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# TILLAGE IN RELATION TO MILLING AND BAKING QUALITIES OF WHEAT

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## TABLE OF CONTENTS

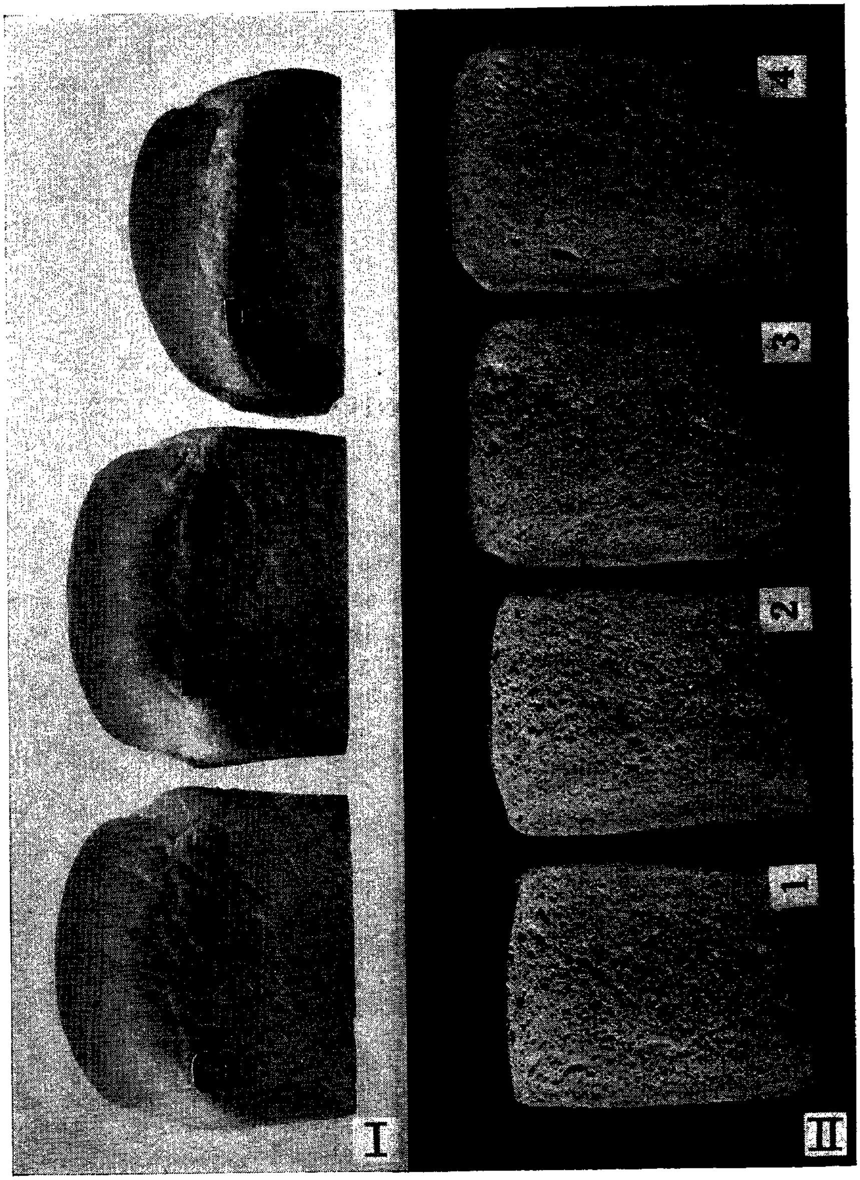


FIG. 1.—The loaves of bread shown in (I) represent the comparative quantities of bread made from wheat produced by (C) July, (D) August, and (E) September plowing in preparing a seed bed for hard winter wheat. The loaves shown in (II) represent the comparative loaf volume and texture of bread produced from wheat grown on land prepared as follows: (1) Weeds allowed to grow during the summer, disked at seeding time; (2) plowed shallow in September; (3) plowed shallow in August; (4) plowed deep (7 inches) in July.

# TILLAGE IN RELATION TO MILLING AND BAKING QUALITIES OF WHEAT[1]

M. C. SEWELL AND C. O. SWANSON

## SCOPE AND PURPOSE OF THE STUDY

The relation of tillage to yield of winter wheat and to the accumulation of soil moisture and nitrates has been presented in a previous publication.[2] The purpose of this bulletin is to show what relation exists between methods of seedbed preparation and the milling and baking qualities of wheat. Starting with 1912, samples of the crop produced by various dates and depths of plowing have been milled and analyzed, and representative portions of the flour have been baked. Yearly records of the relation of certain tillage methods to the milling and baking qualities of wheat are thus available.

The measures of milling and baking qualities of wheat used in the study have been (1) protein, (2) phosphorus, (3) test weight, (4) loaf volume, and (5) texture of bread. The per cent of protein is a convenient measure of quality because it can be quickly and accurately determined. A high-protein wheat in the greater number of cases produces a strong flour, or such as is demanded by the baking trade. Test weight is a measure of milling quality because other things being equal, the higher the test weight, the more flour will be produced from a given quantity of wheat. Strength of flour is shown in evenness of texture of bread, in small cells and thin cell walls, accompanied by large volume. Hence texture and loaf volume are used to measure the comparative milling qualities of different wheats. The per cent of phosphorus in the wheat indicates the proportion of bran to flour. The pericarp, or bran material, of the wheat kernel, is richer in protein and hence in phosphorus than the endosperm, or the starchy material.

According to the averages of the determinations of the above-named measures of milling quality for a 10-year period, as presented in Table I, early summer as compared with late summer

**Acknowledgments.**—The analytical work for the milling, baking, and chemical data presented in this bulletin up to and including 1921, was done by L. A. Fitz, formerly head of the Department of Milling Industry, and Miss Leila E. Dunton, formerly associate professor of Milling Industry, Kansas State Agricultural College.

1. Contribution No. 159 from the Department of Agronomy and No. 28 from the Department of Milling Industry.

2. Sewell, M. C., and Call, L. E. Tillage investigations relating to wheat production. Kan. Agr. Expt. Sta. Tech. Bul. 18:1-55. Tables 24. Figs. 6. 1925.

TABLE I.—Relation of tillage to the milling and baking qualities of wheat grown continuously on the same land.

(Average, 1912 to 1922.)

| Plot No. | TREATMENT. | Test weight. | Yield per acre (1911 to 1920). | Protein in wheat (12.5 per cent moisture). | Protein per acre. | Nitrates in soil in October (1910 to 1919). | Loaf volume. | Phosphorus in wheat. | Phosphorus per acre. |
|---|---|---|---|---|---|---|---|---|---|
| | | *Lbs.* | *Bus.* | *Per cent.* | *Lbs.* | *P. p. m.* | *C.c.* | *Per cent.* | *Lbs.* |
| 1 | Disked at seeding time | 57.9 | 7.7 | 12.11 | 56.0 | 6.7 | 1,801 | 0.495 | 2.29 |
| 2 | Plowed September 15, 3 inches deep | 57.9 | 13.1 | 12.19 | 97.0 | 9.4 | 1,830 | .478 | 3.76 |
| 3 | Double disked July 15; plowed September 15, 7 inches deep | 57.0 | 17.4 | 13.97 | 147.0 | 21.6 | 1,859 | .431 | 4.50 |
| 4 | Double disked July 15; plowed August 15, 7 inches deep | 56.1 | 17.8 | 14.77 | 159.0 | 30.0 | 1,916 | .397 | 4.24 |
| 5 | Plowed September 15, 3 inches deep | 58.2 | 11.3 | 12.20 | 83.0 | 8.1 | 1,863 | .479 | 3.37 |
| 6 | Listed July 15; ridges worked down | 57.8 | 18.0 | 13.99 | 144.0 | 25.1 | 1,882 | .396 | 4.28 |
| 7 | Listed July 15; ridges split August 15 | 56.8 | 18.3 | 13.96 | 154.0 | 29.0 | 1,859 | .408 | 4.48 |
| 8 | Plowed September 15, 3 inches deep | 58.4 | 14.6 | 12.13 | 107.0 | 10.6 | 1,847 | .484 | 4.24 |
| 9 | Plowed July 15, 7 inches deep | 58.1 | 20.7 | 13.93 | 174.0 | 27.6 | 1,889 | .398 | 4.94 |
| 10 | Plowed August 15, 7 inches deep | 57.3 | 19.0 | 13.33 | 153.0 | 18.5 | 1,889 | .404 | 4.60 |
| 11 | Plowed September 15, 3 inches deep | 58.7 | 12.0 | 12.01 | 87.0 | 8.7 | 1,819 | .460 | 3.31 |
| 12 | Plowed August 15, 7 inches deep; not worked till Sept. 15 | 57.7 | 16.8 | 13.26 | 134.8 | 14.7 | 1,875 | .389 | 3.92 |
| 13 | Plowed September 15, 7 inches deep | 58.1 | 11.7 | 12.07 | 85.0 | 7.0 | 1,811 | .447 | 3.14 |
| 14 | Plowed September 15, 3 inches deep | 58.1 | 10.3 | 12.22 | 76.0 | 6.6 | 1,832 | .434 | 2.68 |
| 15 | Plowed July 15, 3 inches deep | 57.3 | 15.0 | 13.73 | 124.0 | 20.0 | 1,850 | .352 | 3.17 |

seedbed preparation has resulted in (1) an increase in the per cent of protein, (2) a decrease in the test weight of grain, (3) an increase in loaf volume, and (4) a decrease in the per cent of phosphorus. All of these measures have been directly correlated with the amount of available nitrates in the soil at the time of fall seeding which, as shown in the publication previously referred to, is definitely related to time of plowing.

## RELATION OF TILLAGE TO PROTEIN OF WHEAT

The relation of the quantity of nitrates in the soil to the per cent of protein in wheat and pounds of protein produced per acre is shown in figure 2. It is apparent that a very close correlation exists between nitrates in the soil and protein in the grain.

The plots plowed in September are Nos. 2, 5, 8, 11, 13, and 14, all of which exhibit a low nitrate content in the soil, a low per cent of protein in the wheat, and a small amount of protein per acre. Plots plowed in July or August show a high nitrate content of the soil and a high protein wheat. It is evident that the early summer

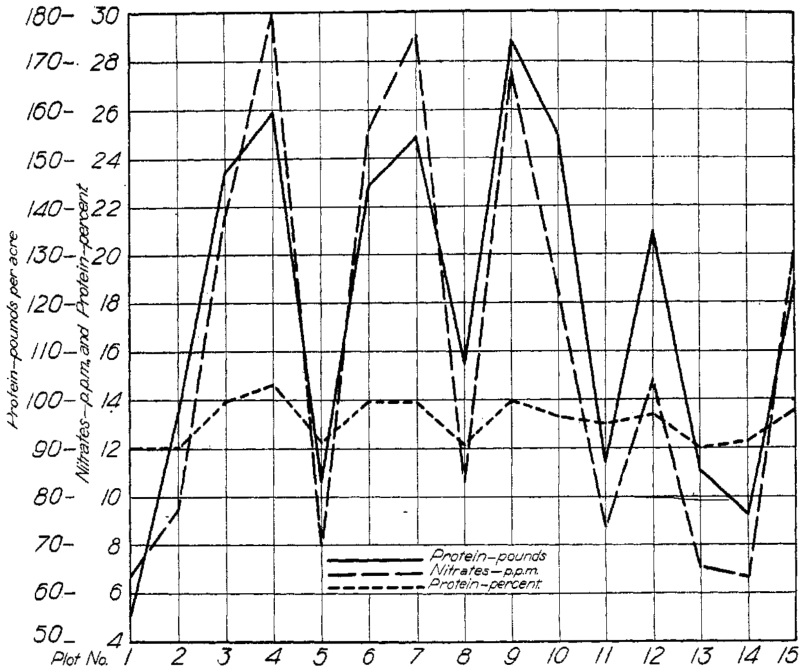


**FIG. 2.—Graphs showing the relation of nitrates in the soil at the time of October sampling to per cent of protein in wheat and pounds of protein per acre. (Ten-year averages on continuously cropped plots.)**

TABLE II.—Relation of tillage to the milling and baking qualities of wheat grown continuously on the same land.

(Average, 1919 to 1922.)

| Plot No. | TREATMENT. | Test weight. | Yield of grain per acre. | Protein in wheat (12.5 per cent moisture). | Protein per acre. | Nitrates in soil in September to a depth of 3 feet (1920 to 1922). | Loaf volume. | Texture of bread. |
|---|---|---|---|---|---|---|---|---|
| | | *Lbs.* | *Bus.* | *Per cent.* | *Lbs.* | *P. p. m.* | *C.c.* | *Per cent.* |
| 1 | Plowed deep in July, winter top dressing of straw | 55.1 | 20.0 | 12.26 | 190 | .......... | 1,745 | 90.5 |
| 2 | Plowed deep in July; top dressing of straw after plowing | 55.1 | 26.5 | 12.30 | 192 | .......... | 1,804 | 87.0 |
| 3 | Plowed shallow in July; top dressing of straw before plowing | 55.8 | 26.5 | 11.95 | 162 | 11.2 | 1,748 | 90.1 |
| 4 | Straw before plowing; plowed deep in July | 55.3 | 28.6 | 12.96 | 222 | .......... | 1,799 | 90.8 |
| 5 | Stubble burned; plowed shallow in July | 52.9 | 24.9 | 13.04 | 200 | 14.7 | 1,814 | 91.5 |
| 6 | Stubble burned; plowed deep in July | 53.5 | 24.5 | 13.64 | 181 | 13.8 | 1,791 | 88.0 |
| 7 | Plowed shallow in July | 56.2 | 26.4 | 12.36 | 195 | 12.6 | 1,773 | 90.2 |
| 8 | Plowed deep in July | 55.8 | 28.0 | 12.90 | 225 | .......... | 1,791 | 91.7 |
| 9 | Plowed deep and shallow in July in alternate years | 56.4 | 28.6 | 12.55 | 240 | .......... | 1,760 | 89.5 |
| 10 | Plowed deep in July every third year | 55.9 | 27.8 | 12.79 | 213 | .......... | 1,726 | 88.2 |
| 11 | Plowed deep in July every sixth year | 56.2 | 25.6 | 12.38 | 223 | .......... | 1,705 | 89.7 |
| 12 | Disked to keep down weeds, not plowed | 52.9 | 19.3 | 13.07 | 153 | .......... | 1,703 | 90.1 |
| 13 | Disked to keep down weeds; plowed shallow in September | 53.3 | 19.6 | 13.49 | 160 | .......... | 1,742 | 89.7 |
| 14 | Disked to keep down weeds; plowed deep in September | 54.1 | 18.3 | 13.38 | 120 | .......... | 1,769 | 90.3 |
| 15 | Weeds allowed to grow; disked at seeding time | 54.6 | 4.2 | 12.34 | 31 | 4.1 | 1,690 | 87.8 |
| 16 | Weeds removed by surface scrapings; disked at seeding time | 56.3 | 17.0 | 12.54 | 125 | 10.7 | 1,785 | 89.6 |
| 17 | Plowed shallow in September | 54.8 | 12.3 | 12.26 | 73 | 5.4 | 1,727 | 87.9 |
| 18 | Plowed deep in September | 54.1 | 12.4 | 12.40 | 87 | .......... | 1,738 | 88.7 |
| 19 | Plowed shallow in August | 55.8 | 12.1 | 12.14 | 154 | 11.8 | 1,738 | 88.0 |

tillage favored an abundant supply of nitrates in the soil which resulted in greater yields and a high production of protein per acre.

The above conclusions are substantiated by the data given in Table II and figure 3, which give the results for four consecutive years (except as otherwise stated) from another tillage experiment, one established in recent years, in which the wheat is also grown continuously on the same land. Here again the plots receiving early summer seedbed preparation contain the greater amount of nitrates in the fall and produce wheat with a relatively high per cent of protein. Nitrate determinations were made only on certain plots.

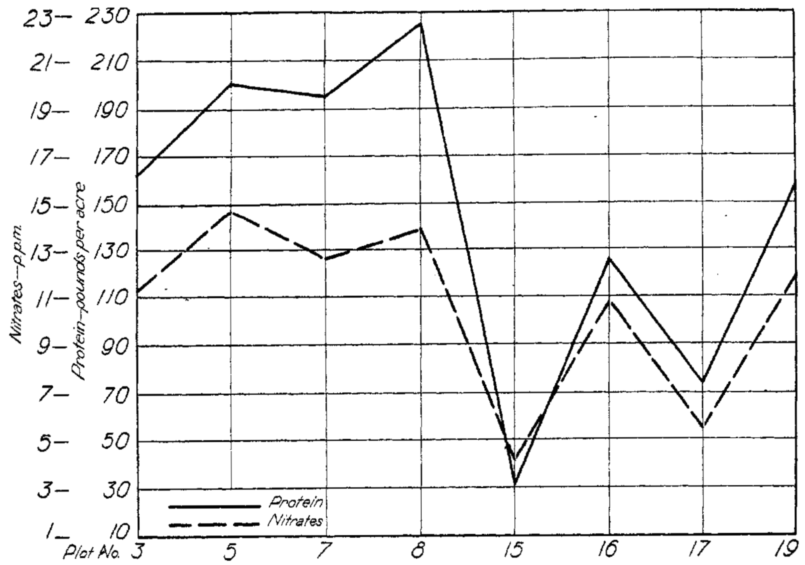


FIG. 3.—Graphs showing the relation of nitrates in the soil to pounds of protein per acre in the wheat produced. (Three-year averages on continuously cropped plots. 1920 to 1922. Second experiment.)

## RELATION OF TILLAGE TO TEST WEIGHT OF WHEAT

The test weight has varied inversely with the protein content, as indicated in figure 4, which shows this relation between test weight and per cent of protein for the earlier of the two experiments. Early summer tillage has consistently produced wheat of high protein content but low test weight.

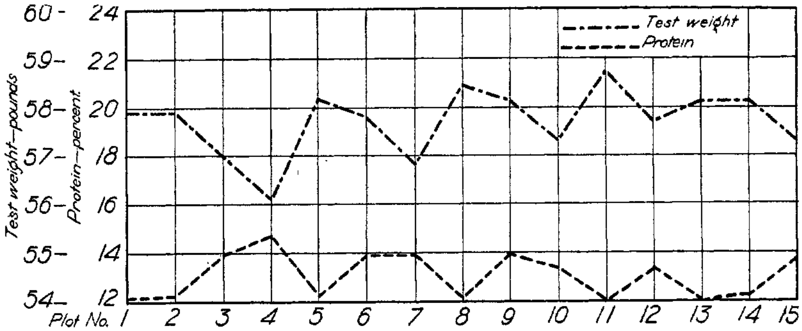


FIG. 4.—Graphs showing the relation between test weight and per cent of protein in wheat for a ten-year period. (First tillage experiment.)

## RELATION OF TILLAGE TO PHOSPHORUS IN WHEAT

In these experiments a relatively low per cent of phosphorus in the wheat has been associated with a high nitrate supply in the soil. This fact is brought out in figure 5. It appears that a soil deficient in nitrates produces a low yield of wheat containing small kernels which have a high proportion of bran. Since the bran contains about four times as much phosphorus as the endosperm, the

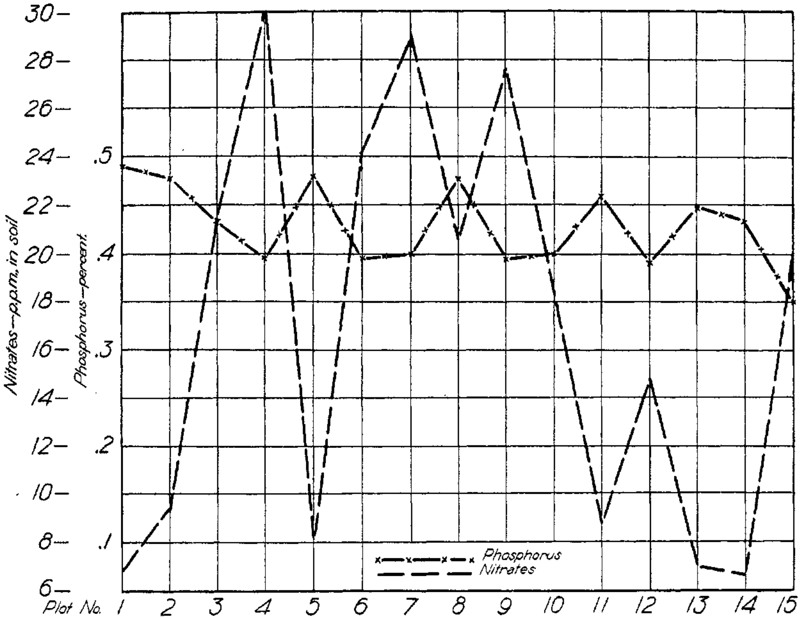


FIG. 5.—Graphs showing the relation of nitrates in the soil at seeding time to per cent of phosphorus in the wheat produced. (First tillage experiment.)

proportion of bran in the small shriveled kernels explains the high per cent of phosphorus where the yield is low.

When the phosphorus per acre in the wheat is compared with the pounds of protein, a direct correlation is found as shown in figure 6. This fact probably indicates that the soil had a sufficient supply of available phosphorus for the higher yields since there was more phosphorus withdrawn from the soil to meet the increased demands caused by the greater supply of available nitrogen.

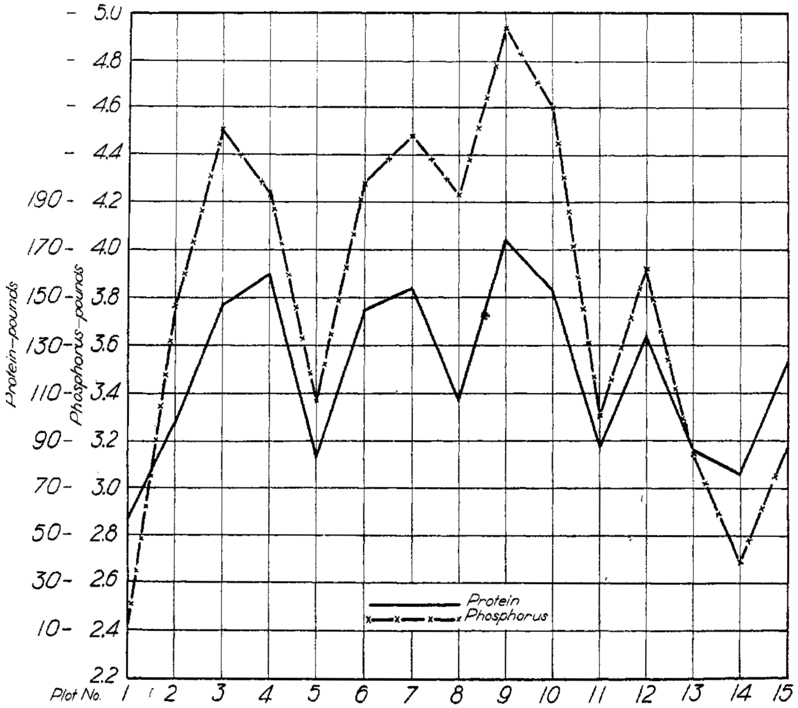


**FIG. 6.**—Graphs showing a comparison of the total number of pounds of protein and the total number of pounds of phosphorus produced per acre of wheat. (First tillage experiment.)

## RELATION OF TILLAGE TO LOAF VOLUME AND TEXTURE OF BREAD

Figure 7 shows the average loaf volume from wheat produced with various tillage treatments for the ten-year period. The larger volumes are from wheat produced on a soil receiving early summer preparation as on plot 4, which was disked in July and plowed in August; plot 6, listed in July; plot 9, plowed 7 inches deep in July; plot 10, plowed 7 inches deep in August; plot 12, plowed 7 inches deep in August but not cultivated until the middle of September; and plot 15, plowed shallow in July. Figure 1 (II) gives another graphical presentation of this relationship.

The range of 115 cc. in loaf volume, with the various tillage treatments as shown in Table I is not large considering the individual loaf. However, from the standpoint of the large commercial baker, preparing perhaps a hundred thousand loaves a day, the differences would be very important.

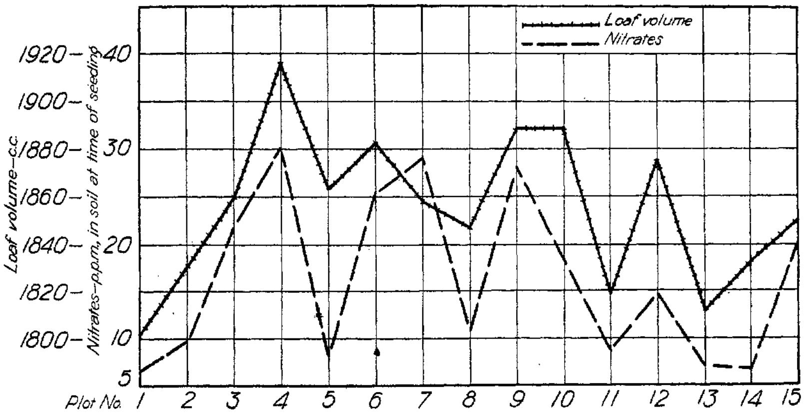


FIG. 7.—Graphs showing a comparison of soil nitrates at the time of fall seeding and of loaf volume. (First tillage experiment.)

## EFFECT OF TILLAGE TREATMENTS IN CROP ROTATION ON MILLING QUALITIES OF WHEAT

As previously reported[3] a rotation of wheat, corn, and oats was conducted as part of the tillage experiments, the ground for wheat being prepared at various dates and by different depths of plowing. The milling and baking data for wheat grown in rotation are presented in detail in Table III and graphically in figure 8.

The per cent of protein in the wheat produced in this rotation does not show much variation with time and depth of plowing except in the case of the 12-inch plowing in July. In this case the protein content of the wheat is markedly higher. The pounds of protein per acre, however, vary directly with the time of plowing because of the introduction of the yield factor. The supply of soil nitrates apparently limits the yield in the case of the August and September plowing, but does not affect the per cent of protein in the wheat.

The data indicate that loaf volume is not so much influenced by

3. Loc. cit. (Sewell, M. C., and Call, L. E. Kan. Agr. Expt. Sta. Tech. Bul. 18.)

TABLE III.—Relation of tillage to milling and baking qualities of wheat grown in rotation.

(Average for nine-year period, 1912 to 1920. Rotation: Corn, oats, and wheat.)

| Plot No. | TREATMENT FOR WHEAT. | Test weight. | Yield per acre (1911 to 1920). | Protein in wheat (12.5 per cent moisture). | Protein per acre. | Nitrates in soil in October (1910 to 1919). | Loaf volume. | Texture of bread. | Phosphorus in wheat (1913 to 1922). |
|---|---|---|---|---|---|---|---|---|---|
| | | *Lbs.* | *Bus.* | *Per cent.* | *Lbs.* | *P. p. m.* | *C.c.* | *Per cent.* | *Per cent.* |
| 1 | Plowed in July, 12 inches deep | 58.4 | 25.7 | 13.37 | 206.2 | 23.0 | 1,888 | 92 | 0.417 |
| 2 | Plowed in July, 7 inches deep | 59.4 | 26.7 | 11.36 | 185.2 | 20.2 | 1,859 | 91 | .422 |
| 3 | Plowed in July, 3 inches deep | 59.5 | 26.8 | 11.90 | 191.7 | 19.5 | 1,858 | 92 | .426 |
| 4 | Plowed in August, 7 inches deep | 59.1 | 23.2 | 11.93 | 166.0 | 14.0 | 1,839 | 91 | .425 |
| 5 | Plowed in September, 3 inches deep | 59.1 | 17.0 | 11.88 | 121.2 | 7.8 | 1,804 | 91 | .463 |

the time of plowing where a rotation is practiced as is the case where the land is cropped continuously to wheat. Also test weight and the per cent of phosphorus in the wheat seems not to be affected by the time of plowing. It appears therefore that, in general, the milling and baking qualities of wheat are not so greatly affected by tillage methods when wheat is grown in rotation with other crops as when grown continuously on the same land.

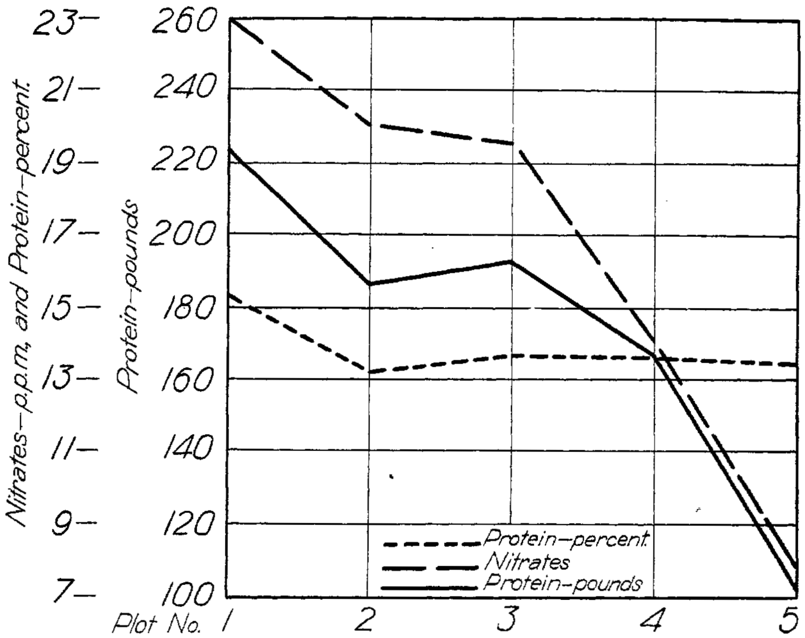


FIG. 8.—Graphs showing the relation of nitrates in the soil at seeding time to the per cent of protein and the pounds of protein per acre in the wheat produced. (Nine-year averages in a rotation of corn, oats, and wheat.)

## GENERAL DISCUSSION

No attempt has been made in this publication to review the literature concerning the effect of soil nitrates upon the milling and baking qualities of wheat. However, it is of interest to note that the relation between the nitrates in the soil during the fall and the protein content, of the wheat as recorded here is in accord with the work of Lawes and Gilbert; Jones, Colver, and Fishburn ; Headden ; Davidson and Le Clerc; Gericke; Neidig and Snyder; and others.

The high percentage of phosphorus in wheat produced on soil plowed late in the summer agrees with the work of Lawes and Gilbert[4]

4. Lawes, J. B., and Gilbert, Henry. On the composition of ash of wheat grain and wheat straw grown at Rothamstead in different seasons and by different manures. Jour. Chem. Soc. (London) 45:305-407. 1884.

and Thatcher.[5] The former found that when wheat was produced with nitrogenous in addition to mineral manuring, there was a higher per cent of protein and a lower per cent of phosphoric acid in the ash and also in the grain. Thatcher found that any condition which results in an increased proportion of endosperm in the kernel is likely to produce low protein wheat. He also found that the pericarp material is richer in protein and hence in phosphorus than endosperm material. This explains what has been observed in the case of the tillage experiments herein cited; namely, that abundant nitrates in the fall result in a high yield of wheat having plump kernels which contain a low proportion of pericarp to endosperm and hence a lower per cent of phosphorus.

Although precipitation data are not presented it is of interest to note that no correlation between rainfall and the protein content of the wheat was observed. This is in agreement with Headden's observation[6] that neither the amount nor the distribution of irrigation water made any material difference in the composition of the grain,

Jones, Colver, and Fishburn[7] showed that the low nitrogen content of wheat grown on raw, irrigated land is due to the low content of available nitrates in the soil and not necessarily to irrigation. When such land is brought into rotation with alfalfa so that the amount of available nitrogen in the soil is increased, a much better quality of grain is secured. Headden[8] found that the application of nitrogen to the soil increased the nitrogen content of all parts of the plant, and that ten parts of nitrate per million were sufficient to produce a hard wheat. According to Davidson and Le Clerc[9] both the yield and quality of grain were influenced by the application of nitrates. Gericke[10] increased the protein content of spring wheat from 8.6 to 15.2 per cent by the application- of nitrates, and both the yield and the quality of grain were also improved. From similar investigations, Neidig and Snyder[11] concluded that when

5. Thatcher, R. W. The progressive development of the wheat kernel. Jour. Amer. Soc. of Agron. 5:203-213. 1913. *Ibid.* 7:273-282. 1915.

6. Headden, W. P. A study of Colorado wheat. Colo. Agr. Expt. Sta. Buls. 208 (1915), 217 (1916), 219 (1916), 244 (1918), 247 (1918).

7. Jones, J. S., Colver, C. W., and Fishburn, H. P. Irrigation and the protein content of wheat. Idaho Agr. Expt. Sta. Bul. 109:1-43. 1918.

8. Loc. cit.

9. Davidson, J., and Le Clerc, J. A. The effect of sodium nitrate applied at different stages of growth on the yield, composition, and quality of wheat. Jour. Amer. Soc. Agron. 9:145-154. 1917. *Ibid.* 10:193-198. 1918.

10. Gericke, W. F. Differences effected in the protein content of grain by applications of nitrogen made at different growing periods of the plant. Soil Science 14:103-109. 1922.

11. Neidig, R. E., and Snyder, R. S. The effect of available nitrogen on the protein content and yield of wheat. Idaho Agr. Expt. Stat. Res. Bul. 1:1-56. Pls. 4. 1922.

nitrogen was sufficient to insure an available supply during the life cycle, both the yield and protein were increased.

## CONCLUSIONS

The data presented would seem to justify the conclusions that for the conditions of these experiments:

1. The per cent of protein in wheat is materially affected by the quantity of nitrates in the soil. The yield in bushels per acre and the quality of protein per acre correlate directly with the quantity of nitrates in the soil, which in turn are contingent upon the methods and time of tillage.

2. The per cent of phosphorus varies inversely with the nitrates and the yield in bushels of wheat per acre, but the quantity of phosphorus in the crop varied directly with the yield, showing that phosphorus was not the limiting growth factor.

3. The tillage treatments which produced the largest quantity of nitrates in the soil, not only produced the largest yield of wheat and the highest per cent of protein, but the flour from this wheat was also of superior quality as measured by loaf volume and texture of the bread.

4. When grown in rotation, different tillage treatments greatly influenced the yield of wheat and hence the quantity of protein per acre, but not the per cent of protein in the wheat and other factors which measure milling quality.

11-2025