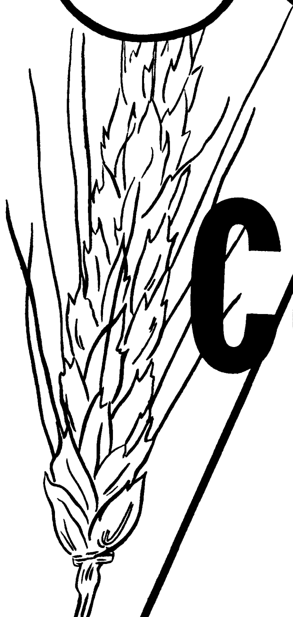
65 Years of Continuous Wheat



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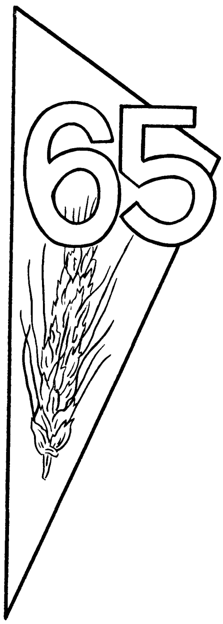

CONTENTS

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Sixty-Five Years of Continuous Wheat on Reddish Prairie Soil in Central Oklahoma

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Wheat has been planted every year on a plot of reddish prairie soil on the Oklahoma Agricultural Experiment Station for the past 65 years. The original planting was made in the fall of 1892 by A. C. Magruder, first professor of agriculture at Oklahoma A&M College (now Oklahoma State University) to obtain information on the ability of the soil to continue to produce good yields of wheat without fertilization. In 1898, half of the 1.25 acre area was fertilized with barnyard manure; and from that time until 1929 this comparison was continued unchanged. Since 1930, portions of the two areas have been subjected to varying fertilizer treatments.

This publication describes the fertilizer treatments on this area from 1893 through 1957, reports wheat yields obtained, and chemical changes in the soil resulting from continued cultivation and fertilization.

History of the Plots

The land on which this study was started was broken from virgin prairie in 1892. From 1893 through 1898[1] it was not fertilized and yield data were taken from the 1.25-acre plot as a unit.

In the summer of 1896, the area was divided into two plots. Yields were taken separately from the north and south halves in order to measure soil variability.

[1]Year dates throughout this publication refer to year of harvest unless otherwise specified. That is, the crop years mentioned above 1892-3 through 1897-8.

From 1899 through 1929, the south half was fertilized with barnyard manure and the north half left unfertilized. No commercial fertilizer was used during this period.

Prior to the 1926-27 seeding, each of the halves was divided into five plots. Individual yields were taken on each of these ten plots in 1927, 1928, and 1929, in order to determine soil variability.

Beginning with the 1930 crop, the 10 plots were given fertilizer treatment as shown in Figure 1 and Table 5.

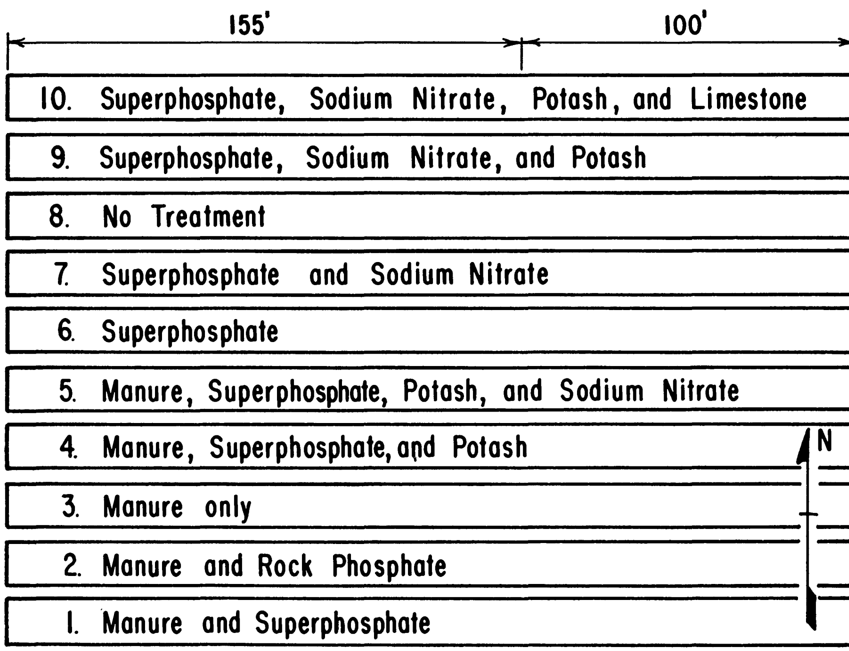

Figure 1. Plot layout and fertilizer treatments 1929-30 through 1946-47. Plots were 14 ft. wide and 255 ft. long with 4 ft. borders. They were cut to 155 ft. in 1934.

In the summer of 1933, it was necessary to abandon a 100-foot strip across the east end of the area to permit construction of a new dormitory (Murray Hall).

In the summer of 1947, construction of another dormitory (Stout Hall) required abandonment of the remainder of the tract. Part of the soil from six plots was moved to a new location, as described on Page 10.

General Conditions

The soil is a Kirkland loam. The surface soil contains 46 percent sand, 38 percent silt, and 16 percent clay. The subsoil is very slowly permeable.

Variety of Wheat

The wheat variety planted on these plots was changed whenever experimental results indicated that a better variety was available. The varieties planted in different years are shown in Table I. Soft red winter wheat was planted until 1912. Hard red winter wheat was planted from 1912 to 1957.

Insect and Disease Damage

The wheat was severely damaged by rust, greenbugs, or chinchbugs in 1905, 1911, 1919, 1921, 1926, 1941, and 1945. Although 1951 was a year of severe greenbug damage in Oklahoma, these plots were affected only slightly.

Rate of Seeding

The wheat was drilled in 7-inch rows prior to 1934. All plantings from 1934 to 1957 were in rows 14 inches apart except in 1948 when a 7-inch spacing was used to decrease competition from henbit (*Lamium amplexicaule*.) The rate of seeding was about 75 pounds per acre in the 7-inch rows and 50 pounds per acre in the 14-inch rows.

Bird Damage

During some seasons English sparrows caused some damage to the grain yield as the wheat approached maturity. More injury occurred on fertilized plots than on unfertilized plots, because the grain on fertilized plots usually ripened several days earlier. (See Figure 2.) The wheat shocks were covered with burlap to protect the grain from the birds until the crop could be threshed.

Bird injury has not been a problem since the soil on these plots was transferred to an open area on the Oklahoma Agricultural Experiment Station Agronomy farm in 1947.

Figure 2. This June, 1940 photo shows unfertilized plot (Number 8) at center. Soil phosphorus deficiency caused this plot to mature several days later than others.

Land Slope and Erosion

The average land slope on the original area (prior to 1947) was 1.4 percent. Consequently, two small terraces were constructed across these plots in 1927 to control sheet erosion.

Procedures and Results

The original intention of this study was to obtain information on the ability of the soil to continue to produce good yields of wheat without fertilization. Yields per acre during the first four years were: 1893, 10.5 bushels; 1894, 20.9 bushels; 1895, crop failure due to severe fall and spring drought; and 1896, 6.9 bushels. In 1897, the yield was 17.9 bushels per acre on the north half and 17.8 bushels on the south half; and in 1898 it was 7.5 bushels on the north half and 7.0 bushels on the south half.

1899-1957: Manure vs. No Manure

In July, 1898, barnyard manure was applied to the south half of the plot; and until 1930 the plot was devoted to a comparison of yields on the unfertilized north half and the south half fertilized with manure[2]. After 1930, this comparison was continued on smaller portions of the original manured and unmanured plots.

The manure applications are described in Table II. The average rate of application during the 59-year period was about 3.5 tons per acre per year. During the earlier years the manure was not applied at the same rate per acre or at regular intervals. The average rate of manure application per year from 1899 to 1911 was 4.5 tons per acre. The average rate of application per year from 1912 to 1936 was equivalent to three tons of moist material per acre. The moisture content of the manure in 1904 was 54 percent. In 1936 the manure was very dry and was applied at the rate of 4 tons per acre which was equivalent to 12 tons of manure containing 75 percent moisture. Beginning in 1941, the manure was applied at the rate of 120 pounds of nitrogen per acre every fourth year.

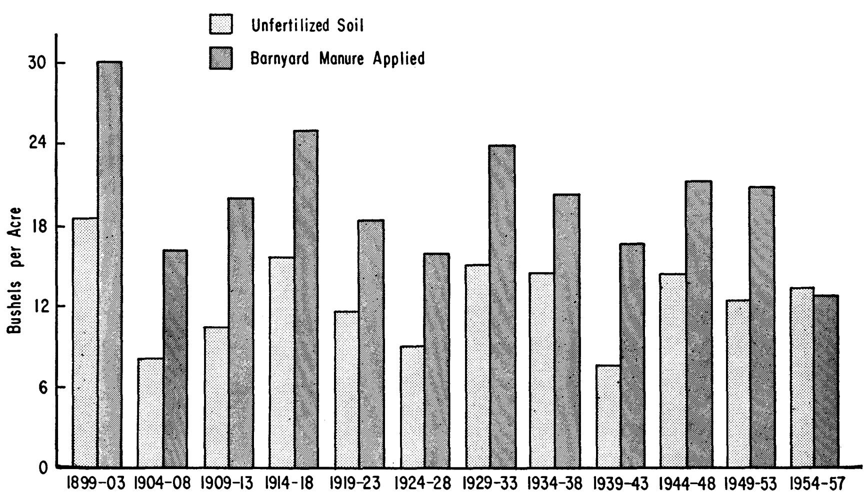

Figure 3. Wheat yields from the manured and unfertilized plots by five-year periods from 1899 to 1957.

Wheat yields on the manured and unmanured plots are shown in

[2]The beneficial effect of barnyard manure on wheat production had been observed in 1894 on another part of the Oklahoma Agricultural Experiment Station farm where 51 wheat varieties had been planted on an area where 20 loads of fresh stable manure had been applied and plowed under a few days before the wheat was planted. The average yield of these varieties was 32.4 bushels per acre on the manured area and 14.4 bushels per acre on the unmanured land. Probably this observation was responsible for changing this continuous wheat study into a barnyard manure-wheat fertility experiment.

Table III. The average yields of wheat obtained from the manured and the unfertilized plots for eleven 5-year periods and for one 4-year period from 1899 to 1957 are shown in Figure 3. Average wheat yields were low during one 5-year interval in each of the three 15-year periods and the 14-year period on this chart.

1929-1947: Manure With and Without Other Fertilizers

Chemical tests made on the plots in 1926 indicated that the soil was deficient in available phosphorus. Consequently, this experiment was modified to measure the effect of applying superphosphate alone and in combination with nitrate of soda and muriate of potash with and without barnyard manure on wheat production. The manured area and the unmanured area were each divided into five plots (Figure 1).

Data on wheat yields were obtained from 1927 to 1929 to study soil variability on these plots. These data are presented in Table IV. The average yield was slightly lower on plot 10 than on the other four unmanured plots (6, 7, 8, and 9). This was partly due to a reduction in available soil moisture resulting from tree roots extending into the north edge of the plot from an adjoining peach orchard. Tree roots were cut between the peach orchard and the grain plot in 1930. However, low yields were produced on this plot in 1934 and in 1936 when drought injury was severe.

Superphosphate was drilled with the wheat at planting time. Rock phosphate was broadcast during the summer before the land was plowed. Nitrate of soda was applied a as top-dressing in February. Muriate of potash was broadcast after the wheat was planted or was applied as a top-dressing with the nitrate of soda.

Fertilizer treatments and the wheat and straw yields during the period are shown in Tables V and VI.

1948-1957: How Soils Were Moved

The surface and subsurface soils from plots 3, 6, 7, 8, 9, and 10 were moved in the summer of 1947 to a location approximately one mile west. The top eight inches of soil was removed with a bulldozer from an area 100 feet in length near the center of each plot and was piled on each end of that plot. (See Figure 4.) The subsurface soil from 8 to 16 inches was excavated and transferred to prepared trenches dug in an east-west direction on the southeast part of series 7200 on the Oklahoma Station's Agronomy farm. These trenches were 17.5 feet wide,

Figure 4. Surface soil from 6 of the old wheat plots was piled so subsurface soil could be removed and transferred to a new location in July 1947.

Figure 5. Surface soil from old wheat plots was moved to Oklahoma Experiment Station Agronomy Farm in July, 1947. Trenches were 17½ ft. wide, 100 ft. long, 16 inches deep.

16 inches deep, and 100 feet long. Top soil from each plot was spread evenly over the subsurface soil from that plot after it was levelled. (See Figure 5.) A four-foot strip of undisturbed soil was left as a border between each plot. The reddish clay subsoil under this area was very similar to the subsoil under the original plot.

Treatments and Results After Moving

Arrangement of plots at the new location is shown in Figure 6. The previous fertilizer treatments were continued on the plots after the soils were moved except that ammonium nitrate was used instead of sodium nitrate, thus doubling the application of nitrogen. Two tons of limestone per acre were applied to plot 10 in 1954.

Grain and straw yields from 1948 to 1957 are given in Tables VII and VIII.

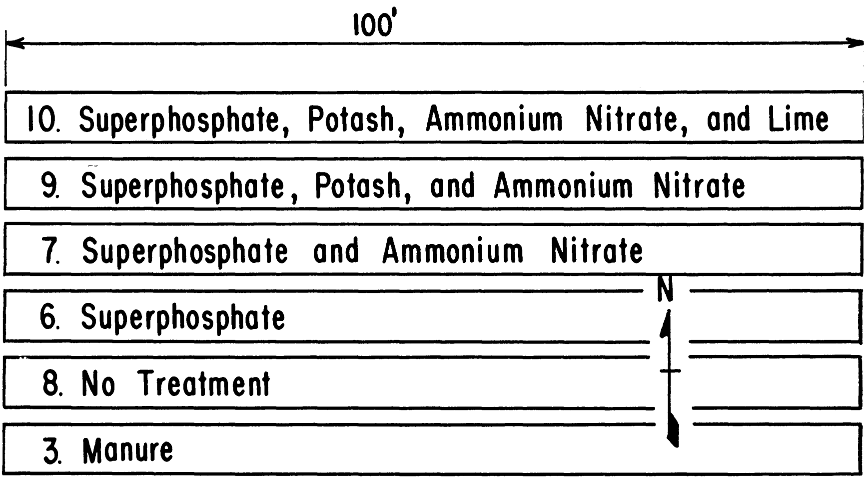

Figure 6. Arrangement of the 6 plots after removal from original location. New plots were 21½ ft. wide, 100 ft. long with 4 ft. borders.

Effect of Moving on Yields

Very high grain yields were obtained from all plots fertilized with superphosphate in 1948, the first year after the soil was moved. However, high grain yields also were obtained during that season from wheat grown in a rotation with legumes on similar land on adjacent plots. The average wheat yield from the manured plot after moving was about one bushel per acre lower than the yield from the superphosphate plot. This difference was caused to a great extent by low grain yields on the manured plot in 1955 and in 1956 when the quantity and distribution of rainfall were unfavorable for wheat production on land fertilized with nitrogen. The average yields for the different fertilizer treatments for the period 1930 to 1957 and for 1948 to 1957 shown in the last two columns in Table VII are very similar. This indicates that moving these soils did not cause much change in their relative crop-producing capacities.

Changes in Soil Composition

Two studies have been made of the soil chemistry of these plots. The most elaborate was made using soil samples collected in December, 1938. The other involved a comparison of the nitrogen and organic matter content of samples taken from manured and unmanured

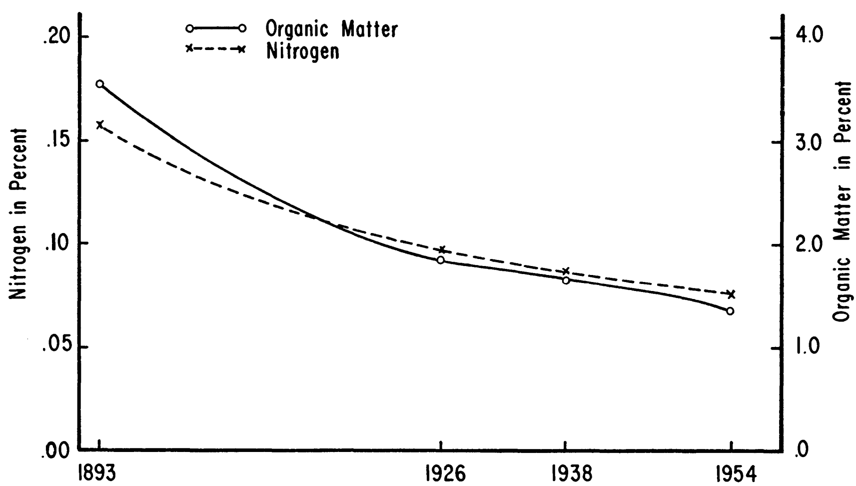

Figure 7. Changes in the organic matter and nitrogen content of surface soil on unfertilized land from 1893 to 1954.

plots in 1926, 1938, and 1954. The data in Figure 7 show that a more rapid loss of organic matter and nitrogen occurred the first years after the virgin soil was plowed than from 1926 to 1954.

Nitrogen and Organic Matter (1926)

Composite samples of surface soil were collected in 1926 from the manured and unmanured plots and also from a fence row along the south side of the plots. The soil in this fence row had never been cropped. These samples were analyzed for nitrogen, organic matter, phosphorus, and acidity. Table IX compares the results with corresponding data taken in 1938 and 1954.

Complete Analysis (1938)

In December, 1938, composite soil samples were collected from each of the 10 plots into which the area was divided at that time. Eleven samples were collected at 10-foot intervals near the center line of each plot at depths of 0 to 6, 6 to 12, 12 to 18, 18 to 24, 24 to 36, and 36 to 48 inches. Soil samples from each depth in each plot were thoroughly mixed to obtain a composite sample for chemical analysis. These samples were analyzed for total nitrogen, total organic matter, total phosphorus, easily soluble phosphorus, easily soluble manganese, pH value, exchangeable hydrogen, total exchange capacity, total exchangeable bases, and exchangeable calcium, magnesium, and potassium. Results of these analyses are shown in Tables X and XI.

Total nitrogen was determined by the Kjeldahl method using selenium powder as a catalyst; organic matter by chromic acid oxidation; and total phosphorus by perchloric acid digestion with subsequent reduction of the phosphomolybdate with hydrazine sulfate[3]. The easily soluble phosphorus and manganese were determined by extracting the soil with .2 normal sulfuric acid for 30 minutes with intermittent shaking, using one part of soil and 10 parts of solvent.

The pH values were determined with a glass electrode. Data on total exchangeable bases were secured by extracting each soil with 1.0 normal neutral ammonium acetate at 70° C. for one hour followed by leaching with the same solution, evaporation of the filtrate, ignition of the residue and titration of the calcium, magnesium and potassium carbonates or oxides with a standard acid. Total exchange capacity was obtained by leaching the excess of ammonium acetate from the soil and measuring the absorbed ammonia by distillation with magnesium oxide. The difference between total exchange capacity and total exchangeable bases was assumed to be exchangeable hydrogen. Exchangeable potassium was determined in the filtrate from the ammonium acetate extraction. Analyses for exchangeable calcium and magnesium were made on solutions obtained by leaching each soil with a sodium acetate-acetic acid solution adjusted to a pH of 4.9.

[3]Iowa State College Journal of Science 15: 403-413 (1941).

Discussion

Effect of Barnyard Manure Alone

Thirty-one wheat crops from the manured land and 29 crops from the unmanured land produced yields that were above average over the 59-year period. (Table III.) The first three crops of wheat harvested after manure was applied in 1898 and in 1899 produced more than 30 bushels of grain per acre. Only five other crops of wheat produced more than 30 bushels per acre on the manured plot, although yields from 25 to 30 bushels per acre were obtained during 12 of the remaining 51 seasons. The average yield of grain from the manured plot from 1899 to 1957 was 20.25 bushels per acre and from the unfertilized plot, 12.6 bushels per acre.

The harmful effect of seasons unfavorable for wheat production has been less severe on the manured plot. Seven crops on the manured land produced yields too low to pay the total cost of crop production, whereas 20 crops on the unfertilized area were too low to pay total production costs. Nine bushels of wheat per acre was used as a break-even point where the value of the wheat equalled production costs on unfertilized soil. The break-even point on the manured plot was calculated at 10.0 bushels per acre.

Each ton of manure applied in this experiment produced an average of 2.16 bushels of wheat. Large quantities of manure per acre have produced less wheat per ton of manure applied in several tests at other locations.[4]

The increase in wheat yield obtained from the application of barnyard manure was due principally to the phosphorus in this material, since very little crop response was obtained from nitrate or potash fertilization during the period 1930-1947 (Table V). Barnyard manure supplied about 55 percent as much phosphorus as was present in the

[4]Wheat production per ton of barnyard manure applied has been measured at several locations as follows:

Location	Tons of manure per acre per year	Bushels of wheat per ton of manure
Broadbalk Field, Harpenden, England	14.0	1.5
Stackyard Field, Woburn, England	8.5	1.5
Stackyard Field, Woburn, England	5.5	1.8
Sanborn Field, Columbia, Missouri	6.0	1.5
Ohio Agri. Expt. Station, Wooster, Ohio	2.5	3.2
Ohio Agri. Expt. Station, Wooster, Ohio	5.0	2.5
Southern Great Plains Field Station, Woodward, Oklahoma	2.5	1.6

superphosphate. The average yield of wheat obtained from superphosphate fertilization was about 18.3 bushels per acre as compared with 20.4 bushels per acre from the manured plot. The average yield of wheat on unfertilized soil was about 12.7 bushels per acre. When superphosphate or rock phosphate was applied with manure on this soil, wheat yields were only slightly higher than those obtained from barnyard manure alone.

Nitrogen Fertilizer

Sodium nitrate applied with superphosphate at the rate of 16 pounds of nitrogen per acre on unmanured land increased the average yield of wheat about 1.3 bushels per acre above that obtained from superphosphate alone (plots 6 and 7, Table V). A profitable increase in yield was not obtained when this form of nitrogen was applied with superphosphate or with superphosphate and potash. Doubling the quantity of nitrogen in 1946 and 1947 and after the plots were moved in 1947 did not produce much increase in the average yield of wheat. A very good increase in wheat production was obtained from nitrogen fertilization in 1953. However, the value of the increase in wheat yield obtained from ammonium nitrate applied to this soil during the 10-year period from 1948 to 1957 would pay only a fraction of the fertilizer cost.

The nitrogen content of this soil has gradually decreased as a result of planting wheat every year. However, during an average season sufficient nitrogen has been released from the decomposition of soil organic matter, a small amount of nitrogen supplied in rain, and from other sources to produce nearly as much wheat as a favorable climatic environment will permit in this area.

Effects of Phosphorus

Table XII shows the effect of superphosphate on wheat yields for the 28-year period, 1930 through 1957, and also the value of this increase above cost of fertilizer and the cost of applying it. The average profit from the use of this fertilizer was $4.91 per acre for the 28-year period. The average annual labor income from wheat produced on the unfertilized plot for the 28-year period was $5.47 per acre[5]. Fertilization of wheat with 0-20-0 fertilizer when the crop was planted increased labor income about 90 percent above that obtained from planting wheat on this land without fertilization.

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[5]Nine bushels of grain per acre was used as the break-even point.

Effects of Potassium

Fifty pounds of muriate of potash applied each year increased the average yield of wheat about .5 bushel per acre (plots 7 and 9, Table V). This soil is high in exchangeable potassium; consequently, a profitable crop response from potash fertilization would not be expected.

Effects of Calcium

Limestone screenings applied in 1929 on plot 10 did not increase the wheat yield appreciably over that obtained on plot 9 which received the same fertilizer treatment, but no limestone.

Soil acidity is not as high on these plots as in some long-time wheat experiments where grain yields were greatly reduced as a result of a toxic soil condition which developed over a period of years where ammonium sulfate was used to increase the supply of available nitrogen for plant development[6].

Relation of Fertilization to Crop Characteristics

During the period 1930 through 1947, 77 percent more straw was produced on the manured plot than on the unfertilized plot. Also more straw was harvested from plots fertilized with manure and superphosphate than where superphosphate and nitrate of soda were applied to the unmanured soil. Straw yields from the unfertilized soil were low because phosphorus was too low to balance the supply of available nitrogen and other plant nutrients. This unbalanced condition has been responsible for a considerable inefficiency in the use of soil nitrogen.

Forage Production for Pasture

The average winter production of oven dry forage was obtained from clipping made on three plots for a seven-year period from 1944 to 1950. The yields were 191 pounds per acre on unfertilized soil, 531 pounds on soil fertilized with 150 pounds of 0-20-0 per acre, and 586 pounds from the manured plot. These clippings, obtained during the third week in March, show that fertilization greatly increased the early growth of winter wheat on this soil. Complete data are shown in Oklahoma Agricultural Experiment Station Bulletin B-414, p. 23.

[6]Stackyard Field, Woburn Agricultural Experiment Station, Woburn, England.

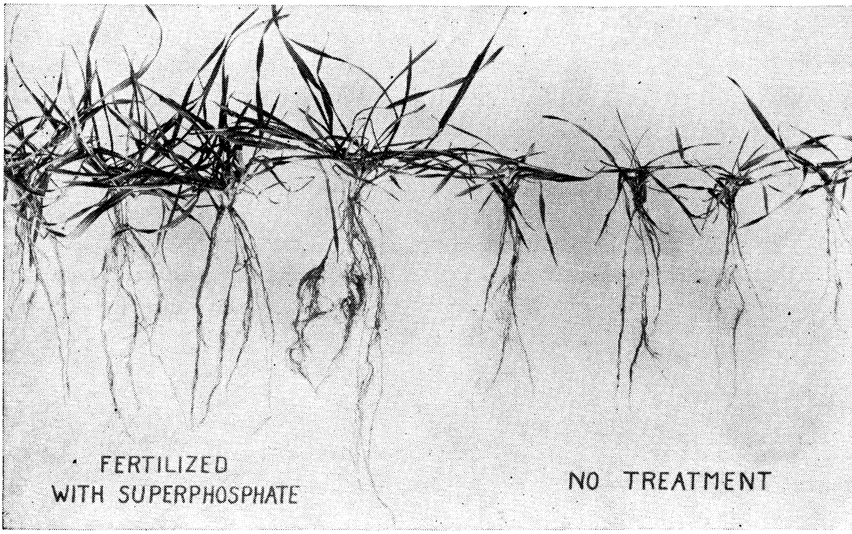

Figure 8. Effect of superphosphate on root and leaf development of wheat seedlings. Fertilizer was drilled in row with seed at time of planting at 150 lbs. per acre.

Figure 9. Effect of phosphate fertilization on the early spring growth of wheat on a phosphorous deficient soil.

The effect of superphosphate fertilization on the early root and top growth of wheat is shown in Figure 8. Figure 9 illustrates the stimulating effect of phosphate fertilization on the spring growth of wheat.

Test Weight and Protein Content

Wheat quality was measured by determining the test weight per bushel of the grain produced on these plots during several seasons. The average weight of the wheat produced on the manured plot for eleven seasons was 58.6 pounds per bushel. The test weight of wheat from the unmanured plot for the same years was 55.9 pounds per bushel.

Seasonal variations have had a greater effect on the protein content of wheat produced on these plots than soil fertility.

Changes in Soil Composition

A high percentage of the nitrogen and organic matter originally present in the virgin soil on which the continuous wheat plot was located has disappeared as a result of continued cultivation (Table IX). Soil samples were not collected from this plot when the experiment was started. However, the nitrogen equilibrium is relatively constant in all virgin soils; consequently, soil samples collected from a fence row adjacent to the continuous wheat plot were used to provide information on the chemical composition of this grassland soil before it was plowed and planted to wheat. Figure 7 shows that a more rapid loss of organic matter and nitrogen occurred from 1893 to 1926 than from 1926 to 1954. Similar results were observed in research studies conducted in Kansas[7].

All of the organic matter in the manure applied plus about six tons of the organic matter originally present per acre in the virgin soil disappeared from the top six inches of the manured plot from 1893 to 1926. The surface soil on the unmanured plot lost about 17 tons of organic matter per acre during this period which was about 1000 pounds of organic matter per acre per year. The nitrogen and organic matter content of this soil will eventually reach an equilibrium between the rate of annual decomposition and annual additions from crops residue. These values will be considerably less than .09 percent nitrogen and 1.7 percent organic matter.[8] Soil temperature, soil texture, and the cropping system affect this equilibrium.

[7]Kansas Agricultural Experiment Station Bulletin 89, 1957.

[8]Chemical studies made on surface soil collected from an unfertilized continuous wheat plot on Broadbalk Field on the Rothamsted Agricultural Experiment Station farm near Harpenden, England, show that the nitrogen content of this clay soil has been about .1 percent, varying from .107 percent in 1865 to a minimum of .093 percent in 1914, and a recent maximum of .106 percent in 1944. The average wheat yield on this soil was about 10.8 bushels per acre from 1865 to 1939.

Slightly larger quantities of nitrogen were removed in the wheat grain and straw harvested from the manured plot during the two periods from 1926 to 1938 and from 1938 to 1954 than was lost from the decomposition of soil organic matter plus the nitrogen applied in the manure during these periods. Nearly twice as much nitrogen was present in the wheat harvested from the unmanured plot from 1926 to 1938 and from 1938 to 1954 as was lost from the surface soil. The nitrogen lost from the unmanured plot fertilized with superphosphate also was less than the quantity removed by the wheat crops. The fixation of nitrogen by Clostridium may be responsible for some of the nitrogen utilized by wheat grain on these soils[9]. Some nitrogen also is present in the rain.

The average nitrogen content in surface soils from the five manured plots was 2400 pounds per acre, and in surface soils from the five unmanured plots 1760 pounds per acre in 1938. These soils contained 2500 pounds, and 1900 pounds of nitrogen, respectively, in 1926.

The nitrogen content of soil samples from the manured plots decreased with depth. However, the nitrogen content of the 0 to 6 inch layer of soil in unmanured plots was lower than in the 6 to 12 inch layer. This characteristic is commonly observed in grassland soils where sod crops have not been grown at regular intervals or large quantities of manure have not been applied to increase their nitrogen content.

Phosphorus Content of Soils

In 1938, the total phosphorus content of the soils from all plots was low and gradually decreased with depth of sampling. (Table X.) A larger quantity of total phosphorus was present in the upper part of the soil profile than in the lower part, due to the presence of phosphorus in the soil organic matter[10]. The total phosphorus in surface soil from manured plots was slightly higher than the total phosphorus in surface soil from unmanured plots. A slight increase in total phosphorus was observed where nine annual applications of superphosphate had been applied to the soil. More total phosphorus was found in the rock phosphate treated plot than in soil from plots which had been fertilized with superphosphate.

[9]Soil Science 48: 461-466, 1939.

[10]About one-third of the total phosphorus in the surface of a grassland soil is chemically combined with organic matter. Some of the phosphorus in the organic compounds is liberated when soil organic matter is destroyed by microorganisms. Consequently, nitrogen, phosphorus, and other plant nutrients in soil organic matter are released in available forms that can be used for plant growth when soil conditions are favorable for the decay of organic residue.

The easily soluble phosphorus in surface soil from the unfertilized plot was lower than on plots treated with barnyard manure, manure and superphosphate, or manure and rock phosphate. Eighty pounds of easily soluble phosphorus per acre was found in surface soil from the plot that had been fertilized with 152 tons of barnyard manure over a period of 40 years. The large quantity of easily soluble phosphorus in the manured soil explains why superphosphate or rock phosphate applied to plots fertilized with barnyard manure produced no appreciable increase in wheat yield.

Soil Acidity in Test Plots

All of the surface soils on the 10 plots in this experiment were acid in 1938. The acidity decreased with depth. The manured land was less acid than the unmanured soil. The quantity of exchangeable hydrogen in these soils was relatively low in relation to the quantity of total exchangeable bases present. However, the intensity of the acidity was medium to high as determined by pH values. The surface soil of plot 10 which was limed in 1929, was only slightly acid in 1938; whereas the surface soil of the other four unmanured plots was strongly acid.

Exchangeable Calcium in Soils

The exchangeable calcium in all surface and subsurface soils was high in 1938. The quantity of exchangeable calcium increased with depth, although some irregularities occurred between different layers. Exchangeable calcium was considerably higher in soil from manured plots than in soil from unmanured plots. This condition would account in part for the lower acidity observed in the manured soil.

Quantity of Manganese

The quantity of easily soluble manganese in surface soil from manured and unmanured wheat plots was high in all samples in 1938. More easily soluble manganese occurred in the surface 0 to 6 inches of these plots than in the lower portion of the soil profiles.

Exchangeable Potassium in Soils

The exchangeable potassium in these soils in 1938 was lower than exchangeable calcium or magnesium. However, the quantity of exchangeable potassium was sufficient for the optimum production of wheat under the climatic conditions which prevail in this area. The exchangeable potassium was higher in surface soils than in subsurface layers. One exception was a soil sample collected at a depth of 36 to 48 inches in plot 7. This sample contained a very large quantity of exchangeable potassium.

Total Exchange Capacity

The total exchange capacity of these soils was affected by the quantity of organic matter in them. Soil from the unfertilized plot was much lower in total exchange capacity in 1938 than was soil from plots fertilized with barnyard manure. (Table XI.) Total exchangeable bases were not always equivalent to the sum of the exchangeable calcium, magnesium, and potassium calculated as milliequivalents per 100 grams of soil. Some variation would be expected since calcium and magnesium were determined by leaching the soils with a sodium acetate solution buffered to pH 4.9 with acetic acid, whereas the total exchangeable bases and exchangeable potassium were determined by extracting the soil with a neutral ammonium acetate solution for one hour at a temperature of 70° C.

Summary

Wheat has been grown every year on a phosphorus-deficient reddish prairie soil near Stillwater, Oklahoma, for 65 years. The first harvest was in 1893. Throughout this period, one portion of the experimental area has never been fertilized. Another has been fertilized only with barnyard manure since 1898 while other plots have been given varying fertilizer treatment for varying periods. Surface and subsurface soils from six of the 10 plots were moved in 1947 to a new location about a mile distant.

The organic matter and nitrogen in the top soil has gradually decreased as a result of tillage. However, the average yield of wheat has not declined appreciably even where no fertilizer has been applied. The average yield on the unfertilized plot has been about 12.6 bushels per acre.

Barnyard manure applied at varying intervals during the past 59 years has produced an average yield of 20.5 bushels of wheat per acre. Only seven crops of wheat on the manured land were too low to pay the cost of production during the 59 years. Whereas, 20 crops of wheat

on the unmanured soil were too low to pay the cost of production during this same period. (Cost of production was estimated to be 10 bushels per acre on manured land and 9 bushels per acre on unmanured soil.)

Superphosphate containing 20 percent of P_2O_5 and applied at the rate of 150 pounds per acre when the wheat was planted increased the average wheat production from 12.9 to 18.55 bushels per acre from 1930 to 1957. This was only one bushel less than the average yield obtained from a plot fertilized with barnyard manure at the rate of 12 tons per acre every four years.

Superphosphate or rock phosphate added to plots fertilized with barnyard manure produced very little increase in wheat yield over that obtained from the barnyard manure alone.

Neither nitrate of soda at the rate of 100 pounds per acre, applied annually from 1930 to 1945, nor a similar quantity of ammonium nitrate applied from 1946 to 1957, produced enough increase in grain production to pay the cost of the fertilizer. Neither muriate of potash nor lime had much effect on grain production when applied to plots receiving superphosphate and either nitrate of soda or ammonium nitrate.

Straw yields were increased when superphosphate or barnyard manure was applied to this soil. The other fertilizer combinations did not produce much increase in the yield of straw.

Winter growth of wheat was much greater on plots fertilized with superphosphate or manure than on unfertilized soil.

The average profit from superphosphate applied in this experiment was $4.91 per acre over a 28-year period. The average profit from continuous wheat for this same period was $5.47 per acre. Superphosphate fertilization increased net income about 90 percent above the income obtained from wheat on unfertilized soil.

Nine of the wheat crops produced on unfertilized soil were unprofitable during the 28-year period 1930 to 1957. Only five crops produced on a plot where superphosphate was applied were unprofitable. However, during seven years superphosphate fertilization did not produce a sufficient increase in wheat yield to pay the fertilizer cost and cost of application.

About 50 percent of the organic matter and nitrogen in the topsoil on the unfertilized land disappeared as a result of the continued production of wheat over a 62-year period from 1893 to 1954. A more rapid loss occurred during the first 34 years than was observed during a second interval of 28 years.

The easily soluble phosphorus in this soil was increased by phosphate fertilization and the application of manure. The quantity of easily soluble phosphate in surface soil on the manured plot is high enough to produce an optimum yield of wheat in this area without an application of superphosphate.

Soil acidity has increased as a result of cultivation. In 1926, the unfertilized topsoil was strongly acid, and the manured soil moderately acid, as compared with slight acidity in an adjacent virgin soil.

Soil samples collected from these plots in 1938 revealed that the top soil from 0 to 6 inches deep on the unfertilized plot contained less nitrogen and organic matter than was present at a depth of 6 to 12 inches. The total phosphorus and easily soluble phosphorus decreased with depth. Manured soil contained more exchangeable calcium, magnesium and potassium than unfertilized soil. Exchangeable calcium was high, and increased with depth. Exchangeable potassium was lower than exhangeable magnesium but was high enough to produce an optimum yield of wheat during an average season without potash fertilization. Easily soluble manganese was adequate for optimum wheat production.

TABLE I. Wheat Varieties Planted in the Continuous Wheat Experiment 1893 to 1957

Year or period	Variety
1893	Fultz
1894	Currell
1895-1907	Fultz
1908-1911	Sibley's New Golden
1912-1916	Kharkov*
1917-1942	Turkey
1943-1945	Tenmarq
1946-1953	Pawnee
1954-1957	Ponca

* A selection from Turkey wheat.

TABLE II. Time, Method and Quantity of Barnyard Manure Applied to the Continuous Wheat Plots from 1898 to 1956.

Year	Month Applied	Tons per acre	Method of Application
1898	July	15	Before plowing
1899	July	11	Before plowing
1904	July	18	Before plowing
1911	November	24	Top dressed on wheat
1913	February	12	Top dressed on wheat
1916	July	12	Before plowing
1920	September	12	After plowing
1928	August	24	After plowing
1932	October	12	After plowing
1936	August	12*	Before plowing
1941	January	12**	Top dressed on wheat
1944	August	12**	After plowing
1948	July	12**	Before plowing
1952	July	12**	Before plowing
1956	November	12**	Top dressed on wheat

* Dry manure applied at the rate of 4 tons per acre.
**Applied at the rate of 120 pounds of nitrogen per acre.

TABLE III. Wheat Yields on the Manured and Unmanured Plots in the Continuous Wheat Experiment, 1899 to 1957.

Harvest Year	Yield (bushels per acre) Fertilized with farm manure	Unfertilized	Harvest Year	Yield (bushels per acre) Fertilized with farm manure	Unfertilized
1899	30.6	12.0	1929	17.3	10.0
1900	36.8	18.1	1930	19.1	7.9
1901	37.7	28.0	1931	25.0	25.6
1902	17.4	15.3	1932	30.2	19.3
1903	27.6	20.3	1933	28.0	12.5
1904	15.7	12.6	1934	12.7	12.7
1905	11.7	4.8	1935	27.7	14.0
1906	23.3	7.1	1936	21.8	19.3
1907	14.9	5.2	1937	28.3	22.0
1908	15.5	12.9	1938	10.2	3.4
1909	25.4	21.7	1939	25.2	15.3
1910	35.2	18.7	1940	28.2	15.2
1911	4.9	2.3	1941	6.4	.9
1912	20.4	5.3	1942	12.5	2.6
1913	14.8	5.6	1943	11.3	4.3
1914	33.5	23.2	1944	23.3	16.1
1915	19.5	15.2	1945	8.1	6.7
1916	13.3	7.9	1946	28.4	11.7
1917	32.0	21.0	1947	21.2	18.7
1918	29.2	10.8	1948	24.9	18.1
1919	11.6	7.0	1949	20.9	9.8
1920	34.0	27.3	1950	23.4	20.3
1921	15.7	7.3	1951	25.9	8.4
1922	7.4	3.8	1952	12.0	8.7
1923	23.5	12.9	1953	21.6	14.7
1924	17.7	7.7	1954	15.0	12.8
1925	20.1	11.4	1955	3.3	7.8
1926	7.0	7.1	1956	12.3	19.6
1927	5.3	1.7	1957	20.8	13.3
1928	28.9	17.8	Average	20.25+	12.60

TABLE IV. Soil Variation on Plots Established in 1929, as Determined by Differences in Wheat Production, 1927 to 1929.

Plot		Straw Yield (pounds per acre)				Grain Yield (bushels per acre)			
No.	Treatment	1927	1928	1929	Aver.	1927	1928	1929	Aver.
1	Manured	1611	3153	4931	3232	4.06	26.25	18.91	16.41
2	Manured	1431	3354	4522	3102	4.06	29.22	18.60	17.29
3	Manured	1664	3535	4069	3089	5.29	29.40	17.26	17.32
4	Manured	1802	3407	4621	3277	5.82	28.87	15.53	16.74
5	Manured	1568	3174	4293	3012	3.88	25.16	13.88	14.31
6	Unmanured	842	2120	2293*	1752	1.85	17.30	10.72*	9.96
7	Unmanured	704	1876	1836	1472	1.32	16.77	8.90	9.00
8	Unmanured	694	1971	1516	1394	1.67	17.83	9.96	9.82
9	Unmanured	604	1696	1655	1318	1.41	16.77	8.72	8.97
10	Unmanured	413	1685	1396	1165	.88	15.83	6.98	7.56

*Some manure scattered on plot 5 fell on the south edge of plot 6. The border between these plots was widened from four to eight feet in 1930.

GRAIN YIELDS, 1930-1947

TABLE V. A comparison of farm manure, rock phosphate, superphosphate, nitrate of soda, and muriate of potash applied alone or in different combinations on the grain yield of the continuous wheat experiment, 1930 — 1947.

Plot No.	Treatment	Rate of application (pounds per acre)*	1930	1931	1932	1933	1934	1935	1936
1	Manure Superphosphate	** 150	20.4	28.5	35.1	30.1	14.1	23.4	21.7
2	Manure Rock phosphate	** 500	20.4	24.7	31.8	30.1	14.2	27.2	20.6
3	Manure	**	19.1	25.0	30.2	28.0	12.7	27.7	21.8
4	Manure Superphosphate Muriate of Potash	** 150 50	19.1	27.4	27.6	31.2	13.9	23.6	18.1
5	Manure Superphosphate Muriate of Potash Nitrate of Soda	** 150 50 100***	18.4	24.4	27.5	26.7	13.0	20.0	19.0
6	Superphosphate	150	7.4	25.2	23.9	22.1	18.7	24.1	19.4
7	Superphosphate Nitrate of soda	150 100***	6.5	28.4	28.6	22.9	18.0	26.1	20.2
8	None		7.9	25.6	19.3	12.3	12.7	14.0	19.3
9	Superphosphate Nitrate of soda Muriate of Potash	150 100*** 50	5.5	32.3	22.7	25.1	21.9	27.0	20.6
10	Superphosphate Nitrate of soda Muriate of Potash Limestone	150 100*** 50 6000****	5.8	32.4	27.5	23.1	12.4	28.0	16.9

Grain Yield (bushels per acre)											Average
1937	**1938**	**1939**	**1940**	**1941**	**1942**	**1943**	**1944**	**1945**	**1946**	**1947**	**1930-1947**
28.7	12.4	28.7	35.3	10.3	16.6	10.1	24.5	6.1	23.5	15.2	21.4
28.5	11.5	28.8	33.0	8.0	16.1	10.4	24.6	5.5	18.6	17.6	20.6
28.3	10.2	25.2	28.2	6.4	12.5	11.3	23.3	8.1	28.4	21.2	20.4
26.8	12.7	28.0	31.3	10.1	14.7	8.6	22.1	3.9	26.2	13.5	19.9
25.6	12.0	26.8	31.5	7.5	13.0	8.7	25.4	4.9	29.9	16.8	19.5
28.8	11.7	25.8	28.6	8.1	10.7	9.2	24.9	6.9	12.9	20.4	18.3
30.3	11.7	24.4	30.6	8.7	10.9	11.9	24.1	6.1	20.9	22.8	19.6
22.0	3.4	15.3	15.2	.9	2.6	4.3	16.1	6.7	11.7	18.7	12.6
32.2	12.4	26.7	33.6	8.2	9.9	10.9	23.1	9.9	15.1	24.1	20.1
32.5	14.1	28.0	33.7	8.5	10.8	12.3	23.6	10.3	12.1	20.0	19.6

*All fertilizers applied annually except manure and rock phosphate which were applied every fourth year.
**Manure treatments averaged 3.6 tons annually.
***100 pounds of ammonium nitrate applied in 1946 and 1947.
****Limestone screenings applied in the fall of 1929, after flowing, at the rate of 6000 pounds per acre.

STRAW YIELDS, 1930-1947

TABLE VI. A comparison of farm manure, rock phosphate, superphosphate, nitrate of soda, and muriate of potash applied alone or in different combinations on the straw yield of a continuous wheat experiment, 1930-1947.

Plot No.	Treatment	Rate of application (pounds per acre)*	1930	1931	1932	1933	1934	1935	1936
1	Manure Superphosphate	** 150	2450	3390	2990	3680	2540	3130	1390
2	Manure Rock phosphate	** 500	2520	3140	2720	3440	2540	3490	1280
3	Manure	**	2670	3190	2880	2890	2260	3240	1330
4	Manure Superphosphate Muriate of potash	** 150 50	2560	2330	2320	3650	2340	2980	1170
5	Manure Superphosphate Muriate of Potash Nitrate of soda	** 150 50 100***	2830	2740	2550	3890	2560	2660	1210
6	Superphosphate	150	1250	2080	2160	2320	2270	2550	920
7	Superphosphate Nitrate of soda	150 100***	1220	2380	2330	2440	2680	3270	820
8	None		1230	1360	1740	1450	1680	1720	1060
9	Superphosphate Nitrate of soda Muriate of potash	150 100*** 50	980	1350	1930	2760	3070	3020	1140
10	Superphosphate Nitrate of soda Muriate of potash Limestone	150 100*** 50 6000****	1010	1950	2210	2740	2230	3050	920

Yield (bushels per acre)											Average
1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1930-1947
2340	2150	3880	4720	3170	2360	1830	3040	2000	1850	1690	2700
2210	1840	3920	4100	2700	2560	1980	3240	1490	1560	1580	2570
2380	1500	3210	3550	2040	2040	2290	2560	1590	2450	2170	2460
2090	1940	3700	3980	2760	2470	1670	2600	1000	2120	1270	2380
1940	1780	3790	3800	2610	2420	2180	3600	2330	2870	1480	2620
2230	1410	2920	3270	1920	1650	2020	2790	1500	1430	1900	2030
2180	1390	2450	3060	1850	1610	2350	2890	1420	2490	2100	2160
1780	440	1420	1700	280	420	1200	1940	1120	1270	1570	1300
2530	1560	2570	3240	1620	1460	2030	2700	1740	1740	1980	2080
2510	1880	2860	3310	1960	1680	2210	2390	1900	1670	2070	2130

*See footnotes to Table V.

GRAIN YIELDS, 1948-1957

TABLE VII. Wheat Yields on Six of the Old Wheat Plots After Moving in the Summer, 1947.

Plot		Pounds	Grain Yield in bushels per acre and year										Average Yield		
No.	Treatment	per acre	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1930-1957	1948-1957	
3	Manure	*	24.9	20.9	23.4	25.9	12.0	21.6	15.0	3.3	12.3	20.8	19.56	18.01	—1.55
8	None		18.1	9.8	20.3	8.4	8.7	14.7	12.7	7.8	19.6	13.3	12.90	13.34	+0.44
6	0-20-0	150	33.0	15.9	24.8	18.5	15.8	24.5	15.6	8.0	19.2	15.3	18.55	19.06	+0.51
7	0-20-0 33-0-0	150 100**	34.4	17.4	26.4	21.4	17.1	32.0	12.5	5.4	15.1	15.8	19.66	19.75	+0.09
9	0-20-0 33-0-0 0-0-60	150 100** 50	34.4	19.7	21.4	24.2	16.7	32.1	15.3	2.5	15.6	17.0	20.00	19.89	—0.11
10***	0-20-0 33-0-0 0-0-60	150 100** 60	33.7	20.4	26.2	29.1	29.0	33.6	16.7	6.5	15.4	14.1	20.60	22.47	+1.87

*Manure applied every fourth year; 120 pounds of nitrogen per acre.
**Ammonium nitrate applied as a top-dressing in February.
***Coarse limestone screenings applied in the fall of 1929 (3 tons per acre) and 2 tons of ground limestone per acre in 1954.

STRAW YIELDS, 1948-1957

TABLE VIII. Straw Yields on Six of the Old Wheat Plots After Moving in the Summer, 1947.

Plot		Pounds	Straw yield in pounds per acre and year										Average yield	
No.	Treatment	per acre	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1930-1956	1948-1956
3	Manure		2290	2650	2530	2150	3040	3040	1545	755	1160	**	2350	2130
8	None		1610	1130	2105	920	1150	1560	1330	1220	1420	**	1330	1380
6	0-20-0	150	2550	2180	2385	2010	3240	2870	1360	775	1495	**	2055	2095
7	0-20-0 33-0-0***	150 100	2790	2090	2560	2160	3060	2970	1095	805	1315	**	2140	2095
9	0-20-0 33-0-0*** 0-0-60	150 100 50	2800	2390	2165	2235	3100	3300	1205	655	1430	**	2100	2140
10****	0-20-0 33-0-0*** 0-0-60	150 100 50	2840	2430	2560	2365	3040	3840	1090	765	1320	**	2170	2250

* Manure applied every fourth year; 120 pounds of nitrogen per acre.
** Plots were harvested with a combine in 1957 and no straw weights were obtained.
*** Ammonium nitrate applied as a top-dressing in February.
****Coarse limestone screenings applied in the fall of 1929 (3 tons per acre) and 2 tons of ground limestone per acre in 1954.

TABLE IX. Nitrogen and Organic Matter Content of Surface Soil from Manured and Unfertilized Wheat Plots, 1893 to 1954.

	Percent nitrogen and year				Percent organic matter and year			
Treatment	1893*	1926	1938	1954**	1893*	1926	1938	1954**
Manured	.160	.125	.119	.078	3.58	2.68	2.32	1.76
Unfertilized	.160	.095	.087	.077	3.58	1.85	1.69	1.35

*Analyses of adjacent virgin soil were made in 1926.
**Samples collected by Fenton Gray.

TABLE X. Chemical Analyses of Composite Soil Samples Collected in 1938 from Surface and Subsurface Layers of the Ten Plots of the Continuous Wheat Experiment.

Plot No.	Treatment	Rate of application (pounds per acre)	Depth of sample (inches)	Total nitrogen (percent)	Total organic matter (percent)	Total phosphorus (percent)	Easily Soluble phosphorus (p.p.m.)*	Easily Soluble manganese (p.p.m.)*
1	Farm manure	**	0-6	.120	2.54	.032	40	131
	Superphosphate	150	6-12	.107	2.10	.024	10	29
			12-18	.108	1.42	.019	4	14
			18-24	.106	.96	.016	2	13
			24-36	.050	.65	.014	2	26
			36-48	.032	.34	.013	2	43
2	Farm manure	**	0-6	.118	2.40	.038	56	114
	Rock phosphate	500 lbs.	6-12	.101	1.98	.024	10	32
		every 4	12-18	.082	1.55	.021	4	26
		years	18-24	.057	.98	.016	2	26
			24-36	.043	.62	.014	2	26
			36-48	.032	.34	.012	2	26
3	Farm manure	**	0-6	.119	2.32	.027	40	119
			6-12	.101	1.89	.023	4	42
			12-18	.076	1.33	.018	2	15
			18-24	.057	.84	.015	2	18
			24-36	.041	.57	.014	2	18
			36-48	.032	.40	.013	2	42
4	Farm manure	**	0-6	.123	2.45	.034	40	131
	Superphosphate	150	6-12	.104	2.00	.025	8	54
	Muriate of potash	50	12-18	.077	1.34	.019	4	15
			18-24	.059	.93	.018	2	65
			24-36	.041	.59	.014	2	31
			36-48	.037	.40	.013	2	43
5	Farm manure	**	0-6	.120	2.41	.034	30	132
	Superphosphate	150	6-12	.106	2.09	.026	12	41
	Muriate of potash	50	12-18	.083	1.55	.022	4	32
	Nitrate of soda	100	18-24	.062	1.06	.018	2	91
			24-36	.043	.62	.014	2	42
			36-48	.036	.31	.013	2	29

Plot No.	Treatment	Rate of application (pounds per acre)	Depth of sample (inches)	Total nitrogen (percent)	Total organic matter (percent)	Total phosphorus (percent)	Easily Soluble phosphorus (p.p.m.)*	Easily Soluble manganese (p.p.m.)*
6	Superphosphate	150	0-6	.092	1.77	.027	28	126
			6-12	.098	1.91	.024	10	66
			12-18	.078	1.34	.019	2	22
			18-24	.062	.95	.017	8	33
			24-36	.043	.63	.015	2	34
			36-48	.032	.32	.012	2	22
7	Superphosphate	150	0-6	.083	1.65	.025	28	114
	Nitrate of soda	100	6-12	.101	1.84	.023	4	40
			12-18	.076	1.36	.020	2	18
			18-24	.062	.98	.017	2	35
			24-36	.041	.57	.014	2	31
			36-48	.032	.43	.012	2	28
8	None		0-6	.087	1.69	.023	12	104
			6-12	.091	1.83	.022	4	51
			12-18	.076	1.30	.018	2	82
			18-24	.057	.92	.017	2	128
			24-36	.042	.47	.014	2	57
			36-48	.030	.30	.012	2	82
9	Superphosphate	150	0-6	.090	1.64	.025	24	104
	Nitrate of soda	100	6-12	.098	1.81	.021	6	35
	Muriate of potash	50	12-18	.074	1.40	.020	2	58
			18-24	.057	.87	.015	2	63
			24-36	.043	.46	.013	2	52
			36-48	.029	.28	.011	2	94
10	Superphosphate	150	0-6	.087	1.70	.023	24	105
	Nitrate of soda	100	6-12	.092	1.76	.020	8	38
	Muriate of potash	50	12-18	.075	1.19	.016	2	102
	Limestone	6000***	18-24	.045	.67	.013	2	78
			24-36	.039	.47	.010	2	87
			36-48	.038	.27	.010	2	74

*p.p.m.=parts per million.
**Average rate of application equivalent to 3.6 tons per year. Moisture and nitrogen content not known.
***Applied in the fall of 1929.

TABLE XI. Total Base Exchange Capacity, Total Exchangeable Bases, Exchangeable Hydrogen, Calcium, Magnesium, Potassium, and pH Value of Composite Soil Samples Collected in 1938 from Surface and Subsurface Layers of the Ten Plots in Continuous Wheat Experiment.

Plot No.	Treatment	Rate of application (lb. acre)	Depth of samples (inches)	pH value	Exchangeable hydrogen (m.e. per 100 g. of soil)	Total Exchange capacity (m.e. per 100 g. of soil)	Total Exchangeable bases (m.e. per 100 g. of soil)	Exchangeable calcium (percent)	Exchangeable magnesium (percent)	Exchangeable potassium (percent)
1	Farm manure	**	0-6	5.7	2.1	13.6	11.5	.128	.029	.022
	Superphosphate	150	6-12	5.9	—	—	12.2	.159	.042	.017
			12-18	6.7	—	—	18.2	.204	.074	.016
			18-24	7.0	—	—	19.2	.199	.084	.014
			24-36	7.4	—	—	18.5	.174	.087	.015
			36-48	7.9	—	—	21.5	.314	.093	.019
2	Farm manure	**	0-6	5.6	2.1	12.5	10.4	.109	.030	.031
	Rock phosphate	500 lbs.	6-12	6.0	—	—	12.5	.140	.044	.011
		every four	12-18	6.8	—	—	16.4	.185	.069	.016
		years	18-24	7.1	—	—	18.4	.181	.069	.016
			24-36	7.5	—	—	18.3	.168	.078	.015
			36-48	7.9	—	—	21.3	.273	.085	.021
3	Farm manure	**	0-6	5.6	3.0	11.8	8.8	.109	.032	.032
			6-12	5.9	—	—	12.2	.161	.048	.016
			12-18	6.7	—	—	17.8	.206	.085	.018
			18-24	7.2	—	—	18.3	.200	.085	.024
			24-36	7.8	—	—	19.5	.264	.089	.028
			36-48	8.0	—	—	21.9	.349	.088	.021
4	Farm manure	**	0-6	5.4	2.5	11.5	9.0	.109	.026	.037
	Superphosphate	150	6-12	5.8	—	—	16.0	.149	.041	.016
	Muriate of potash	50	12-18	6.6	—	—	18.9	.198	.078	.015
			18-24	7.0	—	—	18.4	.184	.082	.015
			24-36	7.1	—	—	17.5	.174	.074	.013
			36-48	7.7	—	—	19.9	.278	.074	.020
5	Farm manure	**	0-6	5.2	3.1	11.7	7.9	.101	.028	.030
	Superphosphate	150	6-12	5.6	—	—	10.7	.133	.037	.021
	Muriate of potash	50	12-18	6.5	—	—	16.6	.198	.072	.013
	Nitrate of soda	100	18-24	7.1	—	—	16.6	.200	.079	.025
			24-36	7.2	—	—	17.6	.186	.077	.018
			36-48	7.5	—	—	18.7	.262	.087	.017

Plot No.	Treatment	Rate of application (lb. acre)	Depth of samples (inches)	pH value	Exchangeable hydrogen (m.e. per 100 g. of soil)*	Total Exchange capacity (m.e. per 100 g. of soil)*	Total Exchangeable bases (m.e. per 100 g. of soil)*	Exchangeable calcium (percent)	Exchangeable magnesium (percent)	Exchangeable potassium (percent)
6	Superphosphate	150	0-6	5.1	3.4	10.0	6.6	.074	.028	.024
			6-12	5.3	—	—	8.4	.098	.031	.014
			12-18	6.3	—	—	16.4	.177	.072	.032
			18-24	6.8	—	—	15.7	.174	.083	.028
			24-36	7.0	—	—	15.9	.164	.072	.016
			36-48	7.3	—	—	15.2	.190	.074	.018
7	Superphosphate	150	0-6	5.1	3.8	10.3	6.5	.090	.029	.023
	Nitrate of soda	100	6-12	5.6	—	—	10.7	.140	.041	.020
			12-18	6.4	—	—	16.1	.188	.079	.013
			18-24	6.7	—	—	16.0	.181	.075	.015
			24-36	7.0	—	—	15.9	.181	.081	.014
			36-48	7.1	—	—	15.7	.205	.075	.084
8	None		0-6	5.1	3.4	9.5	6.1	.064	.025	.024
			6-12	5.7	—	—	11.6	.124	.042	.018
			12-18	6.4	—	—	15.7	.164	.070	.014
			18-24	6.7	—	—	15.9	.172	.081	.013
			24-36	7.0	—	—	17.3	.188	.071	.020
			36-48	7.1	—	—	14.7	.144	.070	.022
9	Superphosphate	150	0-6	5.1	3.2	10.1	6.9	.080	.022	.021
	Nitrate of soda	100	6-12	5.8	—	—	12.0	.144	.045	.013
	Muriate of potash	50	12-18	6.5	—	—	15.8	.182	.072	.021
			18-24	6.8	—	—	16.4	.168	.080	.021
			24-36	7.0	—	—	16.9	.184	.077	.026
			36-48	7.1	—	—	15.4	.148	.075	.034
10	Superphosphate	150	0-6	6.4	.8	10.5	9.7	.120	.025	.020
	Nitrate of soda	100	6-12	6.4	—	—	12.7	.144	.047	.017
	Muriate of potash	50	12-18	7.0	—	—	18.6	.176	.095	.020
	Limestone	6000***	18-24	7.3	—	—	18.6	.164	.100	.025
			24-36	7.4	—	—	18.5	.231	.092	.035
			36-48	7.7	—	—	20.8	.309	.090	.019

* m.e.=milliequivalent or one thousandth of the chemical equivalent of any substance.
** Average rate of application was 3.6 tons per year, moisture and nitrogen not known.
***Applied in fall of 1929.

TABLE XII. Profit from Superphosphate Applied to Wheat Grown on the Continuous Wheat Plots, 1930 to 1957.

Year	Yield and Treatment (bushels per acre) 0-20-0	None	Increase or decrease from fertilization	Gross Income from increased yield*	Annual cost of fertilization per acre**	Profit per acre from the use of fertilizer
1930	7.4	7.9	—.5	$ .0	$2.07	$ 2.07
31	25.2	25.6	—.4	.0	1.91	—1.91
32	23.9	19.3	4.6	1.47	1.88	— .41
33	22.1	12.3	10.1	6.87	1.76	5.11
34	18.7	12.7	6.0	4.86	2.01	2.85
1935	24.1	14.0	9.9	8.51	1.94	6.57
36	19.4	19.3	.1	.10	1.89	—1.79
37	28.8	22.0	6.8	6.52	1.98	4.54
38	11.7	3.4	8.3	4.65	1.98	2.67
39	25.8	15.3	10.5	6.82	1.91	4.91
1940	28.6	15.2	13.4	8.31	1.83	6.48
41	8.1	.9	7.2	6.69	1.83	4.86
42	10.7	2.6	8.1	9.00	2.06	6.94
43	9.2	4.3	4.9	6.76	2.21	4.55
44	24.9	16.1	8.8	12.22	2.19	10.03
1945	6.9	6.7	.2	.29	2.22	—1.93
46	12.9	11.7	.8	1.44	2.51	—1.07
47	20.4	18.7	1.7	3.69	2.72	.97
48	33.0	18.1	14.9	29.50	2.89	26.61
49	15.9	9.8	6.1	11.40	2.90	8.50
1950	24.8	20.3	4.5	9.09	2.84	6.25
51	18.5	8.4	10.1	22.20	3.02	19.18
52	15.8	8.7	7.1	15.05	3.07	11.98
53	24.5	14.7	9.8	20.87	3.08	17.79
54	15.6	12.7	2.9	4.56	3.20	1.36
1955	8.0	7.8	.2	.41	3.20	—2.79
56	19.2	19.6	—.4	.0	3.20	—3.20
57	15.3	13.3	2.0	3.90	3.20	.70
Average	18.5	12.9	5.6	$7.32	$2.41	$4.91

*Based on average price of Oklahoma wheat for that year.
**Based on average price for normal superphosphate for that year, and cost of application.