CORN FERTILIZER STUDIES AT FOUR LOCATIONS IN KANSAS, 1948

by

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INTRODUCTION

Corn is the second most important cultivated crop grown in Kansas. Since it holds such an important place in the economic welfare of the farmers of this state, more information is needed relative to its response with fertilizer usage.

The purpose of this experiment was to obtain information concerning the best time, rate, and method of applying nitrogenous fertilizers to corn, both alone and in combination with phosphatic and potassic fertilizers, under various Kansas conditions. Very little information exists in Kansas at the present time in regard to the response of corn to commercial fertilizers. Other states in the corn belt have accumulated much data on corn fertilization, but because of differences in temperature and rainfall their results cannot be applied to Kansas conditions.

Results of corn fertilization studies in the various states are conflicting. A wide variation exists in the results obtained from different rates of fertilization and from different methods of application. It is agreed generally that previous cropping, nutrient supply of the soil, soil aeration, and number of plants per acre are important factors influencing the effective use of fertilizers.

REVIEW OF LITERATURE

Seem and Richer (27) have made the statement that the number of corn plants per acre should be adjusted to the available plant nutrient supply and to the average rainfall conditions. According to Krantz (14), fertilizer studies in North Carolina gave rather sensational results when 9,000 plants per acre were grown. Ordinarily the farmers of that state plant only 3,000 to 4,000 plants per acre. Even under drier or less fertile soil conditions the greater number of plants per acre did not decrease the grain yields. Eskew and Paden (8) of South Carolina found that 10,000 plants per acre tended to produce the highest yield, especially at the higher rates of side dressing. In Ohio, Reed and Salter (24) have found that to obtain maximum returns from high fertilizer applications, a planting rate of 12,000 to 14,000 plants per acre must be maintained. Caldwell (6) reported that efficient use of fertilizers cannot be obtained in Minnesota unless the plant population is at least 14,000 plants per acre. Yields from fertilized areas growing 9,680 plants per acre were not greater than unfertilized areas where 19,360 plants per acre were grown.

Hoffer (12) found that in order for fertilizers to be effective, the soil must be well drained, in good tilth, and have satisfactory aeration. He believed that the reason for the ineffectiveness of fertilizers, as has been reported in many cases, is due to unsatisfactory tilth and low porosity of the soils. Lawton's (15) results indicated that the absorption of potassium by the plants is more dependent upon soil aeration than upon the uptake of nitrogen and phosphorus.

Outstanding work in corn fertilizer research has been done in Indiana. Scarseth et al. (26) reported that if adequate amounts of phosphorus and potassium are applied to the legumes in the rotation, the major requirements of the corn crop for nitrogen, phosphorus, and potassium could be met. In addition, the pH of the soil should be corrected to about 6.5. They believe that if the yield of corn is from 70 to 80 bushels per acre with the above practice the use of 200 pounds per acre of a 3-12-12 in the drill or 125 pounds per acre in the hill to be the best combination. If the corn yields ranged from 50 to 60 bushels per acre, 400 pounds per acre of a 10-10-10 applied on the plow sole in addition to the row starter fertilizer was advocated. With yields as low as 30 to 40 bushels per acre their recommendations included 800 pounds per acre of a 10-10-10 applied on the plow sole in addition to a small amount of a 3-12-12 applied in the row at planting time. They also expressed the idea that placing fertilizers near the surface promoted weed growth during wet seasons.

In Michigan inconsistent results have been obtained with experiments relative to the application of fertilizer to corn. According to Robertson and Cook (25), the application of phosphorus and potassium to alfalfa during the summer prior to plowing the land for corn did not give a satisfactory response. In addition, the application of fertilizer at planting time through the corn planter did not result in a significant increase in yield. They obtained consistent and significant increases when the fertilizers were placed in bands below and to the side of the seed.

Summarizing corn fertilizer experiments conducted in Iowa on various soil types, Pierre (22) states that responses varied greatly between and within soil areas. These studies indicated that at least 30 percent of the land in that state will respond to the application of 0-20-10 or 10-20-0 fertilizer if it is applied in the hill or in the rows at planting time.

The effect of fertilizers on corn production in Oklahoma has been studied by Harper and Brensing (11). Their recommendations at seeding time for a deep sandy upland or bottomland soil low in available phosphorus, and on which legumes have not been grown, include the application in the row of 150 to 200 pounds per acre of a 4-12-4 or 5-10-5. A 4-16-0 may be used on soils high in potassium. These workers advocate the use of 50 to 100 pounds per acre of ammonium nitrate applied as a side dressing about May 10 to May 20.

Metzger (18) conducted experiments in Kansas relative to the placement of superphosphate as it affected the yields of corn and sorghums. His results indicated that increased yields were obtained only by deep placement of the phosphorus.

A study of the effect of time and method of placement of fertilizer on the yield of corn has been made by Gray (10) in Kansas. Under the conditions of this experiment it was found that side dressing with ammonium nitrate at the last cultivation gave an increase in yield, but the application of superphosphate either on the plow sole or in the row gave no increases in stand count, yield, or ear weight. His results also showed that when nitrogen fertilizer was applied on the plow sole and in the row at seeding time sucker growth was promoted.

In Nebraska the use of 40 pounds of nitrogen per acre applied at the last cultivation is advocated by Fitts, Rhoades, and McHenry (9). When using this method they recommend that the nitrogen be placed in bands two or three inches deep and about eight inches away from the plants.

Worzella and Puhr (32) have found the placing of a fertilizer in a narrow band on the plow sole is superior to all other methods which they studied in South Dakota. The broadcasting of a 4-24-12 on the surface followed by disking in was not effective. Of all the placement methods studied, the row application was the least effective.

Coleman (7) reported that in Mississippi the most effective response was obtained by applying one-half of the nitrogen under the corn at planting time and one-half as a side dressing. If less than 24 pounds of nitrogen per acre is used, only one of these two methods is advocated. He states that phosphorus and potassium do not give profitable returns when applied to corn unless the soils are definitely deficient in these two nutrients.

In another experiment conducted in Mississippi, 30 pounds of nitrogen per acre applied with the seed at planting time and 60 pounds of nitrogen per acre applied as a side dressing gave a good response. According to Jordan (13), the yield increased one bushel for every two pounds of nitrogen used. In areas where complete fertilizers were needed he recommended that 500 pounds per acre of a 6-8-4 o4 6-8-8 be applied at planting time followed by a side dressing with ammonium nitrate when the corn was about knee high.

Terman (29) of Kentucky believed that when corn is grown in a rotation phosphorus and potassium should be applied to small grains preceding corn. Where direct fertilization is practiced, he recommended that fertilizers be applied in bands on the plow furrow or broadcast and plowed under.

As reported by Vittum (31) experiments conducted in New York indicate that there was no difference in yields between broadcasting before plowing and broadcasting before disking. When 100 pounds of nitrogen per acre were broadcast before plowing the yield was 14 bushels greater than the check plot. The addition of phosphorus and potassium to the nitrogen did not increase the yield above the use of nitrogen alone.

METHODS OF STUDY

Location and Description of Plots

Experimental plots were established in Clay County, near Broughton, Kansas, on the Wynn Bauer farm; in Brown County, near Reserve, Kansas, on the Fred Fouth farm; in Shawnee County, near Silver Lake, on the Ben Hook farm; and in Franklin County, near Ottawa, Kansas, on the George Kyle farm.

The soil type at Broughton is Waukesha silt loam. The topography is uniform, and the area is a typical bottom-land soil for that particular region. Only corn had been grown at this location for the past 15 years. Previous corn yields have averaged about 40 bushels per acre.

At the Reserve location the soil type is Marshall silt loam. This soil has excellent profile characteristics. The crop rotation for the past 12 years was corn, oats, and wheat. Corn yields during this period averaged 40 bushels per acre.

The area at Silver Lake has grown corn since 1937 with the exception of 1940 when wheat was grown. The average corn yields for the past several years has been about 45 bushels per acre. The soil type is Waukesha silt loam.

The soil at Ottawa has a claypan in the B horizon of the soil profile. The soil type is undetermined, but the soil class is a silty clay loam. A rotation including corn, sorghums, and small grains has been used for several years. Corn yields have averaged about 30 bushels per acre.

Plan of Experiment

The experimental plan was the same at all locations. The plan consisted of 25 different treatments which constituted one block. Each treatment was replicated four times giving a total of 100 plots. The various treatments with the method of application are indicated in Table 1.

All plots were 120 feet in length and contained four 40-inch rows. The two outside rows served as guard rows. At harvest time 93 feet and eight inches of the two center rows were harvested which was 1/70 of an acre.

Experimental Procedure

Top dressings of nitrogen fertilizer before planting were made by means of a Gandy fertilizer spreader. At planting time nitrogen, phosphorus, and potassium were applied by means of the Iron Age corn and bean planter which was equipped with special hoppers and belts for the distribution of the fertilizer materials. Side dressing applications of nitrogen were accomplished by using a Planet Jr. drill.

The source of nitrogen was 32.5 percent ammonium nitrate, for phosphorus 45 percent treble superphosphate was used, while 50 percent muriate of potash was the source of potassium.

K1784 was grown at Broughton, Carlson's Hybrid at the Reserve area, K2234 at Silver Lake, and Dekalb and Huey's Hybrid were grown in alternate rows at Ottawa. At all locations the stand was thinned so that the plants were 15 inches apart making a total of

Table 1. Fertilizer rates, methods and time of application for corn fertilizer experiment, 1948

Treatment number	Treatment rate per acre	Method of N application*	Total lbs. N applied per acre
1	0-0-0		0
2	0-20-0		0
3	40-0-0	B	40
4	80-0-0	B	80
5	40-20-0	B	40
6	40-20-20	B	40
7	80-20-0	B	80
8	20-20-0 + 20 N	B + P	40
9	20-20-0 + 20 N	B + SdE	40
10	20-20-0 + 20 N	B + SdL	40
11	40-0-0	DP	40
12	80-0-0	DP	80
13	20-20-0	DP	20
14	40-20-0	DP	40
15	40-20-20	DP	40
16	80-20-0	DP	80
17	20-20-0 + 20 N	DP + P	40
18	20-20-0 + 20 N	DP + SdE	40
19	20-20-0 + 20 N	DP + SdL	40
20	40-20-0 + 20 N + 20N	DP + P + SdL	80
21	20-0-0	SdE	20
22	20-20-0	SdE	20
23	20-0-0	SdL	20
24	20-20-0	SdL	20
25	20-20-0 + 20 N	SdE + SdL	40

*All phosphorus and potassium were applied at planting time near to the seed in conventional manner. Symbols for methods of nitrogen application are indicated as follows:

B - Broadcast and plowed under before planting.
P - Applied at planting time near seed.
DP - Applied 3-4 inches below seed at planting time.
SdE - Side dress early when corn was 8 - 12 inches high.
SdL - Side dress late when corn was 30 - 36 inches high.

10,000 plants per acre. The planting dates for the different areas and the dates when the nitrogen was applied by the various methods are given in Table 2.

Chemical Analysis of Soils

Total nitrogen determinations were made according to the procedure given by the Association of Official Agricultural Chemists (2). Analysis for available phosphorus were conducted by the method as given by Bray and Kurtz (4). In order to determine the exchangeable potassium a solution of 1N ammonium acetate was added to 20 grams of soils. After shaking for 10 minutes the suspension was filtered. Five milliliters of 1,100 ppm of lithuim in 1N ammonium acetate were added to the extract and the final determination was made on the flame photometer. For the determination of the pH a 1:1 mixture of soil and water was used. The readings were taken on a glass electrode pH meter.

Physical Analysis of Soils

Soil samples for physical analysis were collected at Reserve and Ottawa. The plots chosen at Reserve for sampling were the no treatment, 0-20-0, 80-0-0 broadcast, and 80-0-0 deep placement. At Ottawa, samples were taken on the no treatment and 80-0-0 broadcast plots. At each location three surface samples and three subsoil samples per plot were collected with the exception of Reserve where two additional samples were taken at a greater depth in the subsoil on a no treatment plot. At Reserve, samples were taken at a depth of 2 to 5 inches in the surface soil and 10 to 13 inches in the subsoil. The deeper subsoil samples were collected in the $16\frac{1}{2}$ to $19\frac{1}{2}$ inch zone. At Ottawa surface samples were taken at a depth of 3 to 6 inches and subsoil samples at a depth of 11 to 14 inches.

Table 2. Dates of planting and dates of nitrogen application by various methods, corn fertilizer experiment, 1948.

Location	Broadcast	Deep placement	Planting	Early side dressing	Late side dressing
Broughton	April 12	May 7	May 7	May 29	June 24
Reserve	April 9	May 14	May 14	June 3	July 14
Silver Lake	April 7	April 30	May 1	June 1	June 30
Ottawa	April 3	April 23	April 24	May 21	June 26

Soil samples were taken at the various depths according to the procedure given by Olmstead (20). In order to obtain cores approximating that of field conditions as nearly as possible a sample cutter containing a brass sleeve three inches long and with an inside diameter of three inches was jacked into the soil until a core of the desired depth filled the sleeve. The exact volume of the sleeve was 347.5 cc.

The pore-size distribution was determined by a variation in the procedure proposed by Leamer and Shaw (17). Modifications of their method included the saturation of the soil samples with water after removal of air in a vacuum desiccator. In addition the tension tables were made up of 1/8-inch asbestos millboard. The larger pores of the asbestos were tightened with Portland cement paste. At the various tensions the first weighing was made at the end of the fifth day followed by a check weighing on the seventh day. Both weighings generally agreed within 0.3 gram.

Aggregate analyses were conducted according to the method given by Yoder (33) with modifications described by Dr. M. L. Nichols, Chief of Research, Soil Conservation Service, in letter 13, dated September 17, 1943. The method of Nijhawan and Olmstead (19) was used for pretreating the samples. Moisture equivalent determinations were made according to the procedure introduced by Briggs and McLane (5).

Chemical Analysis of Grain Samples

The method given by the Association of Official Agricultural Chemists (2) was used for the determination of the total nitrogen. All nitrogen value were multiplied by the factor 6.25 to obtain the protein content. In determining the phosphorus, the digestion of the plant material was made according to the procedure given by Piper (23). Final readings were taken on the photometer as described by Arnold and Kurtz (1).

Miscellaneous

Plant tissue tests were in accordance with the method used by Thornton (30). For the moisture determination one-hundred grams of the grain sample were placed in a Steinlite moisture tester. From the reading obtained the moisture content was determined by referring to prepared tables. Methods outlined by Snedecor (28) and Paterson (21) were used for statistical analysis.

RESULTS

The results are shown in Tables 3 through 52. These data include plant tissue tests, chemical and physical analyses of the soils, yield and moisture data, chemical analyses of grain, and statistical analyses.

Rainfall Data

Table 3. Total rainfall from May 1, 1948 to September 15, 1948, corn fertilizer experiment.

Location	Rainfall inches
Broughton	15.8
Reserve	13.3
Silver Lake	16.0
Ottawa	20.3

Plant Tissue Tests

Table 4. Results of plant tissue tests, Broughton, June 25, 1948.

Treatment	N	P	K
0-0-0	Medium	Low	High
20-0-0 SdE	High	High	Very high
40-0-0 B	High	Low	High
40-20-20 DP	High	Medium	Very high

Table 5. Results of plant tissue tests, Reserve, July 15, 1948

Treatment	N	P	K
0-0-0	High	High	High
0-20-0	Low	Very high	Very high
80-0-0 B	High	High	High
80-0-0 DP	High	High	High
40-20-0 DP	High	High	High
40-20-20 DP	Low	High	High
40-20-20 B	Medium	High	High

Table 6. Results of plant tissue tests, Silver Lake, July 15, 1948.

Treatment	N	P	K
0-0-0	High	Blank	High
0-20-0	Medium to high	Blank	Medium
80-0-0 B	High	Blank	High
80-0-0 DP	High	Blank	High
40-20-0 B	High	Blank	High
40-20-20 DP	High	Blank	High
40-20-20 B	High	Blank	High

Table 7. Results of plant tissue tests, Ottawa, June 26, 1948.

Treatment	N	P	K
0-0-0	High	Blank	High
0-20-0	Medium to high	Blank	Medium
80-0-0 B	High	Blank	High
80-0-0 DP	High	Blank	High
40-20-0 B	High	Blank	High
40-20-20 DP	High	Blank	High
40-20-20 B	High	Blank	High

Chemical Analyses of Soils

Table 8. Summary of chemical analyses on soils, corn fertilizer experiment, 1948.

Location	pH	Available phosphorus (lbs./acre)	Exchangeable potassium (lbs./acre)	Total nitrogen percent
Broughton	5.92	260	617	.120
Reserve	5.54	83	598	.146
Silver Lake	5.58	60	669	.113
Ottawa	5.63	20	135	.126

Physical Analyses of Soils

Table 9. Results of physical analyses, no treatment plot, Ottawa, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
7	Surface	1.252	53.6	0.4	7.5	11.4	13.6			
9	Surface	1.232	54.8	2.9	10.4	12.9	14.6	22.8	24.8	28.4
11	Surface	1.275	53.0	0.7	10.2	13.4	14.9			
8	Subsoil	1.378	55.1	0.8	6.4	7.7	8.7			
10	Subsoil	1.375	50.0	0.7	9.3	11.0	11.8	17.4	18.4	18.8
12	Subsoil	1.414	48.6	0.3	5.1	6.4	7.1			

Table 10. Results of physical analyses, no treatment plot, Ottawa, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
13	Surface	1.263	53.8	1.1	10.2	13.2	14.9			
15	Surface	1.189	55.7	1.9	10.6	14.2	16.0			
17	Surface	1.233	53.8	3.4	12.5	14.7	16.0			
14	Subsoil	1.350	49.7	0.2	1.6	2.2	2.5			
16	Subsoil	1.243	53.1	2.5	6.3	7.1	7.8			
18	Subsoil	1.398	49.0	0.6	8.1	10.1	11.0			

Table 11. Results of physical analyses, 80-0-0 broadcast plot, Ottawa, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
1	Surface	1.244	54.0	1.2	14.7	17.6	18.7	25.0	26.0	26.6
3	Surface	1.336	51.0	0.3	3.6	8.7	10.6			
5	Surface	1.347	50.0	1.1	10.9	13.1	14.0			
2	Subsoil	1.412	52.4	0.5	2.6	10.1	12.0	10.5	11.1	11.6
4	Subsoil	1.338	55.5	0.0	8.0	9.7	10.4			
6	Subsoil	1.385	49.3	0.6	9.4	11.3	12.4			

Table 12. Results of physical analyses, 80-0-0 broadcast plot, Ottawa, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
19	Surface	1.230	53.9	1.4	11.8	14.5	15.9			
21	Surface	1.216	54.8	0.6	10.6	13.3	14.6			
23	Surface	1.178	56.2	3.8	16.8	19.0	20.1			
20	Subsoil	1.433	47.6	0.5	7.7	9.2	9.8			
22	Subsoil	1.326	50.2	0.2	1.5	2.1	2.3			
24	Subsoil	1.419	50.2	0.0	2.4	3.2	3.8			

Table 13. Results of physical analyses, no treatment plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
25	Surface	1.200	55.1	1.6	15.3	18.4	19.7	25.0	26.4	28.8
27	Surface	1.263	53.0	3.2	10.2	12.7	14.2			
29	Surface	1.264	53.1	0.1	9.6	13.7	14.8			
26	Subsoil	1.272	53.1	0.0	12.0	14.9	15.7	17.9	18.8	19.7
28	Subsoil	1.235	52.8	2.6	14.6	16.8	17.6			
30	Subsoil	1.338	51.1	0.8	9.5	12.0	12.7			
65	Deep	1.297	53.4	2.6	13.7	14.9	15.6			
66	Deep	1.228	55.4	0.5	17.6	20.0	10.9			

Table 14. Results of physical analyses, no treatment plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension 0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
37	Surface	1.258	52.4	1.7	10.8	13.6	14.5			
39	Surface	1.352	51.1	0.4	3.7	6.5	8.7	15.4	17.8	20.3
41	Surface	1.182	55.9	0.4	15.9	18.6	19.9			
38	Subsoil	1.340	51.1	0.7	10.3	12.2	12.7			
40	Subsoil	1.289	53.6	0.3	11.6	15.0	16.3	17.5	18.9	19.0
42	Subsoil	1.311	51.3	0.1	10.8	13.6	14.2			

Table 15. Results of physical analyses, no treatment plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension 0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
43	Surface	1.145	56.9	1.9	19.1	21.7	23.0			
45	Surface	1.406	48.2	0.6	3.5	5.7	7.2			
47	Surface	1.245	54.2	1.1	12.9	15.3	16.7	21.0	22.7	23.7
44	Subsoil	1.141	58.1	1.1	18.8	22.4	23.7			
46	Subsoil	1.312	52.5	0.9	11.5	13.7	14.6			
48	Subsoil	1.323	51.3	1.4	10.6	12.6	13.2	16.0	17.2	17.8

Table 16. Results of physical analyses, 0-20-0 plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
55	Surface	1.289	52.8	0.5	9.1	12.3	13.7			
57	Surface	1.282	52.6	1.0	10.6	12.9	14.5			
59	Surface	1.273	53.6	2.6	12.5	15.5	17.0			
56	Subsoil	1.350	50.3	0.2	8.7	10.5	11.1			
58	Subsoil	1.315	52.0	0.2	10.4	12.7	13.6			
60	Subsoil	1.298	52.3	0.7	11.9	14.3	14.9			

Table 17. Results of physical analyses, 80-0-0 broadcast plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
31	Surface	1.335	50.8	1.8	8.3	10.7	12.5			
33	Surface	1.120	57.8	2.2	19.6	22.8	24.4			
35	Surface	1.290	52.3	1.0	10.3	13.2	14.5			
32	Subsoil	1.295	53.0	0.8	12.2	14.7	15.7			
34	Subsoil	1.353	50.8	0.1	9.0	11.2	11.9			
36	Subsoil	1.310	52.5	0.3	12.2	14.5	15.2			

Table 18. Results of physical analyses, 80-0-0 broadcast plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
49	Surface	1.187	53.2	1.5	11.1	13.7	14.9			
51	Surface	1.374	50.2	1.3	4.8	7.5	9.2			
53	Surface	1.334	50.3	0.5	6.5	8.7	10.0			
50	Subsoil	1.268	54.5	1.4	13.6	16.3	17.3			
52	Subsoil	1.269	53.7	1.1	12.8	15.4	16.4			
54	Subsoil	1.261	55.2	0.2	14.8	17.5	18.3			

Table 19. Results of physical analyses, 80-0-0 broadcast plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
61	Surface	1.228	54.1	1.5	12.2	14.3	17.1			
63	Surface	1.244	54.0	2.8	13.0	15.9	17.6			
71	Surface	1.200	55.5	3.4	15.9	18.8	20.5			
62	Subsoil	1.348	51.2	0.0	10.8	13.2	13.9			
64	Subsoil	1.308	51.8	2.2	13.0	14.7	15.4			
72	Subsoil	1.311	51.3	1.1	12.0	13.8	14.8			

Table 20. Results of physical analyses, 80-0-0 deep placement plot, Reserve, 1948.

Sample no.	Depth	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
67	Surface	1.417	47.8	0.0	3.0	5.2	6.6			
69	Surface	1.294	53.4	1.6	12.3	15.0	16.6	21.1	23.1	24.8
68	Subsoil	1.287	53.8	0.1	12.5	15.4	16.5			
70	Subsoil	1.359	50.0	0.0	9.7	11.5	11.7	14.4	15.4	15.9

Table 21. Summary of physical analyses, 1948.

Location	Depth of Sample	Volume wt.	% total porosity	Percent of soil volume drained under tension						
				0.5cm	40cm	80cm	120cm	240cm	480cm	960cm
Ottawa	Surface	1.25	53.7	1.6	10.8	13.8	15.3	23.9	25.4	27.5
Ottawa	Subsoil	1.37	50.9	0.4	5.7	7.5	8.3	14.0	14.8	15.2
Reserve	Surface	1.27	52.8	1.4	10.7	13.4	15.0	20.6	22.5	24.4
Reserve	Subsoil	1.30	52.5	0.6	11.8	14.3	15.1	16.4	17.6	18.2

Table 22. Results of water stable aggregate analyses, 1948.

Sample number	Location	Depth of sample	Aggregates greater than 0.2 mm per cent
1	Ottawa	Surface	33.4
2	Ottawa	Subsoil	83.2
5	Ottawa	Surface	58.6
6	Ottawa	Subsoil	60.2
9	Ottawa	Surface	29.5
10	Ottawa	Subsoil	57.6
25	Reserve	Surface	16.7
26	Reserve	Subsoil	52.7
37	Reserve	Surface	21.5
38	Reserve	Subsoil	73.7
39	Reserve	Surface	20.9
40	Reserve	Subsoil	61.7
47	Reserve	Surface	26.7
48	Reserve	Subsoil	69.8
69	Reserve	Surface	18.9
70	Reserve	Subsoil	69.0

Table 23. Summary of water stable aggregate analyses, 1948.

Location	Depth of sample	Aggregates greater than 0.2 mm per cent
Ottawa	Surface	40.5
Ottawa	Subsoil	67.0
Reserve	Surface	20.9
Reserve	Subsoil	65.4

Table 24. Results of moisture equivalent analyses, corn fertilizer experiment, 1948.

Sample number	Location	Depth of sample	Moisture equivalent per cent
1	Ottawa	Surface	23.4
2	Ottawa	Subsoil	32.4
5	Ottawa	Surface	21.9
6	Ottawa	Subsoil	23.4
9	Ottawa	Surface	23.5
10	Ottawa	Subsoil	25.7
25	Reserve	Surface	25.2
26	Reserve	Subsoil	27.8
37	Reserve	Surface	24.9
38	Reserve	Subsoil	27.7
39	Reserve	Surface	24.9
40	Reserve	Subsoil	27.7
47	Reserve	Surface	25.7
48	Reserve	Subsoil	27.8
69	Reserve	Surface	24.8
70	Reserve	Subsoil	28.1

Table 25. Summary of moisture equivalent analyses, 1948.

Location	Depth of sample	Moisture equivalent percent
Ottawa	Surface	22.9
Ottawa	Subsoil	27.2
Reserve	Surface	25.1
Reserve	Subsoil	27.8

Observations of Plant Growth

The first observation of the plots at Broughton was made on June 2, 1948. At this time the broadcast applications of nitrogen were giving a better response than the deep placed applications. Plots receiving phosphorus in combination with nitrogen had a taller growth of corn than did plots receiving nitrogen alone. On June 24, 1948 it was observed that the deep placement treatments of nitrogen were showing greater growth response than the broadcast applications. Growth differences were recorded photographically on that date as shown in Plates I and II. In addition the early side dressings were giving a good response. No nutrient deficiency symptoms were apparent at any time during the growing season.

Observations of the various fertilizer treatments were made at Reserve on June 3, 1948. Differences in plant growth were not pronounced but minor responses could be noted. Treatments consisting of 40 and 80 pounds of nitrogen per acre applied as a broadcast application caused greater growth response than the same rates applied as a deep placement. Where phosphorus was applied with 40 and 80 pounds of nitrogen per acre the growth was slightly better than the same nitrogen rates alone. Plots receiving 20 pounds of nitrogen per acre applied as a deep placement were not superior to the no treatments. At the time of the second observation on July 15, 1948 differences among treatments were not marked with the exception that growth of plants on plots receiving phosphorus alone were not as tall as other treatments. Potassium in combination with nitrogen and phosphorus appeared no better than the latter two applied together. Differences in growth at that time are shown by the photograph on Plate III. When the third observation was made in September outstanding differences could be noted. Regardless of the method of nitrogen application the higher nitrogen rates were superior to the no treatment plots. In addition, treatments consisting of phosphorus alone indicated an improvement over the check plots.

The first observations of the plots at Silver Lake were made on June 1, 1948. Treatments consisting of phosphorus in combination with the higher rates of nitrogen were giving a better response than the same nitrogen treatments without phosphorus. The check plots showed no deficiency symptoms, but the plants were not as tall as the nitrogen treatments alone and in combination with phosphorus. At the time of the second observation on July 15, 1948 the plots receiving the higher nitrogen rates had a taller growth of corn than the check plots. Phosphorus in combination with nitrogen did not appear any better than the nitrogen treatments alone. Plants on plots receiving only phosphorus were taller than the no treatment plots. The photograph on Plate III indicates the growth differences which existed at that time.

The first observation of the plots at Ottawa was made on May 27, 1948. During this period differences among treatments were outstanding. The characteristic purpling of phosphorus deficient plants was indicated on all plots where no phosphorus had been applied. Plots receiving phosphorus alone and in combination with 40 and 80 pounds of nitrogen per acre had healthy appearing plants; however, 40 pounds of nitrogen per acre in combination with phosphorus was giving a better response than 80 pounds of nitrogen per acre in combination with phosphorus. Where 80 pounds of nitrogen per acre had been applied alone the plants were small and purpled. The complete fertilizer was the most responsive at this time. On June 26, 1948 a definite growth response was still indicated where phosphorus was applied. Growth differences during that time were recorded photographically as shown in Plates IV, V, and VI. The best response was from 40 pounds of nitrogen per acre applied as a deep placement in combination with phosphorus and potassium at planting time. Of all the fertilizer treatments 80 pounds of nitrogen per acre applied as a broadcast or deep placement appeared to be giving the poorest response. Growth on plots receiving 80-20-0 with the nitrogen broadcast was not as good as 80-20-0 with the nitrogen deep placed. At the time of the third observation during the first part of September, the differences among treatments which existed during the early part of the growing season could no longer be noted.

EXPLANATION OF PLATE I

The effect of various fertilizer treatments on growth of corn, Broughton, June 24, 1948.

Fig. 1. 0-0-0
Fig. 2. 0-20-0
Fig. 3. 40-20-20 B

Fig. 1

Fig. 2

Fig. 3

EXPLANATION OF PLATE II

The effect of various fertilizer treatments on growth of corn, Broughton, June 24, 1948.

Fig. 1. 40-20-20 DP
Fig. 2. 80-0-0 B
Fig. 3. 80-0-0 DP

Fig. 1.

Fig. 2.

Fig. 3.

EXPLANATION OF PLATE III

The effect of various fertilizer treatments on growth of corn at Reserve and Silver Lake, July 15, 1948.

Fig. 1. (Reserve, left to right)

40-20-20 B
40-20-0 DP
40-20-20 DP
0-0-0
0-20-0
80-0-0 B
80-0-0 DP

Fig. 2. (Silver Lake, left to right)

0-0-0
0-20-0
80-0-0 B
80-0-0 DP
40-20-20 B
40-20-0 DP
40-20-20 DP

PLATE III

Fig. 1.

Fig. 2.

EXPLANATION OF PLATE IV

The effect of various fertilizer treatments on growth of corn, Ottawa, June 26, 1948.

Fig. 1. 0-0-0
Fig. 2. 0-20-0
Fig. 3. 40-0-0 B

Fig. 1.

Fig. 2.

Fig. 3.

EXPLANATION OF PLATE V

The effect of various fertilizer treatments on growth of corn, Ottawa, June 26, 1948.

Fig. 1. 40-20-20 B
Fig. 2. 40-20-0 DP
Fig. 3. 40-20-20 DP

Fig. 1.

Fig. 2.

Fig. 3.

EXPLANATION OF PLATE VI

The effect of various fertilizer treatments on growth of corn, Ottawa, June 26, 1948.

Fig. 1. 80-0-0 B
Fig. 2. 80-0-0 DP
Fig. 3. 80-20-0 DP

Fig. 1.

Fig. 2.

Fig. 3.

Yield Data

Table 26. Summary of yields, corn fertilizer experiment*, 1948.

Treatment no.	Locations			
	Broughton	Reserve	Silver Lake	Ottawa
	Bushels			
1	87.7	43.6	71.9	81.4
2	84.2	51.8	76.2	82.4
3	99.4	80.2	94.1	78.1
4	101.0	93.9	103.1	79.1
5	97.3	75.5	96.2	83.9
6	98.4	77.4	94.5	85.9
7	97.8	92.9	104.7	86.5
8	98.2	79.1	90.2	75.8
9	96.1	76.7	90.9	87.5
10	98.4	79.3	87.3	79.3
11	100.6	75.0	92.1	76.7
12	105.0	91.2	104.4	81.7
13	97.7	58.8	80.8	83.5
14	104.5	74.4	92.7	80.5
15	104.1	87.3	90.9	88.6
16	104.1	86.9	101.8	80.2
17	96.6	83.9	88.4	86.3
18	101.7	80.9	89.8	85.2
19	97.0	77.8	91.9	82.4
20	100.8	89.5	104.6	86.5
21	102.9	70.4	85.5	83.0
22	98.7	66.3	87.2	80.2
23	99.9	60.7	86.8	83.1
24	92.6	61.7	84.0	78.2
25	96.1	81.2	95.5	81.4

*These yields are the averages of four replications. All yields were converted to a moisture percentage of 15.5 percent. Treatment number refers to corresponding number in Table 1.

Table 27. Effect of rate and placement of nitrogen fertilizer, in pounds per acre, on the yield of corn*, 1948.

Location	Check	Broadcast		Deep placed	
	0-0-0	40# N	80# N	40# N	80# N
	Bushels				
Broughton	87.7	99.4	101.0	100.6	105.0
Reserve	43.6	80.2	93.9	75.0	91.2
Silver Lake	71.9	94.1	103.1	92.1	104.4
Ottawa	81.4	78.1	79.1	76.7	81.7

Table 28. Increase in yield of corn from various treatments over check plots,* 1948.

Location	Treatments, pounds per acre					
	40-0-0	80-0-0	0-20-0	40-20-0	80-20-0	40-20-20
	Bushels					
Broughton	11.7	13.3	3.5	9.6	10.1	10.7
Reserve	36.6	50.3	8.2	31.9	49.3	33.8
Silver Lake	22.2	31.2	4.3	24.3	32.8	22.6
Ottawa	3.3	2.3	1.0	2.5	4.8	4.5

Table 29. Corn yields with and without potassium,* 1948.

Location	Treatments, pounds per acre	
	20# K_2O	No K_2O
	Bushels	
Broughton	101.3	100.9
Reserve	82.4	75.0
Silver Lake	92.7	94.5
Ottawa	87.3	82.2

*Average of 2 treatments with 4 replications of each treatment.

Table 30. Corn yields with and without phosphorus,* 1948.

Location	Treatments, pounds per acre	
	20# P_2O_5	No P_2O_5
	Bushels	
Broughton	98.3	100.7
Reserve	69.5	71.6
Silver Lake	90.0	89.6
Ottawa	80.2	80.7

*Average of 4 treatments with 4 replications of each treatment.

Table 31. Corn yields following early and late side dressing with 20 pounds per acre of nitrogen,* 1948.

Location	Plants 12 inches	Plants 36 inches
	Bushels	
Broughton	102.9	99.9
Reserve	70.4	60.7
Silver Lake	85.5	86.8
Ottawa	83.0	83.1

*Average of 4 replications.

EXPLANATION OF PLATE VII

The effect of various fertilizer treatments on the yield of corn and size of corn ears, Reserve, 1948.

Fig. 1. (left to right)

40-20-20 B
40-20-0 DP
20-20-20 DP
0-0-0
0-20-0
80-0-0 B
80-0-0 DP

Fig. 2. (top row--left to right)

80-0-0 B
80-0-0 DP
40-20-0 B
40-20-0 DP

(bottom row--left to right)

0-0-0
0-20-0
40-20-20 B
40-20-20 DP

PLATE VII

Fig. 1.

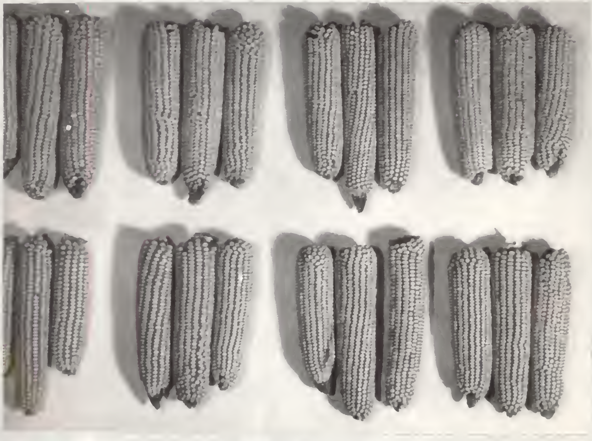

Fig. 2.

Moisture Data

Table 32. Summary of moisture in grain samples at harvest time, corn fertilizer experiment,* 1948.

Treatment no.	Locations			
	Broughton	Reserve	Silver Lake	Ottawa
	Percent			
1	19.50	15.46	14.88	16.25
2	20.00	15.42	14.56	15.59
3	18.92	15.39	14.58	16.28
4	18.99	15.70	14.81	15.40
5	17.14	15.03	14.69	14.80
6	19.15	15.75	14.52	15.84
7	19.58	15.46	15.02	15.27
8	19.09	15.46	14.59	15.41
9	19.09	15.52	14.72	15.59
10	17.79	15.41	15.31	15.42
11	19.15	15.42	14.37	16.63
12	19.64	16.19	15.73	17.58
13	18.98	15.24	14.17	15.40
14	19.71	15.36	14.85	15.76
15	21.25	15.28	14.45	15.33
16	19.28	15.64	15.08	15.69
17	18.37	15.71	14.96	15.46
18	18.92	15.57	14.48	15.74
19	17.88	15.47	14.12	14.91
20	20.04	15.45	14.66	15.77
21	20.60	15.85	14.57	16.56
22	19.70	15.47	14.12	15.54
23	19.70	15.54	15.04	16.38
24	18.96	15.33	14.86	15.45
25	19.12	15.46	14.62	15.38

*These are the averages of four replications. Treatment number refers to corresponding number in Table 1.

Protein Data

Table 33. Protein content of grain from corn fertilizer experiment,* 1948.

Treatment no.	Locations: Broughton	Reserve	Silver Lake	Ottawa
	Percent			
1	9.29	6.90	8.30	9.74
2	8.17	7.36	7.91	9.17
3	9.97	8.12	8.97	9.64
4	9.62	9.29	9.93	10.12
5	8.81	8.38	9.74	9.67
6	9.34	8.13	9.57	9.54
7	9.72	9.20	9.77	10.30
8	9.54	7.96	8.97	9.83
9	10.10	8.25	9.25	9.67
10	9.65	7.80	9.53	9.82

*These are the averages of four replications. Treatment number refers to corresponding number in Table 1.

Phosphorus Data

Table 34. Phosphorus content of grain from corn fertilizer experiment,* 1948.

Treatment no.	Broughton	Reserve	Silver Lake	Ottawa
	Locations			
	Percent			
1	0.29	0.30	0.31	0.24
2	0.30	0.33	0.33	0.26
3	0.32	0.31	0.32	0.24
4	0.28	0.33	0.31	0.24
5	0.28	0.31	0.31	0.26
6	0.26	0.31	0.34	0.26
7	0.30	0.32	0.31	0.25

*These are the averages of 4 replications. Treatment number refers to corresponding number in Table 1.

Statistical Analyses

Table 35. An analysis of variance for the corn yields at Broughton, corn fertilizer experiment, 1948.*

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	6,412.14				
Between treatments	24	2,269.43	94.56	1.67	1.67	2.07
Between blocks	3	60.56	20.12	0.36	2.74	4.08
Error	72	4,082.15	56.69			

*L. S. D. at 1% level = 13.5 bu.
L. S. D. at 5% level = 10.2 bu.

Table 36. An analysis of variance for the corn yields at Reserve, corn fertilizer experiment, 1948.*

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	19,864.89				
Between treatments	24	15,690.02	653.75	11.77	1.67	2.07
Between blocks	3	176.50	65.50	1.18	2.74	4.08
Error	72	3,998.37	55.53			

*L. S. D. at 1% level = 13.8 bu.
L. S. D. at 5% level = 10.5 bu.

Table 37. An analysis of variance for the corn yields at Silver Lake, corn fertilizer experiment, 1948.*

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	8,891.51				
Between treatments	24	6,836.33	284.85	10.15	1.67	2.07
Between blocks	3	34.55	11.52	0.41	2.74	4.08
Error	72	2,020.63	28.06			

*L. S. D. at 1% level = 9.8 bu.
L. S. D. at 5% level = 7.4 bu.

Table 38. An analysis of variance for the corn yields at Ottawa, corn fertilizer experiment, 1948.*

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	5,226.53				
Between treatments	24	1,138.74	47.45	0.97	1.67	2.07
Between blocks	3	559.25	186.42	3.80	2.74	4.08
Error	72	3,528.54	49.01			

*L. S. D. at 1% level = 13.0 bu.
L. S. D. at 5% level = 9.8 bu.

Table 39. An analysis of variance for moisture in grain samples at Broughton, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	423.70				
Between treatments	24	70.71	2.95	0.97	1.67	2.07
Between blocks	3	135.40	4.51	1.49	2.74	4.08
Error	72	217.59	3.02			

Table 40. An analysis of variance for moisture in grain samples at Reserve, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	16.93				
Between treatments	24	4.79	0.20	1.33	1.67	2.07
Between blocks	3	1.27	0.42	2.80	2.74	4.08
Error	72	10.87	0.15			

Table 41. An analysis of variance for moisture in grain samples at Silver Lake, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	29.24				
Between treatments	24	13.07	0.55	2.50	1.67	2.07
Between blocks	3	0.18	0.06	0.28	2.74	4.08
Error	72	15.99	0.22			

Table 42. An analysis of variance for moisture in grain samples at Ottawa, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	99	87.27				
Between treatments	24	34.41	1.43	2.34	1.67	2.07
Between blocks	3	8.85	2.95	4.84	2.74	4.08
Error	72	44.01	0.61			

Table 43. An analysis of variance for protein in grain samples, Broughton, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	39	21.646				
Between treatments	9	11.676	1.30	4.20	2.25	3.14
Between blocks	3	1.616	0.54	1.74	2.96	4.60
Error	27	8.354	0.31			

Table 44. An analysis of variance for protein in grain samples, Reserve, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	39	36.189				
Between treatments	9	19.297	2.14	3.65	2.25	3.14
Between blocks	3	1.026	0.34	0.58	2.96	4.60
Error	27	15.866	0.59			

Table 45. An analysis of variance for protein in grain samples, Silver Lake, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	39	21.740				
Between treatments	9	16.357	1.82	10.40	2.25	3.14
Between blocks	3	0.665	0.22	1.27	2.96	4.60
Error	27	4.718	0.18			

Table 46. An analysis of variance for protein in grain samples, Ottawa, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	39	22.053				
Between treatments	9	3.430	0.38	0.57	2.25	3.14
Between blocks	3	0.729	0.24	0.37	2.96	4.60
Error	27	17.894	0.66			

Table 47. An analysis of variance for phosphorus in grain samples, Broughton, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	27	0.0383				
Between treatments	6	0.0085	.0014	1.00	2.66	4.01
Between blocks	3	0.0050	.0016	1.14	3.16	5.09
Error	18	0.0248	.0014			

Table 48. An analysis of variance for phosphorus in grain samples, Reserve, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	27	0.0077				
Between treatments	6	0.0037	0.0006	4.29	2.66	4.01
Between blocks	3	0.0014	0.0005	3.57	3.16	5.09
Error	18	0.0026	0.00014			

Table 49. An analysis of variance for phosphorus in grain samples, Silver Lake, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	27	0.0164				
Between treatments	6	0.0038	.00063	0.94	2.66	4.01
Between blocks	3	0.0012	.00040	0.60	3.16	5.09
Error	18	0.0114	.00067			

Table 50. An analysis of variance for phosphorus in grain samples, Ottawa, corn fertilizer experiment, 1948.

Source of variance	D/F	S. S.	Variance	Calculated "F"	Table "F" 5%	Table "F" 1%
Total	27	0.0290				
Between treatments	6	0.0025	0.0004	0.57	2.66	4.01
Between blocks	3	0.0142	0.0047	6.91	3.16	5.09
Error	18	0.0123	0.0007			

Table 51. Correlations, corn fertilizer experiment, 1948.

	"r" values			
	Broughton	Reserve	Silver Lake	Ottawa
Protein x phosphorus (n=28)	0.266	0.375*	-0.020	-0.048
Protein x yield (n=40)	0.199	0.666**	0.739**	0.036
Phosphorus x yield (n=28)	0.093	0.381*	-0.194	0.283

* Significant at 5% level.
**Significant at 1% level.

DISCUSSION OF RESULTS

Broughton

From the rainfall data in Table 3 it will be noted that there was an abundant supply of moisture during the growing season. The precipitation which fell during the period of growth was well distributed; consequently the moisture supply was not a limiting factor at this location.

As can be observed from Table 8, the soil at Broughton was well supplied with available phosphorus and exchangeable potassium but slightly low in total nitrogen. This suggested that a response from phosphorus and potassium could not be expected but the application of nitrogen might give a response.

Results of plant tissue tests during the growing season showed that where nitrogen was applied there was an accumulation of nitrates in the conducting tissues of the plant. According to Table 4, only a small amount of nitrates was accumulating within the plants on the check plot. This indicated that the use of nitrogen should promote greater plant growth. In general, tissue tests for phosphorus suggests that phosphorus was being utilized immediately since there was very little accumulation within the plant. The tissue tests indicated that the potassium supply was abundant since there was an accumulation of potassium within the plant.

According to the analysis of variance shown in Table 35, there was a significant difference between treatments as they affected the yields. It can be noted in Table 26 that treatments 12, 14, 15, and 16, which are the higher rates of nitrogen deep placed, gave the greatest increase in corn yields. Reference to the photographs in Plate II shows that during the latter part of June the nitrogen which was deep placed was promoting the best plant growth. Table 27 indicates that the plots receiving the broadcast application of nitrogen yielded a little less than the plots receiving the deep placed applications of nitrogen. This difference in yield from the two methods is not significant, however. It can also be noted that 80 pounds of nitrogen per acre was not much more effective than 40 pounds of nitrogen per acre. These facts are in conformity with the photographs taken during the growing season. Observation of Tables 29 and 30 indicates that there was no yield increase from the use of potassium and phosphorus. The chemical analysis of the soils and the observations of plant growth in June show that this could be expected. It is to be noted from Table 26 that yields from early and late side dressings with 20 pounds of nitrogen per acre compared favorably with the yields from the higher nitrogen rates applied by other methods. It is possible that the reason for the effectiveness of the side dressings is due to the fact that nitrogen was applied at a period when most needed for plant growth. The early side dressing gave a somewhat better yield response than the late side dressing. Where nitrogen was side dressed on plots receiving phosphorus at planting time the yield was less than when phosphorus was not used.

It is to be observed from Table 32 that the percent moisture in the grain samples from all fertilizer treatments was quite high. Since the harvesting of this area was done in September, this is to be expected. There was no significant difference in the amount of moisture between treatments as indicated in Table 39.

Table 33 shows that when phosphorus was applied alone and in combination with 40 pounds of nitrogen per acre broadcast the protein content of the grain was reduced below that of the check plot. With all the other treatments the use of nitrogen increased the protein content above the check plot. The early side dressing in combination with 20 pounds of nitrogen per acre broadcast gave the greatest increase in content of protein. The analysis of variance as shown in Table 43 indicates that there was a significant difference in protein content between treatments.

It can be noted from Table 34 that regardless of the fertilizer treatment the phosphorus content was not varied to any great extent. There was no significant difference between treatments as indicated in Table 47. Correlations in Table 51 showed no significant differences between protein x phosphorus, protein x yield, and phosphorus x yield.

Reserve

The moisture supply at Reserve appeared to be adequate for a good corn yield according to the data in Table 3. This precipitation was well distributed so that a period of prolonged drought did not exist at any time during the growing season.

Chemical analysis of the soil as shown in Table 8 indicated there was an abundant supply of potassium, but the content of phosphorus and nitrogen was about medium. This suggested that the application of the latter two nutrients might give a response in yield.

Plant tissue tests conducted during the growing season indicated that nitrate accumulation was reduced where phosphorus was used alone and in combination with nitrogen and potassium. It can be seen from Table 5 that the use of 80 pounds of nitrogen per acre applied as a broadcast application or deep placed resulted in an accumulation of nitrates in the plant tissue. Plants, therefore, which received only nitrogen had a plentiful supply of nitrates for growth. Since the tissue tests showed an accumulation of phosphorus and potassium it is apparent that the plants were well supplied with these two nutrients at that particular stage of growth.

It is shown from the statistical analysis in Table 36 that there was a significant difference between the yields received from the various treatments. Referring to Table 26 it is seen that the use of 20, 40, and 80 pounds of nitrogen per acre gave a very significant increase in yield. This is exactly opposite from what was expected in July when the photograph shown in Plate III was taken. This photograph clearly indicates that for some unknown reason there was very little difference in growth among the plants receiving the various nitrogen treatments. The observations in September, however, were in agreement with the final yields obtained.

Eighty pounds of nitrogen per acre were more effective in increasing the yield of grain than 40 pounds of nitrogen per acre as shown in Table 27. In addition, different methods of nitrogen application did not cause significant variations in yield. It is to be noted in Table 31 that the early side dressing was much more effective than the late side dressing. Due to wet soil at the time the late side dressing should have been applied this application was delayed which may account for the variation in yield between the two methods. As shown in Table 30 the use of phosphorus with nitrogen did not increase the yield above those plots receiving nitrogen alone; however, phosphorus applied alone resulted in an increase in yield above the check plots. The yield data in Table 29 suggest the possibility of a response from potassium at this location even though the chemical analysis of the soil indicated that no increase should be expected. It should be noted, however, that the increase in yield from potassium was not statistically significant.

The photographs in Plate VII indicate the effect of various nitrogen treatments alone and in combination with phosphorus on yield and the effect on size of ears. Observation of Fig. 2 shows that the largest ears are from the plots receiving the high nitrogen rates. The ears from the no treatment plot are smaller and not as uniform in size.

It can be observed in Table 32 that there was very little variation in the moisture content of the grain samples among the different fertilizer treatments. It is evident that the percentage of moisture is highest in the 80-0-0 fertilizer treatment where the nitrogen was deep placed. The analysis of variance, as shown in Table 40, indicated that there was no significant difference in the moisture content of the grain samples among the treatments, but that there was a significant difference at the five percent level between the blocks.

There was a significant difference in the amount of protein among the various fertilizer treatments according to data in Table 44. The use of 40 and 80 pounds of nitrogen per acre either alone or in combination with phosphorus increased the protein content of the grain samples as shown in Table 33. It cannot be explained why the protein content of the grain samples coming from plots receiving phosphorus alone was higher than that in the grain samples from the check plots.

There was a significant difference in the phosphorus content of the grain among the different fertilizer treatments as well as a significant difference between blocks at the five percent level as shown in Table 48. Results shown in Table 34 indicate that the application of phosphorus alone increased the content of the phosphorus in the grain samples to the greatest extent. The reason for the high content of phosphorus in the samples from the plots receiving 80 pounds of nitrogen per acre broadcast is unknown. The use of phosphorus with nitrogen tended to reduce the phosphorus content of the grain below that found in the samples receiving phosphorus alone. Correlations in Table 51 indicate that protein x phosphorus and phosphorus x yield was significant at the 5 percent level and that protein x yield was significant at the 1 percent level.

Silver Lake

The rainfall was well distributed throughout the growing season at this location. Table 3 suggests that the amount of precipitation was conducive to good corn yields.

Chemical analysis of the soils, as indicated in Table 8, showed the soil to be very high in exchangeable potassium but about medium in available phosphorus and total nitrogen.

Tissue tests indicated that there was an abundant supply of nitrates in the plants on plots where nitrogen had been applied. According to Table 6, the no treatment and phosphorus alone plots were low in nitrates suggesting that the plants on these plots should respond to more nitrogen if applied. Tests for phosphorus showed an accumulation within the plant indicating that the plants had an abundant supply for growth. In general, the tissue tests showed that potassium was not accumulating to a great extent in those plants which had received the higher nitrogen treatments. This suggested the possibility of an unbalance of plant nutrients.

The statistical analysis, as shown in Table 37, indicated that there was a significant difference in yields among the treatments. It can be seen from Table 26 that the five fertilizer treatments consisting of 80 pounds of nitrogen per acre resulted in corn yields greater than 100 bushels per acre. Table 27 clearly demonstrates that 80 pounds of nitrogen per acre were more effective than 40 pounds of nitrogen per acre and that there was no difference in yield between the broadcast and deep placed methods. It can be observed from Table 31 that the early and late side dressings resulted in a significant yield increase but neither method was superior to the other. It was found, as indicated in Table 30, that the addition of phosphorus to the nitrogen treatments, as well as when applied alone, did not increase the corn yields. In addition the use of potassium with the various treatments, as shown in Table 29, did not result in an increased yield. The photographs shown in Plate III suggested that a response from phosphorus alone might have been expected. The plant growth, also, suggested that yield results between 40 and 80 pounds of nitrogen per acre would not be great. The final yields, however, were contrary to these observations.

From Table 32 it can be seen that the difference in moisture content of the grain samples from the various treatments was not marked; however, the analysis of variance, shown in Table 41, indicated that there was a significant difference in moisture content among the fertilizer treatments. It is to be noted that the grain from the 80-0-0 treatment plot having the nitrogen deep placed had the highest moisture content.

Results in Table 45 indicate that there was a significant difference in the content of protein in the grain from the various fertilizer treatments. The results of the protein analysis shown in Table 33 show that the highest content of protein was found in the grain coming from plots receiving 80 pounds of nitrogen per acre. The use of 40 pounds of nitrogen per acre increased the protein content of the grain above the content of the samples coming from the no treatment plots. The application of phosphorus alone reduced the protein below that found in the grain of the check plots.

It is to be observed from Table 34 that the use of phosphorus had no appreciable effect on the phosphorus content of the grain. The highest amount of phosphorus was found in the grain coming from plots receiving phosphorus alone and a complete fertilizer. The statistical analysis indicated that there was no significant difference in the phosphorus content as a result of different fertilizer treatments. The correlations in Table 51 show no difference that was significant between protein x phosphorus and phosphorus x yield but that there was a significant difference at the 1 percent level between protein x yield.

Ottawa

According to Table 3, the Ottawa area received the largest amount of rainfall of all the four experimental locations. This precipitation was well distributed which means that the moisture was not a limiting factor in corn production.

The chemical analysis of the soils, as shown in Table 8, clearly indicates that the soil was low in available phosphorus and exchangeable potassium. Therefore, it appeared that yield increases might be expected from the application of phosphorus and potassium. Since the nitrogen content was at a medium level a response from the addition of nitrogenous fertilizers might be expected also.

Results of the plant tissue tests indicated that in general there was an abundant supply of nitrogen and potassium since these two nutrients accumulated within the plant. Table 7 indicates that the tests for phosphorus on plants growing on plots receiving various fertilizer treatments gave no color reaction. This suggested that the application of more phosphorus might have promoted the growth of plants.

The statistical analysis as shown in Table 38 indicated that there was no significant difference in yield from the fertilizer treatments, but there was a significant difference among the blocks. The reason for the difference among blocks may be explained on the basis of a variation in soil type. From Table 26 it can be observed that the yield responses from the various fertilizer treatments were erratic. The greatest increase in yield of 7.2 bushels per acre was obtained from the complete fertilizer where the nitrogen was deep placed. This yield increase, however, was not significant. Table 30 indicates that the use of phosphorus with various combinations of fertilizer did not increase the yield. The use of potassium increased the yield as shown in Table 29 but not significantly. Observation of Table 28 shows that the different fertilizer treatments increased the corn yields slightly in some cases.

The yield response was not in conformity with the chemical data which indicated that a yield response could be expected. In addition, the plant tissue tests showed that the application of phosphorus should be conducive to plant growth. Observations during the early growth period strongly suggested that marked differences in yield would be realized. Photographs of the plant growth later in the season, as shown in Plate V, indicate that the application of a complete fertilizer should have given a good response. Because of the poor yield response obtained at Ottawa it was decided to analyze this soil physically in comparison with a physical analysis of the soil at Reserve. The analyses for the pore size distribution on the various plots at these locations are indicated in Tables 9 to 20 inclusive. The summary of these results in Table 21 shows that there was little difference in the percent of the soil volume drained under the various tensions in the surface soils at both areas; however, there was a difference in the subsoil. At tensions of 40 to 120 cm the number of pores which drained at Ottawa were only half as great as the number of those which drained at Reserve. This suggests the possibility that the Ottawa subsoil may not be aerated adequately. Fertilizer responses in other states have been erratic when this condition existed. The summary of the water stable aggregates shown in Table 23 indicates that due to soil structure there may be less drainage in the surface soil at Ottawa than at Reserve. According to Table 25, the moisture equivalent data are indicative of the fact that the soils at both locations are similar in texture.

Since the differences in growth among the plots disappeared as the season advanced, it is possible that when the roots of the corn plants penetrated the deeper soil zones where aeration may be restricted, the effectiveness of the fertilizer applications may have been nullified. If this were actually the case, an erratic yield response could be expected as a result.

From Table 32 it can be observed that the grain with the highest percent moisture was that which came from the plots where 80 pounds of nitrogen per acre were applied as a deep placement. The analyses of variance results shown in Table 42 indicate that there was a significant difference in moisture content among the fertilizer treatments. Again, it cannot be explained why there was a significant difference in moisture between the blocks except that a variation in the soil type may be the cause.

Observation of Table 33 shows that the grain having the highest percent protein was that which came from plots receiving 80 pounds per acre of nitrogen broadcast alone or in combination with phosphorus. The phosphorus treatment alone reduced the content of protein slightly below the no treatment which is to be expected. From the statistical analysis indicated in Table 46 it was learned that there was no difference in the content of protein in the grain between the various fertilizer treatments.

It can be seen from Table 30 that the phosphorus content of the grain samples varied only slightly between the fertilizer treatments. According to Table 50, the analysis of variance showed no significant difference in the content of phosphorus among the treatments but a significant difference among the blocks. The difference among the blocks probably can be explained on the basis of a variation in soil type. Table 51 indicated that there was no significant differences in the various correlations.

SUMMARY AND CONCLUSIONS

The following conclusions can be made from the corn fertilizer experiment conducted in 1948:

1. A significant increase in the yield of corn was obtained as a result of fertilizer application at Broughton, Reserve, and Silver Lake. No significant increase in yield above the untreated plots was obtained at Ottawa.

2. The addition of phosphatic fertilizer alone did not significantly increase the yield of corn at any of the locations.

3. The addition of phosphatic and potassic fertilizers to the nitrogen application did not have a significant effect on the yield of corn at any location.

4. Early and late side dressing applications of nitrogen gave a significant increase in yield at Broughton, Reserve, and Silver Lake.

5. The 80-pound nitrogen application was more effective than the 40-pound application at Reserve and Silver Lake. This effect was not so apparent at the Broughton area.

6. There seemingly was little difference in the effectiveness of the nitrogen application at Broughton, Reserve, and Silver Lake with respect to the method of application.

7. It is believed that the erratic yield response at Ottawa was due to poor aeration in the subsoil.

8. The use of nitrogenous fertilizers resulted in significant differences in the protein content of the grain at Broughton,

Reserve, and Silver Lake.

9. The use of phosphatic fertilizers resulted in significant differences in the phosphorus content of the grain at Reserve.

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