Ohio Agricultural Experiment Station.

BULLETIN 53.

WOOSTER, OHIO, MARCH, 1894.

FIELD EXPERIMENTS WITH COMMERCIAL FERTILIZERS.

EXPERIMENTS ON CROPS GROWN IN CONTINUOUS CULTURE.

EXPERIMENTS ON CROPS GROWN IN ROTATION.

CO-OPERATIVE EXPERIMENTS.

THE SOURCE OF PHOSPHORIC ACID IN FERTILIZERS.

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BULLETIN

OF THE

Ohio Agricultural Experiment Station.

NUMBER 53. MARCH, 1894.

FIELD EXPERIMENTS WITH COMMERCIAL AND OTHER FERTILIZERS IN 1893.

[BY C. E. THORNE AND J. FREMONT HICKMAN.]

The general plan of these experiments is as follows:

A tract of uniform land is divided into plots containing one tenth or one-twentieth acre each; the plots are 16 feet wide and are separated by alley-ways 2 feet wide. Under every second alley-way a tile drain is laid. In the case of the wheat plots the soil is clay, lying upon the bowlder clay of the drift, and that upon Huron shale at a depth of 15 to 20 feet. It was formerly covered with forest, in which beech and elm predominated, and was wet and heavy before being drained. The plots on which corn and oats are grown have a gravel sub-soil, which gives partial drainage.

Twenty-two tenth-acre plots are devoted to the continuous culture each of wheat, corn and oats, each plot receiving the same treatment each year. Table 1 gives the order in which the plots are arranged, the quantity and cost per acre of fertilizer applied to each plot, and the quantity per acre of essential ingredients contained. The cost is computed on the basis of the present price per ton in eastern markets, with five dollars per ton added for freight.

TABLE 1.—FERTILIZERS ON WHEAT, CORN AND OATS GROWN CONTINUOUSLY.—Quantity and cost per acre.

Plot No.	Fertilizers.	Quantity.	Essential Ingredients.			Cost.
			Nitrogen.	Phos. acid.	Potash.	
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	
1	Unfertilized					
2	Superphosphate[1]	320		50		$4 00
3	Muriate of Potash	80[4]			40[4]	1 75
4	Unfertilized					
5	Nitrate of Soda	160[2]	25[2]			4 25
6	Nitrate of Soda Superphosphate	160[2] 320	25[2]	50		8 25
7	Unfertilized					
8	Superphosphate Muriate of Potash	320 80[4]		50	40[4]	5 75
9	Nitrate of Soda Muriate of Potash	160[2] 80	25[2]		40	6 60
10	Unfertilized					
11	Superphosphate Muriate of Potash Nitrate of Soda	320 80[4] 320	25[2]	50	40[4]	10 00
12	Superphosphate Muriate of Potash Nitrate of Soda	320 80 320	50	50	40	14 25
13	Unfertilized					
14	Superphosphate Muriate of Potash Nitrate of Soda	320 80[4] 480[3]	75[3]	50	40[4]	18 50
15	Superphosphate Muriate of Potash Sulphate of Ammonia	320 80 120	25	50	40	10 25
16	Unfertilized					
17	Dissolved S. C. Rock Muriate of Potash Nitrate of Soda	320 80[4] 160[2]	25[2]	45	40[4]	8 55
18	Basic Slag[5] Muriate of Potash Nitrate of Soda	300 80[4] 160[2]	25[2]	60	40	9 45
19	Unfertilized					
20	Barnyard manure	8 tons.	75	25	50	
21	Linseed oil-meal	1000	50	20	15	13 00
22	Unfertilized					

[1] "Superphosphate" in all cases is dissolved bone-black.
[2] 480 and 75 pounds in 1888.
[3] 160 and 25 pounds in 1888.
[4] 160 and 80 pounds previous to 1892.
[5] Also known as "odorless phosphate."

Stated in another form, plots 11, 15, 17 and 18 of this experiment each receive at the rate of 520 to 560 pounds per acre of a fertilizer containing about $5\frac{1}{3}$ to 6 per cent. ammonia (ammonia being about 80 per cent. nitrogen), 8 to 9 per cent. available phosphoric acid and 7 to $7\frac{3}{4}$ per cent. potash. On plot 6 the same quantities of nitrogen and phosphoric acid are used, but by omitting the potash the percentages are changed to the equivalent of $6\frac{1}{3}$ per cent. ammonia and $10\frac{1}{2}$ per cent. phosphoric acid.

FERTILIZERS ON WHEAT GROWN CONTINUOUSLY ON THE SAME LAND.

This is the fifth successive crop of wheat grown on these plots. The history of the previous crops is given in Bulletin 49 of this Station.

Immediately after a crop is removed the ground is plowed to the depth of 8 or 9 inches, and it is rolled and harrowed six or seven times between plowing and seeding, the surface being reduced to the condition of a garden and no weeds being allowed to grow.

The fertilizers are spread broadcast, just before drilling the wheat, except the nitrate of soda. This is a coarse, easily soluble salt, and to apply it all in the fall would involve the leaching away of a large part of it before the plant could make use of it.

In 1890 it was all sown in the spring, about the middle of April. For the crop of 1891 the application was divided, half being sown in the fall and half in April. For the crops of 1892 and 1893, dried blood was used in the fall at the rate of forty pounds per acre, and nitrate of soda was sown in April in quantity sufficient to bring the total application up to the desired amount. The sulphate of ammonia is all applied in the fall.

The result of the harvest is given in Tables II, III and IV, together with those of the four preceding harvests, and the average results of the five years' experiments.

[In these and subsequent tables the increase for the fertilized plots has been calculated on the assumption that if the yields of two neighboring unfertilized plots, 1 and 4, for example, were twenty-five and twenty-eight bushels, respectively, the unaided yield of the fertilized plots between, 2 and 3, would have been twenty-six and twenty-seven bushels. The "average yield of unfertilized plots" is given in each table for general comparison, but is not used in calculating the increase.]

TABLE II.—FERTILIZERS ON WHEAT FIVE YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels per acre.*

Plot No.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		1889.	1890.	1891.	1892.	1893.	Av.	1889.	1890.	1891.	1892.	1893.	Av.	
1	None	50.5	31.9	31.8	26.2	32.1	34.5	.....	.....	.....	.....	.....	.....	1
2	Superphosphate (dissolved bone-black)	50 2	35.6	29.3	31.2	35.2	36.3	2.9	3.7	—2.6	4.7	5.6	2.9	2
3	Potash (muriate)	47.5	32.1	30 2	28.2	27.7	33.1	3.5	0.3	—1.7	1.3	0.7	0.8	3
4	None	40.8	31.8	32.0	27 2	24.5	31.3	.....	.....	.....	.....	.....	.....	4
5	Nitrate of soda (1)	40.0	36.5	33.7	27.9	31.6	33.9	—3.0	4.3	0.6	0.2	6.3	1.7	5
6	Nitrate and superphosphate (1)	40.8	38.6	31.2	28.9	33.5	34.6	—4.5	6.0	—3.0	0.8	7.4	1.3	6
7	None	47.5	33.0	35.3	28.6	26.8	34.2	.....	.....	.....	.....	.....	.....	7
8	Superphosphate and potash	41 6	36.4	30.5	30.2	36.0	34.9	—4.7	3.6	—3.4	1.7	8.8	1.2	8
9	Nitrate and potash (1)	45.6	36.8	33.4	29.1	35.4	36.1	0.4	4.2	0.8	0.8	7.9	2.8	9
10	None	44.0 (3)	32.4	31.2	28.1	27.7	32.7	.....	.....	.....	.....	.....	.....	10
11	Superphosphate, potash and nitrate 160 (1)	49.5	36.9	28.8	29.1	38.6	36.6	5.4	5.3	—2.5	1.4	10.9	4.0	11
12	Superphosphate, potash and nitrate 320	49.3	35 7	29.7	29 2	42.7	37.3	5.2	5.0	—1.7	2.0	15.1	5.1	12
13	None	44.2	29.9	31.5	26.8	27.5	32.0	.....	.....	.....	.....	.....	.....	13
14	Superphosphate, potash and nitrate 480 (2)	47.0	34.9	28.8	29 2	39.7	35 9	4.9	4.2	—2.5	2.1	13.0	4.3	14
15	Superphosphate, potash and ammonia	47.0	33.8	29.8	30.4	34.8	35.2	7.1	2.2	—1.2	3.0	8.8	4.0	15
16	None	37.8	32.4	30.8	27.8	25.2	30.8	.....	.....	.....	.....	.....	.....	16
17	Rock phosphate, potash and nitrate (1)	40.0	37.4	33.2	31.1	32.6	34.9	1 3	5.5	2.2	4.1	8.1	4.2	17
18	Slag phosphate, potash and nitrate (1)	39.3	37.3	31.7	31.6	35.2	35.0	—0.3	5.8	0.4	5.4	11.5	4.6	18
19	None	40.5	31.0	31.5	25.4	22.8	30.0	.....	.....	.....	.....	.....	.....	19
20	Barnyard manure	44.5	34.7	27 3	25.4	37.3	33.8	5.3	5.2	—2.7	1.1	13.8	4.5	20
21	Linseed oil meal	38.7	33.9	34.7	27.5	35.5	34.1	0.7	5.9	6.1	4.2	11.3	5.6	21
22	None	36.7	26.5	27.1	22 2	24.7	27.4	.....	.....	.....	.....	.....	.....	22
	Average of unfertilized plots	42.8	31.1	31 4	26 5	26.4	31.6	.....	.....	.....	.....	.....	.....	
	Average increase from fertilizers	.....	.....	.....	.....	.....	.....	1.7	4.4	—0.8	2.3	9.2	3.3	

(1) 480 pounds nitrate in 1889.
(2) 160 pounds nitrate in 1889.
(3) Estimated.

TABLE III.—FERTILIZERS ON WHEAT FIVE YEARS IN SUCCESSION.

Yield and increase of STRAW *in pounds per acre.*

Plot No.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		(3) 1889.	1890.	1891.	1892.	1893.	Average.	1889.	1890.	1891.	1892.	1893.	Average.	
1	None	4,070	3,602	4,540	3,015	2,495	3,544							1
2	Superphosphate (dissolved bone-black)	4,208	3,885	4,995	4,265	3,270	4,125	264	390	642	1,372	1,120	757	2
3	Potash (muriate)	3,850	3,062	3,740	3,190	2,175	3,203	32	—327	—427	418	355	10	3
4	None	3,692	3,282	3,980	2,650	1,490	3,019							4
5	Nitrate of soda (1)	3,560	3,930	3,980	2,710	2,705	3,377	—251	630	— 83	— 13	995	256	5
6	Nitrate and superphosphate (1)	3,512	4,385	5,330	3,830	2 690	3,949	—419	1,064	1,183	1,033	800	732	6
7	None	4,050	3,340	4,230	2,870	2,090	3,316							7
8	Superphosphate and potash	3,304	4,152	4,570	3,625	3,444	3,819	—563	703	557	778	1,372	570	8
9	Nitrate and potash (1)	4,504	3,852	4,395	2,990	2,975	3,743	821	294	598	167	922	560	9
10	None	3,500	3,667	3,580	2,800	2,035	3,116							10
11	Superphosphate, potash and nitrate 160 (1)	4,270	4,725	5,675	4,390	3,985	4,609	754	1,250	2,047	1,582	1,912	1,509	11
12	Superphosphate, potash and nitrate 320	4,262	4,835	5,965	4,360	3,540	4,592	730	1,551	2,298	1,543	1,428	1,510	12
13	None	3,548	3,092	3,710	2,825	2,150	3,065							13
14	Superphosphate, potash and nitrate 480 (2)	3,920	4,592	5,820	4,235	3,515	4,416	344	1,428	2,280	1,447	1,553	1,410	14
15	Superphosphate, potash and ammonia	3,920	3,720	4,660	3,860	3,310	3,894	316	485	1,290	1,108	1,537	947	15
16	None	3,632	3,307	3,200	2,715	1,585	2,888							16
17	Rock phosphate, potash and nitrate (1)	3,460	4,175	4,860	3,720	2,845	3,812	—153	987	1,607	1,090	1,192	945	17
18	Slag phosphate, potash and nitrate (1)	3,542	4,312	4,800	3,870	2,790	3,863	— 49	1,243	1,493	1,325	1,082	1,017	18
19	None	3,570	2,950	3,360	2,460	1,790	2,826							19
20	Barnyard manure	4,030	3,850	4,810	3,110	3,490	3,858	770	991	1,645	787	1,648	1,168	20
21	Linseed oil-meal	3,618	3,775	4,670	2,835	3,154	3,610	668	1,007	1,700	648	1,234	1,051	21
22	None	2,640	2,677	2,775	2,050	1,985	2,425							22
	Average of unfertilized plots	3,588	3,240	3,672	2,673	1,951	3,025							
	Average increase from fertilizers							233	835	1 202	949	1,225	889	

(1) 480 pounds nitrate in 1889. (2) 160 in 1889.

(3) Corrected weight. The weights reported for "straw" in the bulletin for 1890, page 52, include total produce.

RATIO OF STRAW TO GRAIN.

Table IV shows the number of pounds of straw required to carry bushel of grain on each plot of the wheat in continuous culture for eac year of the test and for the five-year average:

TABLE IV.—FERTILIZERS ON WHEAT, FIVE YEARS IN SUCCESSION.

Pounds of STRAW *to one bushel of grain.*

Plot No.	Fertilizers.	Straw to bushel.						Plot No.
		1889.	1890.	1891.	1892.	1893.	Av.	
1	None	80	113	140	115	78	105	1
2	Superphosphate (dissolved bone-black)	82	109	170	137	93	118	2
3	Potash (muriate)	80	95	124	113	78	98	3
4	None	90	103	124	98	61	95	4
5	Nitrate of soda (1)	89	108	118	97	86	100	5
6	Nitrate and superphosphate (1)	86	113	171	132	80	116	6
7	None	85	101	120	100	78	97	7
8	Superphosphate and potash	80	114	150	120	93	111	8
9	Nitrate and potash (1)	99	105	132	103	84	105	9
10	None	80	113	114	100	73	96	10
11	Superphosphate, potash and nitrate, 160 (2)	86	128	197	151	103	133	11
12	Superphosphate, potash and nitrate, 320	86	135	192	149	83	129	12
13	None	80	104	118	106	78	97	13
14	Superphosphate, potash and nitrate, 480 (1)	83	131	202	145	88	130	14
15	Superphosphate, potash and ammonia	83	110	156	127	95	114	15
16	None	96	102	104	97	63	92	16
17	Rock phosphate, potash and nitrate (1)	86	112	146	119	87	110	17
18	Slag phosphate, potash and nitrate (1)	90	116	151	122	79	112	18
19	None	88	95	107	97	78	93	19
20	Barnyard manure	90	111	176	122	94	99	20
21	Linseed oil-meal	93	111	134	103	89	106	21
22	None	72	101	102	90	80	89	22
	Average of unfertilized plots	84	104	116	100	74	95	

(1) 480 pounds nitrate in 1889.
(2) 160 pounds nitrate in 1889.

The crop of 1893 has shown a larger increase from the fertilizers than any other crop of the series. In one case (plot 12) the yield practically reaches the average unfertilized yield on clover sod in 1889, the increase amounting to fifteen bushels per acre. This increase, however, was produced at a cost of $14.25 in fertilizers.

On the plot fertilized with barnyard manure the increase this year gives nearly fourteen bushels of wheat for eight tons of manure, or a bushel and three-fourths of wheat to the ton of manure.

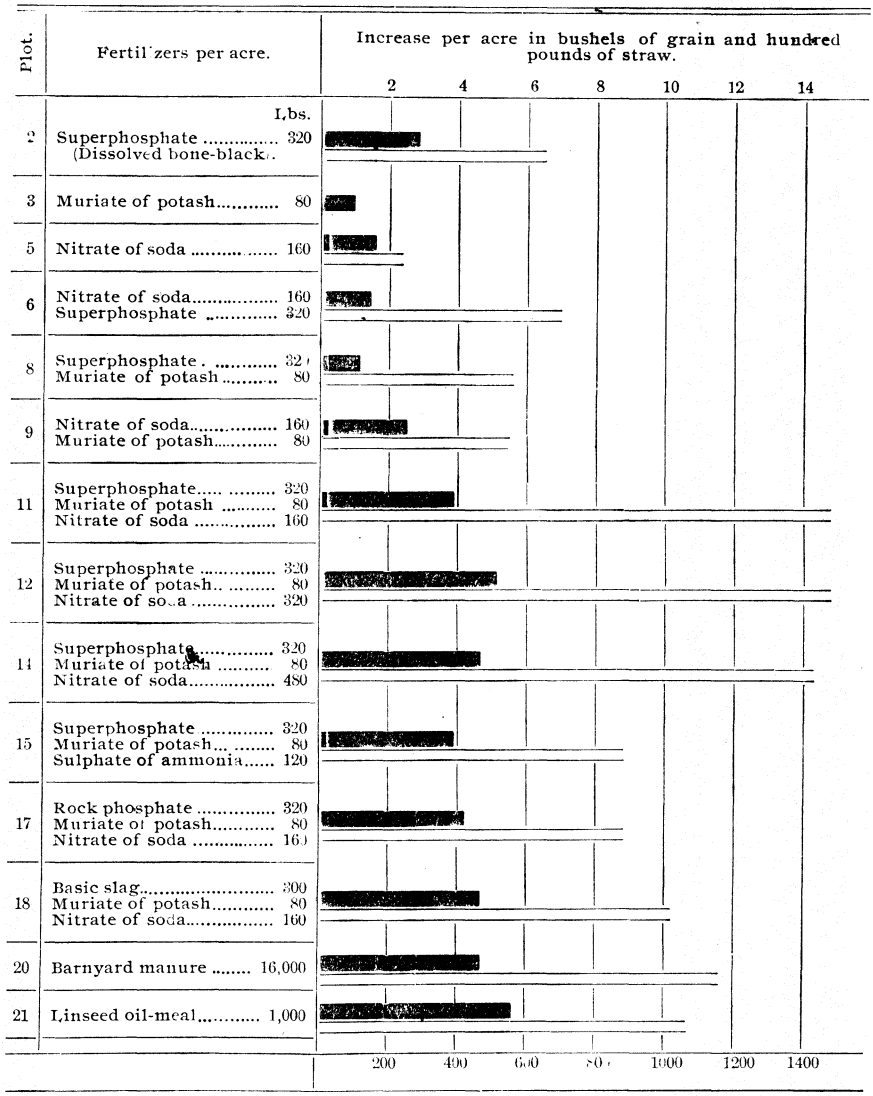
In the five-year average, however, the increase from manure has been but little more than half a bushel to the ton, and in the most favorable outcome it has been less than three-fourths of a bushel to the dollar's worth of chemical fertilizers.

In the following diagram is shown the relative increase of grain and straw for the five years, the increase of grain being shown in shaded lines, that of straw in open lines. Table IV shows that in the general average it has required ninety-five pounds of straw to carry a bushel of grain on the unfertilized plots. Had the fertilized plots carried grain in the proportion of one bushel to 100 pounds of straw the lines showing increase of grain would have coincided with those showing increase of straw, giving a very different result from that actually obtained.

Fertilizers on Wheat in Continuous Culture.

Average annual increase per acre for five years.

Grain ▬▬▬; Straw ═══.



Attention is called to the effect of the different fertilizing constituents, as graphically shown in this diagram, and especially as manifested in the increase of straw. The great increase of straw following the use of phosphoric acid in any form, and especially in the form of bone-black superphosphate, is most conspicuous, as well as the fact that while nitrogen and potash, used without phosphoric acid, have produced comparatively little increase, yet when both nitrate of soda and muriate of

potash have been added to superphosphate they have more than doubled the yield of straw over that given by superphosphate alone, or superphosphate in combination with either the nitrate or muriate, but not with both.

Apparently the rock superphosphate and the basic slag are producing quite as large an increase of grain as the bone superphosphate, although the increase of straw is considerably smaller.

COST AND VALUE OF INCREASE.

During the five years over which this experiment has now extended the cash price of No. 2 spring wheat (the standard grade) has averaged 83½ cents in Chicago, as reported by the *Cincinnati Price Current.* This would represent an average value in Ohio not exceeding 80 cents.

Table V. shows the financial outcome of this attempt at maintaining fertility by the use of chemical fertilizers; the cost of fertilizers being estimated at the present retail cost of fertilizing chemicals in Ohio (which is considerably less than the average cost of the ordinary mixed fertilizers of equal quality, as sold to the farmers) and the value of the product being based upon 80 cents per bushel for wheat and $3.00 per ton for straw. Barnyard manure is valued at 50 cents per ton, a price which will considerably more than cover the cost of getting it from the barnyard to the field on the ordinary farm; but if the manure is purchased in town and hauled several miles its cost may equal that of the chemical fertilizers.

TABLE V.—FERTILIZERS ON WHEAT IN CONTINUOUS CULTURE.

Average value of increase and cost of fertilizers for five years.

Values per acre per annum.

Plot No.	Value of increase.			Cost of fertilizer.	Profit (+) or loss (—).
	Grain.	Straw.	Total.		
2	$2.32	$1.13	$3.45	$4.00	$—0.55
3	0.64	0.01	0.65	1.75	—1.10
5	1.36	0.38	1.64	4.25	—2.61
6	1.04	1.10	2.14	8.25	—6.11
8	0.96	0.85	1.81	5.75	—3.94
9	2.24	0.84	3.08	6.00	—2.92
11	3.20	2.26	5.46	10.00	—4.54
12	4.08	2.26	6.34	14.25	—7.91
14	3.44	2.11	5.55	18.50	—12.95
15	3.20	1.42	4.62	10.25	—5.63
17	3.36	1.42	4.78	8.55	—3.77
18	3.68	1.52	5.20	9.45	—4.25
20	3.60	1.75	5.35	4.00	+1.35
21	4.48	1.58	6.06	13.00	—6.94

It should be distinctly understood that the problem in this case is not the restoring of fertility to a worn out soil, but it is one of not less importance, namely: the maintenance in productiveness of an already fertile soil. Of course, no intelligent farmer would attempt to solve this problem by the continuous culture of wheat manured only with chemicals; but it is only by this method that the actual capacity of the plant for securing its sustenance can be determined. This experiment shows that a method which would at once be condemned as irrational, from the farmer's standpoint, may yet be followed with profit when barnyard manure is substituted for chemicals.

FERTILIZERS ON OATS GROWN CONTINUOUSLY ON THE SAME LAND.

In Tables VI and VII are given the yield and increase of grain and straw for five years in the experiments with oats. It will be observed that each of the three fertilizing substances has apparently produced about the same increase of crop, and that no combination of these substances has added materially to the yield which followed their separate use. The explanation of this is partly to be found in the fact that the oat plant does not find in the climate of southern Ohio the conditions suited to its normal development. It will be noticed that not one of the five crops under review has given what would be called a good yield.

TABLE VI.—FERTILIZERS ON OATS, FIVE YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels of 32 pounds.*

Plot No.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		1889.	1890.	1891.	1892.	1893.	Average.	1889.	1890.	1891.	1892.	1893.	Average.	
1	None	44.2	16.0	[2]										1
2	Superphosphate (dissolved bone black)	46.9	19.4	46.6	29.4	[4]		1.4	3.4	6.4	0.6			2
3	Potash (muriate)	59.5	19.7	45.9	32.5	33.9	38.3	12.6	3.7	5.7	3.7	4.1	5.9	3
4	None	48.2	16.0	40.2	28.8	29.8	32.6							4
5	Nitrate of soda	47.2	21.1	45.6	32.7	39.2	37.2	0.1	3.9	5.3	5.4	8.4	4.6	5
6	Nitrate and superphosphate	48.4	22.3	51.2	32.2	37.6	38.3	2.3	3.8	10.7	6.4	5.7	5.8	6
7	None	45.0	19.7	40.6	24.3	32.9	32.5							7
8	Superphosphate and potash	45.0	21.6	46.6	32.2	32.7	35.6	—0 8	2.3	4.8	4.5	—1.3	1.8	8
9	Nitrate and potash	48.4	23.7	46.6	40 3	38.6	39.5	1.8	4.9	2.7	9.3	3.6	4.4	9
10	None	47.5	18.4	45.6	34.4	36.1	36.5							10
11	Superphosphate, potash and nitrate, 160	52.9	24.7	50.9	40.9	43.9	42.7	5.6	7.4	6.0	3.6	5.3	5.6	11
12	Superphosphate, potash and nitrate, 320	47.8	25.3	52.3	43.1	44.5	42.6	0.8	9.0	8.2	3.0	3.4	4.9	12
13	None	46.8	15.2	43.4	43.0	43.6	38.5							13
14	Superphosphate, potash and nitrate, 480[1]	45.0	20.8	48.4	43.3	46.2	40.7	1.6	4.3	3.9	2.1	6.5	3.6	14
15	Superphosphate, potash and ammonia	51.8	23.9	49.4	40.1	38.7	40.8	11.9	6.0	3.9	0.8	2.8	5.1	15
16	None	36.5	19.2	46.6	37.5	32.0	34.4							16
17	Rock phosphate, potash and nitrate	47.3	21.6	49.7	41.1	44.7	40.9	10.3	4.0	3.7	4.0	12.7	6.9	17
18	Slag phosphate, potash and nitrate	45.7	22.8	51.6	43.6	[4]		8.4	6.7	6.3	6.8			18
19	None	37.9	14.5	44.7	36.4	[4]								19
20	Barnyard manure	42.8	19.1	50.3	36.9	30.8	36.0	2.2	3.3	5.6	0.5	2.7	2.9	20
21	Linseed oil meal	50.6	14.8	46.7	25.8	33.3	34.2	7.2	—2.3	2.0	—10.6	5.2	0.3	21
22	None	46.1	18.4	[4]	[3]	28.1								22
	Average of unfertilized plots	44.0	17.2	43.5	34.1	33.7	35.1							
	Average increase from fertilizers							4.7	4.5	5.3	2.9	4.9	4.4	

[1] Dried blood, 160 pounds, instead of nitrate in 1892. [2] This plot cut into by opening of street. [3] Injured by grasshoppers. [4] Record lost.

TABLE VII.—FERTILIZERS ON OATS, FIVE YEARS IN SUCCESSION.

Yield and increase of STRAW *in pounds per acre.*

Plot No.	Fertilizers.	Yield.						Increase or decrease (—).						Plot No.
		1889.	1890.	1891.	1892.	1893.	Average.	1889.	1890.	1891.	1892.	1893.	Average.	
1	None	3,180	1,900	(2)		(3)								1
2	Superphosphate	3,520	2,370	3,310	2,960			133	343	845	180			2
3	Muriate potash	4,220	2,270	2,680	3,100	1,365	2,727	627	317	215	380	240	300	3
4	None	3,800	1,980	2,465	2,780	1,125	2,430							4
5	Nitrate soda	3,980	2,680	2,540	3,155	1,395	2 750	233	653	100	478	263	345	5
6	Superphosphate and nitrate	4,068	2,900	2,160	3,020	1,405	2,711	375	827	—260	445	267	331	6
7	None	3,640	2,120	2,400	2,472	1,145	2,356							7
8	Superphosphate and potash	3,660	2,580	2,910	3,170	1,205	2,705	—87	300	430	541	77	251	8
9	Potash and nitrate	4,040	3,070	2,810	2,960	1,395	2,855	197	630	250	169	283	305	9
10	None	3,960	2,600	2,640	2,950	1,095	2,649							10
11	Superphosphate, potash and nitrate, 160	4,400	3,210	2620	2,940	1,575	2,949	487	587	5	—68	393	281	11
12	Superphosphate, potash and nitrate, 320	4,300	3,320	2,875	3,020	1,875	3,078	433	673	290	—47	607	391	12
13	None	3,820	2,670	2,560	3 125	1,355	2,706							13
14	Superphosphate, potash and nitrate, 480 (1)	3,880	2,930	2,550	3,665	1,752	2,956	267	450	57	732	450	391	14
15	Superphosphate, potash and ammonia	4,060	3,270	2,670	2,965	1,370	2,867	653	980	243	223	122	444	15
16	None	3,200	2,100	2,360	2,550	1,195	2,281							16
17	Rock phosphate, potash and nitrate	3,800	2,910	2,110	3,435	1,455	2,740	647	860	—120	640	260	457	17
18	Slag phosphate, potash and nitrate	3 500	3,120	2,200	3,205	(3)		363	1,120	100	165			18
19	None	3,060	1,950	1,970	3,285	(3)								19
20	Barnyard manure	3,140	2,650	2,540	3,420	1,615	2,673	—167	450	570	143	450	290	20
21	Linseed oil meal	4,100	2,470	2,215	3,675	1,935	2,879	547	20	245	407	770	400	21
22	None	3,800	2,700	(3)	3,260	1,080								22
	Average of unfertilized plots	3,557	2,252	2,400	2,917	1,166	2,484							
	Average increase from fertilizers							338	586	212	313	350	350	

(1) Dried blood, 160 lbs. instead of nitrate, in 1892 and 1893. (2) Plot cut into by opening of street. (3) Record lost.

FERTILIZERS ON CORN GROWN CONTINUOUSLY ON THE SAME LAND.

Table VIII gives the yield and increase of grain and stalks for 1893 and the average of the six years during which corn has been grown continuously (the experiments with corn beginning with 1888). The yields of grain are reported in bushels of seventy pounds of ears, and by "stalks" is meant stalks and leaves, the corn being cut about four inches from the ground.

TABLE VIII.—FERTILIZERS ON CORN SIX YEARS IN SUCCESSION.

Yield and increase per acre.

Plot No.	Fertilizer.	Yield per acre.				Inc. or dec. (—) per acre.				Plot No.
		Grain.		Stalks.		Grain.		Stalks.		
		1893.	Av. 6 yrs.	1893.	Av. 6 yrs.	1893.	Av. 6 yrs.	1893.	Av. 6 yrs	
		Bu.	*Bu.*	*Lbs.*	*Lbs.*	*Bu.*	*Bu.*	*Lbs.*	*Lbs.*	
1	None	35.6	60.0	2,050	3,769	.....	.....	.....	.....	1
2	Superphosphate (dissolved bone black)	38.3	59.7	2,225	3,520	1.9	—1.1	117	—218	2
3	Potash (muriate)	40.7	61.3	2,550	4,120	3.3	—0.3	363	413	3
4	None	38.2	62.3	2,225	3,676	.....	.....	.....	.....	4
5	Nitrate of soda	37.6	65 0	2,475	4,443	—0.2	3.7	250	742	5
6	Nitrate and superphosphate	38.9	66.4	2,550	4,294	1 4	6.0	325	568	6
7	None	37.0	59.4	2,225	3,751	.....	.....	.....	.....	7
8	Superphosphate and potash	40.0	61.6	2,550	4,067	2 6	1.8	320	298	8
9	Nitrate and potash	40.7	66.6	2,610	4,464	2.8	6.3	575	678	9
10	None	38.3	60.7	2,240	3 804	.....	.....	.....	.....	10
11	Superphosphate, potash and nitrate 160	41.2	65.7	2,750	4,216	1.6	4.3	490	383	11
12	Superphosphate potash and nitrate, 320	40.2	66.8	2,900	4,298	—0.8	4 7	620	441	12
13	None	42.4	62.8	2,300	3,883	.....	.....	.....	.....	13
14	Superphosphate, potash and nitrate, 480	40.2	64.9	2,800	4,355	—0.4	4.3	583	707	14
15	Superphosphate, potash and ammonia	42.0	61.4	2,500	4,274	3.2	3.1	367	821	15
16	None	37.0	56.1	2,050	3,177	.....	.....	.....	.....	16
17	Rock phosphate, potash and nitrate	40.4	63.0	2,275	4 105	2.8	7.3	317	867	17
18	Slag phosphate, potash and nitrate	38.2	62.4	2,525	3,985	0	7.2	658	6 8	18
19	None	38.7	55.0	1,775	3,359	.....	.....	.....	.....	19
20	Barnyard manure	39.8	63.0	2,425	3,737	0.1	5.2	550	322	20
21	Linseed oil meal	42 4	68.4	2,425	4,320	1.7	7.6	450	850	21
22	None	41.7	63.7	2,075	3,526	.....	.....	.....	.....	22
	Average of unfertilized plots	38.6	60.0	2,117	3,618	.....	.....	.....	.....	
	Average increase from fertilizers	.....	.....	.....	.....	1.2	3.8	361	472	

A striking feature of this test is the small increase of crop from the fertilizers in 1893, the sixth year of successive cropping. This is partly explained by the generally low yield, due to the severe drouth of the summer.

In the six-year average the corn on this land has apparently received no benefit from phosphoric acid or potash, used separately or in combination with each other only; but when nitrogen has been added a decided though small increase of crop is shown in every case. The increase in corn has not been so regular as that in wheat, but it will be observed that the general average increase in the three crops, corn, wheat and oats, is approximately the same—about four bushels per acre.

FERTILIZERS ON CROPS GROWN IN ROTATION.

Parallel with the experiments in continuous cropping, an experiment has been conducted on the Columbus farm in which corn, oats and wheat are grown in rotation with clover and timothy. In this experiment five blocks of land, each containing seven plots of one-twentieth acre each, are cultivated in these crops, the cropping being so managed that each crop is represented each year.

Following is the plan of fertilizing each block:

Plot 1. Unfertilized.

Plot 2. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre, * on corn only.

Plot 3. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre, * on wheat only.

Plot 4. Unfertilized.

Plot 5. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre; * nitrate of soda, 160 pounds per acre, on wheat only.

Plot 6. Barnyard manure, 8 tons per acre, on wheat only.

Plot 7. Unfertilized.

*160 pounds, previous to 1892.

In 1889 and 1890 the crops in this rotation were not grown under such conditions as would make them fairly comparable with the continuous cropping. In 1891 and subsequently, however, the crops grown in rotation have received the same treatment, with respect to preparation of soil, seeding, variety used, etc., as that given the crops in continuous culture. Tables IX and X give the results for wheat of the harvests of 1891, 1892 and 1893, with the average for the three years:

TABLE IX.—WHEAT GROWN IN ROTATION.

Yield and increase of GRAIN *per acre.*

Yield per acre.							Increase or decrease (—) per acre.			
1891.		1892.		1893.		Average.	1891.	1892.	1893.	Average.
Plot	*Bushels.*	*Plot*	*Bushels.*	*Plot*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
25	36.7	1	34.2	8	35.2	35.4	.....	.....	.....	.....
26	37.8	2	32.4	9	37.0	35.7	0.2	0.1	1.0	0.4
27	36.2	3	35.7	10	41.2	37.7	—2.4	5.4	4.4	2.4
28	39.5	4	28.4	11	37.6	35.2	.....	.....	.....	.....
29	36.3	5	35.6	12	43.1	38.3	—1.8	6.7	7.6	4.2
30	38.0	6	28.4	13	36.9	34.4	1.2	—0.9	1.5	0.6
31	35.5	7	29.7	14	34.2	33.1	.....	.....	.....	.....
*	37.2		30.8		35.7	34.6				

* Average of unfertilized plots.

TABLE X.—WHEAT GROWN IN ROTATION.

Yield and increase of STRAW *per acre.*

Yield per acre.							Increase or decrease (—) per acre.			
1891.		1892.		1893.		Average.	1891.	1892	1893.	Average.
Plot	*Pounds.*	*Plot*	*Pounds.*	*Plot*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
25	4,800	1	3,530	8	3,285	3,872	.....	.....	.....	.....
26	3,730	2	3,040	9	3,380	3,383	—913	—220	48	—362
27	5,830	3	3,440	10	3,950	4,407	1,343	477	572	797
28	4,330	4	2,680	11	3,425	3,478	.....	.....	.....	.....
29	6,120	5	3,550	12	4,075	4,582	1,877	923	723	1,174
30	4,520	6	2,980	13	3,385	3,628	363	487	107	292
31	4,070	7	2,520	14	3,205	3,265	.....	.....	.....	.....
*	4,400		2,310		3,305	3,538				

* Average of unfertilized plots.

Comparing the average yields of the plots similarly treated in the continuous and rotative cropping, we have the results given in Table XI:

TABLE XI.—CONTINUOUS, COMPARED WITH ROTATIVE CROPPING OF WHEAT.

Fertilizer.	Culture.	Yield of grain per acre.			
		1891.	1892.	1893.	Average.
		Bus.	*Bus.*	*Bus.*	*Bus.*
None	Continuous	31.4	26.5	26.4	28.1
	Rotative	37.2	30.8	35.7	34.6
Superphosphate	Continuous[1]	30.5	30.2	36.0	32.2
	Rotative	36.2	35.7	41.2	37.7
Superphosphate, potash and nitrate	Continuous[2]	28.8	29.1	38.6	32.2
	Rotative	36.3	35.6	43.1	38.3
Barnyard manure	Continuous[3]	27.3	25.4	37.3	30.0
	Rotative	38.0	28.4	36.9	34.4
Average	Continuous	29.5	27.8	34.6	30.6
	Rotative	36.9	32.6	39.2	36.2
Average increase for rotation		7.4	4.8	4.6	5.6

[1] Plot 8; [2] Plot 11; [3] Plot 20, in continuous cropping.

It will be observed that not only in the general average, but in every single instance except that of the plots dressed with barnyard manure in 1893, the plots upon which wheat is grown in rotation have exceeded in yield the similarly treated plots upon which it is grown continuously.

Table XII shows the ratio of straw to grain in the rotative cropping and for the plots similarly treated in continuous cropping:

TABLE XII.—ROTATIVE, COMPARED WITH CONTINUOUS, CROPPING OF WHEAT.

Pounds of STRAW *to one bushel of grain.*

Rotative.					Continuous.				
Plot.	1891.	1892.	1893.	Average.	Plot.	1891.	1892.	1893.	Average.
1	133	103	93	109	.....	.....	.....	.....	.....
2	99	94	91	95	.....	.....	.....	.....	.....
3	161	96	96	117	8	150	120	93	121
4	110	94	91	98	.....	.....	.....	.....	.....
5	169	99	94	119	11	197	151	103	150
6	119	105	91	105	20	176	122	94	131
7	115	85	94	99	.....	.....	.....	.....	.....
Av. unfertilized.	119	94	93	102	.....	116	100	74	97

This table shows that wherever fertilizers or manure was used more straw has been required to carry a bushel of grain in continuous than in rotative cropping. In 1891 and 1892 the wheat lodged badly on several of the plots in continuous culture; but there was little or no lodging on the similarly fertilized plots in rotation.

FERTILIZERS ON OATS GROWN IN ROTATION.

The experiments on oats grown in rotation have been still less satisfactory than those on oats grown continuously, only one crop having thus far been brought into the full plan of fertilization. The results of the three harvests, 1891, 1892 and 1893 are given in Tables XIII and XIV. In 1891 none of the plots had been fertilized, but the yield is given for comparison with the yields of the unfertilized plots in continuous cropping. In 1892 the plots had all been fertilized according to plan. In 1893 only the second plot had been fertilized; and the yields of the last three plots are omitted because of discrepancies.

Apparently, the application of phosphoric acid and potash to oats, either directly or to the preceding crop of corn, is of considerable advantage, while the use of nitrogenous manures has been of doubtful benefit; but it is evidently unsafe to draw any general conclusions as yet from these experiments.

The variety of oats called Japan has been used in these tests in 1891 and subsequently, both in the continuous and rotative cropping.

TABLE XIII.—OATS GROWN IN ROTATION.

Yield and increase of GRAIN *in bushels per acre.*

Rotative cropping.								Continuous cropping.		
Yield per acre.						Increase or decrease (—) per acre.		Yield per acre.		
1891.		1892.		1893.		1892.	1893.	1891.	1892.	1893.
1	46.8	8	29.2	15	29.8	.....	.....	.....	.....	.....
2	46.8	9	37.3	16	37.0	6.7	5.8	46.6	32.2	32.7
3	46.2	10	33.0	17	27.6	1.1	.....	.....	.....	.....
4	45.6	11	33.3	18	33.9	.....	.....	.....	.....	.....
5	45.0	12	35.8	19	.....	3.1	.....	.....	40.9	.....
6	43.7	13	27.7	20	.....	—4.3	.....	.....	36.9	.....
7	41.8	14	31.4	21	.....	.....	.....	.....	.....	.....
*	44.7		31.3		30 4	.....	.....	43.5	34.1	33.7

* Average unfertilized

TABLE XIV.—OATS GROWN IN ROTATION.

Yield and increase of STRAW *in pounds per acre.*

Rotative cropping.										
Yield per acre.						Increase or decrease (—) per acre.		Straw to 1 bushel grain.		
1891.		1892.		1893.		1892.	1893.	1891.	1892.	1893.
1	2,700	8	3,665	15	1,745	.....	.....	58	125	58
2	2,400	9	4,205	16	2,015	583	3.7	51	113	54
3	2,320	10	3,945	17	1,415	368	.....	50	120	51
4	2,740	11	3,535	18	1,575	.....	.....	60	106	46
5	2,460	12	4,855	19	.....	1,500	.....	55	107	.....
6	2,300	13	2,915	20	.....	—260	.....	53	105	.....
7	2,660	14	2,995	21	.....	.....	.....	64	95	.....
*	2,700		3,398		1,669	.....	.....	61	109	52

* Average unfert lized.

FERTILIZERS ON CORN GROWN IN ROTATION.

In the rotation experiments no corn has yet come fully under the plan of the experiment, because of the irregularities in cropping incident to getting the rotation regularly started. The crop of 1890 followed oats, and received the application of superphosphate and muriate of potash on the second plot; the crop of 1891 followed wheat, and both the wheat

and the corn were fertilized according to plan, but there was no intervening crop of clover and timothy; the crop of 1892 followed clover and received phosphoric acid and potash as planned, but the preceding wheat crop was not fertilized; the crop of 1893 followed two crops of clover and timothy, and received phosphoric acid and potash as planned, but the wheat crop was not fertilized. Tables XV and XVI give the yields of these crops:

TABLE XV.—FERTILIZERS ON CORN IN ROTATION.

Yield and increase of GRAIN *in bushels of 70 lbs. ears.*

Yield per acre.								Increase or decrease (—) per acre.			
1890.		1891.		1892.		1893.		1890.	1891.	1892.	1893.
Plot.	*Bu.*	*Plot.*	*Bu.*	*Plot.*	*Bu.*	*Plot.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1	44.0	8	55.0	15	67.4	32	37.9	.....	.....	.....	.....
2	43.8	9	66.4	16	70.6	33	41.0	—0.7	7.7	1.9	0.9
3	46.9	10	71.8	17	72.0	34	40.5	.....	9.2	.....	.....
4	45.4	11	66.4	18	71.1	35	44.4	.....	.....	.....	.....
5	41.1	12	71.6	19	63.1	36	43.4	.....	5.3	.....	.....
6	41.7	13	74.1	20	70.9	37	44.4	.....	8.1	.....	.....
7	44.7	14	65.8	21	66.9	38	37.2	.....	.....	.....	.....
*	44.7	.....	62.4	.....	68.5	.....	39.9	.....	.....	.....	.....
**	46.6	.....	57.3	.....	65.4	.....	38.6	.....	.....	.....	.....

*Average unfertilized. **Average of unfertilized crops in continuous culture, for comparison.

TABLE XVI.—FERTILIZERS ON CORN IN ROTATION.

Yield and increase of STALKS *in pounds per acre.*

Yield per acre.								Increase or decrease (—) per acre.			
1890.		1891.		1892.		1893.		1890.	1891.	1892.	1893.
Plot.	*Lbs.*	*Plot.*	*Lbs.*	*Plot.*	*Lbs.*	*Plot.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	2,411	8	2,680	15	3,600	32	2,300	.....	.....	.....	.....
2	2,090	9	3,280	16	4,100	33	2,700	—117	467	560	366
3	2,039	10	3,540	17	3,500	34	2,800	.....	593	.....	.....
4	1,800	11	3,080	18	3,420	35	2,400	.....	.....	.....	.....
5	1,964	12	3,540	19	2,800	36	2,800	.....	553	.....	.....
6	1,708	13	3,080	20	3,100	37	2,200	.....	207	.....	.....
7	1,646	14	2,800	21	2,800	38	2,000	.....	.....	.....	.....
*	1,952	.....	2,853	.....	3,273	.....	2,233	.....	.....	.....	.....
**	2,478	.....	3,333	.....	3,720	.....	2,117	.....	.....	.....	.....

*Average unfertilized. **Average of unfertilized crops in continuous culture, for comparison.

In 1891 the corn seems to have been benefited by the residue of fertilizers applied to the preceding wheat crop; but with this exception, the fertilizers have had practically no effect. It appears that the yield of grain on the unfertilized plots has been slightly greater from the corn in rotation than from that in continuous culture (except in 1890), while the reverse has been the case, except in 1893, with regard to the stalks.

CLOVER AND TIMOTHY AFTER FERTILIZERS.

Only one hay crop has thus far come under the complete plan of fertilizing, namely: the first crop of 1893. The first crop of 1892 and the second crop of 1893 have received the benefit of the fertilizers applied to wheat, but not of those designed for corn. In Table XVII are given the yields of all the hay crops harvested.

TABLE XVII.—CLOVER AND TIMOTHY AFTER FERTILIZERS.

Yield of HAY *in pounds per acre.*

1891.		1892.				1893.				Average for fertilized crops.	Increase.
1st crop.[1]		1st crop.[2]		2d crop.[1]		1st crop.[3]		2d crop.			
Plot.	*Lbs.*	*Plot.*	*Lbs.*	*Plot*	*Lbs.*	*Plot.*	*Lbs.*	*Plot.*	*Lbs*		
32	3,270	25	4,600	32	6,120	1	4,040	25	[4].....	4,320	.....
33	2,850	26	5,000	33	5,400	2	6,100	26	[4].....	6,100	1,673
34	3,650	27	5,000	34	5,800	3	6,360	27	4,000	5,120	475
35	3,400	28	4,920	35	5,280	4	5,200	28	4,300	4,807	.....
36	3,200	29	5,200	36	5,720	5	5,100	29	4,300	4,867	276
37	3,100	30	5,120	37	5,400	6	5,300	30	3,900	4,773	397
38	2,700	31	4,680	38	5,600	7	4,800	31	3,000	4,160	.....
*	3,123	.....	4,733	.....	5,667	.....	4,680	.....	3,650	4,429	.....

*Average unfertilized.
[1]Unfertilized.
[2]Fertilized, except plot 2.
[3]Fertilized in full.
[4]Data unreliable.

SUMMARY OF INCREASE IN ROTATED CROPS.

In Table XVIII is given the average increase from fertilizers in the crops of this rotation, with the total value of such increase per acre, corn being valued at 35 cents per bushel, oats 33 cents, wheat 80 cents, hay $8.00 per ton and straw and corn fodder $3.00 per ton:

TABLE XVIII.—AMOUNT AND VALUE OF INCREASE PER ACRE IN 5-CROP ROTATION.

Plot.	Grain.			Straw.			Hay.	Total value per acre.	Cost of fertilizers.
	Corn.	Oats.	Wheat.	Corn.	Oats.	Wheat.			
	Bus.	*Bus.*	*Bus.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		
2	[4]2.5	[2]6.2	[4]0.4	[4]419	[2]460	—[4]362	[1]1673	.....	.....
3	[1]9.2	[1]1.1	[4]2.4	[1]593	[1]368	[4]797	[3]475	.....	.....
*	3.8	4.5	1.4	454	429	217	775	$8.79	$5.47
5	[1]5.3	[1]3.1	[4]4.2	[1]553	[1]1500	[4]1174	[3]276	12.17	9.72
6	[1]8.1	—[1]4.3	[4]0.6	[1]207	—[1]260	[4]292	[3]397	3.97	4.00

*Average of 2 and 3. [1] One crop. [2] Average of two crops. [3] Average of 3 crops. [4] Average of four crops.

These figures will doubtless be considerably modified by the results of future cropping. The work in continuous culture has forcibly illustrated the danger of drawing general conclusions from the results of a single harvest; but in the majority of cases the figures in this table represent but one season's outcome. They are published as a report of progress, and for future reference. So far as they go they support the general and reasonable belief that a large part of the benefit from commercial or other manures is to be realized in the crops not directly fertilized, in a well planned rotation.

CO-OPERATIVE EXPERIMENTS WITH FERTILIZERS ON CORN.

Co-operative experiments with fertilizers on corn were made in 1893, as in 1891 and 1892, in Columbiana, Washington and Butler counties, thus representing the extreme eastern, south-eastern and south-western parts of the State.

Tables XIX to XXIV give the plan and results of these experiments, the superphosphate being in all cases dissolved bone black and used at the rate of 320 pounds per acre, the muriate of potash being used at the rate of 80 pounds per acre in 1891 and '92, and 160 pounds per acre previous to 1891; the nitrate of soda at the rate of 160 pounds per acre, the barnyard manure at the rate of 8 tons per acre and the land plaster at the rate of 400 pounds per acre.

FARM TEST IN COLUMBIANA COUNTY.

Made by H. Y. Bentley.

This test has been repeated six years in succession on the same land and under the personal superintendence of the Agriculturist of the Station. The land is high upland and underlaid with slaty rocks, which give partial drainage. Previous to 1888 it had been in pasture for several years, but the growth of grass (chiefly blue grass) had become quite uneven. Tables XIX and XX give the yield of grain and stalks for the six years:

TABLE XIX.—FERTILIZERS ON CORN IN COLUMBIANA COUNTY.

Yield and increase of GRAIN *in bushels of 70 lbs. ears*

Plot No.	Fertilizers.	Yield per acre.							Increase or decrease (—) per acre.							Plot No.
		1888	1889	1890	1891	1892	1893	Average.	1888.	1889.	1890.	1891.	1892.	1893.	Average.	
1	None	35.5	52.9	20.4	21.3	16.0	5.7	25.3								1
2	Superphosphate	35.9	56.4	18.3	22.4	15.7	4.1	25.5	—2.3	1.8	—2.6	—2.0	—2.1	—2.0	—1.5	2
3	Muriate of potash	39.4	56.2	19.5	27.3	18.1	5.9	27.7	—1.6	0	—1.8	—0.3	—1.8	—0.5	—1.0	3
4	None	43.7	57.9	21.8	30.7	21.3	6.8	30.4								4
5	Nitrate of soda	70.8	58.5	30.2	38.2	26.5	5.4	38.3	18.1	—2.0	8.1	6.4	5.1	—1.8	5.6	5
6	Nitrate and superphosphate	90.0	62.2	30.1	37.5	23.8	6.7	41.7	28.4	—1.0	7.6	4.5	2.2	—0.4	6.8	6
7	None	70.6	65.8	22.8	34.1	21.7	8.1	37.2								7
8	Superphosphate and potash	70.6	62.8	14.9	23.7	15.9	7.3	32.5	—0.1	—1.8	—8.1	—8.8	—6.1	—1.2	—4.3	8
9	Nitrate and potash	90.4	67.0	31.7	39.0	26.5	9.6	44.0	20.0	3.6	8.4	8.1	4.1	0.6	7.5	9
10	None	70.2	62.2	23.5	29.3	22.7	9.4	36.2								10
11	Superphos., potash and nitrate	74.8	66.1	24.9	31.9	24.3	9.3	38.5	7.7	5.4	1.4	2.7	2.5	0.4	3.4	11
12	Barnyard manure	61.8	73.8	30.6	28.5	22.7	6.9	37.4	—2.1	14.5	7.0	—0.7	2.4	—1.5	3.3	12
13	None	60.8	57.8	23.6	29.1	19.1	7.9	33.1								13
14	Land plaster	60.0	59.9	20.5	23.5	15.4	6.3	31.0	—0.8	2.1	—3.1	—5.6	—3.7	—1.6	—2.1	14
	Average of unfertilized plots	56.2	59.3	22.5	28.9	20.2	7.6	32.4								
	Average increase from fertilizers								7.5	2.5	1.9	0.5	0.3	—0.9	2.0	

TABLE XX.—FERTILIZERS ON CORN IN COLUMBIANA COUNTY.

Yield and increase of STALKS, *in pounds, per acre.*

Plot No.	Fertilizers.	Yield per acre.							Increase or decrease (—) per acre.							Plot No.
		1888.	1889.	1890.	1891.	1892.	1893.	Average.	1888.	1889.	1890.	1891.	1892.	1893	Average.	
1	None	4,520	2,797	1,914	2,170	2,285	1,200	2,481								1
2	Superphosphate	4,640	2,778	2,064	2,592	2,175	1,140	2,565	37	— 82	246	372	—139	—143	48	2
3	Muriate of potash	5,050	3,001	2,125	2,934	2,282	1,320	2,785	363	77	402	663	— 60	— 47	233	3
4	None	4,770	2,987	1,627	2,321	2,371	1,450	2,588								4
5	Nitrate of soda	5,800	3,030	2,585	2,868	2,531	1,220	3,006	1,093	— 55	869	421	169	—263	373	5
6	Nitrate and superphosphate	6,030	3,167	2,555	3,180	2,406	1,520	3,143	1,387	— 15	751	607	53	— 3	463	6
7	None	4,580	3,280	1,893	2,699	2,344	1,550	2,724								7
8	Superphosphate and potash	5,390	3,502	2,417	3,833	2,153	1,240	3,089	683	253	481	1,111	—209	—360	326	8
9	Nitrate and potash	6,590	3,549	2,762	3,192	2,607	1,600	3,383	1,757	330	783	446	228	— 50	582	9
10	None	4,960	3,188	2,022	2,770	2,397	1,700	2,840								10
11	Superphosphate, potash and nitrate	6,500	3,346	2,285	3,188	2,538	1,620	3,246	1,350	210	461	393	186	— 57	414	11
12	Barnyard manure	5,140	3,757	2,595	3,828	2,474	1,570	3,227	—200	673	969	1,009	168	— 83	422	12
13	None	5,530	3,032	1,428	2,844	2,261	1,636	2,787								13
14	Land plaster	5 810	3,028	1,520	2,480	2,080	1,480	2,733	280	— 4	92	—364	—181	—150	54	14
	Average of unfertilized plots	4,872	3,057	1,777	2,561	2,332	1,506	2,682								
	Average increase from fertilizers								750	231	561	518	24	—128	326	

These tables show that there has been a steady decrease in the yield of corn in this experiment, and that both chemical fertilizers and barnyard manure have utterly failed to maintain the land in a profitable state of productiveness. Of the general character of this soil the owner of the farm on which this test has been made (Mr. Hickman) states:

"A fair crop of corn may be grown on the shaly hills—on one of which this test is located—once in six or seven years, by following a rotation of corn, oats and wheat, followed by one year in meadow and two to four years' pasturing with sheep. Blue grass (*Poa pratensis*) is native, and when the hills are well set in this grass they furnish the best of pasture, which will last indefinitely. One field on this farm has been grazed continuously for thirteen years, and gives promise of continuous good pasture."

Corn grown on sod on this farm in 1893 yielded a fair crop—sixty shelled bushels per acre—while that grown in continuous culture was practically a total failure.

FARM TEST IN BUTLER COUNTY.

Made by B. H. Brown.

Mr. B. H. Brown, of Oxford, Butler county, has made this experiment in 1889, 1891, 1892 and 1893, but each time on fresh ground, the tests of 1889 and 1893 being made on wheat stubble, and those of 1891 and 1892 on timothy sod. The soil is a heavy clay of drift origin. On the test of 1893 Mr. Brown writes:

"The corn was planted June 10, on stubble ground where grasshoppers had killed the clover. The field was plowed early and was harrowed and laid off twice in May, ready to plant, and then heavy rains came and the work had to be done again. When it was planted the ground, naturally wet, was run together and was hard as the road. The fertilizer was applied around the hill on June 20 and cultivated in, but after this time we did not have enough rain to dissolve all of it, so it did very little good."

The results of the four tests are given in Tables XXI and XXII; from which it will be seen that in the average of the tests made on this farm potash has seemed to produce exceptionally good results, but no form of chemical manures has equaled barnyard manure in the average increase.

TABLE XXI.—FERTILIZERS ON CORN IN BUTLER COUNTY.

Yield and increase of GRAIN *in bushels of 70 pounds of ears.*

Plot No.	Fertilizers.	Yield per acre.					Increase per acre.					Plot No.
		1889.	1891.	1892.	1893.	Average.	1889.	1891.	1892.	1893.	Average.	
1	None	18.3	21.4	42.6	23.6	26.5						1
2	Superphosphate	35.9	39.6	42.9	26.7	36.3	15.1	15.4	0.3	3.9	8.7	2
3	Muriate of potash	41.7	32.3	62.1	28.6	41.2	18.3	5.3	19.5	6.5	12.4	3
4	None	25.9	29.9	42.6	21.3	29.9						4
5	Nitrate of soda	26.7	41.4	51.3	27.1	36.6	0.2	12.2	8.8	4.8	6.5	5
6	Nitrate and superphosphate	35.7	41.6	52.1	30.0	39.8	8.6	13.0	9.6	6.7	9.5	6
7	None	27.7	27.9	42.4	24.3	30.6						7
8	Superphosphate and potash	49.9	37.5	51.0	28.3	41.7	23.7	8.7	9.5	4.3	11.5	8
9	Nitrate and potash	37.9	47.7	51.4	29.3	41.6	13.1	18.1	10.3	5.6	11.8	9
10	None	23.3	30.5	40.9	23.4	29.5						10
11	Superphosphate, potash and nitrate	48.0	51.4	45.9	25.0	42.6	22.7	22.6	4.4	2.4	13.1	11
12	Barnyard manure	67.4	60.7	60.7	29.6	54.6	40.0	33.6	18.7	7.9	25.0	12
13	None	29.4	25.4	42.6	20.9	29.6						13
14	Land plaster	33.3	30.3	44.3	21.7	32.4	3.9	4.9	1.7	0.8	2.8	14
	Average of unfertilized plots	29.4	27.0	42.2	22.7	29.2						
	Average increase from fertilizers						16.2	14.9	9.2	4.8	11.3	

TABLE XXII.—FERTILIZERS ON CORN IN BUTLER COUNTY.

Yield and increase of STALKS *in pounds per acre.*

Plot No.	Fertilizers.	Yield per acre.					Increase per acre.					Plot No.
		1889.	1891.	1892.	1893.	Average.	1889.	1891.	1892.	1893.	Average.	
1	None	1,320	1,652	2,710	2,200	1,970						1
2	Superphosphate	2,690	1,952	2,650	2,410	2,425	1,193	417	10	277	474	2
3	Muriate of potash	2,700	1,683	4,210	2,900	2,873	1,027	266	1,640	833	942	3
4	None	1,850	1,300	2,500	2,000	1,912						4
5	Nitrate of soda	2,600	1,447	2,860	2,100	2,087	67	—20	383	100	133	5
6	Nitrate and superphosphate	2,650	2,020	2,950	2,390	2,502	633	387	617	390	507	6
7	None	2,100	1,800	2,250	2,000	2,037						7
8	Superphosphate and potash	3,400	1,761	3,250	2,200	2,652	1,417	—93	950	137	603	8
9	Nitrate and potash	2,550	2,034	3,200	2,400	2,546	683	125	850	274	483	9
10	None	1,750	1,963	2,400	2,190	2,076						10
11	Superphosphate, potash and nitrate	3,370	2,173	2,990	2,050	2,646	1,530	205	557	—76	554	11
12	Barnyard manure	4,680	2,835	3,980	2,400	3,474	2,750	863	1,513	337	1,366	12
13	None	2,000	1,977	2,500	2,000	2,124						13
14	Land plaster	2,380	1,869	2,700	1,980	2,232	360	—108	200	—20	108	14
	Average of unfertilized plots	1,808	1,738	2,472	2,078	2,505						
	Average increase from fertilizers						1,074	227	747	250	574	

FARM TEST IN WASHINGTON COUNTY.

Made by Orlando Trotter.

Mr. Orlando Trotter, of Layman, Washington county, made this test in 1891 and 1892, but on different land each time—a timothy sod in 1891 and a wheat stubble with one year's growth of clover in 1892. In 1893 the test was repeated on the same land on which it was made in 1892. Following is Mr. Trotter's description of the treatment of the land and of the crop:

"After the corn was taken off in 1892 the ground was sown to rye, with commercial fertilizer at the rate of 200 pounds per acre. It was sown late and did not make much growth last fall owing to drought. It thickened up in the spring and was a good stand; was plowed under May 20, when in full bloom; the ground was prepared at once and planted, 3 grains in a hill, 42 inches apart. One-half of the fertilizer was applied in the hill, the other broadcasted on the lots and worked in. The corn was cultivated four times and hoed. It was cut September 22 and husked October 30. The corn was very poor, not more than half a crop, compared with last year. The entire crop of this section of country is about the same—on low ground about two-thirds of a crop, on the hills from one-third to half a crop."

The results of this test are given in Tables XXIII and XXIV:

TABLE XXIII.—FERTILIZERS ON CORN IN WASHINGTON COUNTY.

Yield and increase of GRAIN *in bushels of 70 pounds of ears.*

Plot number.	Fertilizers.	Yield per acre.				Increase or decrease (—) per acre.				Plot number.
		1891.	1892.	1893.	Average.	1891.	1892.	1893.	Average.	
1	None	33.9	28.3	13.5	25.2					1
2	Superphosphate	50.5	25.7	15.7	30.6	15.5	—2.0	2.5	5.3	2
3	Muriate of potash	47.3	22.6	14.2	28.0	11.6	—4.6	1.2	2.7	3
4	None	37.3	26.6	12.7	25.5					4
5	Nitrate of soda	46.1	31.7	16.2	31.3	8.6	6.4	2.7	5.9	5
6	Nitrate and superphosphate	51.2	41.4	23.3	38.6	13.5	17.5	9.0	13.3	6
7	None	37.9	22.6	15.1	25.2					7
8	Superphosphate and potash	47.2	21.4	18.3	29.0	7.9	—3.0	3.3	2.7	8
9	Nitrate and potash	47.8	43.1	22.4	37.8	7.1	16.9	7.6	10.5	9
10	None	42.1	28.0	14.7	28.3					10
11	Superphosphate, potash and nitrat	48.8	60.3	28.3	45.8	8.0	31.2	13.0	17.4	11
12	Barnyard manure	48.0	37.1	23.2	36.1	8.6	6.8	7.4	7.6	12
13	None	38.0	31.4	16.4	28.6					13
14	Land plaster	48.9	26.6	18.3	31.3	10.8	—4.8	1.9	2.7	14
15	Bowker's superphosphate, 100 pounds		26.3				—5.1			15
16	" " 200 "		25.0				—6.4			16
	Average of unfertilized plots	37.9	27.4	13.3	26.6					
	Average increase from fertilizers					10.2	7.2	5.4	7.6	

TABLE XXIV.—FERTILIZERS ON CORN IN WASHINGTON COUNTY.

Yield and increase of STALKS *in pounds per acre.*

Plot number.	Fertilizers.	Yield per acre.				Increase or decrease (—) per acre.				Plot number.
		1891.	1892.	1893.	Average.	1891.	1892.	1893.	Average.	
1	None	1,731	2,780	1,450	1,987					1
2	Superphosphate	1,913	2,520	1,450	1,961	252	—167	108	64	2
3	Muriate of potash	1,890	2,700	1,175	1,922	300	107	—58	116	3
4	None	1,520	2 500	1,125	1,715					4
5	Nitrate of soda	1,905	2,160	1,135	1,733	330	—267	19	28	5
6	Nitrate and superphosphate	1,771	2,860	1,325	1,985	141	507	217	288	6
7	None	1,685	2,280	1,100	1,688					7
8	Superphosphate and potash	1,970	2,640	1,875	2,162	222	340	742	435	8
9	Nitrate and potash	1,850	2,640	1,350	1,947	40	320	183	181	9
10	None	1,873	2 340	1,200	1,804					10
11	Superphosphate, potash and nitrate	1,815	3,020	1,725	2,187	—11	647	459	363	11
12	Barnyard manure	1,962	2,680	1,975	2,206	184	273	625	361	12
13	None	1,731	2,440	1,425	1,865					13
14	Land plaster	1,892	2,520	1,510	1,974	161	80	85	109	14
15	Bowker's superphosphate, 100 pounds		2,350				—90			15
16	" " 200 "		2,630				190			16
	Average of unfertilized plots	1,708	2,468	1,260	1,812					
	Average increase from fertilizers					180	204	263	216	

THE SOURCE OF PHOSPHORIC ACID IN FERTILIZERS.

In the experiments at Columbus, phosphoric acid has been applied to the crops in continuous culture in three different forms, namely: dissolved bone-black, acid phosphate and basic slag.

Dissolved bone-black is bone charcoal which has been treated with sulphuric acid, thus making a superphosphate containing about 16 per cent. of phosphoric acid. The object of treating the charcoal with sulphuric acid is to make the phosphoric acid readily soluble in water, as in the condition in which it is found in raw bone or untreated bone ash or charcoal it dissolves very slowly.

Bone-black is largely used in the refining of oil and sugar, and is ordinarily treated with acid and sold for a fertilizer after having been used in the refineries. It can be bought in Ohio markets at an average cost, including freight, of about $22 per ton, making its phosphoric acid cost about 7 cents per pound.

Acid phosphate is a superphosphate made by treating the crude Carolina rock with sulphuric acid, the object being the same as in the making of superphospate from bone-black. It should contain about 14 per cent. of phosphoric acid.

Acid phosphate is largely distributed from Baltimore, and may be bought there at $12 per ton. The average freight to Ohio in less than car-load lots is about $5 per ton, which would increase the cost in Ohio to $17, making the phosphoric acid cost about 6 cents per pound.

Basic slag, otherwise known as "odorless phosphate," is a fine meal made as a by-product in the making of steel from ores rich in phosphoric acid. It should contain about 20 per cent. phosphoric acid.

Basic slag is controlled by a patent, and is sold in Philadelphia at $18 per ton, or $23 with freight added to Ohio, making its phosphoric acid cost $5\frac{3}{4}$ cents per pound.

In car-load lots each of these materials may be bought at a reduction of one to three dollars per ton, and the freight will also be reduced. By the single bag the price is one or two dollars per ton higher.

In Table XXV is given the average increase per acre on Plots 11, 17 and 18 of the tracts devoted to the continuous culture of corn, wheat and oats, the tests extending over six seasons in the case of corn, five seasons for wheat and four seasons for oats:

TABLE XXV.—INCREASE FROM DIFFERENT FORMS OF PHOSPHORIC ACID.

Plot.	Fertilizer.	Increase per acre.					
		Grain.			Straw.		
		Corn.	Wheat.	Oats.	Corn.	Wheat.	Oats.
		Bus.	*Bus.*	*Bus.*	*Lbs.*	*Lbs.*	*Lbs.*
11	Dissolved bone-black.....	4.3	4.0	5.6	383	1,509	253
17	Acid phosphate.....	7.3	4.2	5.5	867	945	507
18	Basic slag.....	7.2	4.6	7.0	686	1,017	444

The plot receiving basic slag has had a somewhat larger total quantity of phosphoric acid per acre and that receiving acid phosphate a somewhat smaller quantity than that applied in the bone-black, but apparently the phosphoric acid found in the ancient, fossil bone of the Carolina rock is equally efficacious, pound for pound, with that found in the bones of modern animals, when both have been converted into superphosphate, and the mineral phosphoric acid of the basig slag is not inferior to the most active forms of the same substance as derived from bones.

Attention is called, however, to the relative increase of straw of wheat as shown in the diagram on page 8. Should some way be discovered by which the greater growth of straw, produced by the bone-black superphosphate, may be made to bear a proportionate quantity of grain a greater value would have to be assigned to that form of phosphoric acid than the results thus far attained will justify; but at present this excessive production of straw must be looked upon as a disadvantage, in the light of the results in 1891, when every plot dressed with bone-black superphosphate gave a smaller yield of grain than the unfertilized plots adjoining, although the straw was enormously increased, while the rock and slag phosphates gave a more moderate increase of straw with a small increase of grain.

FIELD EXPERIMENTS WITH FERTILIZERS IN WAYNE COUNTY.

It is intended that the field study of the general problem of the maintenance of fertility shall continue to be one of the leading features of the Station's work, and for this purpose about twenty-eight acres of land has been prepared by thorough draining and plotting on the general plan hitherto followed. In this work special attention will be given to rotative cropping, and two rotations are being started, in one of which corn, oats, wheat, clover and timothy are to be grown in a five-crop rota-

tion, and in the other, potatoes, wheat and clover in a three-crop system. In addition to these rotations, corn, oats and wheat will be grown in continuous culture.

Oats and corn were planted in the five-crop rotation and in continuous culture in the spring of 1893, but the experiments were rendered of no value by the excessive drouth of that season, the average unfertilized yield of corn being but twenty shelled bushels per acre, and the average yield of the fertilized plots less than two bushels more. It is hoped that the climatic conditions may be more favorable in 1894.

SUMMARY.

The experiments reported in this bulletin cover five years' continuous culture of wheat and oats on the farm hitherto occupied by the Station at Columbus and belonging to the State University; six years' continuous culture of corn on that farm and in Columbiana county, and three to five years' intermittent culture of corn in Washington and Butler counties. In previous bulletins other co-operative experiments have been reported from five other counties of the State. In all, twenty-one separate experiments have been made with corn, eight with wheat and five with oats, each including fourteen to twenty-eight plots. The experiments have been made on soils varying widely in character, and including some of extreme poverty.

We are as yet only at the beginning of this work. Each year's results serve to emphasize the necessity for long continued, systematic investigation before attempting to formulate any general law; but our results thus far point most forcibly to the conclusion that:

At present prices of cereal crops and of fertilizing materials respectively, the profitable production of corn, wheat and oats upon chemical or commercial fertilizers, or upon barnyard manure, if its cost be proportionate to that of the chemical constituents of fertility found in commercial fertilizers, is a hopeless undertaking, unless these crops be grown in a systematic rotation with clover or a similar nitrogen-storing crop; and the poorer the soil in natural fertility the smaller the probability of profitable crop production by means of artificial fertilizers.

Drainage and thorough tillage are the logical preliminaries to any profitable system of agriculture. When these agencies of amelioration have been systematically employed, the great sheet of drift clay which covers so large a part of Ohio is found to be a mine of fertility.