RELATION OF PHOSPHORUS AND NITROGEN IN SOIL TO THE COMPOSITION OF WHEAT

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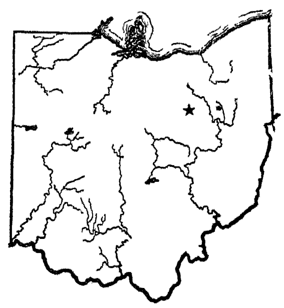

OHIO AGRICULTURAL EXPERIMENT STATION

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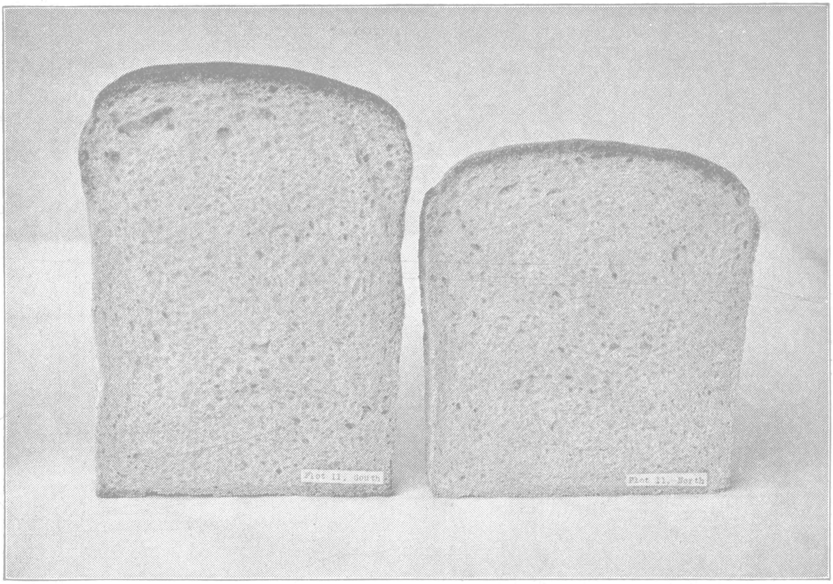
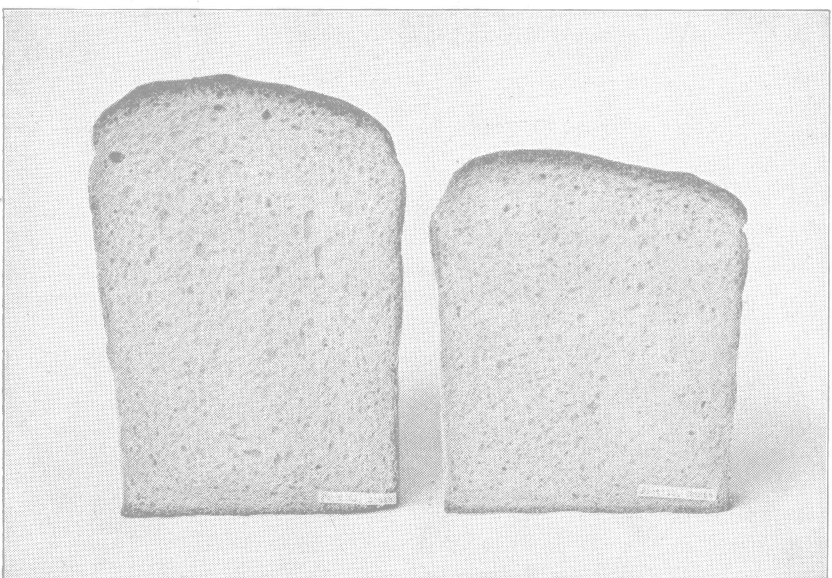


Bread from wheat grown on limed and floats-treated ends of Plot 11, Strongsville



Bread from wheat grown on limed and floats-treated ends of Plot 12, Strongsville

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RELATION OF PHOSPHORUS AND NITROGEN IN SOIL TO THE COMPOSITION OF WHEAT

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The physical characteristics and the composition of any plant are dependent primarily upon many conditions which are the result of climatic influences. While the effect of phosphorus and nitrogen, whether originally present in the soil or supplied by fertilizers, may be of minor consideration as compared with other factors, there is some evidence that when the plant food supplies are so modified as to influence yields decidedly, there are at the same time changes produced in the composition of the crop which may have an influence on the quality.

The object of the work reported in this bulletin has been to determine to what extent the supply of phosphorus and nitrogen in the soil, considered in relation to other conditions influencing the yield, affects the composition of wheat and the quality of flour produced.

The same variety of wheat grown on soils treated with different amounts and combinations of fertilizers, as well as several varieties grown on different soils, have been studied.

STUDIES OF WHEAT IN FIVE-YEAR ROTATION AT WOOSTER

PHYSICAL PROPERTIES OF WHEAT

The soil on which the 5-year rotation fertility plots[1] at Wooster are located is classified as a silt loam and is very responsive to treatment with phosphorus and to treatment with nitrogen when used with phosphorus. Potassium when used in combination with phosphorus and nitrogen produces increased crop yields, but has almost no effect when used without phosphorus or both phosphorus and nitrogen. This soil contains approximately 670 pounds of phosphorus, 1,700 pounds of nitrogen and 33,000 pounds of potassium

[1]For detailed information concerning treatment see Cir 144, p 69, of the Ohio Agr. Exp Sta The rotation is corn, oats, wheat, clover and timothy

per two million pounds of soil over an acre, 6⅔ inches deep. It is deficient in bases and requires liberal additions of lime before it produces the fullest returns from fertilizer and manure.

Data pertaining to the effect of phosphorus, potassium and nitrogen alone and in various combinations on certain physical characteristics and yield of wheat grown in this rotation are given in Table I. These data are arranged in the order of the phosphorus treatment for the purpose of facilitating comparison. The results obtained from separations made of plump, or well-filled, grain as compared with that in a less fully developed condition serve to illustrate the effect of deficiency in elements of plant nutrition essential for the full development of the wheat kernel. The effect of the proportion of available phosphorus to nitrogen is further shown when these figures are considered in connection with the yields.

TABLE I.—PHYSICAL CHARACTERISTICS AND YIELDS OF WHEAT

Plot	Fertilizing elements per acre for one 5-year rotation			Weight per bushel	Plump grain	Shriveled grain	Yield per acre (1911)
	Phosphorus	Potassium	Nitrogen				
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Bushels*
(*)	....	....	....	56.8	43	57	8.78
3	....	108	....	58.6	60	40	7.75
5	....	....	76	56.0	27	73	8.25
9	....	108	76	58.0	55	45	11.33
2	20	....	....	58.7	66	34	15.75
6	20	....	76	57.2	57	43	20.25
8	20	108	....	58.6	77	23	14.00
11	20	108	76	57.9	72	28	24.08
12	20	108	114	57.9	69	31	26.58
30†	30	108	38	59.6	85	15	20.50
18‡	48	112	144	60.0	86	14	30.92
A§	112	81	103	61.0	91	9	38.42

*Unfertilized.

†Nitrogen supplied by tankage.

‡The three elements supplied by manure, 8 tons on corn and 8 tons on wheat, amounts of phosphorus, potassium and nitrogen based on average analysis of manure at Ohio Station.

§Elements supplied by 10 tons of manure with the addition of 400 pounds of untreated rock phosphate for the corn crop; and a fertilizer consisting of steamed bonemeal, 100 pounds; acid phosphate, 200 pounds; potassium chloride, 50 pounds; sodium nitrate, 15 pounds for the wheat; 50 pounds of sodium nitrate is applied broadcast over the wheat in April if the appearance of the crop indicates the need for nitrogen. Oats and clover are left unfertilized, the rotation being corn, oats, wheat and clover.

The smallest percentage of fully developed grain was present in wheat grown on soil to which nitrogen without potassium or phosphorus had been added. It will be noted that the next smallest amount of large, well-filled wheat was found in the crop from soil receiving no phosphorus, potassium or nitrogen.

Addition of potassium to the fertilizer tended to counteract the effect of nitrogen used alone, but to a limited extent only. Potassium used alone, as compared with nitrogen fertilizer only, decidedly affected the physical character of the wheat without increasing the yield. No benefit in this respect followed the use of either of these elements this particular season (1911), although the average yields of wheat for an extended period, more than 20 years, show that potassium and nitrogen used singly have produced slight increases over the unfertilized yield, and that when used in combination the yield has been further increased.

Phosphorus used alone, while only slightly improving the condition of the wheat, so far as plumpness of the kernel is concerned, over that grown on soil where potassium was used alone, decidedly increased the yield. The fullest return from phosphorus on the soil which produced the crops studied is not obtained unless nitrogen and potassium are included in the fertilizer treatment.

The wheat grown on Plot 6, where nitrogen was added to phosphorus, had a larger proportion of shriveled grain than was found where phosphorus alone was used, but the yield was much larger. Where potassium was included with phosphorus and nitrogen (Plot 11), a further increase in the yield was obtained and the character of the grain approached that harvested from Plot 8, where phosphorus and potassium without nitrogen were the fertilizing elements applied to the soil.

An increased supply of nitrogen with the same amounts of phosphorus and potassium (Plot 12) increased the yield and only slightly decreased the proportion of well-filled kernels.

Where the quantity of phosphorus applied was increased 50 percent and the nitrogen was decreased one-half (comparing Plots 11 and 30), there was a decided difference in the proportion of well-filled kernels, but the yield was decreased on Plot 30 where the proportion of nitrogen to phosphorus in the fertilizer was reduced. The nitrogen added to Plot 11 was furnished by nitrate of soda and to Plot 30 by tankage.

The wheat from the barnyard manure plot was similar to that grown on Plot 30 so far as physical characteristics are concerned, but the yield was much larger. On Plot 30 the ratio of phosphorus to nitrogen was approximately 1:1 and on Plot 18 the ratio was 1:3. The availability of the nitrogen is a fact to be regarded as possibly having as much influence as does the proportion of phosphorus to nitrogen on the physical properties and yield. The composition of the wheat in 1916 from the plots treated with manure and with tankage shows that the protein content, as compared with that of the wheat from Plot 11, has been reduced.

The fertilizer treatment on the soil designated Plot "A" furnishes total phosphorus and nitrogen in about equal amounts. A part of the phosphorus, potassium and nitrogen added to this soil is supplied by manure and a part by mineral carriers of these elements. Manure and rock phosphate are applied for the corn; and steamed bonemeal, acid phosphate, potassium chloride and nitrate of soda for the wheat. These materials will furnish phosphorus and nitrogen of approximately equal availability. By this treatment, along with the addition of lime, this particular area has been brought to a high state of fertility and produces more well-filled wheat having a higher weight per bushel than the other plots on soil which was originally of about the same fertility. A 4-year rotation of corn, oats, wheat and clover is followed on this soil.

These variations in the character of the wheat have been briefly discussed because of the relation existing between the yield, physical differences, and the protein and phosphorus content.

PROTEIN CONTENT OF WHEAT AND FLOUR

The conditions for plant growth and for the development of the grain were such that wheat from unfertilized soil contained a higher percentage of protein than wheat from any of the fertilized plots excepting those where nitrogen without phosphorus was applied. The wheat from these plots (5 and 9) contained 17.31 and 15.54 percent of protein, respectively, as shown in Table II; while the wheat grown on Plots 2 and 8, the one plot treated with phosphorus only and the other with phosphorus and potassium, had a much lower protein content than that grown on unfertilized soil. By referring to Table I, it will be observed that those wheats having a higher protein content, compared with those from plots fertilized with phosphorus without nitrogen, were more shriveled or less fully developed. This statement applies especially to Plot 5 where the only fertilizer treatment was nitrate of soda.

TABLE II.—PROTEIN AND PHOSPHORUS CONTENT OF WHEAT AND FLOUR (Moisture-free basis)

Plot	Fertilizing elements per acre for one 5-year rotation			Protein content†		Phosphorus content	
	Phosphorus	Potassium	Nitrogen	Wheat	Flour	Wheat	Flour
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
(*)	....	....	....	15.05	13.50	0.3786	0.1176
3	....	108	....	14.81	13.13	.3675	.1206
5	....	....	76	17.31	15.53	.3525	.1193
9	....	108	76	15.54	13.67	.3466	.1201
2	20	....	....	12.87	11.18	.4172	.1190
6	20	....	76	14.22	12.89	.3657	.1094
8	20	108	....	12.73	11.22	.3890	.1200
11	20	108	76	13.91	12.00	.3898	.1140
12	20	108	114	14.42	12.90	.3640	.1080
30	30	108	38	11.85	10.16	.4591	.1319
18	48	112	144	12.82	11.04	.4188	.1348
A	112	81	103	13.13	10.87	.4922	.1580

*Unfertilized. See Table I for other details.
†Nitrogen X 5.7.

When nitrogen was included with phosphorus in the fertilizer, there was an increased percentage of protein over that produced when phosphorus alone was added, which, in the case of Plot 6, receiving phosphorus and nitrogen without potassium, was accompanied with a larger proportion of shriveled kernels. The protein content of wheat grown on Plot 11, receiving fertilizers which included phosphorus, potassium and nitrogen, shows that the effect of the added nitrogen toward increasing the protein over that found in the wheat grown on soil where phosphorus only has been applied, has evidently been offset by potassium when used in combination with phosphorus and nitrogen.

The smallest percentage of protein was found in wheat grown on Plot 30, where the quantity of nitrogen applied was one-half of that applied to Plot 11 and the phosphorus was increased in amount sufficient to make the ratio of phosphorus to nitrogen approximately 1:1. As the nitrogen applied to Plot 30 has been furnished by tankage, the availability of the nitrogen as well as the ratio of phosphorus to nitrogen may have influenced the composition of the crop as well as the yield, which is much smaller than that from other plots which produced wheat less fully developed and having a lower weight per bushel.

The wheat from the barnyard manure plot had a protein content which is almost the same as that of the wheat from Plots 2 and 8, fertilized with phosphorus in the one case and with phosphorus and potassium in the other, both without nitrogen. The yield for Plot 2, treated with phosphorus alone, was 15.75 bushels and for Plot 8, treated with phosphorus and potassium, 14 bushels. The weight per bushel of these two wheats was practically the same, 58.7 pounds. Plot 18, treated with 16 tons of manure during a 5-year period (8 tons on corn and 8 tons on wheat), produced twice as much wheat having a greater weight per bushel than plots fertilized with phosphorus without nitrogen. These results, as well as those for the other differently fertilized plots, indicate that the composition of wheat grown under such conditions is to a certain extent independent of the yield.

The wheat grown on soil designated Plot "A" produced the largest yield and the best-filled wheat, having a protein content which was greater than that of the wheat from some of the other fertilized plots which produced a much smaller yield.

There is a tendency for the percentage of protein in the flour to parallel that of the wheat. The flour milled from wheat grown on soil where nitrogen without phosphorus or potassium has been applied for more than 20 years contained the highest percentage of protein.

The flours milled from the several wheats were extracted with 1-percent salt solution for the determination of proteids insoluble in 1-percent solution of sodium chloride; and with 60-percent alcohol for the gliadin, which constitutes more than 50 percent of the proteids of wheat flour. With a few exceptions the alcohol-soluble protein, or gliadin, bears a close relation to the total protein. Table III gives the percentages of these proteid separations. A larger percentage of alcohol-soluble protein was extracted from the flour than from the wheat. The protein insoluble in 1-percent salt solution was less in the flour than the corresponding wheats grown on soil fertilized with nitrogen without phosphorus.

TABLE III.—PROTEID SEPARATIONS OF WHEAT AND FLOUR (Percent)

Plot		Total protein	Protein insoluble in salt solution	Gliadin
(*)	Wheat	15.05	11.03	8.34
	Flour	13.50	10.30	9.87
3	Wheat	14 81	10.79	8.09
	Flour	13.13	10.13	9.41
5	Wheat	17.31	12.84	9.65
	Flour	15.53	12.19	11.21
9	Wheat	15.54	11.46	8.91
	Flour	13.67	10.64	9.85
2	Wheat	12.87	8.94	6.94
	Flour	11.18	8.32	8.29
6	Wheat	14.22	9.99	7.95
	Flour	12.89	9.79	9.20
8	Wheat	12.73	8.98	6.96
	Flour	11.22	8.36	7.68
11	Wheat	13.91	9.81	7.72
	Flour	12.00	9.18	8.55
30	Wheat	11.85	8 16	6.47
	Flour	10.16	7.36	6.70
18	Wheat	12.82	8.87	7.20
	Flour	11.04	8.03	7.64
A	Wheat	13.13	8.94	6.14
	Flour	10.87	7.87	7.52

*Average of unfertilized plots. See Table I for details of treatment of plots.

PHOSPHORUS CONTENT OF WHEAT AND FLOUR

As shown under the preceding discussion, the protein content of wheat has been affected by the supply of phosphorus. Increasing the supply of available phosphorus is also reflected to an appreciable extent by the phosphorus assimilated by the wheat plant.

Where phosphorus only was supplied the percentage of phosphorus in the wheat grain is increased over that of the wheat grown on soil to which no phosphorus was added. Increasing the supply of available nitrogen in the soil has generally caused a decreased percentage of phosphorus in the wheat grain. This was found to be the case for the wheat grown on soil where phosphorus was supplied in the fertilizer as well as for the wheat grown on soil receiving nitrogen only.

Where nitrogen was included in the fertilizer with phosphorus and potassium, this effect of nitrogen on the phosphorus content of the wheat was not evident, although the composition of the wheat grown on this soil in other years has shown that nitrogen in the fertilizer with phosphorus and potassium has decreased the phosphorus content of the grain to the same extent as when used with phosphorus only. The phosphorus content of wheat grown on soil where manure has been added was about the same as that of wheat grown on soil where acid phosphate supplied the phosphorus. On the basis of the average composition of manure as determined at this Station for a number of years, there has been approximately 144 pounds of nitrogen added to the soil by the manure during a 5-year rotation, 8 tons of manure applied for the corn crop and 8 tons for the wheat. It is to be noted that this large amount of nitrogen has not had the same effect in reducing the phosphorus content of the wheat as occurred where the more available carrier of nitrogen, nitrate of soda, was used.

A higher percentage of phosphorus was found in the wheat from Plot 30, which received 30 pounds of phosphorus and 38 pounds of nitrogen, the latter element being supplied by tankage. This plot should be compared with Plot 11, which received 20 pounds of phosphorus and 76 pounds of nitrogen. The factors responsible for the increased percentage of phosphorus and decreased percentage of nitrogen in the wheat from Plot 30 as compared with Plot 11 are the ratio of phosphorus to nitrogen and the less available form of the nitrogen applied on Plot 30. The difference in the availability of the nitrogen probably plays as important a part here as in the case of the wheat from the soil treated with barnyard manure, although the manure has furnished more phosphorus than was added to either Plot 11 or Plot 30.

The soil designated Plot "A" received considerably more phosphorus than any of the other plots described, and the wheat grown on it contained the highest percentage of phosphorus. The phosphorus content of the wheat from Plot 30 approached it, but that of the other wheats was considerably less. Attention is directed to the fact that the ratio of phosphorus to nitrogen applied to these two plots is approximately the same, although much smaller quantities of these elements are applied to Plot 30. The phosphorus content of these wheats is considered for the reason that the phosphorus and nitrogen of the wheats grown on the soil on which the several plots are located bear a complementary relation to each other, and that this relation is dependent to a certain extent on the phosphorus and nitrogen available for the wheat plant.

While the composition of the wheat in some instances appeared to be independent of the yields, in other cases there was a close relation. The wheat grown where the largest amount of phosphorus was placed at its disposal produced the largest yield of grain containing the largest percentage of phosphorus. In the case of Plot 2, fertilized with phosphorus alone, and Plot 30, receiving 50 percent more phosphorus than Plot 2, the composition of the wheat indicates a luxury consumption of phosphorus, since the yields obtained from these two plots were much less, and the phosphorus content of the wheat was greater than in most other instances, where the yields were considerably larger and the wheat produced contained a smaller percentage of phosphorus.

Headden[1], in reporting a study of Colorado wheats in which the effect of fertilizers was considered, states that the mineral constituents contained in the berry are influenced by the amount of nitric nitrogen available to the plant, that the phosphorus in the berry is depressed by nitric nitrogen and is not affected by potassium, and that nitric nitrogen increases the nitrogen content of the wheat.

No consistent relation exists between the phosphorus found in the flour and the total phosphorus in the wheat from which it was milled, although the flour corresponding to the wheats from plots receiving phosphorus, potassium and nitrogen which have the highest percentage of phosphorus, contained the largest amounts. The flour milled from wheat grown on soil treated with the largest amount of phosphorus, contained a higher percentage than the other flours.

Data reported by the Kansas Experiment Station[2] concerning the chemical, baking and storage studies of Kansas flours show that flours with a high total phosphorus content contain more soluble

[1]Colo. Agr. Exp. Sta. Bul. 219.
[2]Bul. 202.

phosphorus and that those flours which have a high percentage of water-soluble phosphorus have a short fermentation period and low total expansion.

H. L. White and R. T. Beard[1] report results of a study of phosphorus content of wheat and wheat flour in relation to baking qualities of flour. Comparison of total, organic and inorganic phosphorus content with the volume of loaf was made. The larger loaf volumes were from flours containing less phosphorus than the flours which produced smaller loaves. When the percentage of total phosphorus which existed in organic combination was greatest, it was associated with increased loaf volume.

BAKING TESTS

The results for the baking tests of flours milled from wheat grown under the different conditions of fertilization previously referred to are reported in Table IV.

TABLE IV.—BAKING TESTS OF VALLEY WHEAT GROWN ON DIFFERENTLY FERTILIZED PLOTS

Plot	Fertilizing elements per acre for one 5-year rotation			Loaf volume	Texture	Color	Protein in flour
	Phosphorus	Potassium	Nitrogen				
	Pounds	*Pounds*	*Pounds*	*Cc.*			*Percent*
(*)	....	....	....	2,230	96	95	13.50
3	....	108	....	2,160	98	93	13.13
5	....	....	76	2,370	94	95	15.53
9	....	108	76	2,300	95	95	13.67
2	20	....	....	2,130	98	95	11.18
6	20	....	76	2,130	95	95	12.89
8	20	108	....	2,110	98	95	11.22
11	20	108	76	2,260	95	95	12.00
30	30	108	38	2,080	95	95	10.16
18	48	112	144	2,170	95	95	11.04
A	112	81	103	2,120	88	96	10.87

*Unfertilized. See Table I for other details.

The milling outfit in this work consisted of an Allis-Chalmers small experimental mill having two sets of 7-inch rolls, one set of which is corrugated and the other smooth. Between these two sets of rolls is a jig sifter provided with the necessary sieves and bolting cloth.

The results of the baking tests show that the flours milled from wheats which were grown on soil deficient in available phosphorus, but which received nitrogen supplied by nitrate of soda, have produced the largest loaf volume. The flour from unfertilized wheat and that from soil fertilized with phosphorus, potassium and nitro-

[1] N. Dak. Agr. Exp. Sta. Bul. 106.

gen (Plot 11) gave almost the same loaf volume. The volume of the loaves in the case of Plots 5 and 30 varied as the protein content of the flour.

Of a group of Plots 11, 30, 18 and A receiving phosphorus, potassium and nitrogen, Plot 11, where the most available carrier of nitrogen, nitrate of soda, was used, produced wheat containing somewhat more protein than was found in the wheats produced on the plots to which nitrogen was supplied by organic carriers of nitrogen, tankage and manure. This applies also to the flour from the wheat grown on this plot. The flour milled from this wheat gave a larger loaf volume than the flours from the other wheats in this group. Compared with the highest protein content in case of flour from wheat grown with nitrogen on soil to which nitrate of soda only was supplied (Plot 5) the wheat from Plot 30, treated with the smallest amount of nitrogen and this in a less available form, had the lowest protein content of this group of wheats, and the flour from this wheat produced the smallest loaf volume.

These results show that the protein content of wheat which is affected by the soil supply of nitrogen and phosphorus being modified by fertilizer treatment has an influence on the quality of flour sufficient to be measured by the baking tests.

So far as the differences in yields of wheat obtained from the several plots as a result of the fertilizer treatment are concerned, these variations in the flour milled from wheat with a high protein content and grown on soil producing a small yield as compared with wheat from plots treated with phosphorus, and phosphorus with potassium and nitrogen, and producing large yields, cannot have much practical significance. Nevertheless, the character of the wheat produced on soils differing in productivity does to a certain extent modify the quality of the flour. As stated previously, these wheats were milled in a small experimental mill, and it is a question whether such differences would be apparent in flour produced commercially from wheats having the differences in composition indicated.

The effect of phosphorus in improving the quality and yield of grain is probably a more important factor, since the yield of wheat and the appearance of the grain are decidedly superior when grown on soil supplied with phosphorus as compared with that from soil containing available nitrogen but deficient in its phosphorus supply. As determined by the baking tests, the quality of the flour from wheat which has produced a large yield on soil fertilized with acid phosphate, potassium chloride and nitrate of soda is about the same as that of the flour produced from wheat grown on unfertilized soil.

CONTRIBUTING RESULTS FROM WHEAT CROP OF 1916

Further evidence of the effect of phosphorus and nitrogen supplied by fertilizers on the protein and phosphorus content of wheat is furnished by the crop grown in 1916. The wheats from the plots previously discussed were grown under the same conditions of fertilization except that the fertilizer treatment has been continued for an additional 5 years. Data for these wheats and those from other plots where different carriers of nitrogen were used are included in Table V.

TABLE V.—PROTEIN AND PHOSPHORUS CONTENT OF WOOSTER WHEAT, 1916

Plot	Fertilizing elements per acre for one 5-year rotation			Composition of wheat		Yield	24-year average yield
	Phosphorus	Potassium	Nitrogen	Protein	Phosphorus		
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Bushels*	*Bushels*
(*)	....	....	....	11.17	0.3836	16.19	11.39
5	....	....	76	12.25	.3206	16.92	13.39
9	....	108	76	12.37	.2942	20.54	14.29
2	20	....	....	9.92	.4136	22.29	19.44
6	20	....	76	11.06	.3596	28.29	25.14
8	20	108	....	10.26	.3798	24.54	20.74
11	20	108	76	10.83	.3812	33.33	27.77
12	20	108	114	11.46	.3605	33.46	28.41
30	30	108	38	9.80	.4286	27.58	23.34
17	30	108	38	10.37	.4235	32.25	23.93
23	30	108	38	9.92	.4286	26.46	23.46
24	30	108	38	10.48	.4249	26.96	24.21
18	48	112	144	10.54	.3898	32.21	23.64
A	112	81	103	10.83	.4400	33.67	†31.98

*Unfertilized.
†Average of 15 years.
Note—The fertilizing materials used on these plots are the same as given for corresponding plots in Table VI.

While the protein content of these wheats, compared plot for plot, was lower than that of wheat harvested in 1911, the variations in protein of wheat from the differently fertilized plots were relatively the same. This was also true for the phosphorus, although the percentage of phosphorus was generally somewhat less in the wheat of 1916. The yields for 1916 were much larger than those for corresponding plots in 1911, except from soil designated Plot "A".

The same effect of phosphorus in depressing the protein content was observed in the results for both years, and the same relation existed between the percentages of phosphorus and nitrogen in the plots fertilized with phosphorus alone and those where varying amounts of nitrogen have been supplied with phosphorus. The phosphorus content of the wheats grown on Plots 17, 23 and 24 compared with Plot 11 showed the effect of varying proportions of nitrogen and phosphorus supplied in the fertilizer and the differences in the availability of the nitrogen carriers on the assimilation of nitrogen and phosphorus by the wheat plant. Plot 17 is directly comparable with Plot 11, since the same nitrogen carrier, nitrate of soda, is used on both plots. The effect of the increased amount of phosphorus and the smaller quantity of nitrogen supplied to Plot 17, as compared with Plot 11, was more pronounced for the phosphorus content of these wheats than for the protein content.

Ammonium sulphate supplied the nitrogen on Plot 24; dried blood, on Plot 23; and tankage, on Plot 30. It is to be noted that the phosphorus content of the wheats from Plots 17, 23, 24 and 30 was decidedly increased over that in the wheat from Plot 11. The chief differences in the protein content were found in the wheats on the plots treated with organic carriers of nitrogen as compared with inorganic carriers. The protein content of the wheat from Plots 30 and 23 was less than that from the other plots receiving the same amounts of nitrogen, but supplied by the inorganic carriers, ammonium sulphate and nitrate of soda. The results show the effect of differences in availability of nitrogen supplied in fertilizers.

EFFECT OF FLOATS ON STRONGSVILLE WHEAT

PLUMP GRAIN DUE TO AVAILABLE PHOSPHORUS

Additional data obtained from a study of wheat grown in 1916 on differently treated soil at the Northeastern Test Farm, Strongsville, are of interest with regard to the considerable variation in composition of wheat due to phosphorus supplied in large quantities to soil otherwise variously treated with phosphorus and nitrogen. These plots have been devoted to a 5-year rotation of corn, oats, wheat, clover and timothy since 1896. In addition to the fertilizer treatment on the individual plots, the south half of each plot has been limed and the north half treated with raw phosphate rock (commonly called floats).

This soil, which contains in the surface 6⅔ inches over an acre approximately 3,800 pounds of nitrogen, 950 pounds of phosphorus and 38,000 pounds of potassium, is responsive to treatment with phosphorus. During the earlier years of the fertility experiment on this soil the results obtained from the use of nitrogen and potassium were very slight, but during recent years these elements have been producing an increasing effect.

The fertility plots included in the section from which wheat samples were secured were first treated with lime and with floats at the rate of 1 ton per acre in 1905 and again in 1909. A further addition of 1 ton of ground limestone was made on the limed half of these plots in 1913, but no further addition of floats has been made since 1909. Soybeans had preceded the wheat crop of 1916 on this particular area, and as this crop responds favorably to lime treatment the bean crop was heavier on the limed half of the section. This has apparently increased the nitrogen supply of the limed soil as compared with that treated with floats. An indication of this condition was furnished by the growing wheat crop, for the color of the wheat was much greener, and the heavier growth of the straw also gave indication of a more abundant supply of available nitrogen on the lime-treated halves of the plots.

A striking difference in the appearance of the crops grown on the limed and floats-treated halves of these plots was observed at harvest time. The wheat grain on the end of the plot cross-dressed with floats appeared to be larger and the ripened wheat was much darker in color. These differences in appearance of the growing wheat on soil treated with lime and with floats were more pronounced for the crops on the unfertilized plots and the plots receiving nitrogen but no phosphorus other than was supplied by floats.

Data obtained for the weight and size of the grains, given in Table VI, show that there were variations attributable to the increased phosphorus supply on the halves of the plots cross-dressed with floats. The relative size of the wheat grains was obtained by determining the number of kernels in a 10-gram sample. The weights were determined by weighing 100 cubic centimeters of samples from the various plots. These determinations were made on small samples obtained from the field previous to the harvesting of the wheat.

The results of these tests show that the addition of nitrogen alone to the soil has decidedly decreased the weight and produced much smaller grain than was grown under other conditions of fertilization. Where potassium and nitrogen were used without phosphorus, the kernels were somewhat larger than those of the wheat produced on soil fertilized with nitrogen only, but were smaller than those grown where phosphorus was applied; the weight was not decreased as was the case where nitrogen only was used.

The limed ends of the manure plots have produced wheat with a larger proportion of small grain than was found for the average of the plots receiving mineral fertilizer supplying phosphorus in addition to potassium and nitrogen. Plot 18 received 8 tons of manure each on corn and wheat, while Plot 39 received 16 tons on wheat only.

TABLE VI.—CHARACTERISTICS OF STRONGSVILLE WHEAT IN 5-YEAR ROTATION

Plot	Fertilizing materials in pounds per acre for each 5-year rotation	Limed ends		Floats-treated ends	
		Weight of 100 cc.	Number of kernels in 10 gm.	Weight of 100 cc.	Number of kernels in 10 gm.
		Grams		*Grams*	
(*)	None	79.36	338	80.00	294
2	Acid phosphate, 320	79.30	280	78.50	298
5	Nitrate of soda, 440; dried blood, 50	76.90	400	78.86	274
6	Acid phosphate, 320; nitrate of soda, 440; dried blood, 50	79.70	287	....	....
8	Acid phosphate, 320; muriate of potash, 260	79.55	267	....	....
9	Muriate of potash, 260; nitrate of soda, 440; dried blood, 50	79.90	351	79.92	275
11	Acid phosphate, 320; muriate of potash, 260; nitrate of soda, 440; dried blood, 50	79.20	278	78.53	278
12	Acid phosphate, 320; muriate of potash, 260; nitrate of soda, 680; dried blood, 50	82.98	290	....	....
17	Acid phosphate, 480; muriate of potash, 260; nitrate of soda, 220; dried blood, 25	79.75	278	79.65	278
18	Yard manure, 32,000	77.76	329	81.00	280
1	Same elements as 17, but nitrogen in linseed oilmeal	79.63	271	....	....
3	" " " 17, " " " dried blood	80.19	281	....	....
4	" " " 17, " " " sulphate of ammonia	80.83	277	....	....
6	" " " 11, " phosphorus in bonemeal	80.00	292	....	....
0	" " " 17, " nitrogen in tankage	80.67	265	....	....
9	Yard manure, 32,000	78.48	312	....	....

*Average of check plots.

The effect of phosphorus furnished by floats as a cross-dressing on the fertilized and unfertilized plots is seen from the figures for the wheat samples available from several of the plots from the floats-treated half of the section. The effect of phosphorus where an abundance of nitrogen was present is strikingly shown in the case of Plot 5. The weight of a 100-cubic centimeter portion from the limed half was 76.9 grams and the number of grains in a 10-gram portion was 400, while in the case of the floats-treated half the weight was increased and the size of the grain was decidedly larger. So far as the size of the grain is concerned, the same relation between the two ends is observed for the wheat from Plot 9, receiving potassium and nitrogen. The weight was the same for the floats-treated half as for the lime-treated half of this plot, but the number of grains in the same weight of sample was less. The addition of floats to the soil increased the size of the grains when compared with the limed ends except where acid phosphate was used. In all instances the addition of phosphorus, supplied by either floats or acid phosphate, has increased the size of the grain, which indicates that plumpness of grain is largely dependent upon the amount of available phosphorus present in the soil.

PROPORTION OF STRAW TO GRAIN

Since there were marked variations in the yields of the wheat crop of 1916 on the Strongsville soil which were due to the soil treatment, it was thought that there would be a difference in the proportion of straw to grain. As the appearance of the crop indicated an excess of available nitrogen in the soil cross-dressed with lime as compared with that treated with floats, it was assumed that possibly a larger weight of straw per bushel of grain would be found in the case of the wheat grown on the limed half. Table VII gives the yields and the data pertaining to the proportion of straw to grain.

The results exhibit considerable variations for both the limed and floats-treated land. The nitrogen-treated plots (5 and 9) both had high figures for the weight of straw per bushel of grain on the limed half. On the floats-treated half the straw per bushel of grain was less than on the limed ends of these plots. This condition was accompanied by larger yields of grain on the floats-treated halves of these two plots. Since such wide variations occur for individual plots, no particular significance can be attached to the figures for the crop in general.

TABLE VII.—PROPORTION OF STRAW TO GRAIN, STRONGSVILLE WHEAT CROP, 1916

Plot	Limed half			Floats-treated half		
	Wheat	Straw	Straw per bushel of grain	Wheat	Straw	Straw per bushel of grain
	Bushels	*Pounds*	*Pounds*	*Bushels*	*Pounds*	*Pounds*
(*)	17.10	1,281	75	16.79	1,443	86
2	28.33	2,300	81	11.00	940	85
5	16.38	1,720	105	20.33	1,680	83
6	34.00	2,860	84	28.00	2,420	86
8	28.67	2,180	76	31.67	2,500	78
9	19.33	2,140	111	35.33	3,480	98
11	29.33	2,740	93	33.33	2,700	81
12	33.00	3,220	98	37.67	3,040	81
17	33.00	2,420	73	31.33	2,420	77
18	21.33	2,320	108	24.33	1,840	76
21	27.67	2,640	95	18.00	1,420	79
23	26.33	2,420	92	26.00	1,940	75
24	27.33	2,460	90	29.00	1,960	68
26	26.67	2,200	82	25.00	2,100	84
30	28.33	2,700	95	28.33	2,200	78
39	26.33	2,120	81	18.33	1,600	87

*Average of unfertilized plots.

PROTEIN AND PHOSPHORUS CONTENT

The protein and phosphorus of the wheat grain from the plots previously described have been markedly affected by the soil treatment with floats as compared with lime. The wheats from the limed ends of the plots which have received phosphorus and nitrogen in different amounts and different combinations show measurable differences which are due to the fertilizer treatment added to the soil of the individual plots. These results are given in Table VIII.

TABLE VIII.—PROTEIN AND PHOSPHORUS OF WHEAT GROWN ON STRONGSVILLE SOIL FROM PLOTS TREATED WITH LIME

Plot	Fertilizing elements per acre for one 5-year rotation			Protein	Phosphorus
	Phosphorus	Potassium	Nitrogen		
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*
(*)	......	......	......	10.77	0.2408
5	......	......	76	12.37	.2600
9	......	108	76	11.57	.2519
2	20	......	......	10.15	.3090
6	20	......	76	10.43	.3093
8	20	108	......	9.63	.3762
11	20	108	76	10.09	.3174
12	20	108	114	11.69	.3022
17	30	108	38	10.37	.2839
21	30	108	38	10.03	.3017
23	30	108	38	10.03	.3427
24	30	108	38	9.98	.3328
26	20	108	76	11.12	.3008
30	30	108	38	10.72	.3174
18	48	112	144	11.23	.2763
39	48	112	144	10.09	.3451

*Average of unfertilized plots. For details of fertilizer treatment see Table VI.

The results show that the protein content of the wheat has been affected by the nitrogen supply of the soil as it has been modified by fertilizer treatment on the individual plots. On the limed land the effect of nitrogen fertilization was especially pronounced for the wheat grown on the plot receiving nitrate of soda only. The protein content of this wheat was 12.37 percent, as compared with 10.77 percent for that grown on soil receiving no fertilizer. The protein percentages of the wheat from the plot treated with potassium and nitrogen (Plot 9) and from Plot 12, receiving the equivalent of 710 pounds of nitrate of soda during a 5-year period, were also greater than that of the wheat grown on unfertilized soil.

Plots 11 and 12 are fertilized similarly except that a smaller amount of sodium nitrate, 440 pounds, is added to Plot 11. A comparison of the protein content of the wheats from these two plots shows that there has been an increased assimilation of nitrogen by the wheat grown on the soil to which the larger amount of available nitrogen was added. The wheats from these two plots exhibit a similarity in composition, resulting from the fertilizer treatment, to the wheat crop grown on Wooster soil. The wheats from the plot on which manure was applied and the plot where bonemeal supplied the phosphorus had a higher protein content than was found for similarly fertilized plots on the Wooster soil. The phosphorus content of the wheat has not been influenced by the fertilizer treatment in the same manner as the wheat grown on Wooster soil.

A comparison of the composition of the wheats grown on the halves of the plots cross-dressed with lime and with floats shows that increasing the total phosphorus supply in the soil by heavy applications of floats has affected the composition. Table IX sets forth a comparison of results from limed and floats-treated plots. This addition of phosphorus in the form of floats has decreased the protein content below that of the wheat grown on the limed soil, and has caused an increased assimilation of phosphorus. It is of special significance that these effects have been produced on the wheat grown on the soil which received phosphorus and nitrogen in the fertilizer treatment as well as on the wheat grown on soil which was unfertilized except as it was treated with floats or lime. The increased percentages of phosphorus occurring in the grain from the soil to which floats was applied do not uniformly follow the order of the yields.

The increase of crop where phosphorus is supplied by acid phosphate is always greater on this soil than that obtained from potassium and nitrogen. The yields of wheat for 1916 on the two ends of the plots were somewhat irregular as compared with the average yields for a period of years. For 1916 the average yield from the unfertilized plots was about the same on the two ends of the plots, although the average yields for the entire period during which they have been treated with lime and floats were larger where floats was applied. Where a supply of available nitrogen was furnished by nitrate of soda (Plots 5 and 9) but no phosphorus except that supplied by the floats, this addition of phosphorus caused a decided increase in yield over the limed ends of these plots. Plots 11 and 12, supplied with complete fertilizer, Plot 12 receiving more nitrogen than Plot 11, also produced more wheat on the floats-treated halves of the plots. The addition of floats increased the percentage of phosphorus in the straw as well as in the grain.

TABLE IX.—PROTEIN AND PHOSPHORUS CONTENT OF STRONGSVILLE WHEAT FROM PLOTS CROSS-DRESSED WITH LIME AND WITH FLOATS

Plot	Cross-dressing	Protein	Phosphorus	Carbohydrates
		Percent	*Percent*	*Percent*
(*)	Lime	10.77	0.2408	68.89
(*)	Floats	9.63	.3911	68.92
2	Lime	10.15	.3090	65.92
2	Floats	8.84	.3328	69.30
5	Lime	12.37	.2600	67.05
5	Floats	8.66	.3295	67.77
9	Lime	11.57	.2519	65.29
9	Floats	9.69	.3873	66.64
11	Lime	10.09	.3174	69.66
11	Floats	8.66	.3536	66.78
17	Lime	10.37	.2839	68.92
17	Floats	9.86	.4282	67.50
18	Lime	11.23	.2763	67.18
18	Floats	10.43	.4301	66.77

*Average of unfertilized plots. For fertilizer treatments for individual plots see Table VI.

These pronounced effects where addition of floats has been made to soil indicate that the wheat plant is better enabled to utilize phosphorus from an insoluble phosphate when the soil conditions are made more favorable for plant growth by providing sufficient supply of available nitrogen.

The total carbohydrates, which were determined by direct acid hydrolysis of the finely ground wheat sample without previous removal of sugars, include pentosans and other carbohydrate bodies which would be hydrolized by the treatment with hydrochloric acid. There was some variation in the total carbohydrates found in the different samples, but no direct relation to the protein content was shown.

BAKING TESTS

Baking tests were made of flours milled from wheats grown on several of these plots. The results of these tests, presented in Table X, are of interest in that they show a consistent relation between the protein content of the flour and the quality as indicated by the volume of loaf produced.

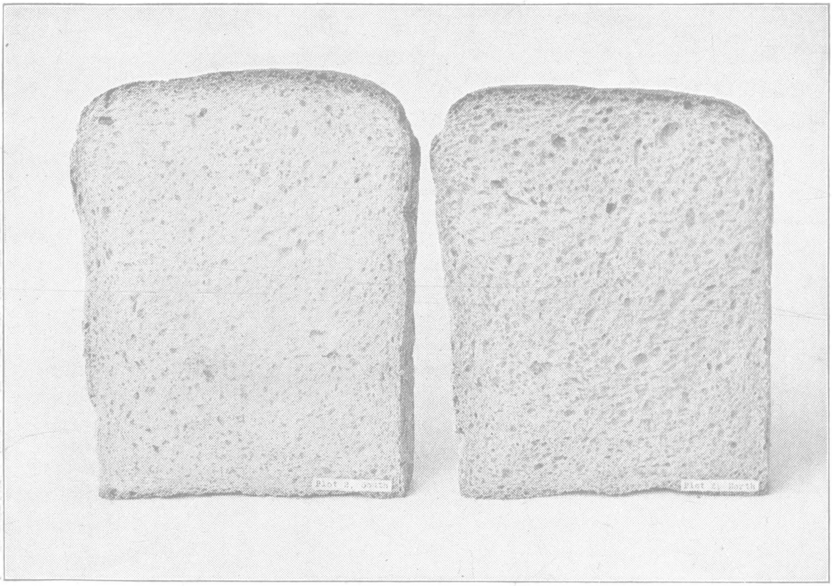
TABLE X.—BAKING TESTS OF FLOUR FROM STRONGSVILLE WHEAT

Plot	Cross-dressing	Loaf volume	Absorption	Yield	Protein content of flour	Gluten content of flour	Ash content of flour	Protein content of wheat
		Cc.	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
2........	Lime..............	1,875	58.00	460	7.67	8.65	0.348	10.15
2........	Floats............	1,800	59.75	460	6.84	7.02	.390	8.84
5........	Lime..............	2,100	56.94	460	9.01	9.80	.350	12.37
5........	Floats............	1,800	56.94	460	6.84	7.20	.336	8.66
9........	Lime,..............	1,875	59.75	473	8.84	9.82	.376	11.57
9........	Floats............	1,775	56.94	455	7.87	8.82	.370	9.69
11........	Lime..............	1,940	56.94	452	7.75	8.97	.330	10.09
11.......	Floats............	1,675	57.24	480	6.84	7.86	.369	8.66
12........	Lime..............	2,000	56.94	451	9.01	10.91	.372	11.69
12........	Floats............	1,675	58.00	481	7.18	8.19	.372	9.08

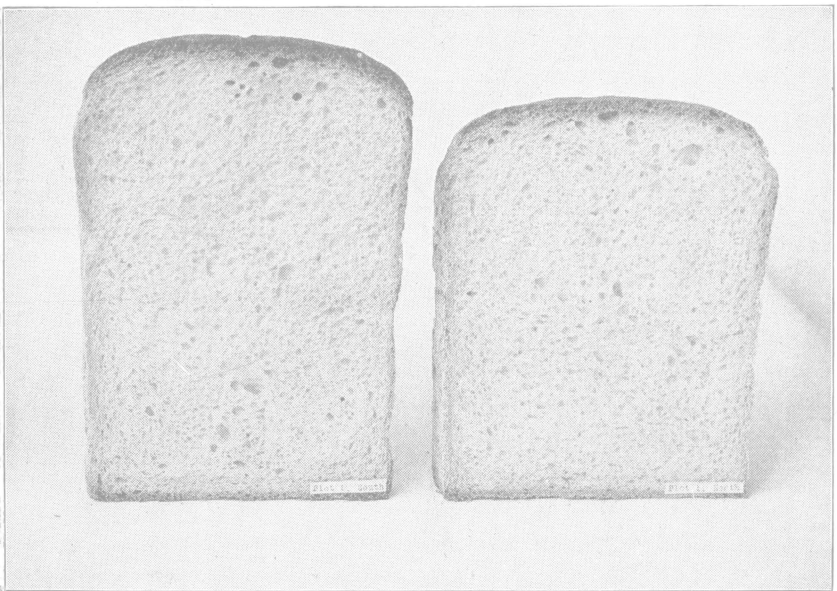
In all cases the wheats from the halves of the plots cross-dressed with floats, which have a lower percentage of protein than wheats from the same plots cross-dressed with lime, gave a smaller loaf volume. The difference in loaf volume was greatest for the flour from wheat grown where nitrate of soda was used alone, and for Plot 12, a completely fertilized plot, receiving an increased amount of nitrate of soda as compared with Plot 11. The differences observed in these two cases followed the same order as the variations in the protein content of flour milled from the wheat grown on the limed and on the floats-treated halves of these two plots. There was more uniformity in the results for the flours milled from wheats grown on land where phosphorus was furnished by floats in addition to the fertilizer treatment than is shown for the limed portions of the same plots.

The differences between the protein content of the wheat from the limed and the floats-treated ends of the individual plots were greater than the corresponding differences in the flour.

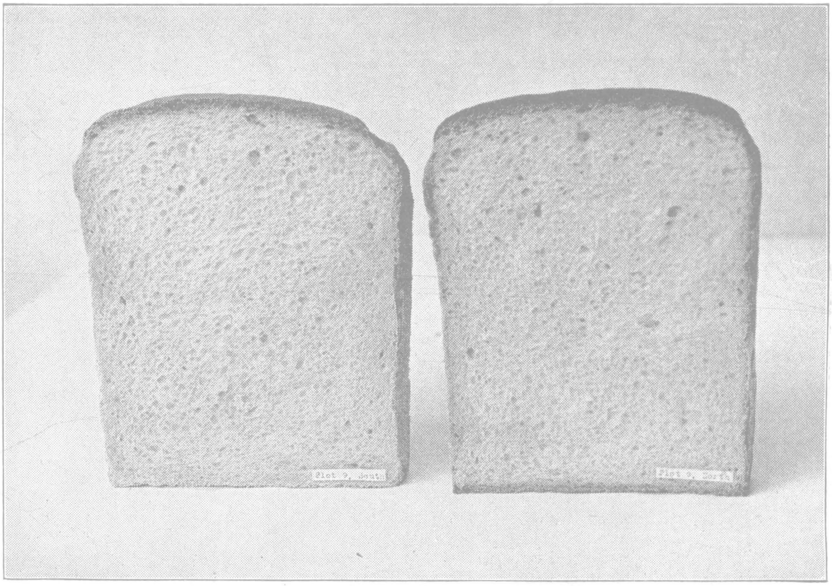
There was a greater difference between the protein content of the wheat and that of the flour milled from it for the crop grown on the limed, than on the floats-treated soil.



Bread from wheat grown on limed and floats-treated ends of Plot 2



Bread from wheat grown on limed and floats-treated ends of Plot 5



Bread from wheat grown on limed and floats-treated ends of Plot 9

The yields of the milling products from these wheats are given in Table XI. These milling and baking tests and those following were made by Miss Mabel K. Corbould.

TABLE XI.—MILLING PRODUCTS, STRONGSVILLE WHEATS

	Plot 2		Plot 5		Plot 9		Plot 11		Plot 12	
	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime
Flour—										
Patent	29.7	30.9	32.1	40.60	43.75	44.05	44.60	42.45	39.65	49.00
Break	17.9	13.9	13.5	10.55	11.65	11.20	7.70	9.30	10.85	6.85
Low	13.2	16.5	14.4	9.60	9.00	9.10	7.65	11.00	10.50	6.50
Total	60.8	61.3	60.0	60.75	64.40	64.35	59.95	62.75	61.00	62.35
Bran	24.5	26.1	28.8	24.35	23.50	22.70	27.70	21.35	27.00	21.60
Middlings	10.2	11.1	9.0	12.20	10.50	9.10	8.30	12.10	9.50	12.75
Loss	4.5	1.5	2.2	2.70	1.60	3.85	4.05	3.80	3.50	3.30

WHEAT GROWN ON DIFFERENT TYPES OF SOIL

For the purpose of determining variations which might be produced in a variety of wheat grown on different soils, data have been obtained for six varieties grown at the central farm at Wooster and at the substations located in Paulding, Montgomery, Meigs, Hamilton and Clermont Counties. Wheats from harvests of 1915 and 1916 were available for this work. The wheat crop on the Paulding soil in 1916 was a failure. The soils of these several farms vary considerably in their productiveness and also exhibit quite wide variations in their supplies of phosphorus and nitrogen.

The composition of the Clyde clay from the Paulding County Experiment Farm shows that it contains much larger amounts of nitrogen and phosphorus than the other soils included in this group. The Clermont soil is exceptionally deficient in both nitrogen and phosphorus. The yields of the several varieties grown in different localities in 1915 are given in Table XII. The same variety of wheat grown on the several soils located in various parts of the State exhibit wide range of variation in the nitrogen and phosphorus content. The same is true for the different varieties grown on the same soil. The only consistent relation shown by the results obtained was with respect to the phosphorus content of the wheat harvested in 1915. The percentage of phosphorus in the Portage wheat was uniformly lower than that of the other varieties grown on the same soil. The Portage wheat is one of the best yielding varieties, and this may be due to the fact that its phosphorus requirement is less than that of some other varieties.

TABLE XII.—YIELDS OF WHEAT ON DIFFERENT TYPES OF SOIL, 1915 (Bushels)

County	Mediterranean	Gladden	Velvet Chaff	Rudy	Turkey Red	Portage
Paulding	28.47	43.18	38.14	35.68	42.99	32.12
Montgomery	22.53	25.24	21.22	19.89	15.76	28.94
Meigs	33.32	33.19	31.77	32.35	23.37	42.19
Hamilton	25.29	28.62	25.67	....	25.56	25.23
Clermont	17.44	20.78	19.28	15.73	19.70	12.66
Wayne	30.12	36.72	33.41	35.80	32.99	40.33

So far as variation due to soil is concerned, it is to be noted that each of the varieties grown on the Clermont soil in 1915 contained a lower percentage of phosphorus than when grown on the other soils; the wheats in 1916 did not show this variation. In general, the wheats in 1916 having a high protein content contained an increased percentage of phosphorus. The phosphorus and nitrogen percentages found are shown in Tables XIII and XIV; baking tests of flour produced from these wheats are given in Tables XV and XVI.

TABLE XIII.—PHOSPHORUS AND PROTEIN CONTENT OF WHEAT GROWN ON DIFFERENT SOILS, 1915 (Percent)

County	Mediterranean	Gladden	Turkey Red	Portage	Rudy	Velvet Chaff
			Phosphorus			
Paulding	0.4360	0.4290	0.4000	0.3963	0.4302	0.4298
Montgomery	.4362	.4130	.4344	.3831	.4088	.4097
Meigs	.4427	.4038	.4315	.3634	.4440	.4315
Hamilton	.4379	.4733	.4517	.3968	....	.5122
Clermont	.3426	.3403	.3340	.3216	.4035	.3411
Wayne	.5277	.4095	.4428	.3470	.5070	.4171
			Protein			
Paulding	10.26	9.06	10.31	9.46	9.29	9.29
Montgomery	11.46	9.12	11.17	9.23	11.11	11.23
Meigs	13.68	10.60	11.57	10.54	11.68	11.06
Hamilton	10.89	9.92	9.75	9.10	....	11.85
Clermont	10.60	9.98	8.89	8.49	9.86	9.18
Wayne	12.14	10.83	11.46	10.15	10.59	11.00

TABLE XIV.—PHOSPHORUS AND PROTEIN CONTENT OF WHEAT GROWN ON DIFFERENT SOILS, 1916 (Percent)

County	Mediterranean	Gladden	Turkey Red	Portage	Rudy	Velvet Chaff	Valley
				Phosphorus			
Montgomery	0.4121	0.3597	0.3722	0.3954	0.4098	0.3782	....
Meigs	.4363	.4325	.4270	.4937	.4432	.4696	....
Hamilton	.4390	....	.4265	.3996	....	.4376	....
Clermont	.4576	.4260	.4683	.4293	.4423	.4427	....
Wayne	.4743	.4371	.4423	.4191	.4497	.4683	0.4371
				Protein			
Montgomery	8.66	8.55	9.41	9.18	9.41	9.41	....
Meigs	9.23	8.84	10.09	9.92	9.23	9.98	....
Hamilton	8.95	....	9.29	8.95	....	9.86	....
Clermont	10.72	8.78	11.17	9.80	9.98	9.75	....
Wayne	11.51	10.49	11.69	10.26	10.77	11.86	11.12

TABLE XV.—BAKING TESTS OF FLOUR FROM WHEAT GROWN ON DIFFERENT SOILS, 1915

County	Volume of loaf	Absorption	Protein in flour	Protein in wheat
	Cc.	*Percent*	*Percent*	*Percent*
MEDITERRANEAN—				
Paulding	1,925	61.80	9.29	10.26
Montgomery	2,050	58.87	8.75	11.46
Meigs	2,175	63.00	10.54	13.68
Hamilton	2,200	62.00	9.12	10.89
Clermont	2,000	60.00	7.75	10.60
Wayne	1,900	61.00	....	12.14
GLADDEN—				
Paulding	1,850	59.45	7.35	9.06
Montgomery	1,900	58.87	7.18	9.12
Meigs	1,750	59.00	8.44	10.60
Hamilton	1,900	59.45	7.38	9.92
Clermont	1,950	59.45	7.78	9.98
Wayne	1,975	60.00	8.15	10.83
TURKEY RED—				
Paulding	1,850	61.37	8.52	10.31
Montgomery	2,100	61.20	9.18	11.17
Meigs	2,200	61.52	9.75	11.57
Hamilton	1,875	60.63	7.95	9.75
Clermont	2,100	59.60	7.44	8.89
Wayne	2,190	60.35	9.69	11.46
PORTAGE—				
Paulding	1,650	58.87	7.46	9.46
Montgomery	1,800	59.75	7.26	9.23
Meigs	1,900	60.63	8.63	10.54
Hamilton	1,775	60.34	7.24	9.10
Clermont	1,700	59.16	6.27	8.49
Wayne	2,050	59.00	8.32	10.15
RUDY—				
Paulding	1,850	58.42	7.47	9.29
Montgomery	2,075	60.18	9.11	11.11
Meigs	2,100	60.76	9.69	11.68
Clermont	2,050	58.72	6.73	9.86
Wayne	2,100	62.10	8.27	10.59
VELVET CHAFF—				
Paulding	1,900	58.42	7.41	9.29
Montgomery	1,975	59.16	8.04	11.23
Meigs	1,950	59.61	9.35	11.06
Hamilton	1,975	59.73	8.95	11.85
Clermont	1,950	59.16	8.09	9.18
Wayne	2,000	59.75	8.89	11.00

TABLE XVI.—BAKING TESTS OF FLOUR FROM WHEAT GROWN ON DIFFERENT SOILS, 1916

County	Volume of loaf	Absorption	Yield	Gluten in flour	Protein in flour	Protein in wheat
	Cc.	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*
MEDITERRANEAN—						
Montgomery	1,950	60.63	462	7.30	6.72	8.66
Meigs	1,800	61.20	468	7.35	7.48	9.23
Hamilton	1,825	62.10	468	7.11	6.97	8.95
Clermont	2,000	62.10	463	9.04	8.54	10.75
Wayne	2,175	65.35	479	9.97	9.73	11.51
GLADDEN—						
Montgomery	1,990	58.87	464	6.78	6.45	8.55
Meigs	1,890	60.30	469	7.16	6.70	8.84
Clermont	1,875	60.04	451	7.00	6.59	8.78
Wayne	1,900	60.93	470	8.05	7.62	10.49
TURKEY RED—						
Montgomery	1,900	63.28	459	7.78	7.30	9.41
Meigs	1,980	64.46	476	8.60	7.88	10.09
Hamilton	1,930	62.40	468	8.02	7.10	9.29
Clermont	1,850	60.04	459	8.86	8.66	11.17
Wayne	2,200	68.28	490	10.51	8.97	11.69
PORTAGE—						
Montgomery	1,825	60.04	460	7.36	6.69	9.18
Meigs	1,825	60.34	459	7.71	7.38	9.92
Hamilton	1,810	59.75	447	6.96	6.91	8.95
Clermont	1,875	62.69	477	7.69	7.20	9.80
Wayne	1,850	61.81	471	7.92	7.53	10.26
RUDY—						
Montgomery	2,000	60.93	465	7.70	6.79	9.41
Meigs	2,080	60.93	469	8.08	7.38	9.23
Clermont	2,000	61.51	461	7.61	7.50	9.98
Wayne	2,075	67.99	488	8.75	8.32	10.77
VELVET CHAFF—						
Montgomery	1,825	57.99	448	8.15	7.16	9.41
Meigs	1,975	60.04	468	8.57	8.14	9.98
Hamilton	1,800	60.34	468	8.26	7.75	9.86
Clermont	1,800	59.16	449	7.69	7.34	9.75
Wayne	1,990	64.16	475	9.60	9.02	11.86

COMPOSITION OF WHEAT RELATED TO QUALITY OF FLOUR

That factors other than the protein content of wheat contribute to the differences found in quality of flour produced is shown by the results obtained in a study made of several varieties of wheat grown on the same soil. The wheats studied in this connection included four varieties which previous milling and baking tests had demonstrated rank among the best of the varieties grown at this Station, and four which were classed as poor varieties. Two of these varieties which produced flour having poor baking quality are included in the list of the 10 highest-yielding varieties grown at this Station.

The results of the baking test show that the volume of the baked loaves made from the flour produced from these two classes of wheat differed considerably. While in some instances the protein content of the wheat producing flour of good baking quality exceeded that found in the poor varieties, in other cases the percentages of protein in the wheat of inferior quality as regards the flour produced, was higher than that of the better varieties. The same thing was found to be true for the flour. Although the protein content of varieties of wheat grown in other years has generally averaged higher for the wheat that produced flour which gave the largest loaf volume, this relation is not always constant.

A high grade of spring wheat flour, bought on the market, was included in this test. It is to be noted that while this flour gave a much larger volume of loaf, the protein content was not appreciably higher than that of the other flours which produced a smaller loaf volume.

An attempt was made to determine, from the chemical composition of the wheat and flour, what factors might have an influence on the quality of the flour produced from the several varieties of wheat grown on the same soil. Separations of the nitrogen compounds were made and the acid and basic constituents of the ash determined. Since most of the data obtained have little significance in relation to the differences found in the quality of the flour, only the results for protein, phosphorus, acidity and ash are reported. These data are included in Table XVII.

TABLE XVII.—ANALYTICAL DATA FOR GOOD AND POOR VARIETIES

		Volume of loaf	Protein	Total phosphorus	Water-soluble phosphorus	Acidity	Ash
GOOD VARIETIES—		*Cc.*	*Per cent*	*Percent*	*Percent*	*Percent*	*Percent*
Buda Pesth	Wheat	....	13.70	0.4853	0.3312	0.675	2.521
	Flour	2,210	11.00	.1554	.0837	.195	.904
Fultz	Wheat	....	13.54	.5022	.3371	.699	2.459
	Flour	2,070	11.20	.1383	.0735	.186	.903
Valley	Wheat	....	13 13	.4922	.3007	.662	2.408
	Flour	2,120	10.87	.1580	.0865	.217	.819
Poole	Wheat	....	12.17	.4842	.2761	514	2.318
	Flour	2,080	10.31	.1591	.0844	.221	.790
Spring wheat flour		2,350	11.45	.1068	.0365	.113	.685
POOR VARIETIES—							
Gold Coin	Wheat	....	12.67	.5017	.3522	.706	2.476
	Flour	1,700	10.42	.1664	.0820	.188	.918
Red Cross	Wheat	....	13.32	.5108	.3476	.695	2.475
	Flour	1,820	10.80	.1524	.0749	.200	.835
Dawson's Golden Chaff	Wheat	....	12.63	.4958	.2927	.609	2.321
	Flour	1,770	10.51	.1453	.0702	.188	.830
Mealy	Wheat	....	12.77	.5065	.2801	.509	2.612
	Flour	1,650	11.69	.1823	.1041	.239	.928

The average phosphorus content of the wheats and flours comprising the group having poor baking qualities was slightly greater than in those varieties classed as being of poor quality. The spring wheat flour contained much less ash and total phosphorus than the other flours. The water-soluble phosphorus and the acidity of this flour were also decidedly less than those found in the flours from winter wheat milled with a small experimental mill.

The Mealy wheat, which produced the poorest flour of the four wheats classed as being poor varieties, contained the largest percentages of phosphorus and ash.

SUMMARY

The data obtained show that the composition of wheat grown on soils which have received the same fertilizer treatment for 20 years is affected by the amounts of phosphorus and nitrogen supplied in fertilizers.

Fertilizers supplying phosphorus increased the size of the wheat grain. Plumpness of grain is largely dependent upon the amount of available phosphorus in the soil.

The effect of the addition of phosphorus without nitrogen to a soil which is more responsive to phosphorus than to nitrogen fertilization has been an increase in yield but a depression of the protein content of wheat.

Where the fertilizer treatment supplied nitrogen with phosphorus the protein content as well as the yield was increased.

Wheat grown on soil where the fertilizer treatment included potassium with nitrogen and phosphorus had a lower protein content and produced a larger yield than when the fertilizer treatment included only phosphorus and nitrogen.

The highest percentage of protein was found in wheat grown on soil deficient in available phosphorus and well supplied with available nitrogen.

Nitrate of soda alone caused the largest increase in protein content of wheat and produced only a slight increase in yield.

The proportion of phosphorus to nitrogen supplied by the fertilizer, and differences in the availability of the nitrogen, have apparently been factors responsible for variations produced in the protein phosphorus content of wheat grown under these conditions.

The protein content of wheat grown on soil where nitrogen was supplied by organic carriers, tankage and dried blood, was less than where nitrate of soda was used, the same additions of phosphorus, potassium and nitrogen being made to the soil in both instances.

There was a tendency for the protein in the flour to parallel the increased protein content of wheat where the supply of available nitrogen in the soil was increased.

Nitrate of soda depressed the phosphorus content of wheat when applied in combination with phosphorus as well as when used alone.

Phosphorus furnished by floats has decreased the protein and increased the phosphorus content of wheat on Strongsville soil. This effect was produced in wheat grown on soil which had received applications of acid phosphate as well as in wheat grown on unfertilized soil, and was most pronounced where nitrogen without phosphorus was applied.

The loaf volume of bread obtained in baking tests of flour produced from these wheats varies as the protein content of the wheat and flour.

Different varieties of wheat grown on the same soil exhibit wide variations in the protein and phosphorus content which do not in all cases have a direct relation to the baking quality of the flour milled from the wheats.

The same variety of wheat grown in different localities throughout the State on soils which contain varying amounts of phosphorus and nitrogen does not show the effect of differences in the total supply of phosphorus and nitrogen that is produced in wheat grown on the same soil where the nitrogen and phosphorus supply has been modified by the fertilizer treatment.