THE COMPOSITION OF WHEAT

OHIO

Agricultural Experiment Station

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BULLETIN

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THE COMPOSITION OF WHEAT

INFLUENCE OF VARIOUS FACTORS ON THE PHOSPHORUS, POTASSIUM AND NITROGEN CONTENT OF THE WHEAT PLANT.

By J W AMES

INTRODUCTION.

The subject of soil fertility is necessarily a broad and complex one. It involves both laboratory and field research. Investigations relating to the physical and biological condition of soils, their chemical composition and reactions are of assistance in the solution of this problem. But it is field experiments, carefully planned and executed, which determine the crop producing capacity and fertilizer requirements of a given soil.

The data here presented are the results of analyses of wheat crops grown on soils on which the fertility investigations of this Station have been conducted for 15 years.

Applications to the soils under experiment, of barnyard manures and chemical fertilizers, in various combinations, have produced results which are becoming more and more valuable.

In order to determine the total amounts of the several essential elements removed from the soil by crop yields it is necessary to know the composition of the crop when harvested. Many analyses of plants have been made by chemists in Europe and America. The results published in the various agricultural works are largely quoted from the work of E. Wolff, and show wide variations in composition, due to soil and climatic conditions.

To secure information which would be accurate for the soils on which the fertility experiments of the Station are being conducted, analyses have been made of the several crops grown on these soils. Owing to the large amount of accumulated data, it has been deemed best to present at this time only that part of the work relating to the composition of the wheat plant.

CROPS ANALYZED

The crops analyzed were sampled from the plots of the 5-year rotation fertilizer tests on the Wooster and Strongsville soils, and from those of the barnyard manure and continuous culture experiments at Wooster. For the years 1907 and 1908, samples of grain and straw were secured from the east and west halves of the Wooster 5-year rotation plots, which have received applications of lime at different times. For the same years samples were taken from the crops grown on the halves of the Strongsville 5-year rotation plots, to which rock phosphate and lime have been applied.

For a complete description of the several fertility experiments the reader is referred to Bulletins 159, 182, 183 and 184, of this Station, by Director Chas. E. Thorne.

The analytical data include the nitrogen, phosphorus and potassium content of the grain and straw* for the different years, as given in detail in the tabulated results.

Especial credit is due to Mr. L. L. LaShell, who assisted in securing samples and made most of the analytical determinations reported.

VARIATIONS IN COMPOSITION

Our analyses of some 200 samples of wheat grain and straw show a considerable variation in their phosphorus, potassium and nitrogen content. The maximum and minimum percentages found, together with an average of all determinations made, are as stated below:

TABLE I—PERCENTAGE COMPOSITION OF WHEAT GRAIN AND STRAW

	Grain			Straw		
	Maximum	Minimum	Average	Maximum	Minimum	Average
	Percent	Percent	Percent	Percent	Percent	Percent
Nitrogen	2 6001	1 4823	1.9750	1.1361	0.2104	0 5280
Phosphorus	0 4841	0.2683	0.3486	0 1148	0.0273	0 0908
Potassium	0 4775	0 2565	0 3547	1 2462	0 4921	0 8304

The differences between the highest and lowest results expressed in percents are approximately uniform for the three constituents in the wheat grain; the results for the straw show greater variations.

VARIATION IN COMPOSITION

	Grain Percent	Straw Percent
Nitrogen	42.99	81.48
Phosphorus	44.58	76.20
Potassium	46.27	60.51

*The straw includes both straw and chaff.

The work of numerous investigators, the most extensive of which is probably that of Lawes and Gilbert,* demonstrates clearly that conditions affecting the development and maturity of a crop are responsible for variation in composition.

The absorption by a plant of an essential mineral element is a physiological process, and depends upon its vital activities. These activities may be affected by any of the conditions which influence crop growth and yields. The principal factors, therefore, which influence variation in composition of the wheat plant may be any one, or a combination of the following conditions: Favorable or unfavorable seasons, composition of the soil, fertilizers applied to the soil, soil moisture, and thickness of stand.

SEASONAL INFLUENCES

Favorable or unfavorable conditions of temperature and moisture influence the proportion of grain to straw, and the deposition of organic matter in the plant. Wheat kernels having a high starch content, which is associated with high yields, contain correspondingly small amounts of total ash and nitrogen.

Lawes and Gilbert state that a season favorable for long and continuous growth after heading produces well-developed kernels and larger yields; that in the better matured grain of favorable seasons, produced under the same conditions of fertilization, there is a lower percentage of potash, phosphorus and nitrogen.

Comparing the phosphorus content of the wheat from Plot 2 in the 5-year rotation at Wooster, which has received phosphorus alone, with the average of the ten unfertilized plots for the years 1904, 1907 and 1908, the results given below show a greater difference in composition due to season than to supply or exhaustion of phosphorus in the soil. The nitrogen results for the ten unfertilized plots and Plot 5, to which nitrogen alone is applied, illustrate further the effect of conditions varying from season to season.

While the amounts of the different constituents of grain and straw, grown under the same conditions of fertilization, vary for the different years, the variation in composition of the crops from plots differently fertilized is relatively the same for most of the years for which we have analytical data.

Aside from the physiological effects of temperature and moisture on the composition of plants, there exists the dissolving action of the rain and dew on the several constituents assimilated during their growth.

*On the composition of the ash of wheat grain and straw. London, 1884.

TABLE II—EFFECT OF SEASON AND PLANT FOOD SUPPLIES ON THE PHOSPHORUS AND NITROGEN CONTENT

Phosphorus content of wheat grain and straw—Percent

Treatment	1904		1907		1908		Maximum variation due to season	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Plot 2, phosphorus.	.395	.072	.3839	.0563	.3545	.0364	.0405	.0356
Average of unfertilized plots	.366	.105	.3053	.0548	.3234	.0469	.0607	.0581
Difference due to fertilization .	029	—.033	.0786	.0015	.0311	—.0105	....	....

Nitrogen content of wheat grain—Percent

	1902	1904	1905	1906	1907	1908	Maximum variation in grain due to season
Plot 5, nitrogen	2.532	2.146	2.600	2.400	2.205	2.000	.600
Average of unfertilized plots	2 261	2 086	2.335	2.100	1.918	1.771	.564
Difference due to fertilization.....	0.271	0 060	0 265	0.300	0.287	0 229	. . .

Nitrogen content of wheat straw—Percent

	1902	1904	1907	1908	Maximum variation in straw due to season
Plot 5, Nitrogen	.944	1.056	.602	.580	.476
Average of unfertilized plots	.818	0.947	.488	.444	.503
Difference due to fertilization. .	126	0.109	.114	.136	....

Numerous investigators have observed that the composition of plants varies during the different stages of growth; that as plants near maturity they contain smaller amounts of mineral matter and nitrogen than at earlier periods. Wilfarth, Romer and Wimmer,[1] from their work which consisted of elaborate experiments with barley, wheat, peas and potatoes, draw the conclusion that the elements of nutrition which are not stored as reserve material in the tissues of the plant migrate down through the stem and thence to the soil through the roots.

Mulder[2] attributes the variation in composition, found on analyzing a plant at different stages of growth, to the removal of a considerable part of the several constituents by rain.

Johnson[3] states that excess of mineral substance may be deposited upon the surface of leaves and stems and be removed by rain.

[1]On the assimilation of the elements of nutrition by plants during different stages of their growth Landw. Vers., Vol. 63, 1905.

[2]Chemie der Ackerkrume 2, p. 305.

[3]How crops grow, p. 203.

The investigations of Le Clerc and Breazeale,[1] who worked with plants grown under conditions which prevented water from coming in contact with the foliage, furnish data which prove that as the plant approaches maturity the salts move upward toward the living tissues rather than downward through the stems and roots into the soil. They also found that considerable portions of the salts thus deposited were removed by rain.

INFLUENCE OF SOIL AND FERTILIZERS

In this connection may be considered the effect of the deficiency of essential elemer.ts of nutrition, and the supply, whether originally present in the soil or furnished by mineral fertilizers and manures. The results of numerous experiments have been reported, which give evidence that the application of fertilizers to depleted soils has increased the relative amounts of the several essential elements removed by various crops.

Lawes and Gilbert's work on the ash of wheat crops, obtained over a period of twenty years from ten differently manured plots, shows that the ash constituents found in the total crop have been increased, but that the amounts stored in the grain are not influenced to any great extent by the quantity taken up, provided this is not deficient.

More recent work can be cited which gives evidence that the composition of crops is influenced by the supply or deficiency of available plant food in the soil. Stutzer[2] found that grain grown in pot culture, with and without addition of phosphorus, contained .297 percent and .375 percent of phosphorus. Chavan,[3] in his work on the influence of phosphorus and potassium on the composition of mixed grasses, grown on soils differently fertilized, obtained the following results:

INFLUENCE OF PHOSPHORUS AND POTASSIUM ON THE COMPOSITION OF MIXED GRASSES—PERCENT

Fertilizers applied	Found in the crop					
	Cellulose	Carbohydrates	Ash	Nitrogen	Phosphorus	Potassium
None	25 13	53.08	6 47	1.64	0.11	1.17
Phosphorus	30.50	50.14	6.05	1.42	0.24	1.49
Potassium	29.17	47.94	6.82	1.76	0.10	2.12
Phosphorus and potassium	36.36	42.17	7.21	1.64	0.25	2.16

[1]Plant food removed from plants by rain and dew, Year Book U. S. D. A., 1908, p. 389.

[2]Landwirtschaftliche Versuchsstationen Bd. 65, 1907.

[3]Annuaire agricole de la Suisse 1908, p. 193.

Applications of phosphorus and potassium have increased the amounts of these elements found in the crop. While potassium has increased the nitrogen content, phosphorus has decreased it. The proportion of cellulose increases with the phosphorus content of the crop. This is attributed to the fact that phosphorus hastens the maturing of the crop and produces an increased yield of straw. The addition of phosphorus to the soil has also increased the potassium content of the crop.

Hall, in a paper on "Analysis of the soil by the plant,"[1] which discusses the composition of crops grown at Rothamstead, concludes that the proportions of phosphoric acid and potash in a given plant vary according to the amounts available in the soil, as measured by the response of the crop to applications of phosphoric acid and potash; that these variations are small and often not as great as those due to seasonal conditions.

It has frequently been observed that crops grown on soil lacking in fertility contain larger proportions of total mineral matter than those grown on productive soils. The statement[2] has been made that this indicates that plants grown on such soils are able to assimilate more mineral matter than they can elaborate into plant tissue. A more plausible explanation of this variation is furnished by the data obtained from the analysis of the wheat plant grown on exhausted soil under different conditions of fertilization.

The results show that while wheat grown on the unfertilized plots of the Wooster and Strongsville soils contains a larger percentage of nitrogen and total mineral matter than wheat of good quality from fertilized plots, the addition of nitrogen produces wheat of as good quality and having a higher nitrogen content than that grown on depleted soil, and that the addition of different carriers of phosphorus to the soil increases the yield of grain and the percentage of phosphorus found therein. These results indicate, therefore, that the increased percentage of mineral matter observed in the crop grown on infertile soils is due, not to the fact that the soil furnishes more available plant food than the plant can utilize, but rather to the lack of one or more elements essential to the full development of the plant's organic structure.

COMPARISON OF THE ANALYSES OF SOIL AND WHEAT CROP

The relation between the nitrogen, phosphorus and potassium content of wheat grain and straw grown on the Wooster and Strongsville unfertilized soils; the percentages of total nitrogen, phosphorus

[1] Journal of Agr Science, Jan , 1905, p 65
[2] Soils of the United States; p 47

and potassium, and of phosphorus and potassium soluble in N/5 nitric acid found in the soil are given in Table III. In this comparison the results for the same year, 1908, are used to eliminate seasonal variations

TABLE III—RELATION BETWEEN CONSTITUENTS OF SOIL AND CROP

Soil	In crop			In soil	
	Grain	Straw	Entire plant	Total	Soluble in N/5 nitric acid
	Nitrogen—Percent				
Wooster	1 72	0 44	0 890	0 098	
Strongsville	2 09	0 42	1 076	0 195	
	Phosphorus—Percent				
Wooster	0 3687	0 0507	0 161	0 054	0005
Strongsville	0 3270	0 0501	0 158	0 047	0005
	Potassium Percent				
Wooster	0 3605	0 7843	0 678	1 614	0063
Strongsville	0 4089	1 0264	0 782	1 957	0163

The total nitrogen content of the Strongsville soil is practically twice that of the Wooster soil; the percentages of total and N/5 nitric acid-soluble phosphorus and potassium are also greater in the Strongsville soil.

The percentages of nitrogen and potassium in the crop are in accord with the amounts found in the soils. A comparison of the amount of the constituents in the crop with those available in the soil, as measured by the increased crop yields obtained from fertilizers on the two soils, shows that the analysis of the crop has given a correct indication of the available nitrogen and potassium supply. Table IV, taken from results contained in Table XVIII of Bulletin 182, by Director C. E. Thorne, gives the total value of increase from the use of phosphorus, nitrogen and potassium alone and in combination on the Wooster and Strongsville soils.

On the Strongsville soil applications of nitrogen and potassium alone, or in combination, have produced only slight increases, which indicates that this soil contains a sufficient supply of both these elements. Phosphorus alone has produced a much greater increase at Strongsville than at Wooster, apparently due to the fact, as stated by Director Thorne in Bulletin 182, "That the phosphorus applied at Strongsville finds already in the soil a supply of available nitrogen and potassium, whereas at Wooster these elements, as well as phosphorus, must be furnished before the full needs of the plant can be met."

TABLE IV—FERTILIZERS ON CROPS GROWN IN 5-YEAR ROTATION, COMPARATIVE VALUE OF INCREASE PER ACRE FOR FIRST TWO ROTATIONS

Plot No.	Fertilizing elements added per acre in total rotation	First rotation		Second rotation	
		Wooster	Strongsville	Wooster	Strongsville
2	Phosphorus, 20 lbs.	$8 18	$13.92	$16.39	$21.79
3	Potassium, 108 lbs	5.03	0.67	4.58	0.90
5	Nitrogen, 76 lbs.....	4.56	0.68	10.19	1.05
6	Phosphorus, 20 lbs..... .... / Nitrogen, 76 lbs ..... \	18.41	17.79	33.66	24.19
8	Phosphorus, 20 lbs..... / Potassium, 108 lbs..... \	13.88	15.52	23 24	18.97
9	Potassium, 108 lbs..... . . / Nitrogen, 76 lbs ..... \	5.67	3.29	10.09	2.59
11	Phosphorus, 20 lbs..... / Potassium, 108 lbs ..... Nitrogen, 76 lbs ..... \	25 33	21.84	40.54	23.62
12	Phosphorus, 20 lbs ..... / Potassium 108 lbs ..... Nitrogen, 114 lbs .... \	25.04	21.85	43.47	25.17
17	Phosphorus, 30 lbs.... ..... / Potassium, 108 lbs..... .. Nitrogen, 38 lbs ..... . \	.....	.....	35.07	25.97

The relation between the phosphorus content of the soil and crop is the reverse of that found in the case of the nitrogen and potassium; the percent of phosphorus in the crop, however, is in accord with the previous history of the soils and the increased yields from the use of phosphorus on the Strongsville soil.

The higher nitrogen content of the Strongsville soil may have a bearing on the percentage of phosphorus found in the crop. The results given in Table V show that the addition of nitrogen alone in nitrate of soda to both the Wooster and Strongsville soils decreases the amounts of phosphorus in the grain below that found in the grain from the unfertilized plots, and when phosphorus and nitrogen are used in combination the percentage of phosphorus is lower than when phosphorus alone is applied.

The crops from Plots 11 and 12 on the Wooster soil, receiving phosphorus, nitrogen and potassium, have a lower phosphorus content than the crop from Plot 6, which receives phosphorus and nitrogen only; while the same treatment on the Strongsville soil increases the phosphorus above that found in the crop fertilized with phosphorus and nitrogen only. On both these soils, however, the additional amount of nitrogen on Plot 12 has decreased the percentage of phosphorus in the crop as compared with Plot 11.

TABLE V—PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON WOOSTER AND STRONGSVILLE SOILS IN 1908—PERCENT

Plot	Treatment	Wooster			Strongsville		
		Grain	Straw	Entire plant	Grain	Straw	Entire plant
	Unfertilized	.3337	.0506	.161	.3270	.0501	.158
5	Nitrogen	.3245	.0589	.155	.2837	.0416	.128
2	Phosphorus	.3642	.0343	.172	.4122	.0447	.186
6	Phosphorus, Nitrogen	.3422	.0331	.157	.3643	.0429	.176
11	Phosphorus, Potassium, Nitrogen	.3380	.0417	.157	.4194	.0458	.197
12	Phosphorus, Potassium, Nitrogen	.3337	.0372	.148	.4153	.0423	.189

Further illustrations of the relation between the composition of the crop and the soil are furnished by the analysis of the crops grown on Strongsville soils receiving applications of insoluble phosphorus. Untreated rock phosphate, or floats, containing 12 percent phosphorus, has been applied to one-half of a series of plots devoted to 5-year rotation fertilizer experiments on the Strongsville soil, and lime to the other half. The average results for four otherwise unfertilized plots, given in Table VI, show a marked increase in the amount of phosphorus in the crop from the soil receiving phosphorus:

TABLE VI—EFFECT OF TREATMENT OF SOIL ON PERCENTAGE OF PHOSPHORUS IN THE CROP

Treatment	Phosphorus in grain	Phosphorus in straw	Phosphorus in entire plant	Phosphorus in soil soluble in N/5 nitric acid
Rock phosphate	.4645	.0511	.203	.0186
Lime	.2947	.0354	.114	.0006

The complete data of the Strongsville crops for the years 1908 and 1909 are given farther on.

Table VII gives the percentages of phosphorus found in the wheat crop grown on seven plots of the manure experiment on the Wooster soil, the amounts of phosphorus soluble in N/5 nitric acid being also shown. Plots 2 and 3 receive 8 tons of manure reenforced with floats, and Plots 5 and 6 the same amount of manure reenforced with acid phosphate. The carriers of phosphorus are added to the manure at the rate of 40 lbs. per ton, or 320 lbs. per acre; the rock phosphate carries 39 lbs. of insoluble phosphorus, and the acid phosphate 20 lbs. of available phosphorus per acre.

TABLE VII-PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON SOIL TREATED WITH YARD AND STALL MANURE REENFORCED WITH FLOATS AND ACID PHOSPHATE
PERCENT

Plot	Treatment	Phosphorus in grain	Phosphorus in straw	Phosphorus in entire plant	Phosphorus in soil soluble in N 5 nitric acid
1	None	3679	0531	1131	0003
2	Yard manure and floats	3887	0657	1624	0010
3	Stall manure and floats	1315	0757	1803	0024
4	None	3209	0482	1302	0003
5	Yard manure and acid phosphate	4083	0548	1621	0005
6	Stall manure and acid phosphate	4205	0656	1731	0005
7	None	3374	0476	1414	0003

Although the above results are not strictly in accordance with the total amounts of phosphorus applied, taken as a whole there are considerable variations in the phosphorus content of the crop and soil from the fertilized and unfertilized plots.

EFFECT OF LIME ON THE PHOSPHORUS ASSIMILATED BY THE WHEAT CROP

The addition of lime to soils having an insufficient supply exerts a beneficial effect in various ways. One of the functions attributed to lime is its action on the insoluble phosphates which are present in the soil, chiefly in the forms of calcium, magnesium, iron and aluminum phosphates. The increased availability of these phosphates may be due to a chemical reaction between the lime and the iron and aluminum phosphates, as well as to the more favorable biological conditions produced by increasing the lime supply.

When phosphorus in the soluble form is applied to the soil it readily combines with the bases present and forms insoluble phosphates, and it is reasonable to suppose that soils supplied with an adequate amount of lime will have a greater proportion of their phosphorus in the form of the more available calcium phosphates than soils deficient in lime.

A comparison of the composition of the wheat crop grown on the same soil, limed at different intervals, shows that the crop from the more recently limed soil contains the larger percentage of phosphorus. Associated with this increased amount of phosphorus are the same variations in the nitrogen and potassium content which are produced by the addition of available phosphorus.

The east and west halves of sections E and B, in the 5-year rotations at Wooster, have received applications of lime as follows: The west half of Section E was limed in 1900, and the east half in 1905, the west half of Section B in 1901, and the east half 5 years later, in 1906, the lime in all cases being applied to the corn crop. The yields of grain and straw obtained from both ends of these sections for the wheat crops of 1907 and 1908 are irregular. The average yields from the fertilized and unfertilized plots are as follows:

TABLE VIII—AVERAGE YIELD OF WHEAT IN POUNDS PER ACRE

	1907				1908			
	Grain		Straw		Grain		Straw	
Date of liming	1905	1900	1905	1900	1906	1901	1906	1901
End of plot	East	West	East	West	East	West	East	West
Average of all plots	1 314	1 276	2 545	2 552	1,617	1 729	2,506	2 818
Average of unfertilized plots	877	784	1 586	1,531	1,065	1 240	1 668	2 103

The average percentages of phosphorus, nitrogen and potassium in the crops are set forth in Table IX, page 12.

The phosphorus content of the grain and straw is uniformly greater on the east half of the plots, and the nitrogen percentages are greater on the west half. Although the percentage of potassium in the entire plant is greatest on the west half, the results show an increased amount in the grain from the more recently limed soil. Table X, page 13 shows that the addition of available phosphorus to the soil increases the phosphorus and decreases the nitrogen and potassium in the wheat plant, and causes a greater transference of potassium from the straw to the grain.

A survey of these results in connection with those set forth in Table IX gives evidence of the effect of lime on the insoluble soil phosphates.

PHOSPHORUS CONTENT

Approximately 80 percent of the phosphorus which is present in the wheat plant at maturity is contained in the grain as organic phosphorus. The ratio of phosphorus in the grain to that in the straw is not uniform for the crops grown under different conditions of fertilization. With an increased supply of available phosphorus there is a tendency toward a greater transference of phosphorus from the straw to the grain.

The addition of nitrogen to the soil not only decreases the total phosphorus content of the plant, but also causes a greater proportion of the phosphorus to be retained in the straw; this is probably due to the effect of nitrogen in prolonging the period of growth.

TABLE IX—EFFECT OF LIME ON PHOSPHORUS, POTASSIUM AND NITROGEN CONTENT OF THE WHEAT PLANT

	Phosphorus in wheat grain				Phosphorus in wheat straw				Phosphorus in entire plant			
	1907		1908		1907		1908		1907		1908	
Date of liming ... / End of plot	1905 East	1900 West	1906 East	1901 West	1905 East	1900 West	1906 East	1901 West	1905 East	1900 West	1906 East	1901 West
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Average of all plots	.3333	.3137	.3508	.3260	.0499	.0492	.0437	.0383	.1471	.1372	.1632	.1471
Check plots	.3124	.2982	.3337	.3131	.0488	.0586	.0506	.0431	.1434	1390	.1614	.1434
Plots receiving phosphorus	.3489	.3230	.3664	.3405	.0495	.0432	.0382	.0345	.1492	.1353	.1680	.1522
	Nitrogen in wheat grain				Nitrogen in wheat straw				Nitrogen in entire plant			
Average of all plots	1.822	1.925	1.683	1.766	.4071	.4190	.3814	.3852	8924	0.9223	.8904	.9071
Check plots	1.843	1.997	1 724	1.825	.4543	5224	.4441	.4441	.9491	1.0251	9442	.9580
Plots receiving nitrogen	1 810	1.880	1.677	1.741	.3940	.3681	.3552	3590	.8663	0 8690	.8691	.8853
	Potassium in wheat grain				Potassium in wheat straw				Potassium in entire plant			
Average of all plots	.3684	.3517	.3630	.3372	.7285	.7818	.8887	0.9232	.6041	.6381	.678	.6990
Check plots	.3814	.3661	.3605	.3292	.7120	.7982	.7843	0.8004	.5930	.6552	.6160	.6233
Plots receiving potassium	.3599	.3445	.3671	.3458	.7645	.7773	.9968	1.0342	.6223	.6324	.7422	.7581

TABLE X—EFFECT OF FERTILIZING ELEMENTS ON THE COMPOSITION OF THE WHEAT PLANT

Treatment	Composition of plant								
	Grain			Straw			Entire plant		
Wooster soil	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Average unfertilized plots.....	1.724	.3337	.3605	.4442	0506	.7843	0.9442	.1612	6161
2, Phosphorus....	1.505	.3642	.3746	.2671	.0343	.6953	0.7880	.1721	.5604
5, Nitrogen...	1.885	.3245	.3512	.5870	.0589	.6888	1.0613	.1550	.5652
3, Potassium	1.710	.3337	.3464	.4335	.0480	.9281	0 9304	.1581	.6963
Strongsville soil									
Average unfertilized plots.....	2.090	.3270	.4089	.4214	.0501	1.0264	1.0762	.1581	7822
2, Phosphorus.....	1.840	.4122	.4735	.3103	.0447	0.9507	0.9011	.1864	.7651
5, Nitrogen	2.160	.2837	.3772	.4721	.0416	1.1505	1.0790	.1281	.8704
3, Potassium	2.160	.3014	.3857	.4632	.0449	1.1387	1.1624	.1504	.8260

Table XI shows the percentages of phosphorus found in the grain and straw and in the entire plant, and the pounds removed per acre by the wheat crop grown on the 30 plots of the 5-year rotation fertility work at Wooster. An inspection of these results shows that in general, the percentage of phosphorus found in the wheat grain has varied with the total quantity of phosphorus given in the fertilizer, excepting that the presence of nitrate of soda in the fertilizer seems to have had a restraining influence on the deposit of phosphorus.

It seems that the addition of potassium alone (Plot 3) has increased the deposit of phosphorus in the grain, whereas the nitrate of soda used alone (Plot 5) or with potassium (Plot 9) has reduced the phosphorus in the grain below that from the unfertilized land. Plot 15, fertilized only on wheat, and Plot 14, fertilized on corn and wheat only, stand between the partially fertilized plots 5 and 9, on the one hand, which receive no phosphorus in the fertilizer, and Plots 6, 11, 26, 27 and 29, on the other hand, which receive the complete application on the three cereal crops, corn, oats and wheat, the nitrogen for all being carried in nitrate of soda; there being a gradual transition in the phosphorus content of the grain in the three groups. Plot 12, receiving the maximum application of nitrate, shows a slight reduction in crop phosphorus, as compared with the group receiving less nitrate associated with the same quantity of phosphorus.

In the next group, receiving 30 pounds of phosphorus and 38 pounds of nitrogen, Plot 17, receiving its nitrogen in nitrate of soda, shows practically the same percentage of phosphorus in the crop as the group receiving 20 pounds of phosphorus and 76 pounds of nitrogen, but all the plots to which the nitrogen is applied in organic form show increased percentages of phosphorus in the crop, excepting Plot 20, which receives the small dressing of 8 tons of yard manure, 4 tons each on corn and wheat. If we compare the yield of this plot with that of Plot 14, which receives chemical fertilizers on corn and wheat only, it would seem that the constituents of the yard manure have been less effective, pound for pound, than those of the chemicals, and this may be the explanation of this apparent discrepancy. When the manure has been applied in the larger quantity, on Plot 18, we find the phosphorus rising in the grain.

Apparently, sulphate of ammonia has also had a slightly restraining effect on the deposit of phosphorus, though less marked than in the case of nitrate of soda.

TABLE XI—PHOSPHORUS CONTENT OF WHEAT CROPS GROWN IN 5-YEAR ROTATION AT WOOSTER, AVERAGE RESULTS FOR 1907 AND 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation			Nitrogen carrier	Average yield per acre			Phosphorus in crop			Phosphorus removed per acre
	Phosphorus	Potassium	Nitrogen		Grain	Straw	Total produce	In grain	In straw	In entire plant	
	Lbs.	Lbs.	Lbs		Bu.	Lbs.	Lbs.	Percent	Percent	Percent	Lbs.
*	..	...	..	Unfertilized	16.53	1,722	2,714	.3143	.0508	.1470	3.99
3	..	108	..	Nonitrogen	19.55	2,131	3,304	.3300	.0478	.1481	5.28
5	..	...	76	Nitrate of soda	20.60	2,373	3,609	.2985	.0533	.1370	4.94
9	..	108	76	" " "	21.06	2,396	3,660	.2955	.0504	.1342	4.92
15	10	41	25	" " "	30 87	3,212	5,064	.3016	.0345	.1321	6.69
14	15	75	51	" " "	34.18	3,623	5,674	.3192	.0348	.1372	7.77
6	20	...	76	" " "	34.43	3,618	5,684	.3326	.0420	.1473	8.36
11	20	108	76	" " "	35 62	3,877	6,014	.3323	.0402	.1434	8.63
26	20	108	76	" " "	29.39	2,901	4,664	.3265	.0431	.1504	7.00
27	20	108	76	" " "	32.54	3,472	5,424	.3362	.0388	.1451	7.90
29	20	108	76	" " "	30.33	3,179	4,999	.3419	.0405	.1506	7.50
12	20	108	114	" " "	34.70	4,047	6,129	.3241	.0403	.1410	8.88
17	30	108	38	" " "	30.37	3,212	5,034	.3388	.0410	.1481	7.49
21	30	108	38	Linseed oilmeal.	26 45	2,782	4,369	.3658	.0388	.1560	6.84
23	30	108	38	Dried blood .. .	25 87	2,542	4,094	.3650	.0440	.1654	6.75
24	30	108	38	Sulphate of ammonia.	28.47	3,061	4,769	.3562	.0416	.1532	7.32
30	30	108	38	Tankage	29.68	3,083	4,864	.3794	.0498	.1714	8.29
20	24	56	72	Yard manure.....	24 98	2,751	4,250	.3350	.0355	.1404	5.98
18	48	112	144	" " ..	31.68	3,263	5,164	.3678	.0484	.1663	8.58
2	20	...	..	No nitrogen. . ..	27.18	2,818	4,449	.3692	.0463	.1642	7.32
8	20	108	..	" "	26.24	2,649	4 223	.3687	.0437	.1641	6.92

* Average of unfertilized plots

Finally, the effect of an excess of available phosphorus in the soil over the nitrogen supply is again shown in the high percentage of phosphorus in the crops grown on Plots 2 and 8. It is interesting to compare these plots with numbers 5 and 9, both with reference to total yields and to composition of the grain.

The larger percentage of phosphorus in the grain from Plot 29 is in harmony with the effect of lime previously noted, the phosphorus carrier for this plot being basic slag. On Plot 26 the phosphorus carrier is raw bonemeal and on Plot 27 it is dissolved boneblack. On all the others, except the manured plots, it is acid phosphate.

The average results shown in Table XI are summarized in Table XII.

TABLE XII—AVERAGE PERCENTAGE OF PHOSPHORUS IN THE WHEAT GRAIN AT WOOSTER

Treatment	Phosphorus in grain
	Percent
Unfertilized	.3143
Nitrogen or potassium without phosphorus	.3080
Phosphorus, without nitrogen	.3690
Phosphorus, with nitrate of soda	.3332
Phosphorus, with organic nitrogen	.3615

In the Strongsville experiments, as in those at Wooster, the wheat is grown in a 5-year rotation of corn, oats, wheat and clover on five tracts of land, Sections A, B, C, D and E, each crop being grown every year. The wheat crops of 1908 and 1909 were harvested from Sections E and A. In 1901 and 1902 one half of each of these sections was dressed with quicklime, applied at the rate of one ton per acre. In September, 1905, the limed half of Section E received another dressing of lime, applied to one half (one-fourth of the entire tract) at the rate of one ton and to the other half at two tons, per acre, and the unlimed half received an application of finely ground phosphate rock, or floats, applied to one quarter at the rate of one-half ton and to the other quarter at one ton per acre.

In the spring of 1907 Section E was dressed with lime and floats applying both materials at the rate of one ton and two tons per acre.

The composition of the wheat harvested in this experiment in 1908 and 1909 has been determined with the results shown in Tables XIII and XIV.

TABLE XIII—PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON STRONGSVILLE SOIL. AVERAGE RESULTS FOR HALVES OF PLOTS RECEIVING LIME AND FLOATS 1908-1909

Plot No.	Fertilizing elements per acre for one 5-year rotation			Phosphorus in					
				Grain		Straw		Entire plant	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
Average unfertilized	..	...	.	.4352	.3108	.0467	.0428	.1877	.1368
2	20	.	.	.4569	.4119	.0489	.0424	.1984	.1718
3	.	108	.	.4502	.3113	.0426	.0391	.1822	.1362
5	..	..	76	.4175	.2806	.0355	.0353	.1691	.1172
6	20	...	76	.4621	.3744	.0389	.0359	2003	.1678
8	20	108	...	4527	.3962	.0404	.0458	.1997	.1811
9	..	108	76	.4285	.3160	0387	.0346	.1595	.1370
11	20	108	76	.4504	.4395	.0460	.0459	.1969	.1862
12	20	108	114	.4520	.4301	.0466	.0463	.1975	.1899

These tables show that the percentage of phosphorus in the wheat is decidedly higher on the land treated with floats than on that dressed with lime, and that it is higher in the crop of 1909, following the larger application of floats, than in that of 1908, whereas the wheat grown on the limed land shows less phosphorus in 1909 than in 1908. In 1908 the further addition of phosphorus in the fertilizer has caused an increase in the phosphorus percentage of the grain, but in 1909 the large dressing of floats has apparently furnished all the phosphorus the plant could utilize.

The average results shown in Table XIII are summarized in Table XIV:

TABLE XIV—AVERAGE PERCENTAGE OF PHOSPHORUS IN THE WHEAT GRAIN AT STRONGSVILLE

Plot treatment	Year and cross dressing			
	1908		1909	
	Floats	Lime	Floats	Lime
	Percent	Perceut	Percent	Percent
Unfertilized	.4059	3270	.4646	.2947
Nitrogen, in nitrate of soda.....	.4168	.2837	.4182	.2775
Phosphorus, without nitrogen or potassium ...	.4449	.4122	.4689	.4116
Phosphorus, with nitrate of soda only	.4572	.3643	.4671	.3845
Phosphorus, potassium and nitrogen	.4287	.4173	.4736	.4522

It will be observed that the reenforcement of phosphorus with potassium, and with nitrogen in nitrate of soda, has apparently increased the deposit of phosphorus in the grain at Strongsville, an effect the

opposite of that observed at Wooster. On referring to Table IV we see that the effect of both nitrogen and potassium on the total yield has been much smaller at Strongsville than at Wooster, an effect in harmony with the analysis of the two soils. The effect of the carriers of organic nitrogen on the composition of the grain has not yet been studied at Strongsville.

TABLE XV—POTASSIUM CONTENT OF WHEAT CROP GROWN IN 5-YEAR ROTATION AT WOOSTER AVERAGE RESULTS FOR 1907 and 1908

Plot No	Treatment for 5 year rotation			Potassium in			Average yield for 1907 1908		Potassium removed by grain and straw
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Entire plant	Grain	Straw	
	Lbs	Lbs	Lbs	Percent	Percent	Percent	Bus	Lbs	Lbs
0*				3591	7737	621	16 53	1 722	17 03
2	20			3621	6675	554	27 18	2 818	24 89
3		108		269	8739	678	19 55	2 131	22 46
5			76	3367	7376	601	20 60	2 373	21 72
6	20		76	3571	7257	584	34 43	3 618	33 25
8	20	108		3528	8875	681	26 24	2 649	29 38
9		108	76	3458	9757	756	21 06	2 396	28 08
11	20	108	76	3366	9398	720	35 62	3 877	43 47
12	20	108	114	3547	9481	734	34 70	4 047	46 28
14	15	75	51	3489	8424	660	34 18	3 623	37 85
15	10	41	25	3429	8645	668	30 87	3 212	33 97
17	30	108	38	3652	8539	673	30 37	3 212	34 18
18	48	112	144	3681	9644	676	31 68	3 263	34 88
20	24	56	72	3413	7819	622	24 98	2,751	26 45
21	30	108	38	3709	8782	690	26 45	2 782	30 48
23	30	108	38	3681	8661	675	25 87	2 542	28 13
24	30	108	38	3633	8982	703	28 47	3 061	33 70
26	20	108	76	3598	9245	704	29 39	2 901	32 92
27	20	108	76	3468	8865	665	32 54	3 472	34 67
29	20	108	76	3519	8921	692	30 33	3 179	34 80
30	30	108	38	3685	8702	6 84	29 68	3 083	33 25

*Average of unfertilized plots

POTASSIUM CONTENT

The potassium percentages found in the wheat grain and straw grown on the differently fertilized plots are given in Tables XV and XVI. Inspection of the results in these tables shows that the addition of potassium alone or in combination with phosphorus and nitrogen has uniformly increased the amount of potassium in the

wheat crop grown on Wooster soil and has generally done so at Strongsville. The percentages found in the crop from the Strongsville soil, as shown in Table XVI, are greater than those found in the Wooster crop and the increase from additions of potassium in the fertilizer are less uniform; this is attributed to the larger supply of potassium in the Strongsville soil.

It will be observed that phosphorus, in the form of raw rock phosphate, has affected the distribution of potassium in the plant in the same manner as applications of the more available phosphorus supplied by acid phosphate; that is, on the floats-treated land a larger percentage of the total potassium is found in the grain than on that not so treated.

TABLE XVI—POTASSIUM CONTENT OF WHEAT CROP GROWN IN 5-YEAR ROTATION AT STRONGSVILLE AVERAGE RESULTS FOR HALVES OF PLOTS RECEIVING LIME AND FLOATS 1908 AND 1909

Plot No	Treatment for 5 year rotation			Potassium in					
				Grain		Straw		Entire plant	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs	Lbs	Lbs	Percent	Percent	Percent	Percent	Percent	Percent
0*				4259	3906	0 9858	1 0463	7817	8160
2	20			4502	4538	0 9702	0 9751	7792	7929
		108		4525	3879	1 1263	1 1841	8954	8975
5			76	4413	3580	1 0137	1 1033	8141	8523
6	20		76	4617	4044	0 8517	0 8931	6995	6982
8	20	108		4586	4296	0 9233	1 0203	7406	7908
9		108	76	4376	3784	1 0058	1 1033	7061	8406
11	20	108	76	4544	4372	0 9561	1 0798	7659	8552
12	20	108	111	4557	4517	0 9858	1 0347	7792	8157

*Average of unfertilized plots

NITROGEN CONTENT

The nitrogen content of the wheat crop grown on the differently fertilized plots of the 5-year rotation work on Wooster soil is given in Table XVII. These results show that the percentage of nitrogen in the wheat plant is influenced by the supply of phosphorus and nitrogen at its disposal. The higher nitrogen content of the wheat plant grown on exhausted soil, over that found in the crops from the plots which have produced normal yields, is apparently due to the decreased elaboration of organic matter.[1]

The addition of nitrogen without phosphorus has increased the percentage of nitrogen in the crop, as well as the total amount removed. In the crop grown under the opposite condition of

[1]The wheat grown on the unfertilized plots and on those receiving no phosphorus in the fertilizer generally weighs less per bushel than that grown on the plots receiving phosphorus especially in unfavorable seasons

TABLE XVII—NITROGEN CONTENT OF WHEAT GROWN IN 5-YEAR ROTATION AT WOOSTER: AVERAGE RESULTS FOR 1907 AND 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation			Nitrogen carrier	Nitrogen content			Average yield per acre, 1907 and 1908		Nitrogen removed per acre	Plot No.
	Phosphorus	Potassium	Nitrogen		Grain	Straw	Entire plant	Grain	Straw		
	Lbs.	Lbs.	Lbs.		Percent	Percent	Percent	Bus.	Lbs.	Lbs.	
*	..	...	...	Unfertilized	1.841	.466	0.968	16.53	1,722	26.25	*
2	20	...	...	No nitrogen	1.660	.301	0.799	27.18	2,818	35.52	2
3	..	108	...	"	1.832	.449	0 940	19.55	2,131	30.85	3
8	20	108	..	"	1.691	.316	0.826	26.24	2,649	35.07	8
15	10	41	25	Nitrate of soda	1.782	.345	0.867	30.87	3,216	43.98	15
14	15	75	51	" "	1.811	.343	0.869	34.18	3,623	49.34	14
5	..	...	76	" "	2.103	.592	1.107	20 60	2,373	39.92	5
9	..	108	76	" "	2.084	.536	1.059	21.06	2,396	38.53	9
6	20	..	76	"	1.831	.355	0.355	34.43	3,618	50.54	6
11	20	108	76	" "	1.823	.368	0.883	35.62	3,877	53.17	11
26	20	108	76	" "	1.741	.370	0.889	29.39	2,901	41.47	26
27	20	108	76	" "	1.714	.340	0 833	32.54	3,472	45.27	27
29	20	108	76	" "	1.742	.352	0.858	30.33	3,179	42.75	29
12	20	108	114	" "	2.004	.411	0.976	34.40	4,047	61.33	12
17	30	108	38	" "	1.661	.300	0.789	30.37	3,212	40.33	17
21	30	108	38	Linseed oilmeal	1.613	.307	0.774	26.45	2,782	33.91	21
23	30	108	38	Dried blood	1.581	.295	0 779	25 87	2,542	32 00	23
24	30	108	38	Sulphate of ammonia	1.634	.310	0.781	28.47	3,061	37.44	24
30	30	108	38	Tankage	1.651	.312	0.803	29 68	3,083	39.28	30
20	24	56	72	Yard manure	1.692	.330	0.807	24.98	2,751	34.34	20
18	48	112	144	" "	1.751	.351	0.866	31.68	3,263	44.82	18

*Average of unfertilized plots.

fertilization, that is, a supply of phosphorus without nitrogen, there has been a decided decrease in the percent of nitrogen, but a much larger quantity of total nitrogen removed.

Comparing the results for plots 11 and 12, which have produced practically equal yields under the same conditions of fertilization, with the exception of an additional amount of nitrogen on plot 12, it will be observed that the nitrogen content of the crop from plot 12 has been materially increased.

The enhanced accumulation of nitrogen in the entire plant is distributed differently than the increases of phosphorus and potassium; the increased phosphorus is transferred to the grain, and the potassium is retained in the straw, while the nitrogen is distributed in both grain and straw.

Table XVIII summarizes the data obtained from the analyses of the wheat crop grown on Strongsville soil. An inspection of these results shows an increased percentage of nitrogen over that found in the crop from the Wooster soil, and a larger percentage in the wheat grown on the limed land than on that cross-dressed with floats. Table XIX gives the yield per acre and the percentage of nitrogen in the grain for each of the two seasons. This table shows that in 1908 there was but little difference between the yield per acre of the land cross-dressed with floats and that treated with lime, while in 1909 the floats treated land produced generally the larger yield.

TABLE XVIII—NITROGEN CONTENT OF WHEAT GROWN IN 5-YEAR ROTATION AT STRONGSVILLE. AVERAGE FOR 1908 AND 1909

Plot No.	Fertilizing elements per acre for one 5-year rotation			Nitrogen content					
				Cross-dressed with floats			Cross-dressed with lime		
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Entire plant	Grain	Straw	Entire plant
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
*	..	...	...	1.812	.305	.852	2.159	.458	1.055
2	20	...	...	1.775	.235	.802	1.942	.338	0.898
3	..	108	...	1.900	.290	.841	2.185	.465	1.085
8	20	108	...	1.740	.258	.831	1.957	.307	0.943
5	..	...	76	1 837	.263	.814	2.290	.485	1.086
9	..	108	76	1.825	.273	.854	2.160	.406	1.033
6	20	...	76	1.770	.237	.823	2.025	.343	1.003
11	20	108	76	1.780	.276	.837	1.967	.351	0.929
12	20	108	114	1.795	.257	.831	1.985	363	0.970

*Average of unfertilized plots.

Our records show that the land on which the wheat was grown in 1908 had received only half the quantity of floats that was used subsequently. In every case however the wheat grown on the limed land has shown a higher percentage of nitrogen than that grown on the land treated with floats.

TABLE XIX—YIELD PER ACRE AND PERCENTAGE OF NITROGEN IN THE GRAIN OF WHEAT GROWN IN 5-YEAR ROTATION AT STRONGSVILLE

Plot No	Fertilizing elements per acre for one 5 year rotation			Yield of grain per acre				Nitrogen in grain			
				1908		1909		1908		1909	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs	Lbs	Lbs	Bus	Bus	Bus	Bus	Percent	Percent	Percent	Percent
*				12 15	15 84	17 47	9 33	1 800	2 096	1 827	2 225
2	20			20 09	18 92	15 67	14 00	1 824	1 843	1 730	2 045
3		108		7 92	11 17	14 67	8 67	1 831	2 161	1 970	2 210
8	20	108		25 33	21 59	18 67	21 67	1 742	1 881	1 740	2 035
5			76	12 09	18 58	20 00	8 67	1 880	2 162	1 795	2 420
9		108	76	15 92	16 12	18 00	11 00	1 830	2 023	1 820	2 300
6	20		76	28 25	24 59	19 67	23 33	1 814	2 061	1 730	1 990
11	20	108	76	29 59	25 08	20 00	20 33	1 751	1 871	1 810	2 065
12	20	108	114	28 67	23 75	22 67	26 67	1 742	1 803	1 850	2 175
Average of all plots				20 00	19 88	18 51	15 96	1 802	1 989	1 808	2 163

*Average of unfertilized plots.

SUMMARY

The percentages of phosphorus, potassium and nitrogen in the wheat crops analyzed exhibit a wide range of variation. In the grain the differences between the maximum and minimum amounts found are practically the same for each of these constituents; the variations in the straw do not show as marked a uniformity.

The composition of the wheat crop grown on the unfertilized plots of two soils, containing different amounts of phosphorus, potassium and nitrogen, is in accordance with the composition of these soils.

The proportion of phosphorus, potassium and nitrogen in the wheat plant is increased by the addition of these elements to the soil.

Although the extent of variation due to seasonal conditions is greater than that produced by changes in the composition of the soil, the variations due to soil treatment are relatively the same for the different seasons.

Phosphorus applied to soil, showing a deficiency of this element as measured by crop yields, increases the amount of phosphorus in the grain. Associated with this increased accumulation of phosphorus there is an increased quantity of potassium and a decreased amount of nitrogen.

The addition of lime to the soil increases the amount of phosphorus assimilated by the wheat plant. With this increase in the phosphorus content there are the same variations in the nitrogen and potassium as are produced by the addition of phosphorus.

The composition of the wheat crop from plots on the same soil treated with five different carriers of phosphorus, namely: acid phosphate, bone meal, dissolved bone black, basic slag, and barnyard manure, shows that the phosphorus content of the wheat plant has been increased to the greatest extent by manure.

The application of untreated rock phosphate to a soil well supplied with nitrogen and potassium, increases the phosphorus content of the wheat plant to a marked extent.

The percentage of nitrogen in the wheat plant varies with the supply at its disposal, and is also influenced to a considerable extent by the supply of phosphorus.

An increase in the potassium supply of the soil is reflected in the potassium content of the straw.

A comparison of the composition of the wheat plant grown on the same soil, under different conditions of fertilization, gives a better indication of the available supply of nitrogen, phosphorus and potassium in the soil than can be obtained from the analysis of the soil itself.*

*For data upon the relation of the soil and its treatment to the composition of Blue-grass the reader is referred to Bulletin 222 of this Station.

ADDENDA

Detailed results are given in the following tables:

Table XX—Nitrogen, phosphorus and potassium content of wheat grain and straw from east and west ends of the 5-year rotation fertilizer plots at Wooster, Section E. 1907.

Table XXI—Nitrogen, phosphorus and potassium content of wheat grain and straw from east and west ends of the 5-year rotation fertilizer plots at Wooster, Section B. 1908.

Table XXII—Nitrogen and phosphorus content of wheat crop, 5-year rotation at Wooster, 1904.

Table XXIII—Nitrogen, phosphorus and potassium content of wheat crop, continuous culture at Wooster, 1908.

Table XXIV—Nitrogen content of wheat grain and straw, 5-year rotation at Wooster, 1902, 1904, 1906, 1907, and 1908.

Table XXV—Nitrogen, phosphorus and potassium content of wheat crop, 5-year rotation, at Strongsville 1908 and 1909. Plots treated with lime and floats.

Table XXVI—Pounds of nitrogen, phosphorus and potassium removed per acre by wheat crop at Strongsville, 5-year rotation, from halves of plots receiving lime and floats, 1908 and 1909.

Table XXVII—Pounds of nitrogen removed per acre by wheat grain and straw, 5-year rotation at Wooster, 1902, 1904, 1905, 1906, 1907, and 1908.

Table XXVIII—Pounds of potassium removed per acre by wheat grain and straw, 5-year rotation plots at Wooster, 1907 and 1908.

Table XXIX—Pounds of phosphorus removed per acre by wheat grain and straw, 5-year rotation at Wooster, 1904, 1907, and 1908.

Table XXX—Ratio of phosphorus to nitrogen. Parts of phosphorus to 100 parts of nitrogen, 5-year rotation at Wooster.

Table XXXI—Percentage increase yield and percentage increase phosphorus removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

Table XXII—Percentage increase yield and percentage increase potassium removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

Table XXXIII—Percentage increase yield and percentage increase nitrogen removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

TABLE XX—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF THE 5-YEAR ROTATION FERTILIZER PLOTS AT WOOSTER, SEC. E., 1907. WEST END LIMED 1900. EAST END LIMED 1905.

Plot No	Fertilizing elements per acre for one 5-year rotation			Grain						Straw						Plot No.
				Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
	Phosphorus	Potassium	Nitrogen	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
1	..	...	...	2.081	2.023	.3012	.3380	.3224	.4161	.5202	.5651	.0628	.0692	1.087	.773	1
2	20	...	..	1 840	1 791	.3521	.4151	.3380	.3880	.2904	.3504	.0426	.0700	0.746	.491	2
3	..	108	..	1 972	1 842	.3443	.3390	.3412	.3831	.5003	.3951	.0481	.0489	0.744	.763	3
4	..	...	.	2 083	1 901	.3110	.3224	.3371	.3790	.4851	.4602	.0588	.0509	0.884	.686	4
5	..	...	76	2.331	2 080	.2912	.3103	.3342	.3841	.6002	.6050	.0526	.0572	0 669	.711	5
6	20	...	76	1.970	1.891	.3260	.3621	.3214	.3513	.3400	.3404	.0451	.0493	0.858	.655	6
7	..	..	..	2.012	1.903	.3081	.3190	.3351	.3832	.4602	.4802	.0567	.0522	0.681	.662	7
8	20	108	..	1.781	1 782	.3334	.3951	.3142	.3814	.3001	.3401	.0414	.0688	0.715	.750	8
9	..	108	76	2.293	2 043	.3014	.2920	3431	.3551	.5504	.5632	.0564	.0576	0.864	.847	9
10	..	...	..	2.112	1 841	.2981	.3181	.3504	.3804	.5203	.4101	.0601	.0443	0 701	.782	10
11	20	108	76	1.902	1.830	.3152	.3422	.3250	.3621	.3204	.3404	.0377	.0423	0.826	.789	11
12	20	108	114	2.113	2.063	.3160	.3181	.3021	.3361	.3902	.4202	.0476	0423	0.801	.835	12
13	..	..	...	2.001	1.882	.2953	.2923	.3761	.3632	.4500	.4851	.0564	.0497	0.698	.710	13
14	15	75	51	1.902	1.881	.3034	.3181	.3423	.3470	.3401	.4103	.0456	.0335	0.716	.668	14
15	10	41	25	1.861	1.840	.2781	.2952	.3241	.3434	.3500	.3650	.0385	.0356	0.739	.765	15
16	..	..	..	2.003	1.841	.2852	.2912	.3943	.3804	.6004	.4301	.0663	.....	0.791	.705	16
17	30	108	38	1.791	1.783	.3381	.2951	.3551	.3591	.3102	.3403	.0406	.0576	0 755	.700	17
18	48	112	144	1.890	1.862	.3382	.3852	.3514	.3790	.4003	.3604	.0489	.0584	0 807	.712	18
19	..	...	...	2.031	1.801	.2880	.3504	.3860	.3672	.5901	.4102	.0547	.0410	0.737	.686	19
20	24	56	72	1.842	1.693	.3004	.3730	.3741	.3352	.3500	.3204	.0402	.0348	0.729	.695	20
21	30	108	38	1.790	1.612	.3451	.3641	.3842	.3514	.3304	.3203	.0406	.0414	0.800	.753	21
22	..	...	...	1.923	1.701	.2953	.2842	.3923	.3713	.5402	.4001	.0559	.0386	0 816	.715	22
23	30	108	38	1.651	1.591	.3480	.3551	.3790	.3731	.2901	.3404	.0461	.0543	0.760	.758	23
24	30	108	38	1.690	1.672	.3404	.3590	.3872	.3622	.3103	.3601	.0418	.0534	0 800	.798	24
25	.	..	...	1.892	1.801	.3041	.2814	.4080	.3590	.5302	.4402	.0613	.0451	0 763	.702	25
26	20	108	76	1.741	1.762	.3152	.3171	.3542	.3732	.3504	.4004	.0431	.0447	0.751	.744	26
27	20	108	76	1.761	1.741	.2970	.3390	.3261	.3491	.3503	.3650	.0387	.0501	0.843	.773	27
28	.	...	...	1.853	1.752	.2924	.3262	.3680	.4154	.5304	.4604	.0530	.....	0 820	.697	28
29	20	108	76	1.751	1.791	.3214	.3214	.3514	.3343	.3502	.3651	.0387	.0460	0.749	.768	29
30	30	108	38	1.730	1.723	.3160	.3690	.3360	.3840	.3501	.3863	.0580	.0601	0.787	.750	30

TABLE XXI—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF THE 5-YEAR ROTATION FERTILIZER PLOTS AT WOOSTER, SEC. B.,
1908. WEST END LIMED 1901. EAST END LIMED 1906.

Plot No.	Fertilizing elements per acre for one 5-year rotation			Grain						Straw						Plot No.
				Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
	Phosphorus	Potassium	Nitrogen	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
1	..	...	...	1.903	1.810	.3112	.3370	.3421	.3661	.4902	.5301	.0474	.0564	0 7841	0 8461	1
2	20	...	...	1.551	1.505	.3441	.3641	.3471	.3740	.3001	.2673	0384	.0343	0 7370	0 6952	2
3	..	108	...	1.810	1 710	.3022	.3332	2790	.3460	.4670	.4351	0466	.0480	1 0604	0 9283	3
4	..	...	...	1.842	1 680	.3190	.3476	.2814	.3602	5021	.4302	.0478	.0605	0 8212	0 6480	4
5	..	...	76	2.123	1.885	2680	.3243	.2761	3513	.5803	.5870	.0443	.0589	0 8813	0 6881	5
6	20	...	76	1.761	1 700	.2991	.3421	3373	3391	.4302	.3121	.0406	.0331	0 7576	0 6304	6
7	..	...	...	1.802	1 715	.3163	.3423	2562	.3412	.3651	.3520	.0341	.0394	0 7871	0 8151	7
8	20	108	...	1.681	1 530	.3582	.3881	.3471	.3691	.3550	2703	.0312	.0335	1 1242	0 9580	8
9	..	108	76	2.050	1.955	.2870	.3012	.3383	.3372	.5152	.5150	.0398	.0478	1 1071	1 0824	9
10	..	...	...	1 963	1 880	.3231	.3140	.3591	3480	.4321	.4152	0398	.0400	0 7653	0 8012	10
11	20	108	76	1 771	1.815	.3332	.3381	2932	3653	.3953	.4201	.0392	0417	1 0981	1 0441	11
12	20	108	114	2 043	1 830	.3270	3334	.4141	.3652	.4254	.4123	.0343	.0372	1 0490	1 1070	12
13	..	..	...	1 832	1.755	.3281	.3201	.3780	.3671	.4500	.4370	.0367	0474	0 8702	0 7802	13
14	15	75	51	1.831	1 640	.3234	.3321	.3553	.3504	.3352	.2904	.0292	.0308	0 9754	1.0081	14
15	10	41	25	1.740	1.680	.3023	.3293	.3352	.3681	.3571	.3121	.0320	.0320	1 0293	0 9242	15
16	..	...	...	1 822	1.680	.3001	.3370	.3324	.3814	.4503	.4404	.0449	.0519	0 9150	0 8681	16
17	30	108	38	1.621	1 480	.3361	.3851	.3780	.3670	.2850	.2651	.0304	.0357	1.0102	0 9491	17
18	48	112	144	1.683	1.590	.3532	.3944	.3804	3614	.3221	.3250	.0355	.0509	0 9871	0 9502	18
19	..	...	..	1 861	1.615	.2941	.3510	.3311	.3691	.4323	.4302	.0372	.0572	0 7614	0 7552	19
20	24	56	72	1 662	1 575	.2946	.3712	.2970	.3583	.2852	.3651	.0273	.0400	0 8021	0 9004	20
21	30	108	38	1.533	1 520	.3580	.3943	3662	.3814	.2871	.2920	.0343	.0390	1 0303	0 9283	21
22	.	...	...	1 812	1.715	.2881	.3301	.3013	.3621	.4453	.4702	.0437	.0544	0.7452	0 7954	22
23	30	108	38	1 601	1 510	.3643	.3914	.3271	.3922	.2672	.2851	.0322	.0435	1.0461	0 8991	23
24	30	108	38	1.642	1 540	.3521	.3720	.3224	.3801	.2771	.2952	.0323	.0388	1 0334	0.9604	24
25	..	...	..	1.741	1 725	.3170	.3212	.3480	.3470	4424	.5420	.0498	.0607	0 8431	0 7651	25
26	20	108	76	1 691	1 785	.3391	.3321	3671	.3431	.2751	.4551	.0376	.0470	1 0780	1 1230	26
27	20	108	76	1 662	1.700	.3450	.3612	.3562	.....	.3252	.2224	.0327	.0335	0.9132	1.0152	27
28	..	...	..	1 693	1 665	.3312	3343	3604	3581	.4350	.3720	.0503	0388	0 7081	0 8541	28
29	20	108	76	1 751	1 690	.3390	.3801	.3501	.3712	.4103	.2871	.0435	0339	1.0142	1 0360	29
30	30	108	38	1.561	1 620	4151	.4160	.3532	.3991	.2351	2852	.0367	0445	0.9570	0.9952	30

TABLE XXII—NITROGEN AND PHOSPHORUS CONTENT OF WHEAT CROP, 5-YEAR ROTATION AT WOOSTER 1904

Plot No	Fertilizing elements per acre for one 5 year rotation			Nitrogen in		Phosphorus in	
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Grain	Straw
	Lbs	Lbs	Lbs	Percent	Percent	Percent	Percent
0[a]				2 085	0 947	3663	.012
2	20		. .	2.146	0 640	.3960	.0724
3		108	.	2.181	0 985	3366	0995
5			76	2 146	1 056	.3187	.0899
6	20	.	76	2 117	0 491	.4034	0799
8	20	108	.	1 845	. ..	.4213	.0921
9		108	76	2 115	0 814	.3423	0943
11	20	108	76	1 950	0 466	3886	0961
12	20	108	114	2 120	0 539	.3737	0860
14	15	75	51	1.930	0 466	3916	0519
15	10	41	25	1.990	0 480	.3750	.0676
17	30	108	38	.....	0 376	.. .	.0755
18	48	112	144	2 035	0 501	.4357	.1030
20	24	56	72	2.050	0.645	4108	.1013
21	30	108	38	1.830	0 440	.4117	.0655
23	30	108	38	1.794	0.435	4357	.0833
24	30	108	38	1.874	0 440	4095	0890
26	20	108	76	1.979	0.640	.4265	0890
27	20	108	76	. ...	0 539	. ....	.0868
29	20	108	76	2.010	0 570	4012	.0816
30	30	108	38	1.866	0 539	.4073	1920

[a] Average of unfertilized plots

TABLE XXIII—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT CROP.
CONTINUOUS CULTURE AT WOOSTER, 1908

Plot No.	Fertilizing elements applied per acre			Nitrogen in			Phosphorus in			Potassium in			Plot No.
	Acid phosphate	Muriate potash	Nitrate of soda	Grain	Straw	Entire plant	Grain	Straw	Entire plant	Grain	Straw	Entire plant	
	Lbs	Lbs.	Lbs.	percent	Percent	Percent	ercent	Percent	Percent	Percent	Percent	Percent	
*	...	...		1.896	.5740	0.9691	.3053	.0552	.1335	.3661	0 7747	.6501	*
2	160	100	160	1 775	.4304	0 8720	.4034	.0499	.1659	.3730	0.7735	.6403	2
3	45	30	160	1 925	.4103	0 9192	.3166	.0418	.1340	.3521	0.7598	.6210	3
5	Yard manure 2½ tons			1.710	.4102	0.8714	.3655	.0518	.1628	.3609	0.7847	.6331	5
6	Yard manure 5 tons			1.660	.3821	0.8271	.3839	.0570	.1707	.3899	0.9096	.7280	6
8	160	100	320	1.970	.5570	1.0460	.4144	.0594	.1820	.3923	1.0627	.8291	8
9	90	60	320	2 065	.6122	1 1232	.3154	.0539	.1458	.3601	0.8219	.6583	9

Average of unfertilized plots.

TABLE XXIV—NITROGEN CONTENT OF WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER—PERCENT

Year	1902		1904		1905	1906	1907		1908		Average		Plot No.
Plot No.	Grain	Straw	Grain	Straw	Grain	Grain	Grain	Straw	Grain	Straw	Grain	Straw	
*	2 261	.818	2.086	0.947	2.344	2.100	1.918	.488	1.771	.444	2.080	.674	*
2	1 974	.452	2.146	0.640	1.880	1.820	1.815	.320	1.527	.283	1.860	.423	2
3	2 329	.681	2.181	0.985	2.440	2.240	1.905	.447	1.760	.451	2 159	.641	3
5	2.532	.944	2.146	1.056	2.600	2.400	2.205	.602	2.002	.583	2.314	.796	5
6	2 088	.562	2.117	0.494	2.150	1.930	1.930	.340	1.732	.371	1.991	.441	6
8	1 701	.393	1.845	.....	1.900	1.650	1.780	.320	1.605	.312	1 746	.341	8
9	2 516	.875	2.115	0.814	2.580	2.320	2.165	.557	2.002	.515	2.283	.690	9
11	1.963	.434	1.950	0 466	2.050	1.900	1.865	.330	1.792	.407	1.920	.409	11
12	2.017	.528	2.120	0.539	2.310	1.920	2.085	.405	1.935	.418	2 064	.472	12
14	1.949	.470	1.930	0 466	2.210	1.800	1.890	.375	1.735	.312	1.919	.405	14
15	2 178	.456	1.990	0.480	2.100	1.900	1.850	.357	1.712	.334	1 955	.406	15
17	1.755	.391	....	0.376	1.900	1.790	1.785	.325	1.550	.275	1.756	.341	17
18	2 006	.485	2.035	0 501	2.000	1.830	1.875	.380	1.635	.323	1.896	.422	18
20	1.948	.572	2.050	0.645	2.250	1.940	1.765	.335	1.620	.325	1.928	.469	20
21	1.618	.356	1.830	0.440	1.980	1.710	1.700	.325	1.525	.289	1.727	.352	21
23	1 641	.369	1.794	0.435	.....	1.740	1.620	.315	1.555	.276	1.670	.348	23
24	1 637	.369	1.674	0.440	1.900	1.930	1.680	.335	1.592	.286	1.768	.357	24
26	2 027	.420	1.979	0 640	2.150	1.930	1.750	.375	1.737	.365	1.928	.450	26
27	1 913	.420	.....	0.539	2.110	1 900	1.750	.357	1.682	.323	1.871	.409	27
29	2.106	.506	2.010	0.570	2.260	2.000	1.770	.357	1.720	.348	1.977	.445	29
30	1 768	.441	1.866	0.539	1.970	1.700	1.725	.365	1.590	.260	1.769	.401	30

*Average of unfertilized plots.

TABLE XXV—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT CROP, 5-YEAR ROTATION AT STRONGSVILLE 1908 AND 1909. PLOTS TREATED WITH LIME AND FLOATS.—PERCENT

Treatment	Grain 1908						Straw 1908						Treatment
	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
Plot No.													Plot No.
1	1 823	2 261	3997	.3290	.4408	.4296	.3314	.5304	.0597	.0470	0.9619	0.9447	1
2	1 824	1.843	.4449	.4122	.4497	.4735	.2101	.3112	.0476	.0447	0.9325	0.9507	2
3	1 831	2 161	.4162	.3014	.4534	.3857	.3006	.4621	.0429	.0449	1.2462	1.1387	3
4	1.870	2 270	.4089	.2744	.4513	.3946	.2921	.4513	.0340	.0439	1.2088	1.0929	4
5	1 889	2 162	.4168	.2837	.4501	.3772	.2811	.4706	.0420	.0416	1.1456	1.1505	5
6	1.814	2 061	.4572	.3643	.4775	.4336	.2512	.3610	.0375	.0429	1.0361	1.0207	6
7	1.781	2.024	.4327	.3546	.4284	.4119	.3220	.3807	.0398	.0560	1.0450	1.0316	7
8	1 742	1 881	.4431	.4239	.4582	.4534	.2702	.2722	.0376	.0599	1.0788	1.0642	8
9	1.830	2.023	.4064	.3502	.4493	.4131	.2713	.3813	.0372	.0406	1.1987	1.1381	9
10	1.804	1 904	4193	.3403	.4332	.4114	.3070	.3224	.0355	.0476	1.0494	1 0570	10
11	1.751	1 871	4315	.4194	.4646	.4477	.3212	.3040	.0480	.0458	0.9632	0.9374	11
12	1.742	1 803	.4260	.4153	.4405	.4485	.2201	.2615	.0402	.0423	0.9995	1.0050	12
13	1.723	2 021	.3691	3368	.3865	3970	.3621	.4213	0425	.0562	1.0368	1.0064	13
*	1.800	2.096	.4059	.3290	.4280	.4089	.3279	.4212	.0423	.0501	1.0604	1.0265	*
	Grain 1909						Straw 1909						
1	1 830	2 185	.4789	3098	.4770	.3622	.2970	.4401	.0556	.0372	0.9101	0.9741	1
2	1 730	2 045	4689	.4116	.4503	.4341	.2603	.3670	0502	.0400	1.0070	0.9990	2
3	1 970	2.210	4841	.3213	.4512	.3904	.2804	.4702	.0424	.0333	1.0061	1.2291	3
4	1 800	2 180	4588	2794	.4370	.3790	.3051	.4472	0542	.0284	0.8462	1.0092	4
5	1 795	2 420	4182	.2775	.4324	.3381	.2470	.5004	0290	.0290	0.8814	1.0560	5
6	1.730	1 990	.4671	.3845	.4451	.3752	.2252	.3271	.0404	.0289	0.6732	0.7653	6
7	1 770	2.315	4614	.2830	.4223	3590	.2471	.5252	.0385	.0344	0.8821	1.0041	7
8	1.740	2 035	4623	.3685	.4590	.4063	.2470	.3451	.0432	.6318	0.7680	0.9762	8
9	1 820	2 300	.4505	.2817	.4251	.3431	.2773	.4324	.0402	.0286	0.8124	1.0680	9
10	1 930	2 270	.4702	.2781	.4073	.3652	.2851	.5604	.0432	.0369	0.9403	1.2053	10
11	1 810	2 065	.4693	.4596	.4441	.4261	.2322	.4021	.0440	.0459	0.9431	1.2224	11
12	1 850	2 170	.4780	4449	.4304	.4553	.2950	.4670	.0530	.0502	0.9723	1.0641	12
13	1 805	2 175	4536	.3259	.4031	.3960	.3221	.5172	.0640	.0402	0.9760	1.1360	13
*	1 827	2.525	4646	.2947	.4293	.3722	.2912	.4980	.0511	.0354	0.9109	1.0657	*

*Average of unfertilized plots.

TABLE XXIV—POUNDS OF NITROGEN, PHOSPHORUS AND POTASSIUM REMOVED PER ACRE BY WHEAT CROP AT STRONGSVILLE, 5-YEAR ROTATION FROM HALVES OF PLOTS RECEIVING LIME AND FLOATS, 1908 AND 1909—

Treatment	Grain 1908						Straw 1908						Treatment
	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
Plot No.													Plot No.
1	9.09	21.46	1.99	3.12	2.20	4.07	3.23	7 47	0.585	0.659	9.42	13.31	1
2	21.29	21.34	5.20	4.78	5.25	5.48	3 84	5.70	0.868	0.820	17 06	17.48	2
3	7.32	20 73	1.65	2.89	1 81	3.70	2 40	6.25	0 340	0.606	9.96	15.48	3
4	11 78	22 70	2.57	2.74	2 83	3.94	2.75	7.20	0 323	0.698	11.48	17.48	4
5	11.84	21 81	1.62	2.86	2 83	3.80	3 50	8.41	0 523	0.742	14.31	20.59	5
6	31.85	29 87	8.04	5.28	8.40	6 28	6 40	7.30	0.956	0.868	26.51	20.71	6
7	10.32	17.97	2.51	3.15	2.48	3.66	3.52	5 13	0 436	0.755	11.49	13.92	7
8	27.48	25 38	6 99	5.71	7.23	6.11	6 42	5 21	0.895	1.152	25.67	20.53	8
9	15.73	23 23	3 49	4 02	3.86	4.74	3.83	6.42	0.528	0.685	17.02	19 22	9
10	11.52	20.71	2.68	3.70	2.77	4 48	3 48	5 08	0.410	0.755	12.17	16.80	10
11	29.40	30.10	7.24	6 74	7.80	7.20	8 57	7.05	1.287	1.074	25.81	22.02	11
12	28 36	26.10	6.94	6.02	7.17	6.50	5 56	5.79	1.017	0.943	25.28	22.40	12
13	11.01	19.18	2.36	3.19	2.47	3.76	4 46	6.76	0.523	0.903	12.85	16.19	13
	Grain 1909						Straw 1909						
1	17 56	12.23	4.59	1.73	4 29	2.02	5.10	5.54	0.956	0.467	15.65	12.28	1
2	16.26	17.17	4.40	3.45	4 23	3 64	5.62	6.67	0 895	0.729	17.93	18.19	2
3	17.33	11.49	4.26	1.66	3.96	2.02	4.53	5.45	0.685	0.384	16.29	14.25	3
4	18.71	10.89	4.76	1.39	4.54	1.89	5.06	5.27	0.899	0.331	14.05	11.90	4
5	21.54	12.58	5.01	1.44	5.18	1.76	5.13	5.80	0.602	0.336	18.33	12.24	5
6	20.41	27.85	5.50	5.37	5.25	5.24	4.77	7.84	0 855	0.689	14.27	18.36	6
7	16.64	12.50	4.33	1.51	3.96	1.93	3.85	6.30	0 598	0.410	13.76	12.05	7
8	19 49	26.45	5.17	4.78	5.13	5.27	4.59	7.93	0.803	0.729	14.28	22 45	8
9	19 65	15.18	4.86	1.85	4.59	2.26	5.04	6.13	0 729	0.406	14.78	15.16	9
10	20.84	12.70	5.07	1.55	4.40	2.04	5.24	6.38	0.794	0.419	17.30	13.74	10
11	21.72	25.18	5.63	5.60	5.33	5.19	4.87	10.77	0.921	1.231	19.80	32.74	11
12	25.16	34.72	6.50	7.11	5.85	7.27	7.25	13 44	1.301	1.445	23.91	30.65	12
13	22.01	13.92	5.53	2.08	4.91	2.53	6.82	7.23	1.357	0.563	20.69	15.90	13

TABLE XXVII—POUNDS OF NITROGEN REMOVED PER ACRE BY WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER, 1902, 1904, 1905, 1906, 1907, 1908.

Year	Nitrogen removed by grain						Nitrogen removed by straw			
	1902	1904	1905	1906	1907	1908	1902	1904	1907	1908
Plot No.										
1	17 07	09 35	08 03	23.01	17 91	23.59	06.80	06.80	10.63	11 86
2	28 98	25 37	17 90	33 53	26 38	27 65	07 79	12.59	09 10	07.91
3	20 10	15 97	07 07	26 09	19 05	23.72	06.40	16.42	08.79	10.11
4	15 80	12 20	06 80	25 24	19 14	21.63	05 89	14.22	08 44	09 94
5	19 78	16 24	08 91	30 60	25 28	26.44	07 59	18.40	13 58	14.54
6	42 48	31.65	27 52	45 40	36 75	38.57	13 20	13 61	12 90	12.84
7	16 81	11 43	06 51	27 09	18 52	20 76	06 61	09.73	08 51	06 22
8	25 78	22 14	17 14	31 97	24.51	28.75	06 97	.....	87.99	08 89
9	21.25	15 76	08 25	37 12	23 05	28.46	08 13	15.51	11.54	14 02
10	13.85	10 75	06 23	27 62	15 45	24.78	10.30	09.64	06 15	09.16
11	43 97	31 39	30 44	48 68	33 32	44.58	11.76	14.40	12.38	16.07
12	49 31	35 93	36 15	50 88	42 38	47.03	15.28	18.08	16.46	16 80
13	14 43	11 96	06 07	21 90	15 65	22.94	05.81	12 96	06 88	08 53
14	41 90	33 80	31 93	43 10	32 50	41 29	12.36	13 79	13.12	11.77
15	46 17	33 57	27 24	46 50	29 96	35 73	11.90	15 18	11.92	10 34
16	14 72	11 55	05.02	26.80	15 76	16 09	06.07	09 91	07 92	06.76
17	35 71	...	22 23	43 50	28 47	31 91	10 22	10 38	10.31	08 97
18	30 75	30 62	22 59	46 75	33 88	32 66	09.16	14 50	13 54	09.56
19	.....	12.15	07 39	28 95	16 91	18 33	07 45	13.01	07.60	07.63
20	19 18	27 37	17 71	43 16	23 82	26 73	06.83	16.23	09.78	08.36
21	25 80	29 73	25 34	39 42	22 23	28 52	06 14	11.55	08.83	08 25
22	11 17	12 83	07.56	26 94	13 19	19 20	04 45	12.34	06 35	08 13
23	23.22	25.91	...	37 58	19 49	29 71	05 59	10.46	07 01	07 79
24	20 87	26.46	24 37	41.15	24 36	31.51	04 99	10.06	10.32	08 69
25	11.49	12.94	08 32	27 32	12 89	19 41	04.29	14 30	06 59	09 62
26	34 45	30.18	22 25	45 35	28 18	33 28	07.98	18 08	11 37	10 11
27	35 10	.. ..	32 60	44 54	30 70	36.17	08 29	16.34	12 70	10.96
28	15 01	12 03	09 69	23 08	14 11	18 71	04.50	11 58	06.75	06 41
29	39 06	27 23	27 74	46 80	29 01	34.34	10.04	16.09	11.47	10 67
30	32 09	25 00	24.48	35.02	29 89	29 18	08.31	15.04	11.90	07.58

TABLE XXVIII—POUNDS OF POTASSIUM REMOVED PER ACRE BY WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF 5-YEAR ROTATION PLOTS AT WOOSTER, 1907 AND 1908

Plot No.	Grain				Straw			
	1907		1908		1907		1908	
	East end	West end	East end	West end	East end	West end	East end	West end
1	3 35	3.02	4.31	4.65	13.88	23.26	14.90	23.07
2	5 26	5.23	6.53	6 50	12.79	23.36	16 69	23 18
3	3.81	3.42	5.58	3.82	14.54	14.99	19.14	25.55
4	3.45	3.40	4.49	3.41	10.36	18.14	13.43	17.95
5	4 30	3.91	5.05	3 35	15 92	15.19	17.23	21.90
6	6.77	6.04	7.58	7 34	25 50	31 80	20 94	27.00
7	3.64	3.17	3 78	3.20	11.45	12.91	11.33	16.37
8	4.94	4 59	5.57	6.91	18.34	18 32	23.29	35.57
9	4 28	3 22	4 70	5 03	19 10	16 27	27.76	31.95
10	3 11	2 62	4.25	4.62	11.89	8 21	15 87	16.83
11	6 66	5 64	9.63	7.14	29.35	31.30	41.37	43.14
12	6.16	6.75	9.18	9.77	30.84	35.81	46.35	40.28
13	3 30	2 67	4.19	5.35	11.01	9.70	14.66	17 11
14	6.10	5 77	8 47	8.32	23 28	25.19	34 90	39.37
15	5.59	5 22	7.26	7.30	24.41	25.79	28 00	32.34
16	3.49	2.80	3 54	3 02	12.69	10.68	13.11	14.00
17	6 06	5.33	6 80	8 40	22 06	24 18	27.24	36 65
18	7 09	6.14	6 78	8.05	26.55	27.58	25 67	31.68
19	3 67	3.01	3.57	3.73	12.21	.....	11.40	15.45
20	4.55	6.01	5.58	5.15	20.31	21.30	22.67	21.22
21	4 39	5.23	6.48	7.44	19.52	22.73	23.38	32.77
22	2.94	2.63	3.18	3.86	9.47	11.18	10.16	15.90
23	4.35	4.70	6.36	7.14	15.13	19.00	21.39	34.48
24	5 28	5 57	6.12	7 50	25.88	23 21	24.49	36.71
25	2 69	2 65	3.36	4.44	8 77	11.06	13.27	18.76
26	6 09	5.63	6.34	7.24	24.03	21.12	30.72	30.52
27	6 36	5 51	....	7.58	27.52	29.95	35.63	29.87
28	3.08	2.43	3 65	4.35	11 19	9.48	11.95	12.38
29	6.03	5.17	8.66	5.84	27 46	21 21	38.39	26.47
30	6.35	6.11	8.54	5.29	23.04	27.28	30.54	25 83

TABLE XXIX—POUNDS OF PHOSPHORUS REMOVED PER ACRE BY WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER, 1904, 1907 AND 1908

Year	Grain					Straw					Year
	1904	1907		1908		1904	1907		1908		
Plot No.		East end	West end	East end	West end		East end	West end	East end	West end	Plot No.
1	1.41	2.72	2.83	3.98	4.23	0.92	1.24	1.34	0.99	1.39	1
2	4.68	5.62	5 47	6.35	0.46	1.42	1.82	1.33	0.82	1 20	2
3	2.46	3.37	3.46	4.41	4.14	1.65	0.93	0.96	0 99	1.12	3
4	1.94	2.93	3.14	4.32	3.88	1 30	0.76	1.20	1.25	1.04	4
5	2 41	3 47	3.40	4.67	3.25	1 56	1.28	1.19	1.47	1.10	5
6	6.02	6.99	6.13	7.66	6.63	2.20	1.92	1.67	1.10	1 44	6
7	2.03	3.03	2.91	3.79	3.94	1.15	0 90	1.07	0.54	0.70	7
8	5 05	5.11	4.86	5.85	7.28	1.74	1.68	1.06	0.81	0.98	8
9	2.54	3.52	2.83	4.20	4.34	1.79	1.30	1.06	1 22	1.14	9
10	1 92	2.61	2.23	3.83	4.40	1.09	0.67	0.70	0.79	0.87	10
11	6 25	6 29	5.47	8.57	8 12	2.96	1.57	1.42	1.65	1.54	11
12	6.33	5.83	7 05	8.39	7.71	2.88	1 55	2.13	1.55	1.31	12
13	2.02	2 65	2.09	3.65	4 65	1.40	0.77	0.78	0.89	0.72	13
14	6 61	5.58	5.10	8 04	7.57	1.53	1.17	1.69	1.06	1.17	14
15	6.32	4.82	4.48	6.55	6.59	2.13	1.13	1.34	0 96	1.00	15
16	2.13	2.67	2.08	3.13	2.72	1.08	. ..	0.89	0.78	0.68	16
17	. ..	4 99	5.08	7.12	7.56	2.08	1.81	1.30	1.02	1.10	17
18	6.55	7.20	5.90	7.42	7.45	2.98	2 17	1.67	1.37	1.13	18
19	2.25	3.50	2 24	3.40	3.31	1.71	0.72	0.73	0.86	0.75	19
20	5.47	5.07	4.02	5.79	5 10	2.54	1.01	1.17	1.00	0.72	20
21	6.68	4.55	4.69	6.71	7 31	1.72	1 07	1.15	0.98	1.09	21
22	2 37	2 26	1.98	2.90	3.70	1.38	0.51	0.76	0.78	0.92	22
23	6.29	4 13	4.32	6.33	7.97	2.00	1.08	1.09	1.03	1.06	23
24	5.78	5.24	4.90	5.99	8.19	2 03	1.73	1.21	0.98	1.14	24
25	2.39	2.10	1.98	3.09	4.05	1 68	0.56	0.89	1 05	1.10	25
26	6.50	5.18	5.02	6.20	6.69	2.51	1.44	1.21	1.28	1 06	26
27	. ..	6.18	5.02	7.84	7 36	2 63	1.78	1.37	1.17	1.06	27
28	2.17	2.98	1.92	3.40	4.00	1.32	....	0.91	0.54	0 87	28
29	5 43	5.84	4.76	8.87	5.66	2.30	1.64	1.07	1.25	1.13	29
30	5.45	6.09	5.74	8.91	6.31	2.57	1.84	2.00	1.37	0.99	30

TABLE XXX—RATIO OF PHOSPHORUS TO NITROGEN. PARTS OF PHOSPHORUS TO 100 PARTS OF NITROGEN. EAST END 5-YEAR ROTATION AT WOOSTER, 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation			Parts of phosphorus to 100 parts of nitrogen		Plot No.
	Phosphorus	Potassium	Nitrogen	Grain	Straw	
	Lbs.	Lbs.	Lbs.			
1	..	....	...	18 59	10 60	1
2	20	....	...	24.18	12.83	2
3	..	108	..	19.51	11.00	3
4	..	....	..	20 69	14.05	4
5	..	....	76	17.11	10 04	5
6	20	....	76	20 12	10.60	6
7	..	....	...	19 95	11.17	7
8	20	108	...	25 36	12 39	8
9	..	108	76	15 41	9.25	9
10	..	....	...	16 72	8 99	10
11	20	108	76	18 59	9.91	11
12	20	108	114	18 20	9 03	12
13	..	....	..	18 24	10.82	13
14	15	75	51	20 25	10 60	14
15	10	41	25	19.60	10 21	15
16	..	....	..	20.08	11.78	16
17	30	108	38	25.97	13 44	17
18	48	112	144	24.79	15 67	18
19	..	....	..	21.74	13 27	19
20	24	56	72	23 57	10 95	20
21	30	108	38	25.97	13 35	21
22	..	....	..	19.21	11 56	22
23	30	108	38	25 89	15 23	23
24	30	108	38	24.14	13 14	24
25	..	....	..	18.59	11 17	25
26	20	108	76	18.59	10 30	26
27	20	108	76	21 26	10 39	27
28	..	....	...	20.03	10.43	28
29	20	108	76	22.48	11.83	29
30	30	108	38	25.71	15.58	30

TABLE XXXI: PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE PHOSPHORUS REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot No.	Grain 1907				Straw 1907				Plot No.
	East end		West end		East end		West end		
	Increase yield	Increase phosphorus removed	Increase yield	Increase phosphorus removed	Increase yield	Increase phosphorus removed	Increase yield	Increaae phosphorus removed	
2	61.27	101.25	60.82	86.18	53.23	70 61	48.34	3.03	2
3	13.64	17 83	1.88	13.77	18.69	2.39	—3.12	—22 37	3
5	21 31	17 08	18.39	11.09	41.49	58.06	13.60	3.00	5
6	106 08	133 04	94.47	105 25	134.78	124.48	90.08	49.60	6
8	42.81	77 03	65.86	81.59	47.28	105.31	54.83	10.95	8
9	39.54	27 93	15.38	15.27	41.82	74.26	33.16	27.89	9
11	116.44	139.53	135 54	150.09	143.13	123.60	204.50	95.80	11
12	107.90	120.46	208.40	230.00	139.61	111.24	239.40	182.08	12
14	92.16	109.67	135 13	144.05	113.38	.....	155.26	95.21	14
15	77.83	80.68	122 50	115 06	85.80	.....	156 05	57.14	15
17	78.53	69 58	100.85	137.55	75 66	.....	137.56	55.20	17
18	92.15	123.88	128.58	169.32	108.75	.....	154.28	112.77	18
20	45.97	65.90	80.22	86.46	79 34	56.37	116.29	58.23	20
21	44.75	72.1[illegible]	92 49	126.52	75.37	84.96	108.82	52.60	21
23	49.38	87.35	87.00	118.28	53.46	104.95	79.01	44.02	23
24	90.82	143.11	119.31	147.90	154.35	217.60	103 72	43.29	24
26	102.48	117.39	143.38	156.34	136.07	.....	107.76	53.59	26
27	111.62	131.15	157.44	158.42	139.43	.. .	183.32	96.87	27
	Grain 1908				Straw 1908				
2	45.18	54.01	42.97	56.77	28.41	—23.57	16 98	—5.46	2
3	8.28	4.97	8.43	3.48	5.48	—14.60	—1.09	—3.38	3
5	20.00	12.63	—.94	—16.55	35.37	49.11	15.76	18.86	5
6	93.92	92.96	78.85	68.96	105.14	46.51	69.09	77.00	6
8	31.71	53.54	58.12	77.82	53 15	30.06	49.67	29.88	8
9	17.90	9.69	14.51	2.36	43.83	73.45	33.77	40.64	9
11	112.79	127.16	76.69	81.20	103.42	100.00	85.13	87.76	11
12	115.60	125.58	68.64	68.92	118.72	81.21	88.17	71.59	12
14	126.14	130.53	88.09	90.55	96.96	24.48	121.70	64.63	14
15	99.02	97 50	102.13	97.64	85.51	18.08	87.46	42.85	15
17	96.07	120.70	128.79	158.12	90.06	18.08	113.94	54.26	17
18	96.46	123.97	99 71	138.40	78 80	64.92	72.27	54.43	18
20	65.92	79 08	46.85	48.10	69 50	20.94	28.08	—11.29	20
21	86.75	118.94	65.39	143.90	72.20	21.62	51.42	25.00	21
23	78.33	113.38	70.47	108.68	54.71	19.09	52.19	7.52	23
24	71.87	97.41	81.86	108.20	55.80	3.19	61.95	9.58	24
26	89.66	93.72	57.15	65.72	68 47	48.48	36.93	3.38	26
27	116.67	137.51	72.91	82.96	132.19	69.18	71.35	11.87	27

TABLE XXXII:—PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE POTASSIUM REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot No.	Grain 1907				Straw 1907				Plot No.
	East end		West end		East end		West end		
	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	
2	61.27	55 39	60 82	66 49	53.23	1.18	48.34	86.06	2
3	13 64	11 65	1 88	4.82	18.69	26.77	—3.12	—24.27	3
5	21 31	22.69	18 39	17.70	41.49	48.33	13.60	—6.96	5
6	106 08	89 76	94 47	86.18	134.78	129.94	90 08	118.23	6
8	42 81	42 68	65 86	53.61	47.28	57.40	54.83	61.09	8
9	39 54	30 30	15 38	14.74	41.82	61.92	33.16	66.10	9
11	116 44	109 66	135 54	113.83	143.13	153.11	204.50	259.73	11
12	107 90	90,25	208 40	154.06	139.61	172.76	239.40	288.90	12
14	92.16	81 48	135.10	112.53	113.38	101.21	155.26	150.95	14
15	77.83	63 19	122.50	89.45	85.80	101.23	156.05	148.95	15
17	78.53	70 79	100 85	85.54	75.66	76.14	137.56	132.11	17
18	92 15	96 32	128 58	109.03	108 75	114.63	154.28	171.84	18
20	45.97	32 92	80 22	74 06	79.34	79.39	116.29	106.60	20
21	44.75	37 76	92 49	89.75	75.37	87.48	108.82	111.59	21
23	49.38	52 32	87 00	78.30	53.46	63.79	79.01	70.43	23
24	90.82	90 71	119.19	111.32	154.35	187.37	103.72	108.81	24
26	102.48	100 54	143 38	119 03	136.07	150 86	107.66	99.68	26
27	111.62	86.82	157 44	119 86	139.43	164.98	183.32	198.42	27
	Grain 1908				Straw 1908				
2	45.18	49.33	42.97	53.52	28.41	14 31	16.98	8.17	2
3	8 28	3.37	8.43	.65	5.48	36 91	—1.09	29.60	3
5	20.00	18.94	—.94	.24	35.37	32.43	15.76	25.91	5
6	93.92	88.84	78.85	128.17	105.14	70.29	69.09	60.35	6
8	31.71	41.26	58 12	88.88	53.15	81.14	49.76	115.86	8
9	17 90	15.01	14 51	19.30	43.83	93.18	33.77	91.72	9
11	112.79	118.82	76.69	42.07	103.42	167.61	85.13	154.08	11
12	115.60	118.14	68.64	87.69	118 72	207.71	88.17	135.99	12
14	126.14	112.70	88.09	83 69	96.96	145 56	121.70	144.30	14
15	99.02	94.49	102.13	95.55	85.51	104.36	87.46	114.25	15
17	96.07	90 90	128.79	161.06	90.06	117.14	113.94	150.00	17
18	96 46	90.00	99.71	129.45	78.80	114 42	72.27	109.21	18
20	65 92	62.16	46 85	35.88	69.50	106.42	28.08	35.95	20
21	86 75	95.25	65 39	94.58	72.20	121.28	51 42	107.95	21
23	78.33	95.90	70.47	75.86	54.71	91.74	52.19	104.78	23
24	71 87	85.89	81.86	76.56	55.80	100.81	61.95	106.34	24
26	89.66	86 02	57.15	64.21	68.47	138.09	36.93	85.05	26
27	116 67	.....	72.91	72.58	132.19	185.96	71.35	107.85	27

TABLE XXXIII:—PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE NITROGEN REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot No.	Grain 1907				Straw 1907				Plot No.
	East end		West end		East end		West end		
	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	
2	61.27	45.82	60.82	42.38	53 23	1.22	48.34	—15.45	2
3	13.64	7.83	1 88	—3.50	18 69	—5.28	—3.12	2.32	3
5	21.31	32.83	18.39	33.95	41.49	83 85	13.60	42.91	5
6	106.08	105.05	94.47	88.73	134.78	68 53	90 08	38.24	6
8	42.81	35.26	65.86	44.73	47.28	9.63	54 83	—3.15	8
9	39.54	53.14	15.38	27.02	41.82	85 17	33.16	46.65	9
11	116.44	114.18	135.54	115.20	143.13	90.22	204 50	96.27	11
12	107.90	129.17	208.40	220.57	139.61	118 92	239.40	180.22	12
14	92.16	93.14	135.13	123.37	113.38	87.53	155.26	73.69	14
15	77.83	76.93	122.50	107.05	85.80	51 36	156.05	63.01	15
17	78.53	73.72	100 85	78 88	75 66	40.92	137.56	23.38	17
18	92.15	97.50	128.58	113 87	108 75	80.75	154.28	71.60	18
20	45.97	39 41	80.22	65.88	79.34	41.08	116 29	32.04	20
21	44.75	34.76	92.49	76.70	75.37	39.32	108.82	23.94	21
23	49 58	37.36	87 00	61.48	53 46	26 49	79 01	—3.20	23
24	96.49	80.05	119.31	95 18	154 35	114.33	103.72	18.60	24
26	102.49	99 23	143.38	125 32	136.07	111.80	107.76	37 29	26
27	111.62	109.25	157 44	143 65	139.43	92.72	183 32	87.04	27
	Grain 1908				Straw 1908				
2	45.18	23.64	42.97	17 89	28.41	—31.33	16.98	—28.99	2
3	8.28	7.49	8.43	5 53	5.48	—.33	—1.09	—7.17	3
5	20.00	33.76	—.94	14.75	35.37	96.78	15.76	46.89	5
6	93.92	93.44	78.85	74.38	105 14	69.72	69 09	77.31	6
8	31.71	13.84	58.12	43.63	53.15	8 07	49 67	37.45	8
9	17.90	26.30	14.51	22.92	43.83	78.86	33.77	67.98	9
11	112 7[illegible]	110.02	76.69	62.91	103 42	92.92	85.13	66.95	11
12	115 60	119 66	68.64	83.99	118.72	105.48	88.17	80.15	12
14	126.14	114.37	88.09	89.15	96.96	30.42	121.70	64.95	14
15	99.02	96.07	102.13	93.83	85.51	31.93	87.46	49.00	15
17	96.07	74.88	128.79	102.61	90.06	15.32	113.94	37.31	17
18	96.46	90.92	99.71	81.42	78.80	34.30	72.27	26.71	18
20	65.92	58.61	46.85	32.88	69.50	39 66	28 08	—16.33	20
21	86.75	68.82	65.39	38.28	72.20	10.32	51 42	—1.29	21
23	78.33	56.79	70.47	52.39	54.71	—10 67	52.19	—8.22	23
24	71.87	53.78	81.86	70.03	55.80	—11.21	61.95	1.44	24
26	89.66	98.56	57.15	53.50	68.47	57.86	36.93	—14.41	26
27	116.67	118.67	72.91	69.34	132.19	75.07	71.35	27.49	27