# CORN FERTILIZER STUDIES IN CLAY, FRANKLIN, SHAWNEE AND BROWN COUNTIES, KANSAS 1949

by

HOWARD EUGENE RAY

B. S., Kansas State College
of Agriculture and Applied Science, 1949

---

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

TABLE OF CONTENTS

# INTRODUCTION

Corn is grown extensively in the eastern third of Kansas, and is second in importance among the cultivated crops of the state. Since corn is important to the economic welfare of many farmers in the state, more information is needed relative to its response to commercial fertilizers. Extensive corn fertilization experiments have been conducted in the other states comprising the corn belt in recent years, but only limited work has been done in Kansas. Although considerable information about corn fertilization has been obtained in surrounding states, it is not entirely applicable under Kansas conditions due to differences in climate, soil, and farming practices.

The purposes of this experiment were: (1) to ascertain the most favorable time, rate, and method of application of nitrogenous fertilizer for corn, (2) to ascertain the need for phosphatic and potassic fertilizers in combination with nitrogen for corn, and (3) to investigate the relationship of plant population to returns from fertilizer.

The growth of corn and its response to fertilizer are often affected by previous cropping practices, nutrient supply of the soil, rainfall, drainage, and soil aeration. Such factors have led to conflicting results in other states and probably account at least in part for the variability of the results obtained in this experiment.

## REVIEW OF LITERATURE

On the basis of extensive corn fertilizer experiments conducted in Mississippi, Coleman (5) recommended that nitrogen fertilizer be applied to all Mississippi soils on which corn is planted. He recommended at least 32 pounds of nitrogen per acre to obtain the most profitable yields. Half of this nitrogen should be applied as a deep placement under the corn and half as a side dressing around the corn. Phosphorus and potassium do not increase corn yields on most Mississippi soils according to this investigator.

Krantz (10) reported that nitrogen has been found to be the most limiting factor for producing corn in North Carolina. Responses to nitrogen have been obtained in both good and droughty crop years. He stated that, on the average, corn yields have been increased about one bushel for each two pounds of nitrogen added. Responses to phosphorus and potassium have been shown to depend on the level of these nutrients in the soil. According to this author, the lowest cost of production per bushel has been obtained where nitrogen was applied at the rate of 120 pounds per acre with adequate phosphorus and potassium.

The effect of fertilizers on corn production in Oklahoma has been studied by Harper and Brensing (9). On deep sandy upland or bottomland where no legumes are grown in the rotation, the authors recommended an application of 150 to 200 pounds per acre of a starter fertilizer such as 4-12-4 or 5-10-5. If the soil is high in potassium, 4-16-0 may be used. An additional application of 50 to 100 pounds per acre of ammonium nitrate as a side dressing to be applied between May 10 and May 20 was also recommended.

In Nebraska Fitts, Rhoades, and McHenry (7) advocated the use of 40 pounds of nitrogen per acre applied at the last cultivation. They recommended that the nitrogen be placed two or three inches deep and about eight inches to one side of the plant.

Summarizing the results of Iowa corn fertilizer experiments, Pierre (15) states that, although responses have varied widely within and between soil areas, corn yields can be economically increased by the proper use of fertilizers on at least 30 per cent of the land in the state. Although nitrogenous fertilizers are needed to supplement the nitrogen supplied to the soil by legumes in the rotation, the fertilizers applied at seeding time which also supply phosphorus and potassium are of even greater importance according to this author. He suggested an application of 100 pounds per acre of a 10-20-10 or 0-20-10 mixture.

On the basis of work done in Indiana, Scarseth et al. (18) reported that the major requirements of corn for nitrogen, phosphorus, and potassium can be met by the use of a good rotation in which adequate amounts of phosphorus and potassium are added to the legume. Also the pH of the soil should be maintained at about 6.5. They recommended 200 pounds per acre in the drill of a 3-12-12 mixture to be used as a starter fertilizer if the average yield of corn with the above practices is 70 to 80 bushels per acre. If the average yield of corn is 50 to 60 bushels per acre an increase of 15 to 20 bushels can be expected with the application of 400 pounds of 10-10-10 on the plowsole in addition to the starter fertilizer. With an average yield as low as 30 to 40 bushels per acre these authors recommended 800 pounds of 10-10-10 applied on the plowsole in addition to a small application of 3-12-12 fertilizer in the row as a starter. They did not recommend placing heavy applications of fertilizer near the surface of the ground as this promotes heavy weed growth in wet seasons.

Results of early experiments in Michigan have shown no consistent increases in corn yields due to the application of fertilizers according to Robertson and Cook (17). In recent experiments, however, heavy applications of a fertilizer high in nitrogen (8-8-8) have caused significant increases in corn yields in rotations which exhaust the nitrogen supply.

A study of the effect of fertilizers on corn production was made by Peterson, Jones, and Smith (14) in Kansas. In general the application of at least 40 pounds of nitrogen gave a significant increase in the yield of corn according to the authors, but no increase in yield was obtained by the addition of phosphorus or potassium.

Ohlrogge, Krantz, and Scarseth (13) found that either plowing under ammonium sulfate in the spring or placing it on the plowsole was very effective. The same amount of fertilizer placed in the row or side dressed just prior to tasseling was much less effective according to these authors. Robertson and Cook (17) reported that in Michigan the greatest increases in yield due to fertilizer have been obtained when the fertilizer was placed below and to one side of the seed.

Recent experiments in Iowa (1) have indicated that for most Iowa conditions a hill fertilizer plus extra nitrogen, where needed, is the most efficient way to fertilize corn. There are cases, however, where larger amounts of phosphorus or potassium or both may give best results when plowed under. Little difference has been found due to method of application of nitrogen provided it is not applied after the second cultivation.

Yield increases due to the application of nitrogen were greatest in Kansas when the nitrogen was applied as a side dressing before the last cultivation according to Gray (8). Krantz (10) states that the conventional side dressing method application is equal or superior to the plowsole method in North Carolina.

Millar et al. (12) in Michigan and Peterson, Jones, and Smith (14) in Kansas have found no significant differences in yield due to method of placement of fertilizer.

Metzger (11) conducted experiments in Kansas comparing the effects of different depths of placement of superphosphate on the yields of corn and sorghum. His results indicated that an increase in yield might be obtained only by deep placement of the phosphorus.

The optimum plant population varies with fertilization practices and the fertility level of the soil according to Krantz (10). He recommended 10,000 to 13,000 plants per acre in North Carolina if adequate nitrogen is present and thinner stands if the nitrogen supply is low. Eskew and Paden (6) have found that 10,000 plants per acre tend to produce the highest yields in South Carolina, especially at the higher rates of side dressing. Harper and Brensing (9) recommended a plant population of 10,000 per acre in Oklahoma also. Caldwell (4), however, stated that the efficient use of fertilizers cannot be obtained in Minnesota with fewer than 14,000 plants per acre. In Indiana Scarseth et al. (18) recommended a stand of 11,000 plants per acre if a yield of approximately 80 bushels per acre is expected. They stated that higher yields require heavier rates of planting.

## METHODS OF STUDY

### Location and Description of Plots

Experimental plots were established in Clay county near Broughton, Kansas, on the Wynn Bauer farm; in Shawnee county near Rossville, Kansas, on the Joe Campbell farm; in Brown county near Reserve, Kansas, on the Fred Fouth farm; and in Franklin county near Ottawa, Kansas, on the Glen Carpenter farm.

At the Broughton location the soil type is Waukesha silt loam. The topography is uniform, and drainage is good. It is a bottomland soil typical of the Republican River valley. Corn or sorghum has been grown at this location for the past several years.

The Rossville location is in the Kansas River valley. The soil type is similar to a Rokeby silt loam. The topography is uniform, and drainage is fair. Alfalfa was produced on this land in 1945, and corn in 1946, 1947, and 1948.

The soil type at the Reserve location is Marshall silt loam. It is a rather typical upland soil, topography is rolling, and drainage is excellent. The crop rotation for the past twelve years has included corn, oats, and wheat.

At the Ottawa location the soil type is undetermined, but the surface soil is a silty clay loam with a claypan underlying the area at a depth of six to twelve inches. Surface drainage is fair, but profile drainage is very poor. It is also an upland soil. The crop sequence for the past three years has been sweet clover (1946), oats (1947), and corn (1948).

## Plan of Experiment

The experimental design at each location consisted of a randomized block layout of 25 treatments. Each block of treatments was replicated four times. The same series of treatments as indicated in Table 1 was used at all four locations with the exception that at Ottawa the complete fertilizer was increased to 80-40-40.

Table 1. Fertilizer rates, methods and times of application, and plant populations, corn fertilizer experiment, 1949.

| Treatment number | Treatment 1/ $N-P_2O_5-K_2O$ | Population Plants/acre | Method of application of nitrogen 2/ |
|---|---|---|---|
| 1 | 0-0-0 | 10,000 | |
| 2 | 0-0-0 | 14,000 | |
| 3 | 0-0-0 | 6,000 | |
| 4 | 0-40-40 | 10,000 | |
| 5 | 40-0-40 | 10,000 | Broadcast |
| 6 | 40-0-0 | 10,000 | Broadcast |
| 7 | 80-0-0 | 10,000 | Broadcast |
| 8 | 40-40-0 | 10,000 | Broadcast |
| 9 | 40-40-40 3/ | 10,000 | Broadcast |
| 10 | 40-40-40 3/ | 14,000 | Broadcast |
| 11 | 40-40-40 3/ | 6,000 | Broadcast |
| 12 | 80-40-0 | 10,000 | Broadcast |
| 13 | 40-40-0 | 10,000 | 20# N Br., 20# N at Pl. |
| 14 | 40-40-0 | 10,000 | 20# N Br., 20# N Sd. |
| 15 | 40-0-0 | 10,000 | Deep placement |
| 16 | 80-0-0 | 10,000 | Deep placement |
| 17 | 20-40-0 | 10,000 | Deep placement |
| 18 | 40-40-0 | 10,000 | Deep placement |
| 19 | 40-40-40 3/ | 10,000 | Deep placement |
| 20 | 80-40-0 | 10,000 | Deep placement |
| 21 | 40-40-0 | 10,000 | 20# N DP., 20# N at Pl. |
| 22 | 40-40-0 | 10,000 | 20# N DP., 20# N Sd. |
| 23 | 80-40-0 | 10,000 | 40# N DP., 20# N at Pl., 20# N Sd. |
| 24 | 20-0-0 | 10,000 | Sidedressing |
| 25 | 20-40-0 | 10,000 | Sidedressing |

1/ Figures refer to total pounds of each nutrient applied. All phosphorus and potassium applied with the seed at planting time.

2/ Broadcast (Br.) applications applied ahead of planting. Deep placement (DP.) applications applied 3-4 inches below seed at time of planting. At planting (at Pl.) treatments applied with seed at planting time. Sidedressings (Sd.) made ahead of second cultivation.

3/ Received 80 pounds of nitrogen at Ottawa rather than 40 pounds.

The plots were 120 feet in length and contained four 40 inch rows. At harvest time 93 feet and eight inches of the two center rows were harvested and the two outside rows served as guard rows.

## Experimental Procedure

Broadcast applications of nitrogen were made with a Gandy fertilizer spreader and disked in before planting. At planting time nitrogen, phosphorus, and potassium were applied by means of an Iron Age corn and bean planter specially fitted with belts and hoppers for the distribution of fertilizer materials. Side dressing applications were made with a Planet Jr. drill.

Ammonium nitrate (33.5 per cent total N) was used as a source of nitrogen. Treble superphosphate (46 per cent available $P_2O_5$) was used as a source of phosphorus and muriate of potash (60 per cent water-soluble $K_2O$) was used to supply the potassium.

K1639 was planted at Broughton, K1784 at Rossville, US13 at Reserve, and Steckley's 100A at Ottawa. A high rate of seeding was used at all locations, and the stands were then thinned to the populations indicated in Table 1. The dates of planting and fertilizer application are given in Table 2.

## Chemical Analyses of Soils

The total nitrogen content of each soil was determined by the method described by the Association of Official Agricultural Chemists (3), and the available phosphorus was determined by the

Table 2. Dates of planting and dates of nitrogenous fertilizer applications by various methods, corn fertilizer experiment, 1949.

| Location | Broadcast | Deep placement | Planting date | Sidedressing |
|---|---|---|---|---|
| Broughton | Apr. 26 | May 3 | May 3 | June 15 |
| Rossville | Apr. 26 | May 6 | May 7 | June 17 |
| Reserve | Apr. 22 | May 31 | June 1 | July 7 |
| Ottawa | Apr. 24 | Apr. 28 | Apr. 29 | June 16 |

method of Arnold and Kurtz (2). Fifty ml of 1N ammonium acetate extracting solution were added to 10 grams of 10-mesh soil in the determination of the exchangeable potassium. The suspension was agitated in an end-over-end shaker for 10 minutes, then filtered. A 20 ml aliquot of the extract was pipetted into a flask and 2 ml of a solution containing 1,100 ppm of lithium in 1N ammonium acetate was added. The final determination was then made on the flame photometer. The pH was determined by using a 1:1 mixture of soil and water and taking readings on a glass electrode pH meter.

## Chemical Analyses of Grain Samples

The total nitrogen content of the grain samples was determined by the method described by the Association of Official Agricultural Chemists (3). Each nitrogen percentage was multiplied by 6.25 to obtain per cent protein. In determining the phosphorus content, wet digestion of the plant material was carried out as described by Piper (16), and the final determinations were made on the photometer as described by Arnold and Kurtz (2).

### Miscellaneous

Plant tissue tests were made according to the method used by Thornton, et al. (20). One hundred grams of grain were placed in a Steinlite moisture tester to determine the moisture content. Galvanometer readings were converted to moisture percentages by referring to prepared tables. Yields were then computed on the basis of 15.5 per cent moisture. Statistical analyses were made according to the methods outlined by Snedecor (19).

## RESULTS

The results are presented principally in tabular form, and include rainfall data, chemical analyses of soils, observations of plant growth, plant tissue tests, chemical analyses of grain samples and yield data.

### Rainfall Data

Table 3. Rainfall data in inches from date of planting to September 1, 1949.

| Location | May | June | July | August |
|---|---|---|---|---|
| Broughton | 4.41 | 1.37 | 1.21 | trace |
| Rossville | No data available | | | |
| Reserve | ---- | 19.00 | 4.00 | 0.70 |
| Ottawa | 4.30 | 5.63 | 8.55 | 4.20 |

## Chemical Analyses of Soils

Table 4. Chemical analyses of the soils used for corn fertilizer experiment, 1949.

| Location | pH | Available P lbs./acre | Exch. K lbs./acre | Total N per cent |
|---|---|---|---|---|
| Broughton | 6.0 | 190+ | 750 | 0.13 |
| Rossville | 5.6 | 145 | 921 | 0.13 |
| Reserve | 5.5 | 93 | 672 | 0.16 |
| Ottawa | 6.0 | 65 | 260 | 0.15 |

## Observations of Plant Growth

No differences in plant growth between treatments were apparent at Broughton during the early stages of growth. By June 15, however, slight differences could be detected. This can be seen in Plate I. All plots receiving nitrogen, regardless of rate or method of application, appeared to be more uniform and slightly taller than those plots which received no nitrogen. These differences persisted throughout the remainder of the growing season. No nutrient deficiency symptoms were noticed in the plants at any time during the growing season.

At Rossville very striking differences were apparent early in the growing season. There was very little response where only nitrogen was applied, but where nitrogen was applied in combination with phosphorus the plants were more vigorous and had a deeper green color. Differences between various rates of nitrogen were very slight. These differences became less pronounced toward the end of the growing season but were still in evidence. Early in the season slight nitrogen deficiencies were noted in a few of the plots receiving no nitrogen.

Rather early in the growing season (July 13) a definite response to both phosphorus and nitrogen was noted at Reserve. The plants on plots receiving forty pounds of nitrogen were noticeably taller and more vigorous than those on plots receiving twenty pounds of nitrogen. The plots receiving a deep placement application of nitrogen appeared to have slightly larger plants than those receiving nitrogen in a broadcast application. The response to phosphorus disappeared later, but the response to nitrogen remained visible to the end of the growing season. A slight nitrogen deficiency was noted on plots not receiving nitrogen.

Excessive rainfall at the Ottawa location resulted in rather uneven growth during the early part of the growing season. However, very marked differences due to fertilizer applications were apparent as can be seen from Plate II. There was no apparent response to nitrogen when applied alone, but where nitrogen was applied in combination with phosphorus, a definite response was noted. The plots receiving deep placement applications of nitrogen showed greater growth than those receiving broadcast applications. Although the response to phosphorus nearly disappeared late in the growing season, the other differences persisted. Slight nitrogen deficiency symptoms were noted on plots receiving no nitrogen.

EXPLANATION OF PLATE I

Fig. 1. Plot receiving no treatment, Broughton, Kansas, June 15, 1949.
Fig. 2. Plot receiving 0-40-40. Broughton, Kansas, June 15, 1949.
Fig. 3. Plot receiving 40-0-40. Broughton, Kansas, June 15, 1949.
Fig. 4. Plot receiving a complete fertilizer (40-40-40), Broughton, Kansas, 1949.

Plate I

Fig. 1

Fig. 2

Fig. 3

Fig. 4

EXPLANATION OF PLATE II

Fig. 1. Plot receiving no treatment. Ottawa, Kansas, June 16, 1949.
Fig. 2. Plot receiving 0-40-40. Ottawa, Kansas, June 16, 1949.
Fig. 3. Plot receiving 40-0-40. Ottawa, Kansas, June 16, 1949.
Fig. 4. Plot receiving a complete fertilizer (80-40-40). Ottawa, Kansas, June 16, 1949.

Plate II

Fig. 1

Fig. 2

Fig. 3

Fig. 4

## Plant Tissue Tests

Table 5. Results of plant tissue tests, Broughton, July 13, 1949.

| Treatment number | Treatment | N | P | K |
|---|---|---|---|---|
| 1 | 0-0-0 | High | Very high | Medium |
| 4 | 0-40-40 | High | Very high | High |
| 7 | 80-0-0 Br. | High | Very high | Medium |
| 8 | 40-40-0 Br. | High | Very high | High |
| 9 | 40-40-40 Br. | High | Very high | High |
| 16 | 80-0-0 DP. | High | Very high | Medium |
| 18 | 40-40-0 DP. | High | Very high | High |
| 19 | 40-40-40 DP. | High | Very high | Medium |

Table 6. Results of plant tissue tests, Rossville, July 13, 1949.

| Treatment number | Treatment | N | P | K |
|---|---|---|---|---|
| 1 | 0-0-0 | Low | Very high | High |
| 4 | 0-40-40 | High | Very high | High |
| 7 | 80-0-0 Br. | High | Very high | High |
| 8 | 40-40-0 Br. | High | Very high | High |
| 9 | 40-40-40 Br. | High | Very high | High |
| 16 | 80-0-0 DP. | High | Very high | High |
| 18 | 40-40-0 D P. | High | Very high | High |
| 19 | 40-40-40 DP. | High | Very high | High |

Table 7. Results of plant tissue tests, Reserve, July 12, 1949.

| Treatment number | Treatment | N | P | K |
|---|---|---|---|---|
| 1 | 0-0-0 | Medium | Medium | High |
| 4 | 0-40-40 | Low | Very high | High |
| 7 | 80-0-0 Br. | High | High | High |
| 8 | 40-40-0 Br. | High | Very high | High |
| 9 | 40-40-40 Br. | High | Very high | High |
| 16 | 80-0-0 DP. | High | High | High |
| 18 | 40-40-0 DP. | Medium | Very high | High |
| 19 | 40-40-40 DP. | Medium | Very high | High |

Table 8. Results of plant tissue tests, Ottawa, July 12, 1949.

| Treatment number | Treatment | N | P | K |
|---|---|---|---|---|
| 1 | 0-0-0 | Low | Very high | Medium |
| 4 | 0-40-40 | Low | Very high | High |
| 7 | 80-0-0 Br. | Low | Very high | High |
| 8 | 40-40-0 Br. | High | Very high | High |
| 9 | 80-40-40 Br. | Low | Very high | High |
| 16 | 80-0-0 DP. | High | Very high | High |
| 18 | 40-40-0 DP. | Low | Very high | Medium |
| 19 | 80-40-40 DP. | High | Very high | High |

## Yield Data

Table 9. Summary of yields, corn fertilizer experiment, 1949.

| Treatment number1/ | Yield in bushels per acre2/ | | | |
|---|---|---|---|---|
| | Broughton | Rossville | Reserve | Ottawa |
| 1 | 15.4 | 53.5 | 36.0 | 61.4 |
| 2 | 6.9 | 63.2 | 23.9 | 59.7 |
| 3 | 27.4 | 48.6 | 35.9 | 53.3 |
| 4 | 20.1 | 57.9 | 33.2 | 62.4 |
| 5 | 21.8 | 67.4 | 56.6 | 74.9 |
| 6 | 26.9 | 59.1 | 50.1 | 72.2 |
| 7 | 24.3 | 59.8 | 62.6 | 74.0 |
| 8 | 20.0 | 62.0 | 48.8 | 79.3 |
| 9 | 24.6 | 63.8 | 53.0 | 84.0 |
| 10 | 9.8 | 59.2 | 37.0 | 88.7 |
| 11 | 36.1 | 58.4 | 49.9 | 65.9 |
| 12 | 21.8 | 57.2 | 64.3 | 76.0 |
| 13 | 22.8 | 61.4 | 45.6 | 66.4 |
| 14 | 21.6 | 56.4 | 40.6 | 76.0 |
| 15 | 22.3 | 69.3 | 50.1 | 76.0 |
| 16 | 19.0 | 71.8 | 63.5 | 85.2 |
| 17 | 27.9 | 62.5 | 35.2 | 63.4 |
| 18 | 21.3 | 64.6 | 48.3 | 79.7 |
| 19 | 19.7 | 59.2 | 46.0 | 83.6 |
| 20 | 19.8 | 64.6 | 63.2 | 80.6 |
| 21 | 18.5 | 56.8 | 46.6 | 66.0 |
| 22 | 21.5 | 71.0 | 38.8 | 75.4 |
| 23 | 21.9 | 65.5 | 57.8 | 79.0 |
| 24 | 21.9 | 68.7 | 37.3 | 67.8 |
| 25 | 24.0 | 63.3 | 32.9 | 81.3 |
| L.S.D. (.05) | 6.9 | N.S. | 9.4 | 13.0 |
| L.S.D. (.01) | 9.2 | N.S. | 12.4 | 17.2 |

1/ Treatment numbers correspond to numbers in Table 1.
2/ n=4, with all yields calculated on a basis of 15.5 per cent moisture.

Table 10. Corn yields in bushels per acre as affected by rate of planting, corn fertilizer experiment, 1949. 1/

| Location | No treatment 6,000 Pl./A. | 10,000 Pl./A. | 14,000 Pl./A. | Complete fertilizer2/ 6,000 Pl./A. | 10,000 Pl./A. | 14,000 Pl./A. |
|---|---|---|---|---|---|---|
| Broughton | 27.4 | 15.4 | 6.9 | 36.1 | 24.6 | 9.8 |
| Rossville | 48.6 | 53.5 | 63.2 | 58.4 | 63.8 | 59.2 |
| Reserve | 35.9 | 36.0 | 23.9 | 49.9 | 53.0 | 37.0 |
| Ottawa | 53.3 | 61.4 | 59.7 | 65.9 | 84.0 | 88.7 |

1/ n=4, with all yields calculated on a basis of 15.5% moisture.
2/ Complete fertilizer is 80-40-40 at Ottawa and 40-40-40 at the other three locations.

Table 11. Corn yields in bushels per acre as affected by addition of phosphorus, corn fertilizer experiment, 1949. 1/

| Location | 40-40-40 | 40-0-40 |
|---|---|---|
| Broughton | 24.6 | 21.8 |
| Rossville | 63.8 | 67.4 |
| Reserve | 53.0 | 56.6 |
| Ottawa | 84.0 2/ | 74.9 |

1/ n=4, with all yields calculated on a basis of 15.5% moisture.
2/ Received 80 pounds of nitrogen rather than 40 pounds.

Table 12. Corn yields in bushels per acre as affected by addition of potassium, corn fertilizer experiment, 1949. 1/

| Location | 40-40-40 | 40-40-0 |
|---|---|---|
| Broughton | 24.6 | 20.0 |
| Rossville | 63.8 | 62.0 |
| Reserve | 53.0 | 48.8 |
| Ottawa | 84.0 2/ | 79.3 2/ |

1/ n=4, with all yields calculated on a basis of 15.5% moisture.
2/ Received 80 pounds of nitrogen rather than 40 pounds.

Table 13. Corn yields in bushels per acre as affected by different rates of nitrogen, corn fertilizer experiment, 1949. 1/

| Location | 20-40-0 | 40-40-0 | 80-40-0 |
|---|---|---|---|
| Broughton | 27.9 | 21.3 | 19.8 |
| Rossville | 62.5 | 64.6 | 64.6 |
| Reserve | 35.2 | 48.3 | 63.2 |
| Ottawa | 63.4 | 79.7 | 80.6 |

1/ n=4, with all yields calculated on a basis of 15.5% moisture.

Table 14. Corn yields in bushels per acre as affected by different methods of application of 80 pounds of nitrogen, corn fertilizer experiment, 1949. 1/

| Location | Broadcast | Deep placed |
|---|---|---|
| Broughton | 23.0 | 19.4 |
| Rossville | 58.5 | 68.2 |
| Reserve | 63.5 | 63.4 |
| Ottawa | 75.0 | 82.9 |

1/ n=8, with all yields calculated on a basis of 15.5% moisture.

Table 15. Corn yields in bushels per acre as affected by different times and methods of application of 20 pounds of nitrogen, corn fertilizer experiment, 1949. 1/

| Location | Deep placed (At planting) | Side dressed (2nd Cultivation) |
|---|---|---|
| Broughton | 27.9 | 24.0 |
| Rossville | 62.5 | 63.3 |
| Reserve | 35.2 | 32.9 |
| Ottawa | 63.4 | 81.3 |

1/ n=4, with all yields calculated on a basis of 15.5% moisture.

## Chemical Analyses of Grain Samples

Table 16. Protein content of grain from corn fertilizer experiment, 1949. 1/

| Treatment number 2/ | Protein content in per cent 3/ | | | |
|---|---|---|---|---|
| | Broughton | Rossville | Reserve | Ottawa |
| 1 | 10.50 | 9.38 | 7.06 | 8.21 |
| 2 | 10.62 | 8.06 | 6.88 | 8.06 |
| 3 | 10.12 | 8.94 | 8.56 | 9.38 |
| 4 | 10.50 | 9.00 | 7.06 | 9.94 |
| 5 | 10.56 | 9.31 | 8.12 | 10.06 |
| 6 | 10.31 | 9.06 | 8.12 | 8.62 |
| 7 | 11.06 | 8.81 | 9.75 | 9.19 |
| 8 | 10.81 | 9.12 | 8.06 | 8.88 |
| 9 | 10.69 | 8.75 | 7.94 | 9.88 |
| 10 | 12.00 | 8.56 | 7.62 | 8.81 |
| 11 | 10.81 | 9.31 | 9.12 | 9.81 |
| 12 | 10.88 | 9.38 | 9.06 | 9.38 |
| 13 | 10.31 | 9.50 | 7.25 | 8.94 |
| 14 | 10.62 | 9.31 | 8.06 | 8.44 |
| 15 | 10.38 | 9.19 | 8.06 | 8.69 |
| 16 | 11.06 | 9.44 | 8.75 | 10.31 |
| 17 | 10.25 | 9.75 | 8.12 | 8.19 |
| 18 | 10.88 | 9.31 | 7.31 | 9.81 |
| 19 | 10.88 | 9.62 | 7.50 | 9.38 |
| 20 | 11.00 | 9.00 | 8.81 | 9.81 |
| 21 | 10.25 | 9.56 | 7.19 | 9.31 |
| 22 | 11.00 | 10.50 | 8.31 | 9.94 |
| 23 | 10.88 | 11.31 | 9.31 | 9.56 |
| 24 | 10.56 | 8.94 | 8.12 | 8.20 |
| 25 | 10.44 | 10.68 | 7.44 | 9.31 |

1/ Differences are significant to the .05 level. L.S.D.=0.81%.
2/ Treatment numbers correspond to treatment numbers in Table 1.
3/ Each determination made on a composite sample from four replications.

Table 17. Phosphorus content of grain from corn fertilizer experiment, 1949. 1/

| Treatment number 2/ | Phosphorus content in per cent 3/ | | | |
|---|---|---|---|---|
| | Broughton | Rossville | Reserve | Ottawa |
| 1 | 0.36 | 0.31 | 0.32 | 0.32 |
| 4 | 0.36 | 0.32 | 0.31 | 0.34 |
| 5 | 0.36 | 0.30 | 0.31 | 0.34 |
| 6 | 0.36 | 0.30 | 0.33 | 0.32 |
| 7 | 0.36 | 0.28 | 0.34 | 0.32 |
| 8 | 0.36 | 0.32 | 0.33 | 0.34 |
| 9 | 0.37 | 0.32 | 0.31 | 0.33 |

1/ No significant differences found.
2/ Treatment numbers correspond to treatment numbers in Table 1.
3/ Each determination made on a composite sample from four replications.

## Correlations

Table 18. Correlations between protein content and yield, corn fertilizer experiment, 1949.

| Location | r |
|---|---|
| Broughton | -0.123 |
| Rossville | 0.056 |
| Reserve | 0.690** |
| Ottawa | 0.370 |

**Highly significant (.01 level).

# DISCUSSION OF RESULTS

## Broughton

Rainfall data as given in Table 3 show that the moisture supply was sufficient in May to give the corn a good start. Droughty conditions in June, July, and August, however, damaged the corn quite badly and resulted in low yields. Also European corn borer damage was serious at this location.

This soil apparently had sufficient available phosphorus and exchangeable potassium for maximum yields of corn, but the total nitrogen supply was rather low (Table 4). This indicated that a response to an application of phosphorus or potassium was unlikely but that a response to an application of nitrogen might be expected.

Plant tissue tests made during the growing season (Table 5) showed an accumulation of nitrates and phosphorus in plants from both fertilized and unfertilized plots. The tissue tests also indicated that sufficient potassium was present for good plant growth.

The plant population significantly influenced the yield at Broughton (Table 10). On both the unfertilized plots and those receiving a complete fertilizer, the highest yields were obtained with a plant population of 6,000 per acre. The yields on plots having a population of 10,000 plants per acre were significantly lower than those having 6,000 per acre, and those having 14,000 per acre were significantly lower than those with 10,000 per acre.

Droughty conditions during the latter part of the growing season probably accounted for the low yields with high plant populations.

Slight differences in yields due to method of application of the nitrogen were non-significant (Tables 14 and 15). When applied in combination with phosphorus, 20 and 40 pound applications of nitrogen increased the yield significantly over the unfertilized plots (Table 13). The 80 pound rate, however, was significantly lower than the 20 pound rate applied in a comparable manner.

No significant differences were found due to the application of either phosphorus or potassium. This can be noted in Tables 11 and 12.

Differences in protein content due to fertilizer treatments were small, but there was a tendency for the plots receiving 80 pounds of nitrogen to have a slightly higher content of protein than those receiving the lower rates of nitrogen (Table 16). No correlation was found between protein content and yield at this location. The phosphorus content of the grain was essentially the same for all treatments as is shown in Table 17.

## Rossville

No rainfall data are available for the Rossville location. The moisture supply throughout the growing season was adequate, however, for good corn yields. Damage from cutworms resulted in an uneven stand.

The soil at this location was well supplied with available phosphorus and exchangeable potassium (Table 4) indicating that no response from the application of these nutrients was likely. The total nitrogen content was rather low suggesting that an application of nitrogen might increase yields.

Plant tissue tests made July 13, 1949 (Table 6) showed little nitrate accumulation in plants from the untreated plots, but did show an accumulation in all of the plants from plots which received fertilizer treatments. Plant tissue from all plots tested showed accumulations of phosphorus and potassium.

The plant population data given in Table 10 are of limited value at this location because of the uneven stand over the entire area. No significant differences were found due to differences in plant population.

As shown in Table 9, no significant differences between treatments were obtained at Rossville. This was probably due to the uneven stand as increases, although erratic, were obtained from plots receiving nitrogen. This can be noted in Table 9.

Differences in protein content between treatments were inconsistent (Table 16), and no correlation was found to exist between protein content and yield. Differences in phosphorus content were non-significant (Table 17).

## Reserve

The rainfall at Reserve was excessive during the month of June (Table 3), and was adequate during July. Although a moderate drought occurred in August, the corn was not seriously damaged. The season as a whole was conducive to relatively high corn yields.

The chemical analyses of this soil (Table 4) showed it to have sufficient available phosphorus and exchangeable potassium for good corn yields. Although the total nitrogen content was higher than at the other locations, it was still rather low. Therefore a response to the application of nitrogen might be expected.

According to the plant tissue tests made July 12, 1949 (Table 7) very little accumulation of nitrates existed in the plants from plots not receiving nitrogen. There was an accumulation of nitrates, however, in nearly all the plants on plots which received nitrogen. The amounts of phosphorus and potassium were sufficient in all plants tested.

There were no significant differences in yields between plant populations of 6,000 per acre and 10,000 per acre on either the fertilized or the unfertilized plots (Table 10). A population of 14,000 per acre, however, significantly lowered the yield on both the fertilized and unfertilized plots. This decrease was probably due at least in part to the low rainfall during August.

No increases in yields above those of the unfertilized plots were obtained by the application of 20 pounds of nitrogen in combination with phosphorus (Table 9). The plots receiving 40 pounds of nitrogen, however, produced yields significantly higher than the unfertilized plots, and the plots receiving 80 pounds of nitrogen produced yields significantly higher than the plots receiving 40 pounds of nitrogen (Table 13). There were essentially no differences in yields due to method of fertilizer application as can be noted in Tables 14 and 15. There was no significant response to phosphorus or potassium at this location (Tables 11 and 12).

The protein content of grain from plots receiving at least 40 pounds of nitrogen at or before planting time was, in general, higher than that of the grain from plots receiving no nitrogen or nitrogen as a sidedressing (Table 16). A significant correlation (Table 18) was found to exist between protein content and yield at this location. The phosphorus content was essentially the same regardless of treatment (Table 17).

## Ottawa

The rainfall (Table 3) was abundant and well-distributed through the growing season. Heavy rains during May caused somewhat of a weed problem, but conditions in general were conducive to high yields of corn.

An abundant supply of exchangeable potassium was present in this soil as is shown by the results of the chemical analyses in Table 4. The amounts of available phosphorus and total nitrogen, however, proved to be rather low. Thus increases in yield due to applications of the latter two nutrients might be expected.

Plant tissue tests (Table 8) showed accumulations of phosphorus and potassium on both the fertilized and unfertilized plots. There was very little accumulation of nitrates, however, even in many of the plants from plots receiving heavy applications of nitrogen.

On the unfertilized plots there were no significant differences between plots having different plant populations (Table 10). On plots receiving a complete fertilizer, however, a plant population of 6,000 per acre produced yields significantly lower than a population of 10,000 or 14,000 per acre. There was no significant difference between the yield obtained from a plant population of 10,000 per acre and that obtained from a population of 14,000 per acre.

Yields from plots receiving broadcast applications of nitrogen were not significantly different from those from plots receiving deep placement applications (Table 14). When in combination with phosphorus, however, 20 pounds of nitrogen applied as a sidedressing produced significantly higher yields than the same amount of nitrogen applied at planting time (Table 15). It is believed that the earlier application of nitrogen was largely lost through leaching due to heavy rains received in May.

On plots receiving 20 pounds of nitrogen at or before planting the yields were not significantly higher than the yields from unfertilized plots (Table 9). Significant increases in yield were obtained, however, on plots receiving 40 and 80 pounds of nitrogen (Table 13). There were no significant differences in yields between plots receiving 40 pounds of nitrogen and those receiving 80 pounds of nitrogen.

Although the application of phosphorus did not produce a significant increase in yield, a small increase was obtained which indicates that further investigations might be desirable (Table 11). No response was obtained to potassium at this location as can be noted in Table 12.

There were small differences in protein content, but they were erratic and no definite trends could be noted. This is shown in Table 16. No correlation was found between protein content and yield. Differences in phosphorus content were not significant as is shown in Table 17.

## SUMMARY AND CONCLUSIONS

The results of the 1949 fertilizer experiments with corn in Kansas may be summarized as follows:

1. When applied in combination with phosphorus, 40 pounds of nitrogen significantly increased the yield of corn over 20 pounds of nitrogen applied in a like combination at two locations, Reserve and Ottawa. At both of these locations the use of 80 pounds of nitrogen with phosphorus likewise increased the yield over the 20 pound rate. At Reserve the 80 pound rate of nitrogen produced yields significantly above the 40 pound application. No significant increases were obtained at Rossville. A significant decrease resulted from the use of 80 pounds of nitrogen at Broughton as compared to the use of only 20 pounds of this element.

2. Deep placement of 80 pounds of nitrogen at planting time did not give results which were significantly different from the same amount of nitrogen broadcast before planting time.

3. Sidedressing with 20 pounds of nitrogen at second cultivation gave a significant increase in yield over the same amount of nitrogen deep placed at planting time at Ottawa when used with phosphorus. No significant difference resulted at any other location. It is believed that the early application of only 20 pounds of nitrogen at Ottawa was largely lost due to leaching by the heavy rainfall which occurred just after planting.

4. The inclusion of potash in a 40-40-40 combination had no significant influence on yield at any location when compared to a 40-40-0 combination.

5. The inclusion of 40 pounds of available $P_2O_5$ in a 40-40-40 combination had no statistically significant influence on the yield at any location as compared to a 40-0-40 combination. There was an indication, however, that phosphorus may have been deficient for maximum yield at Ottawa but not at the other locations. This relationship was apparent from soil tests also.

6. Plant population had the following significant effects:

(a) In the case of unfertilized corn, a population of 10,000 plants per acre significantly reduced the yield at Broughton when compared to a population of only 6,000 plants per acre. Increasing the population to 14,000 plants per acre had a similar, though much more pronounced, effect at this location. A detrimental effect also resulted at Reserve from the use of a plant population of 14,000 per acre. Severe drought conditions prevailed at Broughton during much of the season and at Reserve a moderate drought occurred, late in the season.

(b) At Broughton and Reserve, the relationship between plant population and yield on the plots receiving a complete fertilizer were similar to those existing on the unfertilized plots. However, at Ottawa, where rainfall was quite abundant, an increase in plant population had a favorable effect on yield, but the difference between the 10,000 and the 14,000 plants per acre was not statistically significant. Yields at Rossville were not significantly affected by plant population but indications were that the relationship was more nearly in accordance with those at Ottawa than with those at either Broughton or Reserve.

(c) As evidenced by these results, there was no good indication that plant population should be extended beyond 10,000 per acre in Kansas even under relatively heavy applications of fertilizer and with relatively abundant rainfall as was received at Ottawa.

7. When a stand of 10,000 plants per acre existed, the use of nitrogen fertilizer alone at either the 40 or 80 pound rates increased the yield of corn significantly at all locations except Rossville regardless of the method of application. The use of 20 pounds of nitrogen alone as a side dressing at the time of second cultivation had no statistically significant effect when 10,000 plants per acre were used.

## ACKNOWLEDGMENTS

The author wishes to express his appreciation to his major instructors, Drs. H. E. Myers, and F. W. Smith for their assistance in planning the experiment and writing the thesis; to Verlin H. Peterson and Roscoe Ellis, Jr. for their assistance in the field; to Dr. H. C. Fryer of the Department of Mathematics for his assistance in conducting the statistical analyses; and to the Spencer Chemical Company whose funds made this project possible.

## LITERATURE CITED

(1) Agronomy Department, Iowa State College.
Outline of Third Annual Fertilizer Short Course.
Ames, 1949.

(2) Arnold, C. Y. and T. Kurtz.
Photometer method for determining available phosphorus in soils. Ill. Agr. Expt. Sta. Agron. Dept. Pamphlet AG1306. 1946.

(3) Association of Official Agricultural Chemists.
Methods of analysis. 5th ed. Washington, 1940. p.4.

(4) Caldwell, A.C.
The effect of corn population on the efficiency of use of fertilizer. Proc. of Nat'l. Joint Committee on Fertilizer Application, pp. 55-56. 1948.

(5) Coleman, R.
Value of fertilizer for corn. Miss. Agr. Expt. Sta. Circ. 120:1-11. 1944.

(6) Eskew, E. B. and W. R. Paden.
Influence of high rates of nitrogen on corn yields. Proc. of Nat'l. Joint Committee on Fertilizer Application, pp. 61-63. 1945.

(7) Fitts, J. W., H. F. Rhoades, and J. R. McHenry.
Using nitrogen fertilizers in Nebraska. Univ. of Nebr. Ext. Circ. 163. 1945.

(8) Gray, Carl.
The effect of time and method of placement of fertilizer on the yield of corn. Unpublished M. S. Thesis, Kansas State College, Manhattan, Kansas. 1947.

(9) Harper, H. J. and O. H. Brensing.
Effect of ammonium nitrate in Oklahoma, 1948. Okla. Agr. Expt. Sta. Mimeo. Circ. M-178. 1949.

(10) Krantz, B. A.
Fertilizer corn for higher yields. N. Car. Agr. Expt. Sta. Bul. 366. 1949.

(11) Metzger, W. H.
Effect of depth of placement of fertilizer upon response of corn and sorghum. Proc. of Nat'l. Joint Committee on Fertilizer Application, p. 105. 1940

(12) Millar, C. E., L. S. Robertson, R. L. Cook, C. M. Hansen, W. C. Hulbert, and G. A. Cumings.
The effect of fertilizer placement on the yield and maturity date of corn at the Michigan experiment station in 1948. Proc. of Nat'l. Joint Committee on Fertilizer Application, pp. 51-54. 1948.

(13) Ohlrogge, A. J., B. A. Krantz, and G. D. Scarseth.
The recovery of plowed-under ammonium sulfate by corn. Soil Sci. Soc. Amer. Proc. 8:196-200. 1943.

(14) Peterson, V. H., H. E. Jones, and F. W. Smith.
Corn fertilizer studies in Kansas, 1948. Proc. of Nat'l. Joint Committee on Fertilizer Application, pp. 47-51. 1948.

(15) Pierre, W. H.
Fertilizers, their place in Iowa's corn production. The Fertilizer Review, 21:2-3. 1946.

(16) Piper, C. S.
Soil and plant analysis. New York: Interscience Publishers, pp. 272-274. 1944.

(17) Robertson, L. S. and R. L. Cook.
Efficiency in the use of fertilizer for corn. Mich. Agr. Expt. Q. Bul. 30:374-379. 1948.

(18) Scarseth, G. D., H. L. Cook, B. A. Krantz, A. J. Ohlrogge.
How to fertilize corn effectively in Indiana. Ind. Agr. Expt. Bul. 482:1-39. 1943.

(19) Snedecor, G. W.
Statistical methods. 4th ed. Ames: Iowa State College Press, 1946.

(20) Thornton, S. F., S. D. Conner, and R. R. Fraser.
The use of rapid chemical tests on soils and plants as aids in determining fertilizer needs. Purdue Agr. Expt. Sta. Circ. 204. 1939.