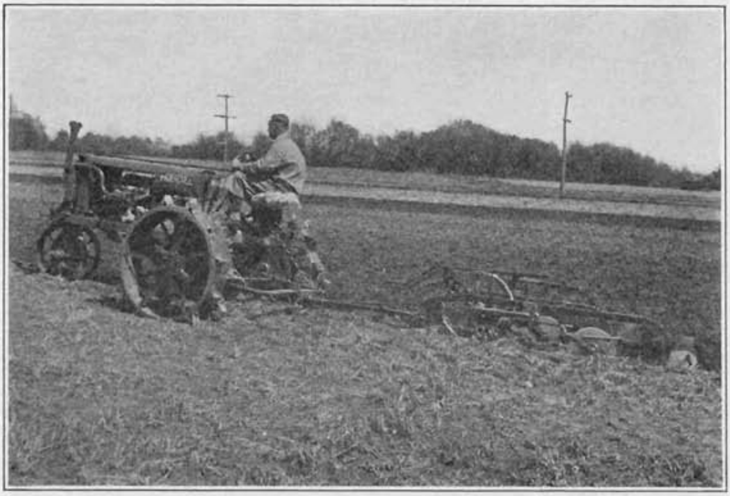

FIGURE 23. Tractor plowing in the open field.

up about alike but within a few days plants in the unsterilized soil began to disappear and the disease ran its normal course. The appearance of the sterilized and unsterilized beds when the plants were three weeks old is shown in Figure 22.

Acetic acid completely prevented the disease in the sterilized bed. Undoubtedly the same results could be obtained by sterilizing with formaldehyde or steam. Acetic acid has the advantage of being cheaper.

RAISING TOBACCO BY TRACTOR

Just as in industry, machine labor is replacing hand labor, so in agriculture, the tractor is rapidly replacing both horse and man labor. In other types of farming, this change has progressed further than in tobacco growing, but even in this intensive farming, the change is inevitable. The many obvious advantages of the tractor make it only a question of a few years and some improvements in tractor machinery before we shall raise tobacco without horses and with much less hand labor. The greatest obstacle to more extensive use of the tractor is the conviction of many growers that it can be used only for a part of the operations

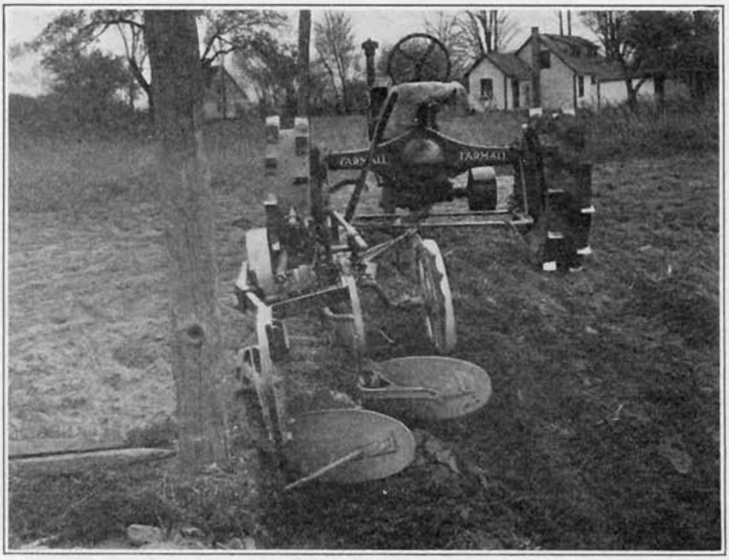

FIGURE 24. The off-set plow which will cut the furrow within two inches of the shade poles.

of growing the tobacco crop and that it will still be necessary to keep horses for the other operations. This means the maintenance of two power systems. If it could be demonstrated that the tractor can do *all* the operations just as well as horses, the substitution would be made rapidly.

To see how effectively all the operations of tobacco growing could be performed by tractor and to make improvements in tractor machinery so that it will be suitable for all necessary operations, an experiment in co-operation with the International Harvester Company was begun on the station farm. During the season of 1929 no horse was used for any operation on the farm. The tractor grown crop was just as good as other crops. It was necessary to experiment with different types of implements, but in the end a suitable one was found for every operation.

Plowing and harrowing the open fields presented no problem because these are already common practices with many growers. The shade fields presented a different problem, the necessity of finding a plow which would turn the furrow up close to the poles and between them. The two bottom plow illustrated in Figures 23 and 24 was finally adopted as suitable for this purpose. It has a very wide adjustable offset. For the furrow directly in the pole

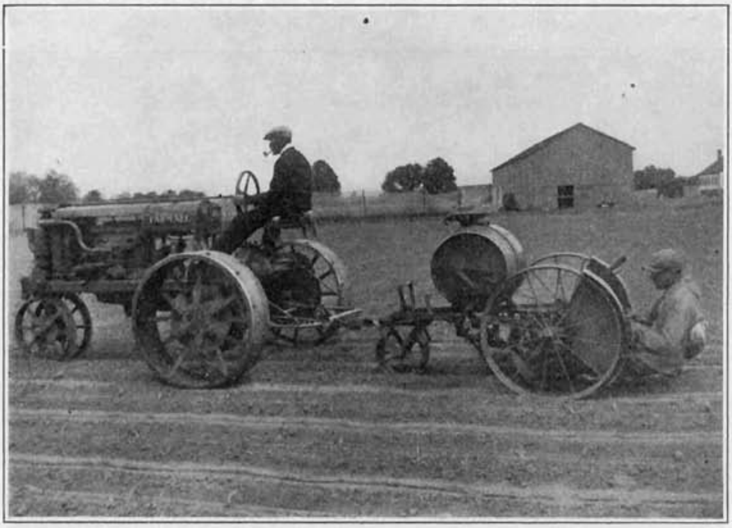

FIGURE 25. Setting by tractor. A two-row transplanter will be substituted next year for this one-row machine.

row a shift lever, not shown in the figure, was attached in such a way that the plow could be shifted around the poles. Although this did not operate as smoothly as desired, it is believed that this difficulty can be overcome so that it will not be necessary to use horses at all. The enormous saving in time and labor in fitting the land by tractor instead of horses needs little demonstration.

Shortening the pole of the fertilizer drill was all that was necessary for the operation of spreading the fertilizer. The same was true for the transplanter. The one-row setter shown in Figure 25 was an ordinary Bemis setter with a short pole. A two-row setter for this purpose has more recently been manufactured and it is preferable to the one-row setter, not only because of the saving in time, but more particularly because it keeps the distance between the pair of rows always the same. This is rather essential for the best operation of the two-row cultivator to be used later. The uniformity of speed of the tractor and its suitability for making perfectly straight rows are distinct advantages over horses.

Cultivating was done with a two-row cultivator. The gangs of this machine are attached to the side of the tractor, where they can be watched by the driver. This also makes it possible to turn the outfit in a very small space at the end of the rows. Any combination of shovels may be used. With this outfit it is possible to cultivate until the tobacco is 30 inches high.

A stock objection to the tractor is that its weight and the broad wheels pack the soil too much. It was found in this experiment that packing could be entirely eliminated by the use of open-face wheels. For drawing the tobacco racks during harvesting it was necessary only to shorten the poles.

Further improvements are being made and the experiment will be continued, but there do not appear at present to be any great mechanical difficulties in the way of substituting tractors for horses entirely in growing tobacco.

CEL-O-GLASS SEED BED SASH

"Cel-o-glass' is a glass substitute made of fine mesh wire screen imbedded in a translucent material, light and somewhat flexible. The manufacturers, the Acetol Products Company of New York, claim that it transmits 80 percent of the sun's rays, including 35 to 40 percent of the ultra violet rays which are excluded by ordinary glass.

It has been suggested that "cel-o-glass" could be substituted for ordinary glass in tobacco seed bed sash with the following advantages:

1. It is flexible and does not break. Hence the labor and expense of replacing glass are eliminated.
2. It is lighter and does not require as heavy a frame. (Frames which we used weighed less than half as much as glass frames.)
3. The labor of handling is greatly reduced.
4. The temperature is more uniform, that is, lower during the day and higher during the night than when ordinary glass is used.

The first three are obvious, since this material is not easily broken and the sash are much lighter than those ordinarily used. To test the fourth claim we made a trial, for which the manufacturers furnished the materials. One section of the 1929 beds was covered with six cel-o-glass sash, while on the next sections the ordinary sash were used. These sections were separated from each other and from the rest of the bed by board partitions.

Observations were made throughout the season, but no continuous temperature records were made. Plants under cel-o-glass did not grow as rapidly as under ordinary glass. It required about ten more days to grow them under the substitute to a size suitable for setting. Otherwise, no differences were observed.