CARRIERS OF NITROGEN IN FERTILIZERS

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In the 5-year cereal rotation which has been conducted in duplicate on the Wooster and Strongsville farms of the Ohio Agricultural Experiment Station since 1894 at Wooster and since 1895 at Strongsville, plots 17, 21, 23, 24 and 30 have received equal quantities of phosphorus, potassium and nitrogen; the phosphorus being carried in acid phosphate on plots 17, 12, 23 and 24 and in acid phosphate and tankage on plot 30. The potassium has in all cases been carried in muriate of potash. The nitrogen has been carried in nitrate of soda on plot 17, in linseed oilmeal on plot 21, in dried blood on plot 23, in sulfate of ammonia on plot 24 and in tankage on plot 30. The same comparison has been repeated in the potato rotation at Wooster. Since 1900 half the land in the cereal rotation has been cross-dressed with ground limestone, applied at the rate of 2 tons per acre while preparing the land for corn. At Wooster the other half of the land has been left untreated, while at Strongsville it has been cross-dressed twice with raw phosphate rock, the total application amounting to $1\frac{1}{2}$ tons per acre.

In these experiments every third plot is left without any fertilizer or manure, and the increase due to the treatment is computed by comparing each fertilized plot with the two unfertilized plots between which it lies, on the assumption that changes in the natural fertility of a field are more likely to be gradual than abrupt.

THE CEREAL ROTATION AT WOOSTER

In tables 1 and 2 the results are shown in comparison both of the total yields of the crops and of the increase due to the treatments.

Table 2 shows that on this acid soil oats and wheat have given larger yields after nitrate of soda than after any other treatment, but corn and the hay crops have given the largest yields after tankage. The explanation seems to be that the nonacidulated phosphate in the tankage has been more favorable to the growth of clover—a fact very evident on inspection of the fields—than acid phosphate, and this improvement in the conditions for clover has been reflected in the timothy associated with it and in the corn immediately following.

Table 2 shows that on the limed land nitrate of soda has been the most effective carrier of nitrogen, with sulfate of ammonia a close second.

TABLE 1

Comparison of carriers of nitrogen; Wooster, cereal rotation, unlimed land

CROP	CARRIERS OF NITROGEN				
	Nitrate of soda	Linseed oilmeal	Dried blood	Sulfate of ammonia	Tankage
Average yield per acre*					
Corn (bushels)	46.77	46.68	47.42	45.79	48.43
Oats (bushels)	54.81	50.53	51.11	51.46	51.32
Wheat (bushels)	27.09	25.38	23.83	24.41	26.50
Clover (pounds)	2,372	2,022	1,923	1,986	2,718
Timothy (pounds)	2,969	2,772	2,730	2,740	3,491
Annual produce (pounds)†	3,970	3,719	3,655	3,676	4,058
Annual value	\$39.09	\$36.56	\$35.99	\$36.09	\$40.40
Average increase per acre					
Corn (bushels)	22.34	21.73	22.10	19.57	20.51
Oats (bushels)	24.78	20.94	21.74	21.73	18.84
Wheat (bushels)	15.34	13.54	12.07	12.39	14.51
Clover (pounds)	1,281	965	844	842	1,435
Timothy (pounds)	858	679	597	512	1,076
Annual produce†	1,702	1,462	1,390	1,360	1,565
Annual value	\$18.56	\$16.19	\$15.39	\$14.83	\$17.75

* Average of 17 crops of corn, 15 of oats, 14 of wheat, 16 of clover and 12 of timothy.

† The "annual produce," as given in this and following tables, includes both grain and straw or stover, while the "annual value" is computed only on the grains and hay, rating corn at \$1.00 per bushel, oats at 75 cents, wheat at \$2.00 and hay at \$20.00 per ton. At these prices it is apparently immaterial, in these experiments, whether we use the total weight of produce, or the value of the grains and hay, as the common denominator for all the crops.

THE CEREAL ROTATION AT STRONGSVILLE

In table 3 is shown the outcome of this test at Strongsville for the 25 years of the experiment, 1905 to 1919, inclusive.

The uniformity shown in the total yields in this test is probably largely due to the apathy of this soil toward nitrogen fertilization.

In table 4 is shown the relative effect of nitrogen in the duplicate experiments at Wooster and Strongsville, in which the same crops are grown in succession, and plots of the same number receive the same treatment, in both kind and quantity of fertilizing materials.

Both nitrogen and potassium are comparatively ineffective on the Strongsville soil.

THE POTATOES-WHEAT-CLOVER ROTATION AT WOOSTER

In the 3-year rotation of potatoes, wheat and clover at Wooster, plot 20 receives its nitrogen in nitrate of soda; plot 21 in linseed oilmeal; plot 23 in dried blood; plot 24 in sulfate of ammonia and plot 33 in tankage. Plot 33 was not included in this test until 1897, and therefore the results are given in table 5 for the 23 years, 1897 to 1919.

The application of lime in this rotation was begun in 1903 but was not completed until 1913. It is not apparent, however, that the liming has materially altered the relative effectiveness of the different nitrogen carriers.

In this experiment the natural fertility of the land is so high that there is less margin for increase from fertilizing than in the tests above described. Repeating the comparison made in table 4, we get the results for the potato rotation as shown in table 6; computed for the entire period of the experiment.

TABLE 2

Comparison of carriers of nitrogen; Wooster, cereal rotation, limed land

CROP	CARRIERS OF NITROGEN				
	Nitrate of soda	Linseed oilmeal	Dried blood	Sulfate of ammonia	Tankage
Average yield per acre*					
Corn (bushels).....	54.64	53.98	54.06	55.35	51.42
Oats (bushels).....	55.63	54.57	53.71	54.64	51.19
Wheat (bushels).....	30.92	28.67	28.89	30.63	27.28
Clover (pounds).....	3,496	3,068	3,140	3,374	3,397
Timothy (pounds).....	4,596	4,039	4,057	4,365	4,381
Annual produce (pounds).....	4,538	4,215	4,250	4,392	4,280
Annual value.....	\$47.77	\$44.66	\$44.82	\$47.00	\$44.43
Average increase per acre					
Corn (bushels).....	24.85	22.98	22.50	23.03	17.81
Oats (bushels).....	21.47	19.25	18.24	18.75	14.32
Wheat (bushels).....	15.84	12.68	13.02	14.73	11.88
Clover (pounds).....	1,813	1,401	1,481	1,643	1,580
Timothy (pounds).....	1,569	1,045	1,051	1,224	1,154
Annual produce (pounds).....	2,160	1,700	1,737	1,868	1,592
Annual value.....	\$21.29	\$17.45	\$17.51	\$19.05	\$15.93

* Average of 17 crops of corn, 15 of oats, 14 of wheat, 16 of clover and 12 of timothy.

TABLE 3

Comparison of carriers of nitrogen; Strongsville, 25-year average yield and increase

CROP	CARRIERS OF NITROGEN				
	Nitrate of soda	Linseed oilmeal	Dried blood	Sulfate of ammonia	Tankage
Average yield per acre					
Corn (bushels).....	41.52	38.66	39.91	37.94	41.81
Oats (bushels).....	52.38	53.00	53.54	54.10	51.29
Wheat (bushels).....	20.78	21.05	21.12	20.87	20.71
Clover (pounds).....	3,052	2,895	2,951	2,892	3,004
Timothy (pounds)*.....	2,180	2,261	2,277	2,203	2,096
Annual produce (pounds).....	3,414	3,430	3,474	3,413	3,378
Annual value.....	\$34.94	\$34.41	\$34.92	\$34.24	\$34.54
Average increase per acre					
Corn (bushels).....	12.85	10.15	11.25	9.60	15.54
Oats (bushels).....	14.52	12.72	12.95	14.07	14.71
Wheat (bushels).....	9.63	9.30	9.15	9.25	10.03
Clover (pounds).....	958	646	706	721	1,068
Timothy (pounds).....	395	372	396	366	454
Annual produce (pounds).....	1,040	922	917	918	1,119
Annual value.....	\$11.31	\$9.69	\$10.06	\$9.90	\$12.37

* Timothy until 1914 and soybeans mown for hay since.

TABLE 4

Relative effect of nitrogen at Wooster and Strongsville; 25-year average value of increase per acre

PLOT	TREATMENT	ANNUAL VALUE OF INCREASE	
		Wooster	Strongsville
2	Acid phosphate.....	\$7.75	\$7.69
6	Acid phosphate and nitrate of soda.....	14.77	10.21
	Gain for nitrogen.....	\$7.02	\$2.52
8	Acid phosphate and muriate of potash.....	\$11.83	\$8.42
11	Acid phosphate, muriate of potash and nitrate of soda.....	18.14	11.24
	Gain for nitrogen.....	\$6.31	\$2.82

TABLE 5

Comparison of carriers of nitrogen; Wooster, potato rotation, 23-year average yield and increase

CROP	CARRIERS OF NITROGEN				
	Nitrate of soda	Linseed oilmeal	Dried blood	Sulfate of ammonia	Tankage
Average yield per acre					
Potatoes (bushels).....	169.13	160.45	160.62	161.98	158.63
Wheat (bushels).....	37.71	37.55	36.40	37.25	37.26
Clover (pounds).....	4,006	3,603	3,680	3,658	4,030
Annual value.....	\$94.87*	\$90.53	\$90.07	\$91.02	\$92.82
Average increase per acre					
Potatoes (bushels).....	39.90	36.76	37.50	39.73	31.65
Wheat (bushels).....	11.74	10.73	11.43	11.62	11.35
Clover (pounds).....	8.24	4.59	5.38	4.97	6.23
Annual value.....	\$23.87*	\$20.94	\$22.01	\$22.87	\$20.19

* Rating potatoes at \$1.00 a bushel, wheat at \$2.00, and hay at \$20.00 a ton.

TABLE 6

Effect of nitrogen in potatoes-wheat-clover rotation at Wooster, 25-year average value of increase per acre

CROP	TREATMENT	ANNUAL VALUE OF INCREASE
2	Acid phosphate.....	\$7.73
6	Acid phosphate and nitrate of soda.....	12.50
	Gain for nitrogen.....	\$4.77
8	Acid phosphate and muriate of potash.....	\$17.73
11	Acid phosphate, muriate of potash and nitrate of soda.....	19.01
	Gain for nitrogen.....	\$1.28

THE TOBACCO-WHEAT-CLOVER ROTATION AT GERMANTOWN

At the southwestern test farm of the Experiment Station, at Germantown, Montgomery County, a 3-year rotation of tobacco, wheat and clover has been in progress since 1903. In this experiment certain plots have received the following treatment:

Plot number	
8	Acid phosphate, muriate of potash, nitrate of soda
26	Same, with 1000 pounds of lime
16	Acid phosphate, muriate of potash, sulfate of ammonia
28	Same, with 1000 pounds of lime
18	Acid phosphate, muriate of potash, tankage
29	Same, with 1000 pounds of lime
22	Acid phosphate, nitrate of potash, nitrate of soda

The fertilizers have been calculated to carry 30 pounds of phosphorus, 75 pounds of potassium and 38 pounds of nitrogen in each case. On plots 18 and 29 all the nitrogen and the larger part of the phosphorus have been given in tankage, and on plot 22 all the potassium and the larger part of the nitrogen have been given in nitrate of potash. The fertilizers have all been applied to the tobacco crop, the wheat and clover following without further treatment.

The average yields obtained in this experiment during the 16 years, 1903-1918, are shown in table 7.

These results indicate a superiority of nitrate of soda over sulfate of ammonia on unlimed land, which disappears when the land is limed. The

TABLE 7
Comparison of carriers of nitrogen; Germantown, average yields per acre

CROP	CARRIERS OF NITROGEN			
	Nitrate of soda	Sulfate of ammonia	Tankage	Nitrate of potash
Unlimed land				
	<i>Plot 8</i>	<i>Plot 16</i>	<i>Plot 18</i>	<i>Plot 22</i>
Tobacco (pounds).....	1,227	1,095	960	1,131
Wheat (bushels).....	26.63	25.82	26.16	25.15
Clover (pounds).....	4,416	4,149	4,360	3,987
Annual values*.....	\$93.82	\$85.79	\$79.97	\$86.61
Limed land				
	<i>Plot 26</i>	<i>Plot 28</i>	<i>Plot 29</i>	
Tobacco (pounds).....	1,069	1,082	959	
Wheat (bushels).....	27.78	28.05	23.96	
Clover (pounds).....	4,139	4,193	4,054	
Annual values*.....	\$85.77	\$86.78	\$77.44	

* Rating tobacco at 15 cents a pound; wheat at \$2.00 a bushel and hay at \$20.00 a ton.

tobacco has shown a marked preference for either of the other carriers of nitrogen over tankage, a preference evident throughout the growth of the crop, but the wheat and clover do not speak so positively on this point. It would seem that the tankage becomes available too slowly for such a short-season crop as tobacco.

The plots in this test are arranged in blocks of 10 plots, the first, fourth, seventh and tenth plot in each block being left continuously unfertilized, and the increase due to the fertilizers is calculated on the assumption that variations in the yields of consecutive unfertilized plots are due to progressive variations in the soil. By this method of calculation the increases due to the separate treatment are found as shown in table 8.

TABLE 8

Comparison of carriers of nitrogen; Germantown, average increase per acre

CROP	CARRIERS OF NITROGEN			
	Nitrate of soda	Sulfate of ammonia	Tankage	Nitrate of potash
Increase on unlimed land				
	<i>Plot 8</i>	<i>Plot 16</i>	<i>Plot 18</i>	<i>Plot 22</i>
Tobacco (pounds).....	656	623	506	600
Wheat (bushels).....	14.09	14.14	15.03	14.67
Clover (pounds).....	1,632	1,368	1,629	1,509
Annual value.....	\$47.63	\$45.14	\$40.75	\$44.81
Increase on limed land				
	<i>Plot 26</i>	<i>Plot 28</i>	<i>Plot 29</i>	
Tobacco (pounds).....	589	626	505	
Wheat (bushels).....	17.11	17.46	13.57	
Clover (pounds).....	1,907	1,934	1,798	
Annual value.....	\$47.21	\$49.39	\$40.29	

TABLE 9

Comparison of carriers of nitrogen; annual values per acre at Wooster and Strongsville

EXPERIMENT	CARRIERS OF NITROGEN				
	Nitrate of soda	Linseed oilmeal	Dried blood	Sulfate of ammonia	Tankage
Value of total produce					
Wooster cereal rotation, unlimed.....	\$39.09	\$36.56	\$35.99	\$36.09	\$40.40
Wooster cereal rotation, limed.....	47.77	44.66	44.82	47.00	44.43
Wooster potato rotation.....	94.87	90.53	90.07	91.02	92.82
Strongsville cereal rotation.....	34.94	34.41	34.92	34.24	34.54
Average.....	\$54.17	\$51.29	\$51.45	\$52.09	\$53.05
Value of increase					
Wooster cereal rotation, unlimed.....	\$18.56	\$16.19	\$15.39	\$14.83	\$17.75
Wooster cereal rotation, limed.....	21.29	17.45	17.51	19.05	15.93
Wooster potato rotation.....	23.87	20.94	22.01	22.87	20.19
Strongsville cereal rotation.....	11.31	9.69	10.06	9.90	12.37
Average.....	\$18.76	\$16.07	\$16.24	\$16.66	\$16.56

The wheat and clover show a larger increase over the unfertilized yields on the limed than on the unlimed land except on the tankage plot, where the wheat falls behind.

Unless the land is exceptionally uniform, the comparison of increases, calculated by the method employed in these experiments, is usually more reliable than that of entire produce.

SUMMARY

In table 9 the annual values found in the experiments at Wooster and Strongsville are collected for convenient comparison.

These results show that, with only two exceptions in the forty comparisons, nitrate of soda has produced the largest yield, and this outcome is supported by the results at Germantown, except on the limed land, where the yields from sulfate of ammonia slightly exceed those from nitrate of soda.