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AGRICULTURAL EXPERIMENT STATION
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Experiments With Fertilizers

BY J. H. STEWART AND HORACE ATWOOD

[The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director Agricultural Experiment Station, Morgantown, W. Va.]

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Experiments With Fertilizers

In practical agriculture the fertility of the soil is of the first importance, for if the soil is so poor that satisfactory yields cannot be obtained then the difference between the cost of producing a crop and its market value may be so small that no adequate profit remains, while if a crop is sufficiently large then the cost of production tends to become relatively smaller, and the profits larger.

It is of course important to select crops adapted to the soil and climate and which have either directly or indirectly a high market value. It is important to select the right variety; to plant good seed in a well prepared seed bed and to give the crop thorough and intelligent cultivation, yet even if these things are all properly done and the soil is so poor that a small yield is obtained then there remains little or no profit to repay the husbandman for his efforts.

The fertility of the soil depends upon and is influenced by many complex factors. The physical condition of the soil; its water-holding capacity; the amount and availability of the different essential plant food materials; the presence or absence of injurious substances or organisms, each and all have their influence in affecting productivity and all are important. Plants cannot grow, however, unless they have food, and other things being equal the luxuriance of growth depends, not upon the total amount of available plant food present in the soil and atmosphere, but upon that particular food material which is present in the smallest amount relative to the needs of the crop. For example, if only enough potash in an acre of soil becomes available in one season for the production of one thousand pounds of hay per acre, then only one thousand pounds of hay per acre will be produced, even though there is present enough available

phosphoric acid, lime, nitrogen, iron, sulphur, magnesia and silica for the production of five tons of hay per acre.

In order to select and use commercial fertilizers or stable manure intelligently it is necessary to know what plant food is especially lacking in the soil to which the fertilizer is to be applied. When this is known a fertilizer can be selected which is rich in the deficient element, or if stable manure is used, and it is not sufficiently rich in the deficient element, then a commercial fertilizer can be used in connection with the stable manure so as to properly "balance" the application, and thus materially increase its effectiveness.

During the past eight years the Station has been studying the fertilizer requirements of the soil of the Experiment Station Farm by means of plat experiments. The plats are one-tenth of an acre in size and the same fertilizer has been applied to the same plat year after year and the crop rotated. The results for the first six years of the test are discussed in bulletin No 99, and as the edition of this bulletin is nearly exhausted, and as it is desirable to make the record of this experiment complete the results and conclusions for the entire eight years are brought together in this publication.

"A fertile soil is one in which the various elements of plant food are present in sufficient and properly proportioned quantities, and in forms which are both acceptable and available, and which moreover possesses a mechanical condition suitable for plant growth."

"Unfortunately, many soils are not fertile. They are either poor by nature or have been impoverished by improper management. The result in either case is the same. The crops are too small. How are the yields to be increased. Farmers in the Eastern States are relying upon the use of commercial fertilizers for this purpose. In West Virginia alone the value of the commercial fertilizer used amounts to about a million dollars annually, and if this large sum of money is to be spent each year by the farmers of this State for the purpose of securing better crops it is quite needless to say that these fertilizers should be

used so as to produce the utmost possible increase in the yields of the crops for which they are applied. The experiments described in this bulletin have been performed so as to throw some light on this subject."

"As soils differ remarkably in respect to their fertilizer requirements it is fortunate that the soil at the Experiment Station farm, where these experiments have been performed, is typical of a large part of the upland soil of the State."

"The soil of the Experiment Station aFrm has been formed almost entirely through the decomposition and disintegration of the strata of rocks which in this section form the protective covering of the Pittsburg vein of coal. It is consequently a lightish soil, of a sandy texture, easily tilled, but which dries out too rapidly in summer. The original timber consisted of oaks, poplars, and chestnuts, together with an occasional locust, maple and beech."

In order to avoid the effect of any possible inequality in the original fertility of the plats every third plat of the series was left unfertilized, and in discussing the results the yields of each fertilized plat has been compared with the average yield of the two nearest unfertilized ones. By this method of comparison the minor differences in the natural fertility of the plats is almost wholly eliminated.

CROPS GROWN.

The crops in this test have been as follows: In 1900 rye was grown; in 1901 wheat; in 1902 clover; in 1903 corn; in 1904 cow-peas; in 1905 corn; in 1906 potatoes; in 1907 rye.

FERTILIZERS USED.

The first application of fertilizer was made in the spring of 1900 as a top-dressing on rye. Later applications have been made with a fertilizer drill, the fertilizers being applied immediately before planting the seed. In 1902 for the crop of clover, and again in 1907 for the crop of rye, no fertilizer was applied

to any of the plats. The first year the carrier of phosphoric acid was Thomas slag, since then acid phosphate has been used.

The following table shows the amount and kind of fertilizer applied annually to each plat, without referring to the exceptions as noted above.

Plat 19. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906); 100 pounds lime in 1900 and 150 pounds lime in 1906.

Plat 20. Two tons stable manure; 100 pounds lime in 1900; 150 pounds lime in 1906.

Plat 21. No fertilizer.

Plat 22. 100 pounds lime in 1900 and in 1903, and 150 pounds in 1906.

Plat 23. Ash from two tons of stable manure, together with an amount of nitrogen in the form of sodium nitrate equivalent to the nitrogen originally present in the stable manure. Applications made in 1900 and in 1901. Since then no further application.

Plat 24. No fertilizer.

Plat 25. Two tons stable manure applied annually except in 1902, 1903 and 1907.

Plat 26. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906).

Plat 27. No fertilizer.

Plat 28. 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906).

Plat 29. 40 pounds sodium nitrate; 15 pounds potassium sulphate (20 pounds in 1906).

Plat 30. No fertilizer.

Plat 31. 40 pounds acid phosphate; 40 pounds sodium nitrate.

Plat 32. 15 pounds potassium sulphate (20 pounds in 1906).

Plat 33. No fertilizer.

Plat 34. 40 pounds acid phosphate.

Plat 35. 40 pounds sodium nitrate.

Plat 36. No fertilizer.

RESULTS OBTAINED DURING THE FIRST YEAR OF THE TEST.

In the spring of 1900 a field which had been sown to rye in the fall of 1899, and fertilized at the rate of 400 pounds of complete fertilizer per acre, was selected for this experiment and divided into plats each one-tenth of an acre in size, two rods wide and eight rods long, with an alley four feet wide extending between them. The plats were sown to clover on the 7th of March and the different fertilizers were applied as a top-dressing on the succeeding day.

Table showing the yield of rye from the different plats:

Plat	Fertilizer	Pounds straw per acre	Pounds grain per acre	Ratio of grain to straw
13	No fert.	2117	1153	1 to 1.83
14	" "	2470	1220	1 to 2.00
15	" "	2318	1182	1 to 1.96
16	" "	2501	1239	1 to 2.01
17	" "	2263	1067	1 to 2.12
18	" "	2385	1215	1 to 1.96
19	N, K ₂ O, P ₂ O ₅ CaO	3524	2076	1 to 1.69
20	Manure, Lime	2762	1578	1 to 1.75
21	No fert.	2064	1186	1 to 1.74
22	Lime	1813	1077	1 to 1.68
23	Ash, N.	3845	2095	1 to 1.83
24	No fert.	2070	1100	1 to 1.88
25	Manure	3587	1913	1 to 1.87
26	N, K ₂ O, P ₂ O ₅	4317	2463	1 to 1.75
27	No fert.	2583	1297	1 to 1.99
28	P ₂ O ₅ K ₂ O	2739	1411	1 to 1.94
29	N, K ₂ O	3560	1980	1 to 1.79
30	No fert.	2540	1340	1 to 1.89
31	N, P ₂ O ₅	4153	2267	1 to 1.83
32	K ₂ O	2678	1402	1 to 1.91
33	No fert.	2600	1330	1 to 1.95
34	P ₂ O ₅	2810	1360	1 to 2.06
35	N.	3716	1914	1 to 1.94
36	No fert.	2380	1220	1 to 1.95

The average yield per acre of the twelve plats which received no fertilizer was 2,357 pounds of straw and 1,212 pounds of grain, while the average of the remaining twelve plats which received different applications of plant food was 3,292 pounds of straw and 1,794 pounds of grain, leaving a balance in favor of the fertilizers of 935 pounds of straw and 582 pounds of grain. It may be repeated here that when the rye was sown the entire field in which the plats are situated received an application of 400 pounds of complete fertilizer per acre, and yet in spite of this somewhat liberal application the various top-dressings applied in the spring gave an average increase of over ten bushels of grain per acre.

In the following table the yield of each fertilized plat is compared with the average yield of the two nearest plats which were not fertilized in the spring of 1900. By this method of comparison the minor differences in the natural fertility of the plats are almost wholly eliminated.

				Straw.	Grain
Plat 19	Excess over average of	18 and 21		1300	876
Plat 20	" " "	18 and 21		538	378
Plat 22	Decrease from	21 and 24		254	66
Plat 23	Excess over	21 and 24		1778	952
Plat 25	" " "	24 and 27		1261	715
Plat 26	" " "	24 and 27		1991	1265
Plat 28	" " "	27 and 30		178	93
Plat 29	" " "	27 and 30		999	662
Plat 31	" " "	30 and 33		1583	932
Plat 32	" " "	30 and 33		108	67
Plat 34	" " "	33 and 36		320	85
Plat 35	" " "	33 and 36		1226	639

SUMMARY FOR THE FIRST YEAR.

Remembering that the different fertilizers were applied as a top-dressing in the spring, the following observations may be made concerning the first year of the test:

1. The table shows that sodium nitrate when applied alone

or in combination with potash or phosphoric acid, materially increased the yield of both grain and straw.

2. Thomas slag when used alone, or with potash, increased the yield but slightly, but when employed with nitrogen was of considerable value.

3. Potassium sulphate when used alone, or combined with either nitrogen or phosphoric acid, was apparently of little benefit.

4. The largest yield was obtained when the three elements, nitrogen, potash, and phosphoric acid were employed, the increase over the average of the two unfertilized plats being 22.5 bushels of grain per acre.

5. The stable manure increased the yield of both grain and straw, acting somewhat more favorably than an application of nitrogen.

6. The ash of stable manure with nitrogen added gave a larger yield than manure alone.

7. Lime when used alone, or in combination with stable manure, or with nitrogen, potash and phosphoric acid, acted injuriously.

RESULTS OBTAINED DURING THE SECOND YEAR OF THE TEST.

The stand of clover upon some of the plats not being satisfactory all of the plats were plowed and prepared for wheat, which was sown October 6, 1900. At the time of sowing the soil was very dry, but rain came on the 7th and 8th of the month, and the wheat promptly came up and made a fairly good growth before winter began.

The same kind and amount of the different fertilizers was applied to the different plats as in the preceding year except that acid phosphate was substituted for Thomas slag, and no more lime was applied to plats 19, 20 and 22. The fertilizers

were applied broadcast before the wheat was sown. The acid phosphate employed had the following composition:

Available phosphoric acid.....15.74%

Total phosphoric acid.....16.30%

The variety of wheat used was the Valley, obtained from the Ohio Experiment Station. It was harvested July 3rd and threshed from the shock shortly after. All of the plats were again seeded to clover on the 18th of March, resulting in a good stand.

The following tables give the results of the test in 1901:

Table showing the yield of wheat from the different plats:

Plat	Fertilizer.	Pounds straw per acre	Pounds grain per acre	Ratio of grain to straw
19	"Complete" fert.	(Lodged severely and not weighed.)		
20	Stable Manure	4560	1840	1 to 2.47
21	No fert.	1160	1140	1 to 1.11
22	Lime in 1900	1490	1010	1 to 1.47
23	Ash and N	3320	1880	1 to 1.76
24	No fert.	1830	1070	1 to 1.71
25	Stable Manure.	4580	1920	1 to 2.38
26	N, K ₂ O, P ₂ O ₅	3950	1750	1 to 2.25
27	No fert.	1780	1120	1 to 1.58
28	P ₂ O ₅ , K ₂ O	3350	1550	1 to 2.16
29	N, K ₂ O.	1820	1080	1 to 1.68
30	No fert.	1650	1050	1 to 1.57
31	N, P ₂ O ₅	3550	1550	1 to 2.29
32	K ₂ O	1670	1030	1 to 1.62
33	No fert.	1990	1110	1 to 1.79
34	P ₂ O ₅	2610	1390	1 to 1.87
35	N.	1770	930	1 to 1.90
36	No fert.	1250	750	1 to 1.66

The average yield of the six plats which were not fertilized was 1610 pounds of straw and 1040 pounds of grain per acre, while the average of the remaining eleven plats was 2970 pounds of straw and 1448 pounds of grain per acre, leaving a balance in favor of the fertilizers of 1360 pounds of straw and 408 pounds of grain per acre.

In the following table the yield of each fertilized plat is

compared with the average yield of the two nearest plats which have not been fertilized, thus bringing out more clearly the influence of the different fertilizers:

Plat		Straw.	Grain
20 Excess over	21	3400	700
22 Decrease from average of	21 and 24	5	95
23 Excess over	21 and 24	1825	775
25 " " "	24 and 27	2775	825
26 " " "	24 and 27	2145	665
28 " " "	27 and 30	1635	465
29 " " "	27 and 30	105	5 (decrease)
31 " " "	30 and 33	1730	470
32 Decrease from	30 and 33	150	50
34 Excess over	33 and 36	990	460
35 " " "	33 and 36	150	0

OBSERVATIONS CONCERNING THESE RESULTS.

1. Sodium nitrate when used alone slightly increased the amount of straw but did not increase the yield of grain.

2. Acid phosphate when used alone increased the amount of straw nearly one thousand pounds, and the yield of grain slightly more than seven and one-half bushels per acre.

3. Potassium sulphate when used alone decreased both the yield of straw and grain.

4. Sodium nitrate when used with acid phosphate materially increased the yield of straw, and slightly increased the yield of grain, when compared with the plat on which acid phosphate was applied alone.

5. Sodium nitrate when used with potassium sulphate slightly increased the yield of straw, but decreased the yield of grain when compared with the two nearest unfertilized plats.

6. Potassium sulphate when applied with acid phosphate materially increased the yield of straw and slightly increased the yield of grain when compared with the plat to which acid phosphate was applied alone.

7. Sodium nitrate and potassium sulphate when used with

acid phosphate gave a larger increase of both grain and straw than when they were individually applied with acid phosphate

8. A comparison of the preceding observations clearly shows that for wheat phosphoric acid is decidedly deficient in this soil, and that as soon as this deficiency is overcome there is a lack of both potash and nitrogen.

9. Stable manure gave a larger increase in the yield of grain than any other fertilizer or combination of fertilizers.

10. The ash of stable manure with an equivalent amount of nitrogen applied in the form of sodium nitrate did not give as large an increase as stable manure alone.

11. The plat to which lime was applied alone in 1900 did not give as large a yield as the average of the two adjoining unfertilized plats; when applied in connection with stable manure, however, the yield of straw was larger than on any of the other plats, and undoubtedly the yield of grain would have been larger if the wheat upon this plat had not lodged severely before the heads were filled.

RESULTS OBTAINED DURING THE THIRD YEAR OF THE TEST.

The clover on plats 19 to 36 inclusive was not fertilized, as it was desirable to study the after-effect of the previous manurings. Plats 13 to 18 inclusive, which had received no fertilizer since the beginning of the test, received applications of potassium sulphate and the double sulphate of potash and magnesia. The application of these manures was made in order to study the effect of an excessive amount of magnesia in the soil, as it has been claimed that too much magnesia in the soil, especially when there is a deficiency of lime, is very deleterious. The potassium sulphate used contained 48.90% potash and the double sulphate of potash and magnesia 24.40% potash and

11.42% magnesia. These fertilizers were applied as a top dressing on April 7th so as to supply 100 pounds of potash per acre to the plats as follows:

Plat 13	Potassium sulphate.
" 14	" magnesium sulphate.
" 15	" sulphate.
" 16	" magnesium sulphate.
" 17	" sulphate.
" 18	" magnesium sulphate

The first crop of clover was cut June 23rd and the second crop August 20th. The following table shows the total yield of field cured hay from each plat. The hay when weighed was not cured quite as much as was desirable, but it was dry enough so that it kept well in the mow.

Plat	Yield	pounds of hay per acre.						Both crops.	
Plat 13	2100								
Plat 14	2400	"	"	"	"	"	"	"	"
Plat 15	2600	"	"	"	"	"	"	"	"
Plat 16	2750	"	"	"	"	"	"	"	"
Plat 17	2500	"	"	"	"	"	"	"	"
Plat 18	2800	"	"	"	"	"	"	"	"
Plat 19	6700	"	"	"	"	"	"	"	"
Plat 20	8850	"	"	"	"	"	"	"	"
Plat 21	2050	"	"	"	"	"	"	"	"
Plat 22	1500	"	"	"	"	"	"	"	"
Plat 23	7900	"	"	"	"	"	"	"	"
Plat 24	2100	"	"	"	"	"	"	"	"
Plat 25	9550	"	"	"	"	"	"	"	"
Plat 26	7250	"	"	"	"	"	"	"	"
Plat 27	2850	"	"	"	"	"	"	"	"
Plat 28	5500	"	"	"	"	"	"	"	"
Plat 29	2000	"	"	"	"	"	"	"	"
Plat 30	2650	"	"	"	"	"	"	"	"
Plat 31	7900	"	"	"	"	"	"	"	"
Plat 32	2500	"	"	"	"	"	"	"	"
Plat 33	2200	"	"	"	"	"	"	"	"
Plat 34	5400	"	"	"	"	"	"	"	"
Plat 35	2600	"	"	"	"	"	"	"	"

The clover showed no bad effect from the application of the double sulphate of potash and magnesia. The average yield of the three plats to which potassium sulphate was applied was 2400 pounds of hay per acre, while the average yield of the three plats receiving potassium magnesium sulphate was 2650 pounds per acre. It is possible that some crops are more susceptible to an excess of magnesium than others. It is to be observed, also, that the average yield of these six plats agrees closely with the yield of plat 32, which has received only potassium fertilizers since the beginning of this experiment.

The following table shows the excess, or decrease, in the yield of the remaining plats as compared with the average yield of the two nearest unfertilized ones.

					Lbs. Hay per acre.
Plat 19	Excess over plat 21.....				4650
Plat 20	“ “ “ 21.....				6800
Plat 22	Decrease from average of plats 21 and 24.....				575
Plat 23	Excess over “ “ 21 and 24.....				5825
Plat 25	“ “ “ “ 24 and 27.....				7075
Plat 26	“ “ “ “ 24 and 27.....				4775
Plat 28	“ “ “ “ 27 and 30.....				2750
Plat 29	Decrease from “ “ 27 and 30.....				750
Plat 31	Excess over “ “ 30 and 33.....				5475
Plat 32	“ “ “ “ 30 and 33.....				75
Plat 34	“ “ “ “ 33.....				3200
Plat 35	“ “ “ “ 33.....				400

SUMMARY FOR THE THIRD YEAR.

1. The table shows that former applications of sodium nitrate and potassium sulphate when applied alone did not materially increase the crop of clover, while former applications of phosphoric acid were of decided benefit.

2. Former applications of sodium nitrate and phosphoric acid combined gave a considerably larger excess than phosphoric acid when applied alone, while former applications of a mixture

of sodium nitrate and potassium sulphate seem to have acted injuriously.

3. The plat to which phosphoric acid and potash had been applied in combination did not give as large an increase over the average of the two nearest unfertilized plats as the plat to which phosphoric acid was applied alone.

4. The plat which received sodium nitrate, potassium sulphate and phosphoric acid did not give as large an increase over the unfertilized plats as the plat to which only sodium nitrate and phosphoric acid had been applied.

5. It is thus seen that in this test former applications of a mixture of sodium nitrate and potassium sulphate when used either with or without phosphoric acid acted injuriously.

6. The largest increase over the average of the two nearest unfertilized plats was obtained from the plat to which stable manure had been applied, next in order stands the plat which, in addition to stable manure, had received an application of lime.

7. Comparing the excess yields of plats 23 and 25 to the first of which has been applied ash of stable manure and nitrogen, and to the second only stable manure, it is seen that the stable manure plat gave a considerably larger increase.

8. Plat 22, which received an application of lime in 1900 did not yield as well as the average of the two nearest unfertilized plats; also when the excess yields of plats 19 and 20 are compared with the excess yield of plats 26 and 25, respectively, it is seen that the lime has acted injuriously on this particular soil when used either with a complete fertilizer or with stable manure.

9. The average yield per acre of the five plats, 21, 24, 27, 30 and 33, which have received no fertilizers since the beginning of the experiment, was 2370 pounds of hay per acre, while the average yield of the remaining twelve plats which have been fertilized was 5637 pounds per acre, or more than twice as much as the continually unfertilized plats.

RESULTS OBTAINED DURING THE FOURTH YEAR OF THE TEST.

The clover sod was plowed April 21st, 1903, harrowed thoroughly and planted to corn May 16th, an unnamed yellow dent variety being employed. The fertilizers were applied broadcast immediately before planting and harrowed into the soil. No lime was applied to plats 19 and 20, and only one-half of the usual amount of sodium nitrate was applied, immediately before the corn was planted, to plats 19, 26, 28, 29, 31 and 35, the other half being applied June 15th. No more fertilizer was applied to plats 23 and 25, and acid phosphate was substituted for Thomas slag for all plats receiving phosphoric acid. Owing to the difficulty of burning the stable manure and applying the ashes, which are very light and easily blown about by the wind, this portion of the experiment was discontinued. Except as noted the same kind and amount of fertilizer was applied to the plats as in the first year of the test.

The season of 1903 was very unfavorable for the growth of corn. The latter part of May, and the months of June and July were excessively wet while only 2.48 inches of rain fell from the first of August until the 25th of September, when the corn was cut.

The corn was husked October 10th, and the stalks and the corn in the ear weighed at once.

The following tables show the yield of corn and stalks from various plats:

Plat.	Corn.	Forage.	Plat.	Corn.	Forage
No. 13	180	335	No. 25	523	650
No. 14	197	350	No. 26	562	700
No. 15	153	300	No. 27	198	345
No. 16	153	295	No. 28	516	620
No. 17	174	285	No. 29	150	330
No. 18	195	290	No. 30	132	360
No. 19	620	680	No. 31	540	700
No. 20	770	940	No. 32	200	375
No. 21	200	380	No. 33	193	360
No. 22	162	320	No. 34	457	575
No. 23	441	580	No. 35	133	330
No. 24	177	365	No. 36	150	310

NITROGEN, POTASH, PHOSPHORIC ACID AND LIME.
PLAT 19.

RYE IN 1907.

NO FERTILIZER.
PLAT 18.

NO FERTILIZER.
PLAT 21.

RYE IN 1907.

STABLE MANURE AND LIME.
PLAT 20.

ASH AND NITROGEN.
PLAT 23.

RYE IN 1907.

LIME.
PLAT 22.

STABLE MANURE.
PLAT 25.

RYE IN 1907.

NO FERTILIZER.
PLAT 24.

NO FERTILIZER.
PLAT 27.

RYE IN 1907.

NITROGEN, POTASH AND PHOSPHORIC ACID.
PLAT 26

NITROGEN AND POTASH.
PLAT 29.

RYE IN 1907.

PHOSPHORIC ACID AND POTASH.
PLAT 28.

NITROGEN AND PHOSPHORIC ACID.
PLAT 31.

RYE IN 1907.

NO FERTILIZER.
PLAT 30.

NO FERTILIZER.
PLAT 33.

RYE IN 1907.

POTASH.
PLAT 32.

NITROGEN.
PLAT 35.

RYE IN 1907.

PHOSPHORIC ACID.
PLAT 34.

The average yield of plats 13, 15 and 17, which received an application of potassium sulphate in 1902, was 171 pounds of corn and 307 pounds of stalks per plat, while plats 14, 16 and 18, which received potassium magnesium sulphate, gave an average yield of 182 pounds of corn and 312 pounds of stalks per plat. As the difference in the yields is so slight it is probable that the presence of the magnesium salt has influenced the results neither one way nor the other. The slight difference in the yields, however, both with corn and clover, has been in favor of the double salt.

The following table shows the excess or decrease in the yield of the remaining fertilized plats as compared with the average yield of the two nearest unfertilized ones:

Plat		Corn.	Stalks
19	Excess over plat 21.....	420	300
20	" " 21.....	570	560
22	Decrease from the average of plats 21 and 24...	26	52
23	Excess over " " 21 and 24...	253	208
25	" " " " 24 and 27...	336	295
26	" " " " 24 and 27...	375	345
28	" " " " 27 and 30...	326	268
29	Decrease from " " 27 and 30...	40	22
31	Excess over " " 30 and 33...	353	340
32	" " " " 30 and 33...	13	15
34	" " " " 33 and 36...	286	240
35	Decrease from " " 33 and 36...	38	5

OBSERVATIONS CONCERNING THE RESULTS SHOWN IN THE PRECEDING TABLE.

1. The plat to which only sodium nitrate was applied did not yield as well as the average of the two nearest unfertilized plats.

2. The application of acid phosphate materially increased the yield of both corn and stover.

3. Potassium sulphate when applied alone increased the yield but slightly when compared with the average of the two nearest unfertilized plats.

4. Plats 28 and 31, to the former of which potash and phosphoric acid have been applied, and to the latter nitrogen and phosphoric acid, yielded considerably more than the plat which has received only phosphoric acid.

5. Plat 29, fertilized with sodium nitrate and potassium sulphate, did not yield as well as the average of the two nearest unfertilized plats.

6. The plat which received all three constituents gave a larger increase than where sodium nitrate or potassium sulphate have been individually applied with acid phosphate.

7. Comparing the yields of plats 23 and 25, it is seen that the plat which has received two applications of stable manure gave a larger increase than the plat which has received the ash of stable manure and sodium nitrate.

8. Plat 22, which has received two small applications of lime, did not yield as well as the average of the two nearest unfertilized plats.

9. Comparing the excess yields of plats 19 and 26, which have been uniformly fertilized with nitrogen, potash and phosphoric acid, with the addition of lime to plat 19, in 1900, it is seen that the limed plat gave a larger yield of corn with a smaller growth of stalks than the other plat.

10. The largest excess yield was obtained from plat 20, which in addition to three applications of stable manure was limed in 1900.

FIFTH YEAR OF THE TEST.

After the corn was removed in the autumn of 1903, rye was drilled upon all of the plats as a cover crop, no fertilizer being used. The small amount of growth which resulted was plowed under in the spring of 1904, and the land prepared for cowpeas, which were sown June 9th, the black variety being employed.

The fertilizers were applied shortly before the seed was sown and thoroughly harrowed into the soil. The same kind and amount of fertilizer was applied as was the case the first year of the test, and with the exception that no more lime was applied to plats 19, 20 and 22; no further application was made to plat 23: and acid phosphate was substituted in all cases for Thomas slag.

The plats were cut for hay October 6th. The vines were allowed to cure for about one week and were then weighed. The following table shows the weight of the hay obtained from the different plats:

Pounds Hay.		Pounds Hay	
Plats 13 to 18 inclusive....	800	Plat 27	220
Plat 19	695	Plat 28	440
Plat 20	675	Plat 29	230
Plat 21	125	Plat 30	210
Plat 22	120	Plat 31	515
Plat 23	275	Plat 32	195
Plat 24	135	Plat 33	245
Plat 25	610	Plat 34	365
Plat 26	630	Plat 35	250

The following table shows the increase or the decrease in the yields of the fertilized plats when compared with the average of the two nearest plats which have remained unfertilized:

Plat 19 Excess over 21.....	570 lbs
Plat 20 " " 21.....	550 lbs
Plat 22 Decrease from the average yield of 21 and 24....	10 lbs
Plat 23 Excess over " " 21 and 24....	145 lbs
Plat 25 " " " " 24 and 27....	433 lbs
Plat 26 " " " " 24 and 27....	453 lbs
Plat 28 " " " " 27 and 30....	225 lbs
Plat 29 " " " " 27 and 30....	5 lbs
Plat 31 " " " " 30 and 33.. .	288 lbs
Plat 32 Decrease from " " 30 and 33....	32 lbs
Plat 34 Excess over 33.....	120 lbs
Plat 35 " " 33.....	5 lbs

OBSERVATIONS CONCERNING THESE RESULTS.

1. Plat 35, to which sodium nitrate was applied, yielded practically the same as plat 33, to which no fertilizer has been applied since the beginning of the test.

2. The application of acid phosphate to plat 34 materially increased the yield.

3. Plat 32, to which potassium sulphate was applied, gave a smaller yield than the average of the two nearest unfertilized plats.

4. In the case of plats 28 and 31, to the former of which potassium sulphate, and to the latter sodium nitrate was used in connection with acid phosphate, the application of these salts in connection with acid phosphate practically doubled the excess yields as compared with the plat to which acid phosphate was applied alone.

5. Plat 29 fertilized with potassium sulphate and sodium nitrate, yielded practically the same as the average of the two unfertilized plats.

6. Plat 26, to which sodium nitrate, potassium sulphate and acid phosphate were applied, gave a slightly larger excess than the plat to which stable manure was applied. This plat also gave a much larger excess than plats 28 and 31, to which sodium nitrate and potassium sulphate were individually applied with acid phosphate.

7. Plat 23, to which the ash of stable manure and nitrogen were applied during the first two years of the test still shows the influence of this fertilization.

8. Former applications of lime to plat 22 seem to have exerted a deleterious influence.

9. Comparing the excess yields of plats 19 and 26, it is seen that the plat which has received one application of lime in addition to other fertilizers gave a larger excess yield than the plat to which no lime has been applied. This plat also gave the largest actual, as well as the largest excess yield, of any of the

plats, closely followed by plat 20, which has been continuously fertilized with stable manure, except when the land was in clover, and has received in addition one application of lime.

SIXTH YEAR OF THE TEST.

The plats were plowed in the spring and prepared for corn, which was planted May 23rd, the Ensilage Red Cob variety being used. The rows were three and one-half feet apart, and the hills two feet apart in the row, and the corn planter was adjusted so as to plant two kernels in a hill.

The fertilizers were applied broadcast a few days before the corn was planted and harrowed into the soil. No lime was applied to plats 19, 20 and 22; no more fertilizer was applied to plat 23; and acid phosphate was used instead of Thomas slag. Except as noted the same kind and amount of fertilizer was applied to the different plats as in the first year of the test.

The corn on these plats was used for ensilage. It was cut and shocked on the 23rd and 25th of September, and photographed and weighed on the 26th. When cut the kernels on the plats which have been fertilized were mostly glazed, while the grain on the unfertilized plats was mostly in the milk.

The following table gives the weight of the crops from the different plats.

	Pounds.		Pounds
Plat 18	930	Plat 27	1256
Plat 19	2770	Plat 28	1616
Plat 20	3470	Plat 29	1500
Plat 21	1120	Plat 30	1096
Plat 22	980	Plat 31	1896
Plat 23	1530	Plat 32	1186
Plat 24	1210	Plat 33	876
Plat 25	3480	Plat 34	1416
Plat 26	2900	Plat 35	1026

The following table shows the increase or the decrease in the yields of the fertilized plats when compared with the average of the two nearest plats which have been unfertilized:

Plat 19	Excess over the average of plats	18 and 21....	1745 lbs.
Plat 20	" " " "	18 and 21....	2445 lbs.
Plat 22	Decrease from " "	21 and 24....	185 lbs.
Plat 23	Excess over " "	21 and 24....	365 lbs.
Plat 25	" " " "	24 and 27....	2250 lbs.
Plat 26	" " " "	24 and 27....	1670 lbs.
Plat 28	" " " "	27 and 30....	440 lbs.
Plat 29	" " " "	27 and 30....	330 lbs.
Plat 31	" " " "	30 and 33....	910 lbs.
Plat 32	" " " "	30 and 33....	200 lbs.
Plat 35	Excess over plat 33.....		540 lbs.
Plat 35	" " 33.....		150 lbs.

OBSERVATIONS CONCERNING THESE RESULTS.

1. Somewhat in contrast with the results obtained in former years, sodium nitrate and potassium sulphate when applied alone were of some benefit. The acid phosphate, however, gave an increase more than three times as large as that derived from the use of sodium nitrate and more than two and one-half times as large as the increase from the use of potassium sulphate.

2. Plat 31, which received a mixture of sodium nitrate and acid phosphate, gave a larger increase in the yield than the total increase on the three plats, 32, 34 and 35, which were fertilized with potassium sulphate, acid phosphate and sodium nitrate. This agrees fully with the results obtained with corn during the fourth year of the test.

3. The application of the mixture of sodium nitrate and potassium sulphate to plat 29 produced about the same increase as the total increase on the two plats to which they were applied alone.

4. Plat 28, which received a mixture of potassium sulphate and acid phosphate, did not yield as large an increase as plat 34, to which only acid phosphate was applied.

5. Plat 26, which received the three constituents, nitrogen, potash and phosphoric acid, gave a much larger excess than was produced by a mixture of any two constituents.

6. The largest yield and the largest excess yields were produced by plats 20 and 24, which have been fertilized with stable manure. The actual yield of the two plats are practically identical, but plat 20, which has been limed, gave a slightly larger excess.

7. Plat 23, which received the ash of stable manure, still shows the beneficial effect of the ash constituents.

8. As in former years, the yield of the limed plat has failed to come up to the average of the unfertilized plats.

SEVENTH YEAR OF THE TEST.

In the autumn of 1905 the plats were seeded to rye as a cover crop. This was plowed under in the spring of 1906, and the land prepared for potatoes. The various fertilizers were applied April 28th, and the potatoes were planted May 4th. The variety employed was Early Ohio, and 15 bushels of seed were used per acre. The rows were furrowed out by a one-horse plow, 3 feet 3 inches apart, and the seed potatoes dropped about 8 inches apart in the rows.

Owing to the wet spring which delayed the planting of the potatoes, and to early blight which began to kill the foliage in July, the yield of potatoes was small. The following table shows the total pounds of potatoes harvested per acre. Digging was begun August 11th and completed a day or two afterwards.

YIELD OF POTATOES IN POUNDS PER ACRE.

Plat 19	6120	Plat 28	6360
Plat 20	13060	Plat 29	3520
Plat 21	2600	Plat 30	2140
Plat 22	1520	Plat 31	3830
Plat 23	2500	Plat 32	2630
Plat 24	2610	Plat 33	2400
Plat 25	11300	Plat 34	3800
Plat 26	7030	Plat 35	2250
Plat 27	2850	Plat 36	2180

The following table shows the increase or the decrease in the yields of the fertilized plats when compared with the average of the two nearest plats that have remained unfertilized.

Plat 19	Excess over the yield of 21.....	3520 lbs
Plat 20	“ “ “ 21.....	10460 lbs
Plat 22	Decrease from the average yield of 21 and 24....	1085 lbs
Plat 23	“ “ “ “ 21 and 24....	105 lbs
Plat 25	Excess over “ “ 24 and 27 ..	8570 lbs
Plat 26	“ “ “ “ 24 and 27....	4300 lbs
Plat 28	“ “ “ “ 27 and 30....	3865 lbs
Plat 29	“ “ “ “ 27 and 30....	1025 lbs
Plat 31	“ “ “ “ 30 and 33....	1560 lbs
Plat 32	“ “ “ “ 30 and 33....	360 lbs
Plat 34	“ “ “ “ 33 and 36....	1510 lbs
Plat 35	Decrease from “ “ 33 and 36....	40 lbs

OBSERVATIONS CONCERNING THE RESULTS SHOWN IN THE PRECEDING TABLES.

1. Sodium nitrate when used alone as on plat 35, or when used with acid phosphate as on plat 30, was apparently of little or no value. When used with potassium sulphate, however, there was a slightly increased yield as compared with the plat to which potassium sulphate was applied alone.

2. Acid phosphate when used alone increased the yield about 25 bushels per acre, as compared with the no-fertilizer plats, and when used in connection with potassium sulphate the yield was increased about 64 bushels per acre.

3. Potassium sulphate when used alone or in connection with acid phosphate or sodium nitrate increased the yields, the largest increase taking place when used in connection with acid phosphate.

4. When a mixture of all three of the fertilizing materials was used the total and also the excess yield was greater than when any two of the materials were used together.

5. The two plats, 20 and 25, which received stable manure produced by far the largest and most satisfactory yields. The vines on these two plats grew more luxuriantly than upon any

of the others, and much of the foliage remained green and thrifty after the vines on adjoining plats were dead and withered.

6. Lime when used alone or in connection with commercial fertilizer decreased the yield. When used in connection with stable manure the yield of potatoes was the heaviest of any in the test, being slightly more than 200 bushels per acre.

EIGHTH YEAR OF THE TEST.

The plats from which potatoes had been harvested were plowed in the early part of September, harrowed and drilled to rye September 28th, five pecks of seed being used per acre. As it was desirable to study the residual effect of the previous manurings no fertilizer was applied to any of the plats.

The rye was cradled July 10th-15th, bound by hand, and set up in shocks. These were photographed July 19th, and the cuts show the appearance of the plats at that time.

Owing to difficulty in procuring a threshing machine the shocks remained in the field until September 24th, and it is probable there was more or less loss of grain on account of birds and mice. The rye was then weighed and threshed. The shock of rye on plat 22 was struck by lightning and burned while standing in the field, and consequently was not weighed.

The following table shows the yield of grain and straw from the various plats stated in pounds per acre:

YIELD OF RYE IN 1907.

	Straw.	Grain.		Straw.	Grain.
Plat 19	3030	1170	Plat 28	1850	850
Plat 20	4860	2140	Plat 29	260	140
Plat 21	360	140	Plat 30	250	160
Plat 22 Struck by lightning and not weighed.			Plat 31	2270	1030
Plat 23	280	170	Plat 32	360	140
Plat 24	380	140	Plat 33	280	120
Plat 25	4420	1880	Plat 34	1930	770
Plat 26	2530	1170	Plat 35	290	210
Plat 27	290	160	Plat 36	270	130

The table shows that the crop on all but five or six of the plats was very small.

In the following table the yield of grain from each plat that has been fertilized is compared with the average yield of the two nearest plats that have been continuously unfertilized:

Plat 19	Excess over yield of plat 21.....	1030 lbs
Plat 20	" " " 21.....	2000 lbs
Plat 23	Excess over average yield of plats 21 and 24....	30 lbs.
Plat 25	" " " " 24 and 27....	1730 lbs.
Plat 26	" " " " 24 and 27....	1020 lbs
Plat 28	" " " " 27 and 30....	690 lbs.
Plat 29	Decrease from " " 27 and 30....	20 lbs.
Plat 31	Excess over " " 30 and 33....	890 lbs.
Plat 32	" " " " 30 and 33....	0 lbs
Plat 34	" " " " 33 and 36....	645 lbs.
Plat 35	" " " " 33 and 36....	85 lbs

Remembering that no fertilizer was applied to any of the plats for this crop of rye, the following observations may be made:

1. The plat to which acid phosphate has been applied alone produced a much better crop than the plats to which either sodium nitrate or potassium sulphate have been applied alone, and about 11 bushels per acre more than the no-fertilizer plats.

2. Former applications of a mixture of sodium nitrate and potassium sulphate seem to have a depressing effect upon the yield of rye, while former applications of a mixture of sodium nitrate and acid phosphate, or of potassium sulphate and acid phosphate increased the yields, the former mixture acting somewhat more beneficially than the latter.

3. Former applications of a mixture of all three fertilizing constituents acted somewhat more beneficially than a mixture of any two of them.

4. The stable manure plats, 20 and 25, gave the largest total and also the largest excess yields. Plat 20, which in addition to stable manure had received lime, yielded at the rate of slightly more than 38 bushels of rye per acre, while the no-fertilizer plats averaged slightly less than 3 bushels of rye per acre.

For the purpose of comparing the results obtained during the different years the following table has been prepared, showing the excess yields for the eight years under consideration:

SUMMARY OF "EXCESS YIELDS" STATED IN POUNDS
PER ACRE.

Plat	RYE 1900.		WHEAT 1901.		CLOVER 1902.	CORN 1903.		COWPEAS 1904.	CORN 1905.	POTATOES 1906.	RYE 1907.
	Straw	Grain	Straw	Grain	Hay	Corn	Stover	Hay	Entire Crop	Potatoes	Grain
19	1300	876		...	4650	4200	3000	5700	17,450	3520	1030
20	538	378	3400	700	6800	5700	5600	5500	24,450	10,460	2000
22	-254	-66	-5	-95	-575	-260	-520	-100	-1850	1085	
23	1778	952	1825	775	5825	2530	2080	1450	3650	105	30
25	1261	715	2775	825	7075	3360	2950	4330	22,500	8570	1730
26	1991	1265	2145	665	4775	3750	3450	4530	16,700	4300	1020
28	178	93	1635	465	2750	3260	2680	2250	4400	3865	690
29	999	662	105	-5	-750	-400	-220	50	3300	1025	-20
31	1583	932	1730	470	5475	3530	3400	2880	9100	1560	890
32	108	67	-150	-50	75	130	150	-320	2000	360	0
34	320	85	990	460	3200	2860	2400	1200	5400	1510	645
35	1226	639	150	0	400	-380	-50	50	1500	-40	85

5. The plat which had received lime only was not weighed as already noted, but the cut of this plat shows that the yield was no greater than that on the adjoining no-fertilizer plats. Comparing the excess yields of plats 19 and 26, it is seen that the use of lime on plat 19 was without effect upon the yield of grain, although the growth of straw seems to have been favored by the presence of the lime. Plat 20, which has received stable manure and lime, gave a larger yield of both grain and straw than plat 25, which has received stable manure only. Plat 20, however, has received, since the beginning of the test, two tons of stable manure more than has been applied to plat 25, which possibly might account for some of this difference.

1. NITROGEN. The only time that sodium nitrate has been of any particular benefit, when applied alone, was when it was used as a top-dressing in the spring on rye. When used in connection with phosphoric acid it has uniformly increased the yields when compared with the plat to which phosphoric acid has been applied alone. When used in connection with potassium sulphate the yields have been unsatisfactory, except in one instance when the mixture was applied to rye as a top-dressing in the spring, and then the beneficial effect was probably due to the presence of the readily soluble sodium nitrate.

2. POTASH. When potassium sulphate has been used alone the yields have been either only slightly larger or actually smaller than the average of the two nearest unfertilized plats. When used with phosphoric acid the excess yields have been, in general, only slightly larger than when phosphoric acid has been used alone.

3. PHOSPHORIC ACID. When applied alone Thomas slag and acid phosphate have uniformly increased the yields. When a mixture containing the three constituents, nitrogen, potash and phosphoric acid, has been applied the excess yields have been larger, with a single exception, than when any one or any two constituents have been employed.

4. POTASH AND NITROGEN. The mixture containing potash and nitrogen has given poorer results than the mixture containing either potash and phosphoric acid, or nitrogen and phos-

phoric acid except in the first year of the test when the fertilizer was applied in the spring as a top-dressing. This indicates *that in this soil the stock of available phosphoric acid is so low that the deficiency of this constituent must be supplied before either nitrogen or potash can be of any particular value.*

5. NITROGEN AND PHOSPHORIC ACID. With rye, wheat clover, corn and cowpeas the mixture containing nitrogen and phosphoric acid gave larger excess yields than did a mixture containing potash and phosphoric acid, or, in other words, *after the deficiency of phosphoric acid is supplied the crops mentioned feel the lack of nitrogen in this soil more acutely than they do of potash.* In the case of potatoes, however, the opposite seems to be true, as the plat fertilized with a mixture of phosphoric acid and potash gave a considerably larger excess yield than the plat to which phosphoric acid and nitrogen were applied.

6. STABLE MANURE. Stable manure has increased the yields materially and uniformly. Plat 25, which received two applications of stable manure during the first and second years of the test, yielded almost as much corn in 1903 as plat 26, which had received up to that time three applications of complete fertilizer. During the first year when it was applied as a top-dressing the excess yield was somewhat smaller than that obtained from the complete fertilizer plat. During the second year the excess yield was larger, and during the third year when no fertilizer was applied to any of the plats, the yield of clover hay was almost double that obtained from the plats to which the complete fertilizer had been applied. During the last two years the excess yields were in one case smaller and in the other case larger than the excess yields of plat 26, which has received a mixture containing nitrogen, potash and phosphoric acid.

7. LIME. The two applications of lime applied to plat 22 have reduced the yields as compared with the averages of the two nearest unfertilized plats. Comparing the excess yields of plats 19 and 26, it is seen that the lime applied to plat 19 during the first year of the test seems to have reduced the yield during the first three years and to have acted somewhat favorably during the last three years. During the first three years of the test plats

20 and 25 received the same amount of stable manure. The lime applied to plat 20 seems to have favored the growth of the crop during the second year, as the wheat grew so luxuriantly that it lodged badly. In 1902 the excess yield of clover hay was slightly lower than in the case of plat 25, and the yields during succeeding years are not strictly comparable, as plat 20 received a dressing of stable manure in 1903, which was not given plat 25. So in general we may say that with lime the results on this soil have been totally unsatisfactory.

8. HUMUS. During the first two years of the test plat 25 received two applications of stable manure and plat 23 two applications of the ash of stable manure and an equivalent amount of nitrogen in the form of sodium nitrate. Neither of these two plats received any further application of fertilizer for the next two years. We may compare, therefore, their yields for the first four years of the test.

Except during the first year of the test, the plat which has received stable manure has produced a larger excess yield than the plat receiving the ash of stable manure and nitrogen. Whether this favorable effect of the stable manure has been due to the gradual liberation of plant food during the growing season; to the greater amount of moisture which the soil is capable of holding and supplying to the crop; or to other factors, is a matter which has not been answered definitely. It is entirely probable that several factors may have aided in producing the larger yields of the stable manure plat.

9. THE FERTILIZER REQUIREMENTS OF DIFFERENT CROPS. From the results obtained in this test it may be stated that, within the limits of the crops grown, a fertilizer which gives good results with one crop will give good results with another crop grown upon the same or similar soil. For example, the application of a fertilizer containing phosphoric acid gave good results with rye, wheat, clover, cowpeas, and corn. Similarly, stable manure gave good results in all cases. The table shows, however, that there are some minor exceptions to this general rule. For if the yield of cowpeas and corn are compared during the last two years of the test, it is seen that the cowpeas which

received a mixture of sodium nitrate, acid phosphate, and potassium sulphate (plats 19 and 26), gave a larger excess yield than when supplied with stable manure (plats 20 and 25), while in the case of corn in 1905 the exact opposite is true. Also in 1903 the corn on plat 20, fertilized with stable manure gave a larger excess than on plat 19, dressed with commercial fertilizer, and the same probably would have been true in the case of plats 25 and 26 had not the stable manure plat been injured and the yield reduced by a very heavy thunder shower which caused a stream of water to cut a channel diagonally across this plat. From this evidence we may conclude *that corn responds more favorably to a dressing of stable manure than it does to an application of commercial fertilizer, while with cowpeas the exact opposite is true.* This conclusion, also, is in entire agreement with common farm practice in which stable manure is generally used for corn, and commercial fertilizer for cowpeas. It may be observed here that although the roots of these cowpeas are well supplied with nodules yet the plats receiving all three fertilizing constituents (plats 19 and 26) gave larger excesses than when any one or any two constituents were supplied. Also that a mixture of sodium nitrate and acid phosphate gave slightly better results than a mixture of potassium sulphate and acid phosphate, although cowpeas are supposed to be able to obtain their supplies of nitrogen from the free nitrogen of the air when provided with root tubercles. Also that potatoes seemed to respond better to applications of potash salts than any of the other crops.

PRACTICAL SUGGESTIONS.

This experiment shows that this soil is very deficient in available phosphoric acid, and that as soon as this deficiency is supplied then there is a lack of nitrogen and to a less extent of potash also

When commercial fertilizers are relied upon entirely to maintain a high degree of crop production a fertilizer containing all three constituents, nitrogen potash, and phosphoric acid will give better results than a fertilizer containing only one or

two of these constituents. Aside from the fact that a fertilizer should be especially rich in phosphoric acid these experiments do not indicate the exact proportion in which nitrogen, potash and phosphoric acid should enter into a fertilizer for best results. This will be made the subject of further study.

If leguminous crops are raised and either plowed under or fed on the farm and the resulting manure carefully saved and applied to the soil it is very probable that in practice it will be necessary to purchase only phosphoric acid in order to increase the productiveness of soils of this type and to maintain them in a condition of high fertility.

Stable manure has demonstrated again its great value as a restorer of fertility to a poor worn out soil. More manure should be produced on West Virginia farms, it should be protected from leaching and heating more carefully, and should be applied to the soil more systematically and more intelligently than is the case at the present time.