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Dark Tobacco: Fertility experiments at the Clarksville station - Results from a 10-year period (1913-1922)

University of Tennessee Agricultural Experiment Station

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UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
Knoxville

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DARK TOBACCO

FERTILITY EXPERIMENTS AT THE CLARKSVILLE STATION—RESULTS FROM A TEN-YEAR PERIOD—1913-1922

BY
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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

DARK TOBACCO

FERTILITY EXPERIMENTS AT THE CLARKSVILLE STATION—RESULTS FROM A TEN-YEAR PERIOD—1913-1922

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THE PROJECT

In 1913 a 16-acre tract of land about a mile out of Clarksville, on the Port Royal Pike, was obtained from Messrs. Wesley Drane and C. E. Frey, for a ten-year period, to be used as an experimental field in tobacco culture. The project was undertaken jointly by the Tennessee Agricultural Experiment Station and the Office of Tobacco and Plant Nutrition Investigations, Dr. W. W. Garner, in charge, of the U. S. Department of Agriculture.

THE SOIL

The soil was typical of the kind commonly used in the production of dark tobacco in this part of the State. It was a poor, gray-colored silt loam, containing gravel and large pieces of chert, and would be classified as Clarksville stony loam. The subsoil was red-colored and rather heavy, containing more clay than the surface soil. A chemical analysis* of a similar gray soil from a near-by farm gave the following results:

	Per cent
Insoluble residue	90.57
Potash (K_2O)	0.20
Lime (CaO)	0.16
Magnesia (MgO)	0.24
Manganese oxide (MnO)	0.07
Ferric oxide (Fe_2O_3)	1.96
Alumina (Al_2O_3)	3.97
Phosphoric acid (P_2O_5)	0.05
Sulphuric acid (SO_3)	0.03
Volatile matter	3.34
Humus	0.75
Nitrogen (N)	0.08

The land in the vicinity of Clarksville is undulating, or "rolling," and much damage has been done by erosion. The experimental field was about an average in these respects, and because of its uneven character only a small part was considered to be adapted to plot experiments. The most suitable areas were selected for this purpose

*By the official method, strong hydrochloric acid being used as a solvent.

and the balance of the field was used chiefly for demonstration crops.

THE CLIMATE

The rainfall and temperature figures given in Tables 1 and 2 were obtained from records of the Weather Bureau of the U. S. Department of Agriculture. The data indicate the general nature of the seasons.

TABLE 1—*Rainfall at Clarksville during the ten-year period* 1913-1922—*from records of the U. S. Weather Bureau.*

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Jan.	14.70	1.65	6.31	9.15	5.91	3.83	3.84	11.64	4.12	2.73
Feb.	4.78	3.24	1.68	1.52	3.48	1.99	2.94	3.25	5.11	4.05
March	8.39	3.96	1.97	3.13	5.63	.76	8.92	4.08	10.73	9.31
April	2.06	4.20	1.27	2.81	4.90	4.48	4.07	8.85	4.77	4.51
May	2.09	3.14	7.81	7.28	3.53	2.61	10.74	6.63	1.69	3.17
June	2.31	2.46	1.64	5.33	4.64	2.33	4.54	3.08	4.53	2.03
July	2.43	1.98	4.30	4.08	5.92	1.70	2.57	4.05	2.04	8.19
Aug.	1.53	6.47	5.33	1.23	3.26	2.58	8.47	4.18	4.62	2.35
Sept.	1.65	2.34	4.75	4.35	.59	2.56	5.28	1.35	5.76	3.66
Oct.	3.74	4.96	1.98	2.84	2.42	3.28	10.90	.74	2.56	1.90
Nov.	1.81	1.56	5.55	1.02	.93	1.48	6.82	2.27	7.69	3.10
Dec.	2.30	6.90	7.45	.95	1.97	6.20	4.80	4.51	3.12	6.35
Total	47.79	42.86	50.04	46.41	43.18	33.80	73.89	54.63	56.74	51.35

TABLE 2—*Mean monthly temperature at Clarksville during the ten-year period,* 1913-1922—*from records of the U. S. Weather Bureau.*

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.	Deg's.
Jan.	45.6	43.6	35.9	43.9	40.6	24.2	39.6	36.8	42.7	38.0
Feb.	38.2	37.6	44.1	38.4	39.6	45.1	40.8	40.0	44.6	43.9
March	49.6	45.6	41.2	46.7	49.4	56.0	49.8	48.9	60.3	51.8
April	58.4	59.8	62.9	56.1	58.6	57.8	59.7	56.8	60.4	63.2
May	69.4	69.6	69.6	69.0	60.3	72.2	65.9	67.6	68.7	70.6
June	78.6	82.4	74.7	72.2	72.4	78.8	78.6	74.0	80.6	78.7
July	81.8	82.6	80.2	78.8	76.0	78.2	81.8	78.0	83.8	79.2
Aug.	81.9	79.5	74.8	77.6	73.5	83.6	77.8	76.4	78.5	78.4
Sept.	72.7	71.6	74.6	68.2	69.0	65.8	72.8	74.6	79.0	75.6
Oct.	59.6	62.0	60.7	58.8	53.6	64.8	66.8	64.1	59.3	62.2
Nov.	54.7	49.5	50.8	49.0	47.5	48.0	49.4	46.9	52.0	51.2
Dec.	42.0	35.1	40.3	37.2	30.0	46.4	37.8	41.4	44.8	44.8
Average	61.0	59.9	59.2	58.0	55.9	60.1	60.1	58.8	62.9	61.5

RELATIVE VALUES OF FERTILIZER, LIME, AND MANURE IN A FIVE-YEAR CROP ROTATION

OUTLINE OF THE EXPERIMENTS

Experiments were conducted throughout the ten-year period to determine the relative values of moderate applications of fertilizer, lime, and manure in a five-year rotation of tobacco, soybeans, wheat, and clover and grass for two years.

Thirty 1/40-acre plots, each 60.5 x 18 feet, with a 2-foot path between plots, were used in this series. One set of five plots was used without fertilizer or other manurial treatment. In two sets, of five plots each, full treatments, consisting of the following applications per acre, were made at each round of the rotation:

Tobacco	200 pounds acid phosphate 25 " muriate of potash 160 " nitrate of soda
Soybeans	No treatment
Wheat	200 pounds acid phosphate 25 " muriate of potash 6 tons manure 2 " ground limestone
Clover and grass	No treatment
Clover and grass	No treatment

The third set of five plots received full treatment with the exception of manure. The fourth set received full treatment with the exception of liming. The fifth set received full treatment with the exception of fertilizer. In every set, each of the five crops was grown annually in rotation; one plot in tobacco, another in soybeans, a third in wheat, and two in clover and grass; and the following year the plot that was in tobacco was planted to soybeans, the plot in soybeans was planted to wheat, and the plot in wheat was followed by clover and grass. Special effort was made to have the work throughout as nearly uniform as possible, so that difference in treatment, as outlined, would be practically the only variable. Some variation in soil productivity is to be expected, but the results, as given in Table 3, are considered to be trustworthy, at least to the extent of the following general conclusions:

TABLE 3—*Yields obtained under various conditions of liming, manuring and fertilizing in a five-year rotation of tobacco, soybeans, wheat, clover and grass (2 years)— five 1/40-acre plots to each series. Soil, Clarksville stony loam.*

Crop	Year grown	Yields per acre from various treatments				
		1 No treatment	2 Lime, manure and complete fertilizer	3 Lime and complete fertilizer (no manure)	4 Manure and complete fertilizer (no lime)	5 Manure and lime (no fertilizer)
		Pounds	Pounds	Pounds	Pounds	Pounds
Tobacco	1913	356	606	808	595	395
	1914	170	895	1080	830	260
	1915	450	900	1000	1300	520
	1916	350	1335	1260	1310	1010
	1917	320	1350	1250	1050	950
	1918	340	1400	1300	1270	910
	1919	350	1320	1140	1450	660
	1920	280	1435	990	1370	740
	1921	250	1050	880	1040	820
	1922	250	1215	950	1200	350
Average		312	1151	1066	1142	662
		Tons	Tons	Tons	Tons	Tons
Soybean hay	1914	0.76	1.27	1.24	1.08	0.80
	1915	0.63	1.09	1.25	1.12	0.67
	1916	0.48	.70	0.58	0.58	0.47
	1917	0.60	2.31	2.50	2.00	1.74
	1918	0.45	1.48	1.33	1.08	1.38
	1919	0.62	1.11	1.20	1.06	0.80
	1920	0.43	1.40	1.56	2.18	0.82
	1921	0.38	1.72	1.20	1.64	0.84
	1922	0.26	2.44	2.66	2.12	1.82
Average		0.51	1.58	1.50	1.43	1.04
		Bushels	Bushels	Bushels	Bushels	Bushels
Wheat	1914	8.5	36.4	41.4	37.4	36.2
	1915	1.6	7.2	3.6	3.6	3.1
	1916	3.0	14.5	10:5	16.5	9.3
	1917	0.5	10.6	3.5	6.5	2.5
	1918	4.9	23.3	19.3	21.5	20.7
	1919	1.1	15.1	7.8	10.9	5.1
	1920	0.5	7.1	5.2	3.0	3.8
	1921	0.8	6.8	5.6	6.8	4.8
	1922	1.3	8.8	6.0	10.4	9.8
Average		2.5	14.4	11.4	13.0	10.6

TABLE 3—(Continued)

Crop	Year grown	Yields per acre from various treatments				
		1 No treatment	2 Lime, manure and complete fertilizer	3 Lime and complete fertilizer (no manure)	4 Manure and complete fertilizer (no lime)	5 Manure and lime (no fertilizer)
		Tons	Tons	Tons	Tons	Tons
Clover and grass hay	1914 1)	0.00	0.53	0.21	0.56	0.20
	2)	0.00	0.05	0.00	0.13	0.00
	1915 1)	0.00	1.82	0.28	0.30	1.12
	2)	0.00	1.20	0.56	1.13	0.33
	1916 1)	0.37	2.40	1.77	2.62	1.07
	2)	0.13	2.79	1.86	1.62	2.42
	1917 1)	0.13	0.95	0.42	0.49	0.20
	2)	0.00	0.16	0.00	0.21	0.00
	1918 1)	0.00	1.00	0.45	0.93	0.03
	2)	0.00	0.55	0.55	0.60	0.12
	1919 1)	0.03	1.55	0.42	1.32	1.38
	2)	0.08	0.94	0.84	0.96	0.36
	1920 1)	0.00	1.86	1.52	1.42	0.86
	2)	0.05	1.17	1.00	1.16	1.23
	1921 1)	0.00	0.95	0.72	0.40	0.40
	2)	0.00	1.28	0.13	0.46	0.30
	1922 1)	0.00	1.16	0.05	0.64	0.54
	2)	0.00	1.96	0.92	1.73	0.47
Average 1)		0.06	1.36	0.65	0.96	0.64
2)		0.04	1.12	0.65	0.89	0.59

1. *The yields of tobacco*:

(1) Eight years out of ten the largest yields were obtained where the full treatments of fertilizer, manure, and lime were given, the average yield being 1151 pounds per acre.

(2) The next highest yields were obtained where the lime was omitted, and averaged within one per cent of as much as the full-treatment sets.

(3) The "no-manure" set ranked third, the yields falling off appreciably in the latter years of the trial. The average production was 93 per cent of that of the full-treatment sets.

(4) The omission of the fertilizer resulted in the most marked

reduction in yield, the average being only 58 per cent of that of the full-treatment sets, although practically double that of the untreated set. Also the maturing of the unfertilized crop was delayed from ten days to two weeks.

2. *The yields of soybean hay*:

(1) The full-treatment sets gave the largest average, which was closely followed by the "no-manure" and "no-lime" sets.

Tobacco on a "check," or no-treatment, plot of five-year rotation.

Tobacco on a five-year rotation plot receiving full treatment excepting lime.

Wheat on a "check," or no-treatment, plot.

Wheat on a plot receiving fertilizer and lime.

(2) The omission of the fertilizer gave only 66 per cent of a full crop, but this was nearly twice that of the no-treatment series.

3. *The yields of wheat*:

(1) The yields of wheat were unsatisfactory under all treatments.

(2) The highest average yield was obtained on the full-treatment series, but was only 14.4 bushels per acre.

(3) The crops in the no-treatment series were practically unharvestable, averaging only 2.5 bushels per acre.

4. *The yields of clover and grass hay*:

(1) The full-treatment sets gave decidedly the highest average yields, which were 1.36 tons per acre for the first-year crops, and 1.12 tons for the second-year crops.

(2) The yield of the "no-lime" set was only 74 per cent of that of the full-treatment sets; the yield of the "no-manure" set was 52 per cent, that of the "no-fertilizer" set only 49 per cent.

(3) The no-treatment set did not produce harvestable crops.

DISCUSSION OF THE RESULTS

The most outstanding result was the indication of the importance of the fertilizer, the omission of which greatly reduced the yields of all crops. A consideration of the small amounts used in the course of the five-year rotation makes this result especially striking; the average annual amounts per acre being about 80 pounds of acid phosphate, 10 pounds of muriate of potash, and 32 pounds of nitrate of soda. The nitrate would be expected to be of little value except for the tobacco, to which it was applied, but the acid phosphate and muriate of potash undoubtedly would be utilized by all crops, and can reasonably be credited with the major part of the increase in the case of the tobacco. The average cost of the fertilizers for the five-year period was about $16.00, and the gross return from its use was in the neighborhood of $110.00.

The light application of 6 tons of manure once in five years gave noticeable returns for all crops except soybeans, but the slight effect on this crop is not surprising when it is considered that nearly five years have elapsed since the application. The gross return is in the neighborhood of $7.00 per ton of manure.

This soil did not prove to be especially in need of lime. With the aid of the fertilizer and manure, but without liming, fair stands of clover and grass were obtained. Liming, however, resulted in slight increases in the yields of both soybean hay and wheat, and in a material increase in the yields of clover and grass hay. Calculated as for the other treatments, the gross value of the increase attributable to liming was about $15.00 for each round of the rotation.

FERTILIZER EXPERIMENTS

RATE-OF-APPLICATION TRIALS WITH ACID PHOSPHATE AND NITRATE OF SODA

Three experimental ranges were set aside for fertilizer experiments, which were continued for the ten-year period.

The soil was naturally low in productiveness, as may be seen from the yields of the check plots. For the first three years tobacco was grown continuously on the ranges, but with a rye cover crop through the winter. Thereafter for the next seven years a rotation of tobacco, wheat, and clover and grass was followed, so that tobacco occupied only one of three ranges each year.

As a result of previous experiments in the county, the assumption was made at the outset that this soil was in need of phosphate and nitrogen and that the potash supply was fairly good. Accordingly the experiments were planned with the prime object of determining the most profitable amounts to be used of both acid phosphate and nitrate of soda.

The experiments carried out for the first three years and reported in Table 4 may be looked upon as preliminary to those that followed for the next seven years, which are reported in Table 5. The fertilizer treatments as indicated in the tables were made for each tobacco crop. In addition all plots, including the checks, received a dressing of 100 pounds of sulphate of potash per acre. The acid phosphate and nitrate of soda were mixed together and applied broadcast without delay, after which low ridges were laid off in preparation for transplanting.

Tables 4 and 5 show the results at the Clarksville Station from rate-of-application experiments with both acid phosphate and nitrate of soda. Sulphate of potash was applied to all plots alike.

TABLE 4—*Average results from the first three years' trial. Tobacco grown continuously on the same land.*

Nitrate of soda per acre	Amount of acid phosphate applied and yield and valuation of crop per acre after deduction of cost of fertilizer								Average	
	None		200 pounds		300 pounds		400 pounds			
	Yield	Value	Yield	Value	Yield	Value	Yield	Value	Yield	Value
Pounds	Pounds		Pounds		Pounds		Pounds		Pounds	
None	647	$37.00	.....	.....	.....	.....	.....	.....	647	$37.00
70	.....	.....	876	$45.00	.....	.....	.....	.....	876	45.00
100	.....	.....	962	54.00	1013	$56.00	.....	.....	988	55.00
140	.....	.....	941	45.00	.....	.....	1026	$59.00	984	52.00
150	.....	.....	.....	.....	1040	60.00	.....	.....	1040	60.00
200	.....	.....	.....	.....	903	49.00	1013	60.00	958	55.00
270	.....	.....	.....	.....	.....	.....	946	49.00	946	49.00
Average	647	$37.00	926	$48.00	985	$55.00	995	$56.00		

TABLE 5—*Average results from the last seven years' trial. Tobacco grown in a three-year crop rotation of tobacco, wheat, and clover and grass.*

Nitrate of soda per acre	Amount of acid phosphate applied and yield and valuation of crop per acre after deduction of cost of fertilizer								Average	
	None		100 pounds		200 pounds		300 pounds			
	Yield	Value	Yield	Value	Yield	Value	Yield	Value	Yield	Value
Pounds	Pounds		Pounds		Pounds		Pounds		Pounds	
None	928	$173.00	.....	.....	.....	.....	.....	.....	928	$173.00
80	.....	.....	1049	$178.00	1184	$224.00	1230	$218.00	1154	207.00
120	.....	.....	1223	244.00	1271	249.00	1327	252.00	1274	248.00
160	.....	.....	1203	224.00	1253	250.00	1300	268.00	1252	247.00
Average	928	$173.00	1158	$215.00	1236	$241.00	1286	$246.00		

Note—All of the tobacco crops were carefully graded by experts to determine the effect of the fertilizer treatment on the quality of the leaf, and the prevailing prices were used in the calculation of the crop value. The Station is indebted to several men for this work, but in particular to Mr. A. B. Killebrew and Mr. C. K. Smith, who did the grading for several years.

DISCUSSION OF THE RESULTS

Acid Phosphate

Acid phosphate probably accounts for a large part of the increase over the check, or untreated, plots. The results for the first three years, during which the tobacco was grown continuously on the same land, show a profitable increase from the 300-pound rate, as compared with the 200-pound rate. Four hundred pounds per acre was indicated to be of doubtful value over 300 pounds.

Of the three rates of application under trial for seven years in the three-year rotation of tobacco, wheat, and clover and grass, 300 pounds per acre of acid phosphate produced both the largest and most profitable yields, the average annual increase being 128 pounds of total leaf more than was obtained where only 100 pounds was applied, and the increased annual value, after deducting the cost of the fertilizer, was $31.00 per acre.

Nitrate of Soda

The results for the first three years indicated that an application of nitrate of soda greater than 100 pounds per acre was unprofitable, but of the three rates of application continued for the seven-year period, 120 pounds per acre produced both slightly larger yields and slightly more profitable returns than 160 pounds, and the average annual increase from 120 pounds over that from 80 pounds was 120 pounds of leaf tobacco per acre, with an increased value, after deducting the cost of fertilizer, of $41.00.

Supplemental Trials

Two additional sets of like experiments were made in which 100-, 200-, and 300-pound applications of acid phosphate were compared, one on the farm of A. B. Killebrew, in 1911, and the other on the farm of Ewing Rollow, in 1918. The results are summarized in Table 6. On each farm the 300-pound application gave higher yields and proved more profitable than either of the others.

TABLE 6—*Results from supplemental rate-of-application experiments with acid phosphate. Muriate of potash and nitrate of soda applied alike to all plots.*

Amount of acid phosphate applied and yield and valuation of crop per acre after deduction of cost of fertilizer							
None		100 pounds		200 pounds		300 pounds	
Yield	Value	Yield	Value	Yield	Value	Yield	Value
On farm of A. B. Killebrew—1911							
Pounds 1360	.....	Pounds 1421	.....	Pounds 1668	.....	Pounds 1772	.....
On farm of Ewing Rollow—average results from a duplicate series in 1917							
297	$24.00	1070	$151.00	1295	$193.00	1430	$214.00

General Conclusions from the Acid Phosphate and Nitrate of Soda Series with Tobacco

The results from all series are in agreement that 300 pounds per acre was the most profitable quantity of acid phosphate. It is probably not too much under average conditions as they prevail in this section.

One hundred and twenty pounds of nitrate of soda was indicated as the most profitable amount of this material, and is considered to be a reasonable application where 300 pounds of acid phosphate have been applied.

AFTER EFFECTS ON THE WHEAT AND ON THE CLOVER AND GRASS CROPS OF FERTILIZERS APPLIED FOR THE TOBACCO

Table 7 gives the average yields obtained from four crops of wheat and five crops of clover and grass hay in the three-year rotation of the fertilizer experiments reported in Table 5.

TABLE 7—*Influence of fertilizers applied for tobacco on the yields of wheat, and of clover and grass hay following—average yields per acre of four crops of wheat and of five crops of hay as obtained in connection with the fertilizer experiments reported in Table* 5.

Nitrate (applied to tobacco only)	Amount of acid phosphate and yield per acre (phosphate applied to tobacco only)								Average	
	None		100 pounds		200 pounds		300 pounds			
	Wheat	Hay	Wheat	Hay	Wheat	Hay	Wheat	Hay	Wheat	Hay
Pounds	Bushels	Tons	Bushels	Tons	Bushels	Tons	Bushels	Tons	Bushels	Tons
None	7.4*	0.78*	.....	.....	.....	.....	.....	.....	7.4	0.78
80	.....	.....	6.6	0.88	9.5	1.38	9.6	1.51	8.6	1.26
120	.....	.....	9.3	1.17	10.0	1.47	12.3	1.68	10.5	1.44
160	.....	.....	8.7	1.21	10.1	1.41	11.0	1.63	9.9	1.42
Average	7.4*	0.78*	8.2	1.09	9.9	1.42	11.0	1.61		

*Average of four "check" plots which received neither nitrate nor phosphate.

FERTILIZER EXPERIMENTS

No phosphate and no nitrate. **Phosphate and nitrate**

No fertilizer was used except that applied for the tobacco. The results show unmistakably that increased yields of both wheat and hay can be attributed to the fertilizer as applied, the yields on the fertilized plots not only being greater than those on the check plots, but also increasing with the increase of acid phosphate, so that the 300-pound rate leads in both grain and hay production.

The data are considered to be trustworthy, especially since the average yields as reported were obtained from experiments on at least three different ranges, so that not one but three plots were involved in the getting of each result. Also the number of crops involved, four for wheat and five for hay, adds greatly to the reliability of the data. This being the case, it is noteworthy that the increased yield of wheat, not to mention the increase in the hay crop, would pay for the 300-pound application of the acid phosphate.

SUBSTITUTES FOR ACID PHOSPHATE

The results of a brief comparative trial of three different phosphates are reported in Table 8. Much longer trials would be desirable, but the results indicate that either basic phosphate or precipitated bone may be used as a substitute for acid phosphate.

TABLE 8—*Results obtained in a comparison of different phosphates. Nitrate of soda and muriate of potash applied alike to all plots.*

Kind and amount of phosphate and yield and valuation of crop per acre after deduction of cost of fertilizer							
None		Acid phosphate 200 pounds		Basic slag 190 pounds		Precipitated bone 120 pounds	
Yield	Value	Yield	Value	Yield	Value	Yield	Value
On farm of H. E. Bryan—2 years, 1917 and 1918							
Pounds		Pounds		Pounds		Pounds	
1452	$320.00	1742	$356.00	1640	$338.00	1733	$362.00
On farm of Ewing Rollow—one year, 1918							
297	$24.00	1295	$193.00	1360	$206.00	1225	$177.00

NITROGENOUS FERTILIZER MATERIALS

Widely different materials are used to supply fertilizer nitrogen, but their crop-producing values, pound for pound of nitrogen furnished, are by no means alike. Nitrate of soda is generally recognized as the standard because its nitrogen is unsurpassed in ready availability and effectiveness. On the other hand, the availability of the nitrogen in ground, untreated leather is so low that its use is prohibited by law in many states. Ranking between these two extremes are a number of commercial materials. Tankage, a slaughterhouse product, furnishing nitrogen of relatively low availability, is much used by fertilizer manufacturers, especially in low-grade mixtures, such as the common 8-2-2 fertilizer. Not only can an appreciable saving in the cost of the fertilizer be made by home-mixing, but also more efficient materials can be used.

A comparative trial of several of the best of these nitrogenous

materials was made for four years on the farm of A. H. Pace, and for one year on the farm of Ewing Rollow. In these trials the several materials were used in quantities furnishing practically equal amounts —24 pounds per acre—of nitrogen. Acid phosphate and sulphate of potash were applied alike to all plots and well worked into the soil before the plants were set out. The nitrogenous fertilizers were mixed with the phosphate and potash and applied with them. A summary of the results obtained is given in Table 9.

TABLE 9—*Results of experiments with four high-grade nitrogenous fertilizers. Phosphate and potash applied alike to all plots.*

Kind and amount of nitrogenous fertilizer applied and yield and value of crop per acre after deduction of cost of fertilizer—24 pounds of nitrogen per acre furnished by each material

None		Nitrate of soda 160 pounds		Cottonseed meal 380 pounds		Calcium cyanamide 180 pounds		Ammonium sulphate 130 pounds	
Yield	Value	Yield	Value	Yield	Value	Yield	Value	Yield	Value
On farm of A. H. Pace—average results in a 4-year trial									
Pounds		Pounds		Pounds		Pounds		Pounds	
1285	$144.00	1443	$156.00	1366	$153.00	(1306)*	($145.00)*	1408	$159.00
On farm of Ewing Rollow—average results from a duplicate series in 1917									
967	$138.00	1190	$179.00	1085	$153.00	1090	$156.00	1140	$169.00

*The calcium cyanamide was included for only three years of the experiments. The figures in parenthesis were modified to show their relative standing with the four-year data.

DISCUSSION OF THE RESULTS

Nitrate of soda and ammonium sulphate not only produced the greatest increases in yield, but also proved the most profitable. This result is of especial interest because both of these materials have a tendency to reduce the quality of the tobacco. This tendency did not prove to be material in these experiments. Cottonseed meal ranked third, but is considered a valuable source of nitrogen, especially as it can be readily obtained anywhere in the State, is in excellent condition to be mixed and applied with other fertilizers, and is considered to produce a high quality of leaf. Calcium cyanamide is not so widely used as the other three, and in these trials did not turn out especially well. Also there are some disadvantages in the handling of this material.

POTASH FOR TOBACCO

The need of phosphate by Montgomery County soils, like other Highland Rim soils, is very pronounced. The need of potash, on the other hand, is not well established. The better class of Rim soils,

especially where livestock farming is practiced, are not considered to need it. The poorer types of soil have been found to respond to an application of potash when made in connection with phosphate. Rarely, if ever, has potash been found to give increased yields when applied without phosphate. In fact, under such a condition a decreased yield is usual. The kind of crop is, however, a matter of importance because, for example, potato and hay crops may give increased yields from potash added to the phosphate, while on the same soil corn and wheat show no increase from the added potash.

EXPERIMENTAL RESULTS

Beginning in 1908 experiments with fertilizers for tobacco were made from time to time on different farms in Montgomery County. Plots both with and without an application of potash were included in trials on five farms.

A summary of the results obtained is given in Table 10.

TABLE 10—*Summary of various trials of potash as a fertilizer for tobacco. Acid phosphate and nitrogenous fertilizer applied alike to all plots.*

On farm of	Year	Yield per acre of total leaf and lug	
		With potash (100 pounds of sulphate)	Without potash
		Pounds	Pounds
C. E. Frey	1909	1300	1400
P. L. Harned	1909	760	738
P. L. Harned	1910	1305	1293
A. H. Pace	1916	1222	1274
H. E. Bryan	1917	1740	1490
H. E. Bryan	1918	1730	1900
Average		1343	1349

Discussion of the Results

The results do not show a definite need of potash. In three instances it appears to have given an increased yield, but in three others the yield was less. Plot inequality possibly accounts for all the differences.

Since the yields obtained indicate that better than average soils were taken for these experiments, it may be advisable, on poorer soil, to use a small amount of potash salt in the fertilizer mixture, especially if the soil has been cropped for some time with little or no return of manure. The recommendation for such a case is 25 pounds of muriate of potash, or its equivalent of other potash salt, to every 300 pounds of high-grade acid phosphate. Such a mixture would analyze nearly 15 per cent of available phosphoric acid and nearly 4 per cent of potash.

FERTILIZER FORMULAS FOR TOBACCO

The relative proportions of phosphoric acid, nitrogen (or its equivalent in ammonia), and potash that will give the best results is a question of considerable practical importance. Three hundred pounds of high-grade acid phosphate, analyzing 16 per cent of available phosphoric acid; 120 pounds of nitrate of soda, of the usual guarantee of 15 per cent of nitrogen or 18.2 per cent of ammonia, and 25 pounds of muriate of potash, are equivalent to a mixture analyzing 10.8 per cent of available phosphoric acid, 4.9 per cent of ammonia, and 2.8 per cent of potash. If 280 pounds of high-grade cottonseed meal were used instead of 120 pounds of nitrate, all the ingredients could be mixed together and the mixture would analyze 9.1 per cent of available phosphoric acid, 3.6 per cent of ammonia, and 2.8 per cent of potash. In these calculations the cottonseed meal was assumed to contain 7.9 per cent of ammonia, 2.5 per cent of phosphoric acid, and 1.5 per cent of potash.

In this connection it may be of interest to note that a ton of an 8-2-2 mixture, which in the past has been extensively used as a tobacco fertilizer, can be obtained by mixing together 950 pounds of 16 per cent acid phosphate, 500 pounds of high-grade cottonseed meal, 70 pounds of muriate of potash, and 480 pounds of sand or soil. It will be noted that the formulas recommended are much richer in plant food, especially in ammonia.

A COMPARISON OF FOUR CROP ROTATIONS

In Table 11 are given the yields obtained in each of four crop rotations. In the five-year rotations, full manurial treatments were made according to the plan given on page 5. In the three-year rotations the treatments were as follows:

Tobacco	120 pounds acid phosphate 15 " muriate of potash 96 " nitrate of soda
Wheat	120 pounds acid phosphate 15 " muriate of potash 3-3/5 tons manure 1200 pounds ground limestone
Clover and grass	None

The average annual applications are the same for both the five-year and three-year rotations.

TABLE 11—*Comparative yields per acre in four different rotations. Manurial treatments alike over a series of years.*

Crop	Year grown	Five-year rotation—tobacco, soybeans, wheat, clover and grass two years	Five-year rotation—tobacco, soybeans, wheat, Japan clover two years	Three-year rotation—tobacco, wheat, clover	Three-year rotation—tobacco, soybeans, wheat, and crimson clover
		Pounds	Pounds	Pounds	Pounds
Tobacco	1913	682	705	512	676
	1914	900	800	1120	(1120)
	1915	1200	1330	1180	1120
	1916	1510	1680	1480	1480
	1917	1450	1510	1290	1240
	1918	1450	1670	1450	1430
	1919	1490	1530	1210	1360
	1920	1440	1700	1300	1220
	1921	1120	1280	1200	980
	1922	1160	1560	1220	1030
Average		1240	1377	1196	1166
		Tons	Tons		Tons
Soybean hay	1914	1.53	1.30		1.16
	1915	1.52	1.46		1.66
	1916	.87	1.12		.89
	1917	2.50	2.40		2.00
	1918	1.78	1.64		.95
	1919	1.06	1.35		1.08
	1920	2.18	2.28		2.42
	1921	2.04	1.92		1.64
	1922	2.94	2.59		2.01
Average		1.82	1.78		1.54
		Bushels	Bushels	Bushels	Bushels
Wheat	1914	37.1	33.9	32.6	37.4
	1915	8.4	5.6	7.5	8.5
	1916	16.5	18.0	17.5	18.3
	1917	16.8	17.1	20.0	9.3
	1918	23.0	35.3	42.0	18.5
	1919	18.4	14.5	15.3	12.3
	1920	7.7	10.8	6.1	4.6
	1921	8.2	10.5	9.9	11.0
	1922	16.8	10.5	11.0	7.2
Average		15.9	17.4	18.0	14.1

TABLE 11—(Continued)

Crop	Year grown	Five-year rotation—tobacco, soybeans, wheat, clover and grass two years	Five-year rotation—tobacco, soybeans, wheat, Japan clover two years	Three-year rotation—tobacco, wheat, clover	Three-year rotation—tobacco, soybeans, wheat, and crimson clover
		Clover and grass hay*	Japan clover hay	Clover hay	
		Tons	Tons	Tons	
Hay	1914	0.46	0.00	0.47	
	1915	1.85	0.00	2.14	
	1916	3.00	1.19	2.40	
	1917	0.87	1.73	1.05	
	1918	1.25	1.39	1.38	
	1919	1.21	1.24	1.56	
	1920	1.77	1.16	2.44	
	1921	1.55	0.00	0.88	
	1922	1.74	2.60	1.48	
Average		1.52	.89	1.53	

*First- and second-year crops averaged.

The number of plots concerned was the same as the number of years of the rotation; that is, five for each of the five-year rotations and three for each of the three-year rotations. This permitted each crop of each rotation to be grown annually.

DISCUSSION OF THE RESULTS

THE FIVE-YEAR ROTATIONS

Owing to the possibility of there being some inequality in the natural productivity of the plots, attention is called only to the indications or trend of the yields.

The comparison between the two five-year rotations is of special interest, because Japan clover, which was sown in the spring on the wheat, can be obtained on almost any soil without the aid of lime. Red clover, on the other hand, cannot be obtained on many soils until limed, even if a moderate dressing of manure is given. The yields obtained indicate that under some conditions the Japan clover rotation may be of practical value. Following this legume, not only was the yield of tobacco good, but the quality of the crop was high. The chief drawback to it is the uncertainty of Japan clover for a hay crop, as indicated by its failure to make a harvestable crop in three seasons out of nine.

THE THREE-YEAR ROTATIONS

The three-year rotations are more intensive, and therefore better suited to a small farm, than the five-year rotations. The tobacco-wheat-clover rotation is in common use, but to be successful requires that the soil be well supplied with lime. In the other rotation soy-

beans are utilized as a hay crop instead of red clover, and crimson clover is brought in for soil cover and improvement. The only advantage in this rotation is that it can be carried out on a soil somewhat deficient in lime. Its serious disadvantage is the large amount of labor required in soil preparation. The yields of both tobacco and hay are not greatly different in these two rotations, but the average yield of wheat is appreciably in favor of the clover and grass rotation, in which the wheat follows tobacco.

WHEN SHOULD MANURE BE APPLIED?

Two sets of the five-year rotations with full manurial treatments were run for the ten-year period with the object of getting data as to the returns from manure applied directly for the benefit of the tobacco as compared with a similar amount applied as a top-dressing in the spring on the wheat. A portion of the area used for the set in which the manure was applied for the tobacco occupied lower and richer ground than the other, so that the results cannot be taken as conclusive. There was, however, an unmistakable increase in the yield of clover and grass hay in the set on the poorer ground where the manure was top-dressed on the wheat, the annual increase averaging .44 of a ton of hay per acre. The average increased yield of tobacco in the set receiving the manure for this crop was 232 pounds of total leaf and lug.

DEMONSTRATION ACRES ON A POOR HILLSIDE
FIVE-YEAR ROTATION

A five-acre tract on an eroded hillside was run in the five-year rotation of tobacco, soybeans, wheat, and clover and grass for a period of eight years. Full treatments of lime, manure, and fertilizer were made as in the plot-rotation experiments. The acre yields as given in Table 12 are noticeably similar to the yields obtained on the plots.

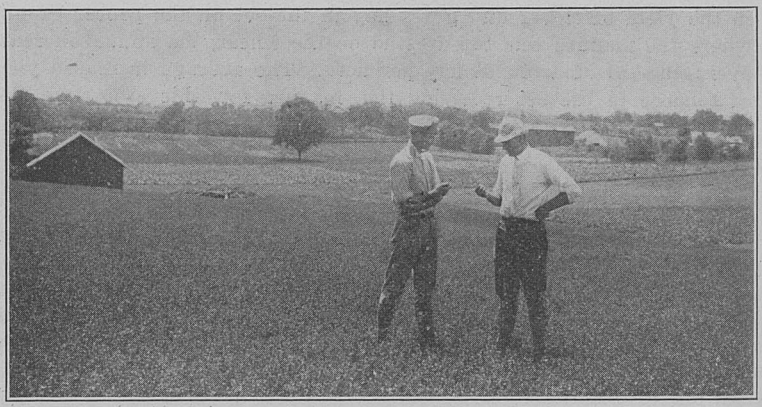
TABLE 12—*Yields per acre of crops grown in rotation for demonstration purposes on a poor hillside, one acre of each crop being grown each year. Manurial treatments similar to those of Series 2, Table 1.*

Year	Tobacco	Soybeans	Wheat	Clover and grass (1st year)	Clover and grass (2nd year)
	Pounds	Tons	Bushels	Tons	Tons
1915	1222	1.78	.....	.....	.....
1916	1367	1.63	14.3	2.63	.....
1917	1306	1.50	6.5	.32	1.21
1918	1430	2.52	11.5	.93	.76
1919	1110	1.90	13.0	2.08	1.66
1920	1140	1.60	6.0	1.20	1.60
1921	1064	1.74	11.5	1.69	1.80
1922	1002	2.78	12.0	2.26	.74
Average	1205	1.93	10.7	1.59	1.30

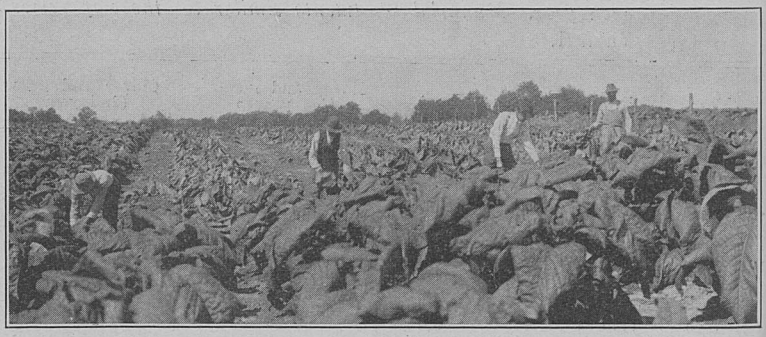
ALFALFA

In the summer of 1914 a 1½-acre portion of the hillside was limed with 3 tons of ground limestone and received in addition 450 pounds of acid phosphate, 75 pounds of muriate of potash, and 6 tons of manure, the manure being applied to only one-half the tract, or three-fourths of an acre. After good soil preparation, including the drilling in broadcast of 200 pounds of soil from an old alfalfa field, alfalfa was sown September 18. An excellent stand was obtained and profitable crops were harvested for the next six years, with yields of cured hay as follows:

	Tons
1915	2.95
1916	4.45
1917	4.03
1918	4.05
1919	4.61
1920	2.58



General View from the Alfalfa Field.



Harvesting the Tobacco Acre.

During the last two years crab-grass became increasingly prominent and made up a considerable part of the crop, so that the limit of profitableness had about been reached. The ease with which a good stand of alfalfa was obtained and maintained, both on the hillside and in other trials, justifies increased attention in this part of the State to this valuable crop, which not only gives large yields of very nutritious hay, but also brings about greatly increased soil productivity, as shown in the tobacco or other crop which follows.

MISCELLANEOUS ITEMS

VARIETIES OF TOBACCO

Throughout the dark section two varieties are in high favor, Yellow Mammoth and Madole. The former is broad-leaved and the latter medium-broad-leaved and long-leaved. A varietal trial including several other kinds was made for only a single season, and the results indicated that the two varieties mentioned were the best. In the fertilizer and rotation experiments Yellow Mammoth was usually grown.

WIDTH OF ROWS

Dark tobacco in comparison with bright, or Burley, tobacco is wide-spaced. A common distance, and one generally used throughout the experimental work, was 3½ x 3½ feet, one plant to the hill. Some spacing experiments were carried out, and while the results were inconclusive the indications were that closer spacing, possibly 3 x 3 feet, would have given somewhat higher yields, especially on the well-fertilized plots.

TOBACCO AFTER SWEET CLOVER AND ALFALFA

Although no special effort was made to compare the yields of tobacco following sweet clover and alfalfa with the yields after other legumes, tobacco was grown from time to time after both of these crops and was found to do unusually well, especially after sweet clover.

APPLICATION OF FERTILIZER

In the experimental work the applications of both acid phosphate and muriate of potash were made broadcast and well harrowed into the soil prior to the making of the low ridges on which the plants were set. It is probable that a light application of 100 or 200 pounds to the acre would have been more effective if applied in the row before bedding. The results secured by the method used were considered good, however, and the wider distribution was considered desirable and probably more beneficial to both the wheat and the clover and grass following than the row application.