Ohio Agricultural Experiment Station.

BULLETIN 80

WOOSTER, OHIO, JULY, 1897.

THE MAINTENANCE OF FERTILITY.

FIELD EXPERIMENTS WITH FERTILIZERS

....in 1896....

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FERTILIZERS ON WHEAT GROWN IN FIVE-YEAR ROTATION.

View of Plots 27, 28 and 29, Section E., with parts of Plots 26 and 30 at the extreme left and right respectively. Taken in June , 1897.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 80. July, 1897.

FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. E. THORNE, J. FREMONT HICKMAN AND W. J. GREEN.

Bulletion 71* of this Station, dated April, 1896, gave the plan of the field experiments in the use of fertilizers and manures then in operation at the Central Station and Sub-stations, together with a report of the results attained up to the close of the year 1895. In the present bulletin is reported the continuation of the work for 1896.

FERTILIZERS ON CROPS GROWN IN 5-YEAR ROTATION.

In this experiment, corn, oats and wheat are grown in succession, one year each, followed by clover and timothy two years. The soils under experiment are (1) the light, yellow clay of the Central Station in Wayne county, (2) the heavy, white clay of the Northeastern Sub-station at Strongsville, Cuyahoga county, and (3) the black upland (beech and elm) of that portion of the farm of the State University at Columbus on which this particular test is located.

The plan of the experiment at the Central Station and the Northeastern Sub-station is the same, except that the latter test includes 10 additional plots. In this plan, "superphosphate" has hitherto meant dissolved bone black, and is applied at the rate of 80 pounds per acre, when used as the only carrier of phosphoric acid, or in quantities sufficient to bring up the total application of phosphoric acid to that contained in 80 pounds of dissolved bone black on corn and oats and 160

*ERRATA IN BULLETIN 71.

P. 115, between sixth and seventh lines from bottom insert: "would be required for this increase of wheat and nearly as much more as"

P. 117, fourth line from top: for "phosphoric acid" read "potash."

P. 131, under "Explanation" in Table X, for "Beric slag" read "Basic slag."

P. 174, Table XXXVI, for heading "Quality" read "Quantity," and in Formula No. 3, under "available phosphoric acid," for "142 and 202" read "147 and 207."

pounds on wheat, when used in connection with other phosphatic materials. When other carriers of phosphoric acid, (wheat bran, acid phosphate and slag meal) are used as the sole carriers of phosphoric acid the quantity applied is intended to carry the same amount of phosphoric acid as that found in the standard dressing of dissolved bone black.

Nitrate of soda is used as the standard carrier of nitrogen ("ammonia") and is applied at the rate of 160 pounds per acre when used alone, or in quantities sufficient to bring up the total nitrogen to that found in 160 pounds of nitrate of soda when used in connection with other nitrogen carrying materials (wheat bran, oil meal, bone meal) except on Plot 12, where the nitrate is increased to 240 pounds, and on Plots 32 and 33 at Strongsville, where it is reduced to 80 pounds and 40 pounds respectively.

Muriate of potash is used as the carrier of potash, and is applied uniformly at the rate of 80 pounds per acre on corn and oats and 100 pounds on wheat, except on Plots 17 and 21, where allowance is made for the potash in the bran and oil meal; on Plot 30, where it is used at the rate of 10 pounds only, and on Plots 35 and 36 at Strongsville, where the quantity is reduced to 40 and 20 pounds respectively.

On Plot 17 wheat bran is used as the carrier of all the phosphoric acid and part of the nitrogen and potash, and on Plot 21 linseed oil meal is used as the carrier of all the nitrogen and part of the phosphoric acid and potash. On Plot 23 dried blood, and on Plot 24 sulphate of ammonia is substituted for nitrate of soda. On Plot 26 raw bone meal is used as the carrier of the phosphoric acid and part of the nitrogen, the total nitrogen being brought up, by the addition of nitrate of soda, to the quantity used on other standard plots. On Plot 26 acid phosphate, and on Plot 27 basic slag is used as the carrier of phosphoric acid. On Plot 30 is used a mixed fertilizer, having approximately the composition of the average ready mixed fertilizers sold in the state. For the crops of 1894 and 1895, at the Central Station, this fertilizer was mixed from dissolved bone black, nitrate of soda and muriate of potash. In 1895 a ready mixed fertilizer, having approximately the same analysis, ("ammonia, 3 to 4 per cent., phosphoric acid, 8 to 10 per cent., potash, 2 to $2\frac{1}{2}$ per cent.") was used at Strongsville, and in 1896 the fertilizer was mixed from tankage, acid phosphate and muriate of potash for both experiments.

In the tests here reported the corn was grown on old sod land at Strongsville, and at Wooster in 1894, and on land that had grown cowpeas and clover the preceding season at Wooster in 1895 and 1896. The land at Wooster has been underdrained by tile drains laid 36 feet apart. That at Strongsville had not been drained previous to the growth of the crops here reported, but was plowed in narrow lands, giving partial surface drainage. 1895 was a dry season, and the crop was exceptionally good for that land, but in 1896 it suffered from excess of rain.

In both 1895 and 1896 the wheat crop on the thin land on which this test is located at the Central Station suffered severely from winter killing followed by Spring drouth, the average yield of the unfertilized plots falling to three bushels per acre in 1895, and to one bushel in 1896. The destruction of crop was only partially prevented by fertilizers. On the heavy clay of the Sub-station the wheat was so completely destroyed that no attempt was made to harvest it separately; the most heavily fertilized plots showed but little if any more wheat than the unfertilized plots at the Central Station. At Columbus the wheat in both the continuous and rotative culture was almost as completely destroyed as at Strongsville. It was harvested carefully, but it was mixed with a heavy growth of weeds, and the continuous rains of July rotted it in the shock, and though an attempt was made to thresh it separately no trustworthy data as to yield could be obtained.

Table I gives the plan of fertilizing in this experiment; Tables II and III give the average yields and increase for 1896 at the Central Station. Table IV gives the average annual increase or decrease per acre on the fertilized plots for the three years, 1894–96, together with the weight of the total average increase on each plot, and Table V gives the estimated value of the average increase, together with the quantity and cost of the fertilizers used in producing it.

TABLE I—PLAN OF FERTILIZING IN FIVE-YEAR ROTATION, CENTRAL STATION AND N. E. SUB-STATION.

Fertilizers in pounds per acre.

Plot No.	On corn.			On oats.			On wheat.		
	Superphosphate.	Nitrate soda	Muriate potash.	Superphosphate.	Nitrate soda.	Muriate potash.	Superphosphate.	*Nitrate soda.	Muriate potash.
1...									
2...	80			80			160		
3...			80			80			100
4...									
5...		160			160			160	
6...	80	160		80	160		160	160	
7...									
8...	80		80	80		80	160		100
9...		160	80		160	80		160	100
10...									
11...	80	160	80	80	160	80	160	160	100
12...	80	240	80	80	240	80	160	240	100
13...									
14...	80	160	80				160	160	100
15...							160	160	100
16...									
17...	A	80	65	A	80	65	B		70
18...	C						C		
19...									
20...	D						D		
21...	30	E	70	30	E	70	110	E	90
22...									
23...	80	F	80	80	F	80	160	F	100
24...	80	G	80	80	G	80	160	G	100
25...									
26...	H	150	80	H	150	80	I	135	100
27...	K	160	80	K	160	80	L	160	100
28...									
29...	M	160	80	M	160	80	N	160	100
30...	O						O		
31...									
32...	80	80	80	80	80	80	160	80	100
33...	80	40	80	80	40	80	160	40	100
34...									
35...	80	160	40	80	160	40	160	160	50
36...	80	160	20	80	160	20	160	160	25
37...									
38...							P		
39...							Q		
40...									

*On wheat, one-third dried blood, applied in the fall, and two-thirds nitrate of soda, applied in April; all other fertilizers for wheat are applied in the fall.

A Wheat bran, 500 pounds.
B Wheat bran, 1,000 pounds.
C Barnyard manure, eight tons on wheat and corn only.
D Barnyard manure, four tons on wheat and corn only.
E Linseed oil meal, 500 pounds.
F Dried blood, 200 pounds.
G Sulphate of ammonia, 120 pounds.
H Raw bone meal, 55 pounds.
I Raw bone meal, 110 pounds.
K Acid phosphate, 85 pounds.
L Acid phosphhte, 170 pounds.
M Basic slag, 65 pounds.
N Basic slag 130 pounds.
O Mixed fertilizer, 210 pounds on corn and wheat only.
P Mixed fertilizer, 420 pounds on wheat only.
Q Barnyard manure, 16 tons on wheat only..
Plats 31 to 40 inclusive, at the N. E. Sub-station only.

TABLE II—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Yield per Acre—1896.

Plot No.	Corn. Section B.		Oats. Section E.		Wheat. Section D.		Clover. Sec. C.	Timothy. Sec. A.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	Hay.	Hay.
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.	Pounds.
1	55.64	1,870	31.56	1,410	0.87	127	1,370	3 800
2	54.21	1,480	35.39	1,427	4.00	530	2,360	3,000
3	53.89	1,610	32.65	1,415	1 67	230	1,600	4,550
4	47.57	1,580	30.23	1,632	0.96	162	1,700	4,050
5	54.43	1,560	33.91	1,215	1.37	277	2,460	3,500
6	61.68	1,790	42.81	1,780	4.92	655	3,320	3,380
7	59 64	1,620	29.92	1,422	0.75	95	1,450	3,650
8	61.43	1,860	33.12	1,420	6.50	670	2,350	4,030
9	57.68	1,870	25.78	1,195	2.37	260	1,960	4,050
10	53.93	1,600	21.02	857	1.21	277	1,350	3,700
11	68.57	1,950	37.34	1,725	9.04	1,057	3,050	3,450
12	63.32	2,030	42 42	1,782	6 37	717	3,450	3,000
13	53.71	1,700	24.22	1,135	1.42	265	1,210	3,920
14	65.36	2,170	31.87	1,580	8.08	975	2,820	3,520
15	53.32	1,890	23.91	985	4.00	510	1,980	3,570
16	49.71	1,810	24.84	1,155	1.41	215	1,140	3,750
17	56.89	1,700	35.00	1,540	6.04	767	2,770	4,000
18	58.75	1,970	31.25	1,320	7.00	1,030	3,870	4,950
19	53.86	1,680	26.09	1,075	1.45	212	1,650	3,710
20	55.68	1,940	26.56	1,060	4.79	612	3,400	4,650
21	54.86	1,950	30.31	1,590	8.54	937	2,560	4,150
22	44.79	1,630	20.15	935	0.75	255	1,050	3,840
23	55.00	1,850	31.56	1,140	6.58	665	2,750	4,100
24	62.00	2,200	36.94	1,617	6.70	847	2,700	4,030
25	50.96	1,660	21.41	1,025	1.16	160	1,580	4,350
26	59.43	2,240	36.09	1,585	6.16	920	4,000	4,100
27	62.04	1,950	37.81	1,620	5.16	590	3,650	3,930
28	50.16	1,850	20.94	900	0.66	70	2,400	4,380
29	62.36	2,150	41.09	1,865	6.58	665	3,760	4,200
30	57.68	1,920	37.19	1,690	4.62	702	3,400	4,540
*	52.00	1,700	25.04	1,155	1.06	184	1,490	3,915

*Average of unfertilized plots.

TABLE III—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Increase or decrease (—) per acre—1896.

Plot No.	Corn. Section B.		Oats. Section E.		Wheat. Section D.		Clover. Sec. C.	Timothy. Sec. A.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	Hay.	Hay.
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.	Pounds.
2	1.26	—293	4.27	—57	3.10	391	880	—883
3	3.63	—67	1.98	—143	0.74	80	10	583
5	2.84	—33	3.78	—347	0.48	137	843	—417
6	6.06	183	12.79	288	4.10	538	1,787	—403
8	3.69	247	6.17	186	5.60	514	933	363
9	1.85	163	1.79	150	1.31	44	577	367
11	14.71	317	15.25	775	7.76	784	1,647	—323
12	9.54	363	19.27	740	5.02	448	2,193	—847
14	12.98	433	7.44	438	6.66	727	1,633	—343
15	.....	.....	.....	.....	2.59	278	817	—237
17	5.80	—67	9.74	412	4.62	553	1,460	263
18	6.27	247	5.58	218	5.56	817	2,390	1,227
20	5.02	277	2.45	32	3.57	386	1,950	897
21	7.05	303	8.18	608	7.56	696	1,310	354
23	8.15	210	10.99	175	5.99	442	1,523	90
24	13.10	550	15.95	622	5.68	655	1,297	—150
26	8.74	517	14.84	599	5.18	790	2,147	—260
27	11.61	163	16.71	678	4.33	490	1,523	—440
29	12.20	300	20.15	965	5.92	595	1,360	—180
30	7.52	70	16.25	790	3.96	632	1,000	160

TABLE IV—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Average annual increase or decrease (—) per acre for three years—1894-1896.

Plot No.	Corn.		Oats.		Wheat.		Hay.	Weight of total increase.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.		
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.	Pounds.
2	1.9	—114	4.6	89	1.7	360	—127	501
3	1.0	—81	0.6	—142	1.8	224	493	691
5	0.1	—18	2.7	—85	0.2	73	448	524
6	6.7	84	9.2	261	2.2	416	887	2,543
8	4.1	184	7.1	237	3.8	354	949	2,466
9	—1.6	96	1.0	—16	1.7	71	891	1,064
11	8.4	262	12.1	487	5.1	811	771	3,612
12	6.7	211	13.3	533	4.8	763	1,009	3,699
14	6.6	253	8.4	324	3.4	734	960	3,206
15	.....	.....	.....	.....	2.3	479	552	1,167
17	2.6	—9	7.2	304	4.5	571	1,277	2,825
18	1.4	182	7.0	360	2.6	714	2,803	4,537
20	0.8	87	2.9	205	2.5	526	2,071	3,188
21	4.4	261	5.5	304	5.5	875	1,123	3,377
23	5.3	182	8.1	193	4.8	655	955	2,903
24	7.2	365	10.0	405	5.2	651	658	3,215
26	4.8	354	9 0	299	2 0	653	1,160	3,210
27	5.1	124	9.0	440	3.5	734	540	2,693
29	7.3	277	9.7	532	4.1	690	640	3,206
30	7.8	153	8.2	405	3.0	507	533	2,586
*								

*Average of two crops.

TABLE V—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Value of average increase and cost of fertilizers per acre.

Plot No.	Value of average increase.				Quantity and cost of fertilizers.				Cost of fertilizer.	
	Grain.	Straw.	Hay.	Total.	Superphosphate.	Nitrate soda.	Muriate potash.	Total quantity.	In home mixtures.	In commercial mixtures.
					Pounds.	Pounds.	Pounds.	Pounds.		
2	$3.04	$0.50	−0.51	$3.08	320	.....	.....	320	$2.88	.....
3	1.62	0	1.97	3.59	.....	.....	260	260	6.50	.....
5	0.87	−0.05	1.79	2.61	.....	480	.....	480	12.00	.....
6	6.39	1.14	3.55	11.08	320	480	.....	800	14.88	$18.00
8	4.91	1.16	3.80	9.87	320	.....	260	580	9.38	11.75
9	0.77	0.23	3.56	4.56	.....	480	260	740	18.50	23.30
11	9.70	2.34	3.08	15.12	320	480	260	1,060	21.38	26.70
12	9.17	2.26	4.04	15.47	320	720	260	1,300	27.38	34.10
14	6.94	2.97	3.84	12.75	240	320	180	740	14.66	18.25
15	1.52	0.72	2.20	4.44	160	160	100	420	7.94	9.85
17	5.91	1.30	5.11	12.32	[1]1,500	160	200	1,860	[9]19.00	26.70
18	3.91	1.89	11.21	17.01	.....	.....	.....	6 tons	.....	.....
20	2.71	1.23	8.28	12.22	.....	.....	.....	8 "	.....	.....
21	6.68	2.16	4.49	13.33	170	[2]1,500	230	1,900	[10]22.28	26.70
23	7.29	1.54	3.82	12.65	320	[3]600	260	1,180	[11]16.88	26.70
24	7.77	2.13	2.63	12.53	320	[4]360	260	940	[12]20.18	26.70
26	5.48	1.96	4.64	12.08	[5]220	435	260	915	[13]20.12	26.70
27	7.59	1.95	2.16	11.70	[6]310	480	260	1,080	[14]2'.05	26.70
29	8.00	2.25	2.56	12 81	[7]260	480	260	1,000	21.10	26.70
30	7.08	1.60	2.13	10.81	[6]200	[8]200	20	420	[14]3 75	6.25

[1]Wheat bran. [2]Linseed oil meal. [3]Dried blood. [4]Sulphate ammonia. [5]Bone meal. [6]Acid phosphate. [7]Basic slag. [8]Tankage. [9]Bran @ $10. [10]Oil meal @ $20. [11]Dried blood @ $25. [12]Sulph. ammonia @ $60. [13]Bone meal @ $25. [14]Acid phosphate @ $15.

In Table IV is given the average increase per acre for three crops each of corn, oats and wheat, in the five-year rotation, for the years 1894, 1895 and 1896, and of two crops of clover and one of timothy, harvested in 1895 and 1896. To complete the full series of 3 rotations there should be one more crop of clover and two more of timothy. These will be harvested in 1897 and 1898. The estimated increase given in the hay column is based upon the assumption (which present appearances justify) that these crops will show as large an average increase as the three which have been harvested.

In computing the value of the increase as given in Table V, corn, oats and wheat have been estimated at 38, 26 and 66 cents per bushel respectively, these being the average prices of standard grades of these grains in the Chicago market for the 5 years ending with 1896, as computed by the *Cincinnati Price Current*. Straw and stover have been estimated at $3.00 per ton, and hay at $8.00.

On the basis of these prices the total value of the increase on Plot 2 is found to be $3.03, all of which came from increase of grain and straw. To produce this increase 320 pounds of dissolved bone black was applied in three dressings, two of 80 pounds each (on corn and oats) and one of 160 pounds (on wheat). This total application carried the equivalent of about 50 pounds of available phosphoric acid, the cost of which, in ordinary, ready-mixed fertilizers, is about 6½ cents per pound, or, in its cheapest form—acid phosphate or tankage—about 5 cents at retail. As actually bought for this test in dissolved bone black the cost was a little less than 6 cents.

Plot 3 received a total of 260 pounds of muriate of potash, carrying about 130 pounds actual potash. Muriate of potash may be bought at retail in New York at about 2¼ cents per pound, and the freight to Ohio is about ¼ cent additional, making the cost of its actual potash to the Ohio purchaser who buys direct from the New York importing houses about five cents per pound. It is ordinarily sold in ready mixed fertilizers at 6 cents and upwards. The increase from this application amounts to a total value of $3.59, or a little more than half the cost of the fertilizer. The muriate is the cheapest source of potash now on the Ohio market, as the pound of actual potash in kainit and Canada ashes costs considerably more than that in the muriate, notwithstanding the much lower price per ton at which these materials are sold, because of their low percentage in potash and the correspondingly large quantity of useless material upon which freight must be paid when they are used. The actual potash in the sulphate usually costs about a cent a pound more than in the muriate.

Plot 5 received a total of 480 pounds of nitrate of soda, in three equal dressings. The value of the increase is found to be $2.61. This application carries about 75 pounds of nitrogen, equivalent to 90 pounds

of " ammonia," and its cost, when bought direct of importers, is about $2\frac{1}{2}$ cents per pound, freight paid, equivalent to about $13\frac{1}{3}$ cents for "ammonia", which is fully 3 cents per pound less than the cost of ammonia in the ready-mixed fertilizers of commerce. Dried blood may be bought in Ohio at about $25 per ton, at retail, at which price its ammonia will cost approximately 8 cents per pound. In tankage, as will be shown further on, ammonia may be bought at 5 cents or less. Experments indicate, however, that the ammonia of dried blood or tankage is only about two thirds as effective as that in nitrate of soda. Tankage is the ordinary source of ammonia in ready-mixed fertilizers.

Plot 6 received the same quantity of dissolved bone black as Plot 2, and the same quantity of nitrate of soda as Plot 5, raising the total application to 800 pounds, costing $14 88 as applied, or equivalent to $18.00 in ready-mixed fertilizers. The value of the increase is $11.08, or double the combined values of the increase from the separate applications, forcibly illustrating the importance of combinations in the use of fertilizers.

On Plot 8 the dressings of Plot 2 and 3 were combined, resulting in a total value of increase of $9.87, which is considerably greater than the combined values of the increase from the same fertilizers when used separately, and is a little larger than the cost of the fertilizers in home mixtures.

On Plot 9 the dressings of Plot 3 and 5 were combined, but the increase on Plot 9 is not quite equal to the combined increase on Plots 3 and 5.

On Plot 11 the dressings of Plots 2, 3 and 5 were combined, giving a complete fertilizer, containing nitrogen, phosphoric acid and potash, all three, and here we have an increase 60 per cent. greater than the combined increase from the three plots separately fertilized. Evidently this soil, in its present condition, requires a complete fertilizer, in order to produce the maximum yield of crop.

The total application on Plot 11 contained 480 pounds nitrate of soda, 320 pounds dissolved bone black, and 260 pounds muriate of potash per acre, and carried about 90 pounds ammonia, 50 pounds available phosphoric acid and 130 pounds of potash. The cost in the materials actually used was $21.38 and the cost of an equivalent ready-mixed fertilizer would have been over $26.00, while the total value of the increase amounts to but $15.12. The increase however, was not only greater than the combined increase from the several constituents of this fertilizer used singly, but greater than from that of either pair of constituents with the addition of that from the third constituent used alone.

Three questions arise here: (1) May it not be that all the fertilizing constituents in this test have been used in larger quantity than could be utilized to the best advantage? (2) May it not be that one or two of these constituents have been used in larger quantity than was needed for the

complete utilization of the whole? (3) May it not be that cheaper carriers of fertility may be found than those used in this test?

On the first point we have the light given by Plots 14 and 15. Plot 14 receives the same fertilizers on corn and wheat as Plot 11, but none on oats. The cost of the application is thus reduced from $21.38 to $14.66 in home mixtures, a difference of $6.72, while the value of the increase falls only $2.37 or from $15.12 to $12.75. On Plot 15 only the wheat crop is fertilized, the cost being $7.94 in home mixtures, while the value of the increase on that crop alone is $4.44, with the after effect on the following crops of the rotation yet to be ascertained.

Further light on all these points is given by Plot 30, which is fertilized on the corn and wheat crops with a mixture of 100 pounds slaughter house tankage, 100 pounds acid phosphate and 10 pounds muriate of potash, a total of 420 pounds for the entire rotation, applied at an actual cost for materials of $3.75. This dressing carries about the same quantity of phosphoric acid as that given to Plot 11, but only about one-sixth as much ammonia and one-tenth as much potash. The total dressing is but 100 pounds more than that given to Plot 2, and about two-fifths that given to Plot 11, while the cost is less than one-fifth that on Plot 11 and the increase thus far is two-thirds as great.*

These results would seem to indicate a smaller ration of fertilizers; but on the other hand, in the work in continuous culture, reported further on, it is found that an application of 1,500 pounds of fertilizer per acre, distributed over three seasons, has produced more than double the increase obtained from half that quantity of fertilizer.

Taken collectively, these results seem to justify the inference, either that the soil upon which this test is being conducted is at present relatively more deficient in phosphoric acid than in nitrogen and potash, or else that the phosphoric acid in the fertilizing substances in common use is so much less readily available to plants than the nitrogen and potash, that it must be used in relatively large quantity in order to produce a complete utilization of the other two constitutents.

On Plot 17 wheat bran is used as the carrier of the phosphoric acid and part of the nitrogen and potash. With bran at $10 per ton the total cost of the application is reduced to $19.00, while the value of the increase is found to be $12.25.

On Plot 21 linseed oil meal is used as the carrier of the nitrogen and part of the phosphoric acid and potash. With oil meal at $20 per ton the

*The latest official analysis, published by the Secretary of the State Board of Agriculture, gives this tankage 8.20 per cent. ammonia and 14.26 per cent. total phosphoric acid, 8.32 per cent. of which is available. It retails at $17.00 per ton. Adding $2.00 for freight and allowing 3½ cents per pound for the insoluble phosphoric acid (the official rating for insoluble acid in animal matter) the cost of the 330 pounds of ammonia and available phosphoric acid in the ton of tankage would be less than $15.00, or less than 5 cents per pound.

cost is raised to $22.28, or a little more than with nitrate of soda, but it is still below the average cost of ready mixed fertilizers of similar composition. In effectiveness the oil meal compares well with other fertilizers.

On Plot 23 the nitrogen is carried in dried blood, and with blood at $25 per ton the cost of the dressing is materially reduced.

Sulphate of ammonia is used on Plot 24. At 3 cents per pound it is slightly less expensive as a carrier of nitrogen than nitrate of soda, but it seems to be somewhat less effective.

Part of the nitrogen and all the phosphoric acid are furnished by bone meal on Plot 26. At $25 per ton there is no saving in cost.

The phosphoric acid is carried in acid phosphate on Plot 27. Our work hitherto has indicated that a pound of phosphoric acid in acid phosphate is as effective as a pound of the same constituent in dissolved bone black. In this test this conclusion is not supported, but it is possible that there may be other reasons for the discrepancy in this case.

On Plot 29 the phosphoric acid is carried in basic slag. At prices prevailing hitherto, this carrier has not materially reduced the cost of the fertilizers, but it is probable that the price will be reduced in the future.

Plots 11, 17, 21, 23, 24, 26, 27, 29 are intended to receive the same number of pounds each of nitrogen, phosphoric acid and potash, but in different carriers. For easier comparison the values of the increase on these plots are repeated below :

Plot.	Fertilizer.	Value of increase.
11	Nitrate soda, Diss. bone black, muriate potash.....	$15.12
17	Nitrate soda, wheat bran, muriate potash.....	12.35
21	Linseed oil meal, Diss. bone black, muriate potash.....	13.33
23	Dried blood Diss. bone black, muriate potash.....	12.65
24	Sulph. ammonia, Diss. bone black, muriate of potash...	12.53
26	Nitrate soda, bone meal, muriate potash	12.08
27	Nitrate soda, acid phosphate, muriate potash.....	11.70
29	Nitrate soda, basic slag, muriate potash....	12.81
	Average...	$12.82

It will be observed that there is a remarkably close agreement in values on Plots 17 to 29 inclusive. To produce this increase it is estimated that about seventy-five pounds of nitrogen, equivalent to over ninety pounds of "ammonia," fifty pounds available phosphoric acid and 130 pounds of potash have been distributed over the three grain crops of the five-year rotation. At the rate these materials have hitherto been sold in the average ready mixed fertilizers sold in Ohio, the cost per acre of this dressing would amount to about $27, or more than double the value of the increase.

Plot 20 receives eight tons of barnyard manure in the course of five years, in two dressings of four tons each, on corn and wheat. According

to average analyses this should carry about the same quantity of phosphoric acid as the 320 pounds dissolved bone black used in the standard fertilizer mixture on Plot 11, with more nitrogen and less potash than are carried in the nitrate of soda and muriate of potash. The average increase from the eight tons of manure has been nearly the same as from the complete fertilizers used, and more than from the mixture used on Plot 30. In other words, eight tons of barnyard manure on Plot 20 has produced increase worth twelve dollars—a dollar and a half for each ton of manure—and on Plot 18 the heavier dressing of sixteen tons in total has produced seventeen dollars worth of increase.*

On ordinary farms manure can be moved from barnyard to field and spread at 30 to 40 cents a ton, counting wages of man and team and use of spreader at $3.00 per day. As the manure lies in the barnyard it represents no expenditure, under conditions of ordinary farm management in Ohio, as it is expected that the food consumed by animals will be fully accounted for in the milk, growth or wool produced.

When it is further considered that one of the most useful feeding stuffs known to American agriculture—wheat bran—may be used directly as a fertilizer in competition with the ordinary, mixed fertilizers of commerce (as shown in Plot 17) and that in its use as a feeding stuff much the larger part of its fertilizing properties passes through the animal either unchanged or improved, it would seem that the making and using of barnyard manure might well occupy the most careful attention and study of those Ohio farmers who are purchasing fertilizers.

At the Northeastern Sub-station two crops of corn and one of oats have been grown in this experiment. Wheat was sown in the fall of 1895, but it was so completely destroyed by winter killing that no attempt was made to harvest it. The first clover crop will be cut in 1897.

Table VI gives the yields and increase of the corn and oats for 1896, with the average results for the two corn crops.

It will be seen from this table that the results in the main agree with those for the similar rotation at the Central Station, in showing the relative importance of phosphoric acid and nitrogen, and in emphasizing the necessity for combination, if the highest yield is to be attained.

*In the experiments with crops grown continuously on the same land, reported further on, a dressing of eight tons of manure per annum has produced more than twice as great an increase as one of four tons per annum.

TABLE VI—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT N. E. SUB-STATION.

Yield and increase or decrease(—)per acre, 1896, and average increase or decrease, 1895 and 1896.

Plot No.	Corn, 1895 and 1896.						Oats, 1896.			
	Yield per acre, 1896.		Increase or decrease(—)per acre.				Yield per acre.		Increase or decrease(—) per acre.	
			1896.		2-year average.					
	Grain.	Stover.	Grain.	Stover.	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.
	Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*
1	22.50	1,300					26.17	1,337		
2	27.21	1,270	3.95	—70	3.02	—111	30.23	1,732	4.89	363
3	25.79	1,350	1.76	—30	1.79	31	23.36	1,472	—1.14	72
4	24.79	1,420					23.67	1,432		
5	28.79	1,480	4.72	112	2.86	62	23.44	1,745	—1.85	268
6	32.29	1,585	8.93	268	7.64	62	35.94	1,815	9.04	293
7	22.64	1,265					28.52	1,567		
8	21.29	1,100	—1.80	—128	1.05	—191	31.09	1,730	5.18	256
9	25.43	1,225	1.98	43	2.71	—98	26 09	3,035	2.78	655
10	24.00	1,140					20.70	1,287		
11	34.71	1,430	10.23	273	10.15	123	33.12	1,935	10.91	483
12	32.29	1,530	7.53	357	7.44	147	34.22	2,010	10.50	393
13	25.14	1,190					25.33	1,782		
14	33.71	1,440	4.69	75	6.59	72	31.33	1,872	6.98	238
15	25.14	1,265					27.81	1,615		
16	36.79	1,715					22.58	1,337		
17	30.36	1,615	—5.24	—50	0.72	—68	31.64	1,912	10.55	587
18	39.64	1,800	6.18	185	8.74	71	28 20	1,487	8.59	175
19	31.79	1,565					18.12	1,300		
20	33.50	1,575	1.71	10	2.91	—76	25.78	1,570	4.27	118
21	17.71	1,150	1.64	90	2.76	—38	27.87	2,087	2.98	484
22	16.07	1,060					28.28	1,755		
23	18.36	1,120	3.36	67	6.04	—166	32.50	2,770	3.85	843
24	15.07	1,110	1.14	63	3.80	—43	35.69	2,847	6.68	749

TABLE VI—Concluded.

Plot No.	Corn, 1895 and 1896.						Oats, 1896.			
	Yield per acre, 1896.		Increase or decrease(—)per acre.				Yield per acre.		Increase or decrease(—) per acre.	
			1896.		2-year average.					
	Grain.	Stover.	Grain.	Stover.	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.
	Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*
25	12.86	1,040					29.38	2,270		
26	14.21	1,190	1.83	180	3.12	201	41.25	2,525	11.72	399
27	16.50	1,180	4.59	200	5.73	203	37.03	2,640	7.34	657
28	11.43	950					29.84	1,840		
29	19.50	1,110	6.38	150	6.42	33	39.53	2,260	11.25	433
30	24.86	1,200	10.05	230	9.82	162	35.94	2,300	9.22	487
31	16.50	980					25.16	1,800		
32	18.43	1,135	1.48	52			37.19	2,515	12.14	730
33	23.00	1,250	5.59	63			37.73	2,567	12.78	797
34	17.86	1,290					24.84	1,755		
35	29.50	1,625	9.14	272			36.80	2,392	13.13	665
36	32.57	1,650	9.71	240			36.87	2,315	14.37	615
37	25.36	1,470					21.33	1,672		
38	26.93	1,490					27.73	2,363		
39	29.21	1,460					33.67	1,882		
40	28.29	1,500					22.97	1,815		
*	22.56	1,277								

*Average of unfertilized plots.

For plan of fertilizing, see page 146.

FERTILIZERS IN THREE-YEAR ROTATION OF POTATOES, WHEAT AND CLOVER.

This experiment was continued during 1896, on the plan described in Bulletin 71, but the results were materially affected by the winter-killing of the wheat, which completely destroyed the crop at the Northeastern Sub-station and largely reduced the yield in both the other tests. The potato crop was also seriously injured by the excessive rains of July. The potatoes at the Central Station were grown upon newly cleared land, which has not yet been completely drained, as have other portions of the field in which this test is conducted. The land was plowed into narrow lands, each the width of a single plot, and the furrows between gave partial drainage, but the outside rows were considerably affected and have been excluded from the computations which follow, and which are based upon the four interior rows of each plot, (as planted, each plot contained six rows). At the Northeastern Substation the test was likewise conducted on undrained land, and although this was also plowed in the narrow lands just described, the furrows did not afford sufficient drainage, and the injury to the crop was so irregular that no trustworthy conclusions can be drawn from the results.

The damage was not so great on the yellow sand of the Northwestern Sub-station, although even there the results were somewhat obscured by the season.

Table VII gives the plan of fertilizing in this experiment, and the tables which follow give the results to date.

TABLE VII—PLAN OF FERTILIZING IN THREE-CROP ROTATION.

Fertilizers in pounds per acre.

Plot No.	On potatoes.			On wheat.			Explanation.
	Superphosphate.	Nitrate soda.	Muriate potash.	Superphosphate.	Nitrate soda.*	Muriate potash.	
1							
2	160			160			A. Barnyard manure, 4 tons
3			100			100	B. " " 8 "
4							C. Wheat bran, 500 lbs.
5		80			160		D. " " 1,000 "
6	160	80		160	160		E. Linseed oil meal, 250 lbs.
7							F. " " 500 "
8	160		100	160		100	G. Dried blood, 100 lbs.
9		80	100		160	100	H. " " 200 "
10							I Sulphate ammonia, 60 lbs.
11	160	80	100	160	160	100	K. " " 120 "
12	160	160	100	160	240	100	L. Bone meal, 110 lbs.
13							M. Acid phosphate, 170 lbs.
14	320	160	200	160	160	100	N. Basic slag, 130 lbs.
15	480	320	300				
16							
17				A			
18				B			
19							
20	80	C	85	D		70	
21	120	E	95	110	F	90	
22							
23	160	G	100	160	H	100	
24	160	I	100	160	K	100	
25							
26	L	55	100	L	135	100	
27	M	80	100	M	160	100	
28							
29	N	80	100	N	160	100	
30	B						
31							

*On wheat, one-third dried blood, applied in the fall, and two-thirds nitrate of soda, applied in April; all other fertilizers for wheat are applied in the fall.

TABLE VIII—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT CENTRAL STATION.

Yield and increase or decrease (—) per acre—1896.

Plot No.	Yield per acre.				Increase or decrease (—) per acre.			
	Potatoes, Sec. C	Wheat, Sec. B		Clover. Sec. A	Potatoes.	Wheat.		Clover.
	Total yield.	Grain.	Straw.	Hay.		Grain.	Straw.	Hay.
	Bushels.	Bushels.	Pounds.	Pounds.	Bushels.	Bushels.	Pounds.	Pounds.
1	161.96	16.67	1,340	5,250	.....	.....	.....	.....
2	200.20	17.83	1,780	5,000	23.56	4.52	708	33
3	202.90	11.50	1,030	4,150	11.58	1.56	227	—533
4	206 00	6.58	535	4,400	....	.....	.....	.....
5	235.83	8.79	972	5,000	30.50	2.63	455	400
6	259.09	10.58	915	5,430	54.42	4.83	417	630
7	204.00	5.33	480	5,000	.....	.....	.....	.....
8	218.28	10.29	872	4,850	10 13	4.45	330	—67
9	221.00	11.75	1,005	5,030	8.71	5 39	400	197
10	216.44	6.87	667	4,750	....	.....	.....	.....
11	228.48	15.20	1,187	4,450	12.79	8.14	505	—117
12	226 44	13.54	1,217	5,000	11.49	6.28	853	617
13	214.20	7.45	712	4,200	....	.....	.....	.....
14	251.00	18.50	1,340	4,350	38.50	11.13	673	407
15	240.72	14.33	1,040	4,880	29.92	7.04	418	1,197
16	209.10	7.21	577	3,430	....	.....	.....	.....
17	184.00	10.25	865	4,660	.....	3.39	844	1,223
18	177.88	11.83	960	4,9[illegible]0	....	6 51	466	1,505
19	176.44	6 16	410	3,450	....	.....	.....	.....
20	218.88	9.12	762	4,600	38.63	3.42	338	1,150
21	208.08	10 62	852	4,200	24 01	5.37	314	750
22	187.88	4.79	452	3,450	....	.....	.....	.....
23	218.28	8.83	820	3,380	33.69	3.33	290	147
24	189.72	9.16	660	3,450	8.43	2.96	53	453
25	178.00	6 91	685	2,800	....	.....	.....	.....
26	178.13	10.29	1,082	3,050	—6.83	3.60	377	117
27	213.04	12.41	1,085	3,480	21.12	5.94	360	417
28	198.88	6.25	745	3,200	....	.....	.....	.....
29	198 86	11.87	1,187	4,650	4.61	5.62	442	1,577
30	255.00	5.66	580	4,600	65.37	—0.59	—165	1,653
31	185.00	.....	.....	*2,820	....	.....	.....	.....
32	174.80	.....	.....	.....	....	.....	.....	....
33	197.86	.....	.....	.....	12.20	.....	.....	.....
34	186.00	.....	.....	.....	....	.....	....	.....

*Average of Plots 31 to 34 inclusive.

TABLE IX—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT CENTRAL STATION.

Average annual increase or decrease (—) per acre, 1894-1896.

Plot No.	Increase or decrease (—) per acre.				Value of increase per acre					Fertilizers per acre.	
	Potatoes 3-years.	Wheat-2 years.		Hay, 1896.	Potatoes.	Wheat.		Hay.	Total.	Quantity.	Cost.
		Grain.	Straw.			Grain.	Straw.				
	Bushels.	Bushels.	Pounds.	Pounds.						Pounds.	
2	26.87	4.04	545	33	$8.96	$2.67	$0.82	$0.13	$12.58	320	$2 88
3	6.51	1.31	40	—533	2.17	0.86	.06	—2.13	.96	200	5.00
5	10.50	2.30	235	400	3.50	1.52	.35	1.60	6.97	240	6.00
6	37.74	7.43	441	630	12.58	4.90	.66	2.52	20.66	560	8.88
8	27.49	7.95	463	—67	9.16	5.25	.69	—0.27	14.83	520	7.88
9	16.18	4.43	254	197	5.39	2.92	.38	.79	9.48	440	11.00
11	25.11	8.08	485	—117	8.37	5.33	.73	—0.47	13.96	760	13.88
12	38.06	8.96	902	617	12.69	5.91	1.35	2.47	22.42	920	17.88
14	49 22	10.69	679	407	16.41	7.06	1.02	1.63	26.12	1,100	19.82
15	54 04	8.94	509	1,197	18.01	5.90	.76	4.79	29.46	1,100	19.82
17	.....	2.56	187	1,223	.....	1.69	.28	4.89	6.86	4 tons.	.....
18	.....	4.81	273	1,505	.....	3.17	.41	6.02	9.60	8 tons.	.....
20	41.54	2.93	154	1,150	13.85	1.93	.23	4.60	20.61	1,735	12.10
21	33.07	7.50	484	750	11.02	4.95	.73	3.00	19.70	1,165	14.20
23	42.53	6.39	370	147	14.18	4.92	.55	.59	19.54	820	11.63
24	34.47	6.25	206	433	11.49	4.12	.31	1.73	17.65	700	13.28
26	15.11	5.53	389	117	5.04	3.65	.58	.47	9.74	610	13.75
27	27.94	6.77	255	417	9.31	4.47	.38	1.67	15.83	780	13.55
29	16.91	8.45	491	1,577	5.64	5.58	.74	6.31	18.27	600	.....
30	40.66	1.52	0	1,653	13.55	1.00	0.00	6.61	21.16	8 tons.	.....

Table IX includes the average results of three potato crops, two wheat crops and one hay crop at the Central Station. Several of these crops were grown under abnormal climatic conditions, and we must expect that present indications may be materially modified by the results of future work.

In respect to the effect of the three fertilizing constituents, it will be observed that phosphoric acid produced the greatest effect and nitrogen next, while potash caused practically no increase where used alone and relatively little when added to the combination of phosphoric acid and nitrogen. The yield on Plot 6, fertilized only with superphosphate and nitrate of soda, is equal to the average yield from the plots receiving the same dressings of super phosphate and nitrate, with potash added, and greater than that on several of these plots, but some of these irregularities, especially that on Plot 11 and possibly that on Plot 26, should probably be ascribed to inequalities of soil rather than to differences in fertilizing.

It would not be safe, from this one experiment, to draw the conclusion that potash is not needed in a fertilizer for potatoes. On the contrary, in other localities potash has seemed to occupy the importance in a potato fertilizer which must be given to phosphoric acid on this soil.

In one respect the results of this test differ widely from those in the 5-year rotation described above, and that is in showing a profit from the use of the fertilizer in nearly every case. The columns giving the value of the increase show clearly that this profit comes from the relatively high value of the increase from the potatoes, when rated at 30 cents per bushel. With potatoes at average price of the last two seasons the profit would in most cases disappear. It is notable that the increase from potatoes rises with the quantity of fertilizer used, until that quantity reaches 1,100 pounds per acre, applied to this crop alone.

Not only does this method of treatment give the largest increase of potatoes, but the combined increase of the wheat and hay crop following is larger than when the same quantity of fertilizer is divided between the potato and wheat crops.

This experiment confirms the one on the 5-year rotation in showing the relative value of wheat bran and oil meal. A ton of average wheat bran contains about 53 pounds of nitrogen, equivalent to 65 pounds of ammonia, 58 pounds of phosphoric acid and 32 pounds of potash. At the rates paid for the nitrate of soda, acid phosphate and muriate of potash used in these experiments, the ton of bran would be worth about $13.00 as a source of ammonia, phosphoric acid and potash, as compared with the carriers named; or, if compared with the ready-mixed fertilizers of commerce, its value would be about $16.50.

It will be observed that in these experiments the bran has been reinforced with superphosphate and muriate of potash. It is probable that

an addition of superphosphate at least (either dissolved bone black or acid phosphate) will increase its effectiveness under ordinary conditions.

On Plots 17 and 18 the barnyard manure shows a total value of increase amounting to $1.20 to $1.70 per ton, although the potato crop is yet to be heard from. On Plot 30 the total increase amounts to more than $2.50 per ton of manure, nearly two-thirds of the total coming from potatoes.

With the potato crop of 1897 begins the second course in this rotation, in which the full plan of fertilizing comes into effect.

At the Northwestern Sub-station three crops of potatoes and two of wheat have been harvested in this experiment, but no clover as yet, through failures in seeding. Table X gives the results for 1896 and the average results to date.

In this test irregularities in the soil have obscured the results on plots 16 to 30 inclusive and it is deemed best to omit these plots from the general average at present.

It will be observed that the increase, on both potatoes and wheat, has been considerably smaller on this sandy land than on the loam at the Central Station, and that potash is apparently of greater importance here than at the Central Station.

As already stated, both wheat and potatoes were practically a failure at the Northeastern Sub-station in 1896, and the first clover crop in the rotations there is yet to be harvested, consequently there is no report to be made on the work there in this rotation additional to that given in Bulletin 71.

TABLE X.—FERTILIZERS ON CROPS GROWN IN 3 YEAR ROTATION AT N. W SUB-STATION.

Yield and increase or decrease(—)per acre.

Plot No.	Yield per acre—1896.			Increase or decrease(—)per acre.						
	Potatoes.	Wheat.		1896.			Average—1894-1896.			
	Total.	Grain.	Straw.	Potatoes.	Wheat. Grain.	Wheat. Straw.	Potatoes.	Wheat. Grain.	Wheat. Straw.	Value of average increase.
	Bushels.	Bushels.	Pounds.	Bushels.	Bushels.	Pounds.	Bushels.	Bushels.	Pounds.	
1	118.7	3.83	550							
2	153.5	3.00	360	20.6	—0.33	—167	12.6	—0.14	—102	$3.55
3	155.1	3.00	420	8.0	0.17	—23	18.3	2.97	217	7.64
4	161.4	2.33	390							
5	170.8	2.50	430	23.1	0.17	40	11.7	—0.77	—60	2.97
6	171.5	2.50	350	37.6	0.67	120	22.1	3.02	280	8.85
7	120.2	1.83	230							
8	154.5	1.67	290	22.9	—0.27	47	15.0	1.46	107	5.54
9	163.0	3.50	550	20.0	1.44	293	14.4	2.75	385	6.55
10	154.3	2.17	270							
11	187.4	8.50	600	30.0	6.44	300	23.8	8.52	523	13 03
12	197.4	3.67	510	36.8	1.73	180	28.6	5.43	394	12.43
13	163.8	1.83	360							
14	200.0	8.00	720	24.4	5.17	280	28.0	8.03	568	14.05
15	207.0	6.83	500	19.5	3.00	—20	31.0	7.89	511	14.79
16	199.4	4.83	600							
17	192.3	5.00	500		0.17	—100				
18	194.7	3.50	490		—1.33	—110				
19	189.5	3.83	410							
20	200.7	5.67	660	30 1	1.28	270				
21	203.2	6.67	840	51.3	3.63	470				
22	133.0	2.50	350							
23	151.3	2.33	320	13.2	0.27	10				

TABLE X—Concluded.

Plot No.	Yield per acre—1896.			Increase or decrease(—)per acre.						
	Potatoes.	Wheat.		1896.			Average—1894–1896.			
	Total.	Grain.	Straw.	Potatoes.	Wheat.		Potatoes.	Wheat.		Value of average increase.
					Grain.	Straw.		Grain.	Straw.	
	Bushels.	Bushels.	Pounds.	Bushels.	Bushels.	Pounds.	Bushels.	Bushels.	Pounds.	
24	138.5	2.50	350	—4.7	0.89	80				
25	148.2	1.17	230							
26	176.9	1.50	410	28.7	0.16	157				
27	183.7	4.67	420	35.6	3.17	143				
28	148.1	1.67	300							
29	161.1	5.00	500	13.0	3 55	233				
30	162.4	2.67	340	14.3	1.45	107				
31		1.00	200							
*	153.7	2.45	354	153.7	2.45	354		9.60	745	

*Average of unfertilized plots.

FERTILIZERS ON CROPS GROWN CONTINUOUSLY ON THE SAME LAND.

These experiments, begun at Columbus on corn in 1888 and on oats and wheat in 1889; at East Liverpool on corn in 1888, and at Wooster on corn, oats and wheat in 1894, were continued in 1896 according to original plans. The results are summarized in the following tables, the wheat crop at Columbus being omitted because of its complete destruction by winter killing, as already noted.

In the experiments at Columbus and East Liverpool there has been practically no increase of corn from superphosphate or muriate of potash used alone. Nitrate of soda has given a small increase when used alone and a larger one when combined with phosphoric acid or potash, one or both, but in neither of these tests has the increase from any fertilizer or combination of fertilizers been sufficient to pay the cost of the fertilizer, and this is also true of the results at Wooster, although the average increase here has been several times as great as that in either of the other tests.

The experiments on oats at Columbus have suffered from chinch bugs and from errors in harvesting or weighing, so that a satisfactory report can only be made on Plots 4 to 16, inclusive. The data thus far accumulated do not show any wide divergence in the results on oats from those on corn.

Both oats and corn, at Columbus, are grown on land underlaid with gravel. The wheat land, however, has a hard-pan subsoil.

It will be observed that the increase on oats and corn in the continuous work at Wooster is much greater than in that at Columbus.

TABLE XI—FERTILIZERS ON CORN NINE YEARS IN SUCCESSION AT COLUMBUS.

Plot No.	Fertilizers per acre.	Yield per acre. 1896.		Increase or decrease (—) per acre.			
				1896.		9-year average.	
		Grain.	Stover.	Grain.	Stover.	Grain.	Stover.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
1	None	44.93	2,200				
2	Superphosphate, 320 pounds	49.86	2,000	2.48	—217	0.14	—74
3	Muriate of potash, 80 pounds	52.50	2,650	2.66	417	0.97	446
4	None	52.29	2,250				
5	Nitrate of soda, 160 pounds	53.79	2,650	2.48	450	2.91	614
6	Superphosphate, 320; nitrate, 160	47.57	2,200	—2.77	50	4.04	502
7	None	49.36	2,100				
8	Superphosphate, 320; potash, 80	58.57	3,200	10.47	1,033	3.26	434
9	Nitrate, 160; potash, 80	54.71	1,800	7.88	—433	6.28	472
10	None	45.57	2,300				
11	Superphosphate, 320; potash, 80; nitrate, 160	56.43	2,650	9.88	383	5.17	427
12	" " " 320	61.00	2,450	13.48	217	5.43	408
13	None	48.50	2,200				
14	Superphosphate, 320; potash, 80; nitrate, 480	52.00	2,980	5.43	820	3.98	593
15	Sulph. ammonia, 120. potash, 80; nitrate, 160	53 36	2,320	8.72	200	4.01	227
16	None	42.71	2,080				
17	Acid phosphate, 320; potash, 80; nitrate, 160	53.43	2,650	9.29	490	7.30	749
18	Slag phosphate, 320; potash, 80; nitrate, 160	55.00	2,550	9.43	310	6.78	525
19	None	47.00	2,320				
20	Barnyard manure, 8 tons	47.86	2,100	1.96	—180	4.44	249
21	Linseed oil meal, 1,000 pounds	47.14	2,300	2.33	60	6.46	568
22	None	43.71	2,200				
	Average of unfertilized plots	46.76	2,206			52.31	3032

TABLE XII—FERTILIZERS ON CORN NINE YEARS IN SUCCESSION AT EAST LIVERPOOL.

Plot No.	Fertilizers per acre.*	Yield per acre		Increase or decrease (—) per acre.			
		1896.		1896.		Nine-year average.	
		Grain.	Stover.	Grain.	Stover.	Grain.	Stover.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
1	None	30.44	1,430				
2	Superphosphate, 320 pounds	27.91	1,093	—3.12	—268	—1.25	—34
3	Muriate of potash, 80 pounds	31.25	1,287	—0.37	—6	—0.13	126
4	None	32.21	1,224				
5	Nitrate of soda, 100 pounds	29 45	1,770	—2.00	336	4 58	231
6	Superphosphate, 320; nitrate, 160	33.05	2,608	2.36	1,063	6.51	396
7	None	29.93	1,855				
8	Superphosphate, 320; potash, 80	30.22	1,623	—0.09	—298	—3.13	71
9	Nitrate, 160; potash, 80	34.73	2,734	4.05	747	6.54	424
10	None	31.06	2,053				
11	Superphosphate, 320; Nitrate, 160; potash, 80	43.54	3,969	13.71	1,673	6.15	536
12	Barnyard manure, 8 tons	43.00	4,011	14.39	1,473	6.33	572
13	None	27.38	2,781				
14		30.00	2,112	2 62	—669	—1.49	—154
	Average unfertilized yield	30.20	1,869			28.12	2,499

*Double these quantities, 1895 and 1896.

TABLE XIII—FERTILIZERS ON CORN THREE YEARS IN SUCCESSION AT WOOSTER.

Plot No.	Fertilizer per acre.	Yield per acre, 1896.		Increase per acre,			
				1896.		3-year average.	
		Grain.	Stover.	Grain.	Stover.	Grain.	Stover.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
1	None	51.93	1,670				
2	Superphosphate, 160; nitrate soda, 160; muriate potash, 100	73.18	2,380	21.17	727	11.42	539
3	Superphosphate, 60; nitrate soda, 160; muriate potash, 30	67.96	2,000	15.86	363	6.68	221
4	None	52.18	1,620				
5	Barnyard manure, 2½ tons	61.86	1,850	10.87	243	6.70	235
6	" 5 tons	68.82	2,020	19.02	477	14.14	505
7	None	48.61	1,580				
8	Superphosphate, 160; nitrate soda, 320; muriate potash, 100	74.36	2,340	27.82	830	18.20	546
9	Superphosphate, 120; nitrate soda, 320; muriate potash, 60	71.89	2,310	27.43	870	14.22	1,110
10	None	42.39	1,370				
	Average unfertilized yield	48.78	1,560				

TABLE XIV—FERTILIZERS ON OATS EIGHT YEARS IN SUCCESSION AT COLUMBUS.

Plot No.	Fertilizers per acre.	Yield per acre, 1896.		Increase or decrease (—) per acre.			
				1896.		3-year average.	
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
1	None	22.34	2,000				
2	Superphosphate, 320 pounds	25.47	2,085	1.57	—143		
3	Muriate of potash, 80 pounds	27.50	2,720	2.03	263		
4	None	27.03	2,685				
5	Nitrate of soda, 160 pounds	35.94	3,425	9.29	928	4.99	357
6	Superphosphate, 320; nitrate, 160	42.03	3,655	15.75	1,347	7.20	481
7	None	25.90	2,120				
8	Superphosphate, 320; potash, 80	29.38	3,010	3.31	778	2.42	213
9	Nitrate, 160; potash, 80	40.00	4,570	13.76	2,227	6.02	555
10	None	26.41	2,455				
11	Superphosphate, 320; potash, 80; nitrate, 160	34.69	4,340	8.85	1,850	5.57	514
12	" 320; " 80; " 320	45.23	5,052	19.97	2,527	7.27	717
13	None	24.69	2,560				
14	Superphosphate, 320; potash, 80; nitrate, 480	41.81	6,012	17.88	3,361	6.15	153
15	" 320; " 80; sulp'te ammonia, 120	38.36	4,172	15.18	1,431	6.48	582
16	None	22.42	2,832				
17	Rock phosphate, 320; potash, 80; nitrate, 160						
18	Slag phosphate, 320; " 80; " 160						
19	None	29.84	3,145				
20	Barnyard manure, 8 tons	32.19	3,920	4.80	672		
21	Linseed oil meal, 1,000 pounds	29.53	4,030	4.58	678		
22	None	22.50	3,455				
	Average of unfertilized plots	25.14	2,656				

TABLE XV—FERTILIZERS ON OATS THREE YEARS IN SUCCESSION AT WOOSTER.

Plot No.	Fertilizers per acre.	Yield per acre, 1896.		Increase or decrease (—) per acre.			
				1896.		Three-year average.	
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
1	None	22.19	880				
2	Superphosphate, 160; potash, 100; nitrate, 160	44.37	2,110	21.56	1,123	11.82	616
3	" 55; " 50; " 160	39.22	1,815	15.78	722	8.35	330
4	None	24.06	1,200				
5	Barnyard manure, 2½ tons	26.41	1,155	2.14	—42	1.39	—122
6	" " 5 "	30.00	1,270	5.52	77	5.58	38
7	None	24.69	1,190				
8	Superphosphate, 160; potash, 100; nitrate, 320	54.37	2,700	29.84	1,528	18.42	837
9	" 110; " 100; " 320	52.19	2,650	27.81	1,497	16.79	720
10	None	24.22	1,135				
	Average of unfertilized plots	23.79	1,101				

TABLE XVI—FERTILIZERS ON WHEAT THREE YEARS IN SUCCESSION AT WOOSTER.

Plot No.	Fertilizers per acre.	Yield per acre, 1896.		Increase per acre.			
				1896.		Three-year average.	
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
		Bushels.	Pounds.	Bushels.	Pounds.	Bushels	Pounds.
1	None	1.12	92				
2	Superphosphate, 160; potash, 100; nitrate, 160	6.08	775	4.90	673	6.53	625
3	" 45; " 30; " 160	3.08	315	1.23	112	3.28	296
4	None	1.29	122				
5	Barnyard manure, 2½ tons	2.83	380	1.65	258	2.04	369
6	" " 5 "	5.29	692	4.22	570	3.74	594
7	None	0.96	122				
8	Superphosphate, 160; potash, 100; nitrate, 320	6.50	860	5.47	709	6.78	817
9	" 90; " 60; " 320	3.91	485	2.82	304	4.98	598
10	None	1.16	210				
	Average of unfertilized plots	1.13	136				

TABLE XVII—FERTILIZERS ON CROPS GROWN CONTINUOUSLY AT WOOSTER.

Summary of Tables XI to XVI.

Plot No.	Fertilizers per acre.	Average increase per acre.			Value of increase.	
		Grain.	Straw or stover.	Total.	Per acre.	Per ton of fertilizer.
	Pounds.	Pounds.	Pounds.	Pounds.		
2	420	470	647	1,117	$4.75	$22 62
3	250	279	313	592	2.70	21.40
5	2½ tons.	181	192	373	1.62	0.64
6	5 tons.	398	445	840	3.59	0.72
8	580	616	804	1,420	6.08	20.96
9	500	544	876	1,420	5.57	22.28

In Table XVII the average results of the work in continuous culture at Wooster are collected in a summary giving the average quantity of fertilizers applied to each plot each year for each of the three crops, the average weight of increase each year, whether in grain or in straw, cobs and stover, and the value of this increase per acre and per ton of fertilizer or manure used in producing it.

It will be observed that thus far in this experiment the increase of crop has been closely proportionate to the quantity of fertilizers applied. Comparing Plots 3 and 9, on which the fertilizers are of identical composition, the increase from 500 pounds per annum is proportionately larger than from 250 pounds, and the same is true of the manured plots. The increase in weight of fertilizers used on Plot 8 as compared with Plot 2, all comes from nitrate of soda, and the result indicates a less effective application, pound for pound, although there is a greater total increase.

The effect from barnyard manure is considerably smaller in this continuous culture than in the long rotation, and this is explained by reference to Table V, which shows that of the total value of increase from manure in that rotation, more than two-thirds is found in the hay crops, whereas in the case of the chemical fertilizers, much the larger part of the total value of the increase is found in the grain.

CONCLUSIONS.

On the clay soils, which have been under test in most of these experiments, phosphoric acid seems to have been the most effective constituent of a fertilizer for cereal crops and clover grown in rotation, but the full effect of the phosphoric acid was not attained until both potash and nitrogen were added.

It appears, however, that the quantities of potash and nitrogen actually used in most of these mixtures were greater than was required for the full utilization of the phosphoric acid, and that the most effective fertilizer, in proportion to cost, would be one containing nitrogen and potash in approximately equal quantities, with phosphoric acid largely in excess.

In the continuous culture of cereals nitrogen appears to be the most important constituent of the fertilizer, but, as in rotative cropping, it is the complete fertilizer, containing phosphoric acid and potash as well as nitrogen, which produces the maximum effect.

Potash seems to have a relatively greater effect on the sandy land employed in one of the tests than on the clay, but further investigation on this point is needed.

At the price at which "ammonia," phosphoric acid and potash are sold in the fertilizer markets of Ohio, the cost of the fertilizer has been greater than any increase produced from it in crops grown continuously on the same land in these experiments. When the cereals have been grown in rotation with clover the cost of the fertilizer has been

recovered, with a margin to spare, provided nitrogen and potash were used in small proportion relatively to phosphoric acid; and when potatoes formed one crop in a three-year rotation with wheat and clover, it has been comparatively easy to secure a profit on the fertilizer.

In rotative cropping, ordinary barnyard manure has produced increase to the value of a dollar to a dollar and a half for each ton of manure, this increase being found chiefly in the hay crops, whereas the increase from chemical or slaughterhouse fertilizers is shown chiefly in the grain crops.

The nitrogen, phosphoric acid and potash in wheat bran and linseed oil meal seem to be nearly or quite as effective in producing increase of crop as the same constituents in the ordinary mixed fertilizers of commerce. Since the larger portion of these constituents passes into the manure in feeding, the inference is justified that, by proper care of the manure, a large portion—probably the larger portion—of the cost of these valuable feeding stuffs may be recovered in the manure.

A ton of clover hay carries fertilizing constituents to the value of more than eight dollars, as compared with the prices at which mixed fertilizers are sold in Ohio, and assuming that these constituents are equally available with those in mixed fertilizers. It is probable that they are not quite so quickly available, but the apparent fact that commercial fertilizers can be used with profit in the production of cereals only when these cereals are grown in rotation with clover, and the high value as fertilizers which bran and oil meal are shown to have, all combined, most forcibly indicate that through the feeding of live stock, the careful saving of the resultant manure, and its intelligent employment in a scientific rotation of crops, lies today, as of old, the road to the economical maintenance of fertility.

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