THE EFFECT OF TIME AND METHOD OF PLACEMENT OF FERTILIZER ON THE YIELD OF CORN

by

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INTRODUCTION

Most of the early studies of fertilizer placement were concerned primarily with vegetable crops, especially potatoes, tomatoes, peas and beans. The effects on the yield and quality immediately stimulated interest in the possibilities of different methods of fertilizing more extensively farmed crops, particularly corn and cotton. Results of investigations of fertilizer placement on corn began to appear in the literature in 1935, but many of these early studies were comparing rate and kinds of fertilizer rather than time and method of placement.

Investigators throughout the area where corn is grown have contributed information to the problem of fertilizer placement, and the results have been erratic and conflicting. Not all workers have compared the same rates or time of application. Few of the earlier writers included all of the data of soil class, acidity, soil aeration and moisture, and climate, which are essential to interpretation of the results. Hoffer (1) and Kirk (2) have explained the conflicting results of fertilizers on corn in the Midwest on the basis that soil aeration as well as the supply of chemical elements is a function of plant growth and nutrition. Krantz, Ohlrogge, and Scarseth (3) have shown that nutrient availability is dependent on the moisture supply and that erratic results may be due to the effects of droughty periods.

The outstanding work by Scarseth (4) on plow sole fertilizer placement has encouraged the general use of fertilizers on corn. Farmers in Kansas have been applying fertilizers to corn according to either practices followed in other states or by guess work because there is no available information under Kansas conditions.

Metzger (5) obtained results for the 1940 growing season at the Kansas Agricultural Experiment Station on sorghums, which indicated that only deep placement of superphosphate resulted in any significant increase in the yield of grain.

The widespread use of fertilizers by farmers with little information as to how or when it should be applied under Kansas conditions suggested the need for a study of the effect of time and method of placement of fertilizers on the yield of corn.

REVIEW OF THE LITERATURE

Plow Sole Method of Fertilizer Application

Beard and Slipher (6) list two main possible advantages of placing nutrients deep in the soil. First, the plow sole is more consistently moist during the growing season than the surface layer, favoring an uninterrupted rate of solution of the nutrients. Second, the greater mass of the corn roots lies below the upper plow layer so that the deep application of the nutrients places them nearer to the root zone where they will be more readily taken up by the plant. In addition, the deep placement of nutrients increases the efficiency of fertilizers during droughty seasons. The weed hazard set up in wet seasons by the use of nitrogen-containing fertilizers in the upper layer of the soil is eliminated and the danger of losing applied nutrients by erosion on sloping land is avoided.

Fertilizer demonstrations carried out on different farms in Wisconsin by Chapman (7), using 500 pounds per acre of 10-10-10 applied on the plow sole, gave increases in corn yields of from 3.2 bushels per acre on a high-fertility plot to 35.9 bushels per acre on a soil with a low level of fertility.

Scarseth (4), studying placement of fertilizers on corn on Indiana soils, concluded that where nitrogen is needed for corn it can be used directly by plowing it under in adequate amounts (80 pounds per acre), but it must be balanced with adequate amounts of phosphate and potash. When moisture becomes the first limiting factor, fertilizers will not increase yield, even if the corn shows large differences in vegetative growth, because the larger plants, stimulated by the added nutrients, require more water and may suffer more for the lack of it. Scarseth (4) found that corn will not suffer as much from a mild drought where the fertilizers are placed deep as when placed shallow.

Weidemann (8) stated that there is reason for thinking that fertilizer treatments which result in a large growth of stalk, particularly in the early summer, are not conducive to large yields of grain unless the latter part of the season is especially favorable. In seasons of low precipitation, plow sole placement of fertilizer containing a low amount of nitrogen (2-12-6) resulted in decreased yields. This was accounted for by the tendency of the fertilizer to increase the early growth of the corn and to stimulate the production of suckers which resulted in smaller ears and a higher percentage of barren stalks.

Millar (10) observed that corn grown on silt loam, loess, claypan prairie and residual limestone soils of Missouri with 800 pounds per acre of 10-10-10 plowed under withstood drought conditions for 10 days to two weeks longer without serious firing than did corn receiving fertilizer in the row or corn which received no fertilizer.

Chapman (11) reported increases in corn yields due to plow sole applications of 400 to 800 pounds of 8-8-8 fertilizer ranged from 10 to 40 bushels per acre. He found that on Wisconsin soils, where the fertility level is high or above average, there will not be any marked response to fertilizer treatments but that on those fields where the fertility level is low and where manure is not available, profitable returns can be expected from the use of fertilizers.

Reed and Salter (12) reported that significant increases in yield have been obtained from plow sole treatments on Ohio soils of high fertility level as well as on the poorer soils. The lack or excess of soil moisture at critical growth periods may completely overshadow responses from added plant nutrients.

Terman (13) showed that the application of 500 pounds per acre of 10-8-8 by surface and plow sole methods in Kentucky during the 1944 season, which was generally unfavorable for corn due to drought and high temperatures at tasseling time, showed no significant increases in yield of ear corn, no matter how it was applied, with the exception of a single test. On some tests an actual decrease was obtained. During the 1945 season, which was generally favorable for corn, there was a greater response to deep placement than to the surface application of fertilizers.

Row Treatment Method of Fertilizer Application

Klemme (10) states that on Oswego silt loam in Missouri an application of 150 pounds per acre of 4-12-4 in bands in the row at planting time may increase the corn yield 5 to 12 bushels per acre in years when the rainfall is well distributed throughout the growing season, but yields may be decreased in seasons with short droughts, especially if they occur during the tasseling and silking stages.

According to Scarseth (4), if the soil is very dry during the period that corn should be making its maximum growth, the plant roots cannot take in much nitrogen, phosphorus, or potassium from the soil when these nutrients have been placed near the surface or in the row at the usual depth of about two inches. He observed that under droughty conditions the phosphate and potash remained in place in the dry soil, while the nitrogen moved to the surface as nitrates where it accumulated, causing all of the nutrients to be out of reach of the roots which were reaching deeper into the moist soil.

Chapman (7) obtained increases in corn yields ranging from 14 to 71.8 bushels per acre from the addition of 150 pounds per acre of 10-10-10 in the hill as a starter fertilizer to plow sole treatments as compared with yield increases of 3.2 to 35.9 bushels per acre for plow sole treatments without the row treatment.

Ohlrogge, Krantz and Scarseth (14) pointed out that nitrogen in the form of ammonium sulfate applied in the row on Vigo silt loam stimulated early vegetative growth but did not materially affect the yield if the corn was short of nitrogen at tasseling time.

Side Dressing Method of Fertilizer Application

Krantz (15) studied the effect on corn yield of a side dressing application of nitrogen, with nitrogen applied in bands in the row at seeding time. On four sandy loam soils under adequate moisture conditions with 20 pounds of nitrogen per acre in bands at seeding time, a side dressing application of 40 pounds of nitrogen increased yields an average of 36 bushels per acre, while 100 pounds gave an increase of 57.8 bushels per acre. On these sandy loam soils side dressings of 20 and 60 pounds of nitrogen per acre in addition to the row treatment gave marked increases in yields but 100-, 140-, and 180-pound applications gave no further increases in yield.

Previous studies by Krantz (16) show that on sandy loam soils with 65 per cent of normal rainfall in June, July and August the addition of 40 pounds of nitrogen per acre as a side dressing with 20 pounds of nitrogen per acre in the row increased corn yields 30.6 bushels or one bushel for each 1.3 pounds of nitrogen applied. Eighty pounds of nitrogen as a side dressing increased the yield only 37.6 bushels per acre. Krantz (16) drew the conclusion from these studies that droughty weather is an important limitation in producing high yields but that it appears that corn yields can be increased by adequate fertilization, even under droughty conditions.

Recent work by Prince and Blood (17) with sweet corn resulted in marked increases in yield of ears with a side dressing of 200 pounds per acre of nitrate of potash (14-14-0) in a season of ample rainfall, but in the drier seasons the increases in yield were very slight.

Coleman (18) reported that over a period of eight years, an application of 24 pounds of nitrogen per acre under the corn at planting time produced the same amount of corn as 24 pounds of nitrogen applied as a side dressing. Splitting the treatments to apply 12 pounds of nitrogen per acre under the corn at planting time, and 12 pounds as a side dressing, was definitely superior to any other method of application studied. The side dressings were applied at one-foot, two-foot, three-foot and tasseling stages of growth. There was no difference in the amount of corn produced by the different side dressing treatments.

MATERIALS AND METHODS

Location and Description of Plots

This experiment was carried out on three farms in 1946. The first location was the Lind-Mullen farm five miles southwest of Manhattan. The second location was on the H. H. Carnahan farm at Stockdale, 12 miles north of Manhattan, and the third plot was located on the Scott Kelsey farm at Rossville, 30 miles east of Manhattan. All three plots were on level alluvial soils.

Previous yields indicated that the fertility level of the soil on the Lind-Mullen farm is not high but is capable of producing yields of 50 bushels of corn per acre under the most favorable conditions. The field in which the plots were located has been continuously cropped to corn for 25 years. The plot area was level, well drained and uniform in texture.

The soil on the Carnahan farm is high in organic matter, level and well drained. Corn had been grown on the plot location for the previous three years and maximum yields of 60 bushels per acre have been obtained.

The corn plots on the Kelsey farm followed soybeans, which had been harvested for grain. Previous corn yields in most seasons have reached 80 bushels per acre. The soil is high in organic matter but not well drained, as it is located in a section of the flood plain where the watertable is close to the surface.

Soil analyses were made on each location and are given in Table 1. The available phosphorus and exchangeable potassium were determined by the photometer method as described by Arnold and Kurtz (19) and Bray (20).

Plan of Experiment

The statistical design used in this experiment was the split-plot method as described by Snedecor (21) and Paterson (22) and is

Table 1. Summary of soil analyses of corn-fertility plots.

Farm	Soil class	pH	Available phosphorus (pounds per acre)	Exchangeable potassium (pounds per acre)
Lind-Mullen	Silt loam	6.14	136	450
Carnahan	Silty clay loam	5.62	44	324
Kelsey	Very fine sandy loam	5.30	260	405

Table 2. Plan of experiment for time and methods of fertilization for corn in 1946.

Replication	Fertilizer treatment: Plow sole treatment	Row treatment: 1	2	3	4	5
1	NP mix[1]	Untreated	NH_4NO_3(ST)[2]	NH_4NO_3(LC)[3]	43% Super	NP mix
	NH_4NO_3	43% Super	NH_4NO_3(ST)	NP mix	Untreated	NH_4NO_3(LC)
	43% Super[4]	NP mix	NH_4NO_3(LC)	43% Super	NH_4NO_3(ST)	Untreated
	Untreated	Untreated	43% Super	NH_4NO_3(LC)	NP mix	NH_4NO_3(ST)
2	NH_4NO_3	NP mix	NH_4NO_3(ST)	NH_4NO_3(LC)	Untreated	43% Super
	NP mix	43% Super	Untreated	NH_4NO_3(LC)	NP mix	NH_4NO_3(ST)
	43% Super	Untreated	43% Super	NP mix	NH_4NO_3(LC)	NH_4NO_3(ST)
	Untreated	NH_4NO_3(LC)	43% Super	Untreated	NH_4NO_3(ST)	NP mix
3	Untreated	NH_4NO_3(ST)	43% Super	NP mix	Untreated	NH_4NO_3(LC)
	NH_4NO_3	Untreated	NH_4NO_3(ST)	43% Super	NP mix	NH_4NO_3(LC)
	43% Super	Untreated	NH_4NO_3(LC)	NP mix	43% Super	NH_4NO_3(ST)
	NP mix	NP mix	NH_4NO_3(ST)	Untreated	NH_4NO_3(LC)	43% Super
4	43% Super	Untreated	NH_4NO_3(ST)	NH_4NO_3(LC)	43% Super	NP mix
	Untreated	NP mix	NH_4NO_3(ST)	43% Super	Untreated	NH_4NO_3(LC)
	NH_4NO_3	43% Super	NH_4NO_3(LC)	NH_4NO_3(ST)	NP mix	Untreated
	NP mix	NP mix	NH_4NO_3(LC)	NH_4NO_3(ST)	43% Super	Untreated

[1] Fertilizer mix containing both NH_4NO_3 and 43% superphosphate

[2] ST indicates that bands are beside the seed in the row at seeding time

[3] LC indicates side dressing at last cultivation

[4] 43% treble superphosphate

presented in Table 2. The analysis of variance showing the sources of variation with corresponding degrees of freedom (DF) for this design is given in Table 3.

Table 3. Analysis of variance of split-plot experiment.

Sources of variation	Degrees of freedom
Complete plots	
Plow sole treatments	3
Replications	3
Error (a)	9
Subplots	
Row treatments	4
Plow sole x row treatment interaction	12
Row treatment x replication interaction	12
Error (b)	36

The plow sole treatments were randomized within each block, but the row treatments were only partially randomized, as each row treatment must appear once and only once on each plow sole treatment plot.

This design provides a more critical comparison of the subplots or row treatments and a more general or less critical comparison of the complete plots or plow sole treatments.

Each complete plot or plow sole treatment was 14 feet wide and 200 feet long, which contained 0.064 acre, and was replicated four times.

The subplots or row treatments were 14 feet wide and 40 feet long, which contained 0.0128 acre, and were replicated 16 times.

Four rows of corn 42 inches apart were planted on each plot so that the two outside rows would serve as borders, while the two center rows were to be harvested for yield. The rows on the Carnahan farm were 38 inches apart.

Experimental Procedure

The fertilizer materials were distributed on the plow sole at a depth of seven inches with a plow fertilizer attachment that applied one band in the bottom of each furrow. A cultivator with two large shovels was used to open furrows three to four inches deep and 42 inches apart in which the corn was to be planted. The subplots or row treatments were applied by distributing the fertilizer by hand in a continuous band. Two bands were placed in each furrow from five to seven inches apart and then covered to a depth of 1½ to 2 inches. The corn was then planted with either a horse-drawn or tractor-mounted planter in the same manner as the rest of the field. This placed a band of fertilizer from 2½ to 3½ inches to either side and at the same depth as the seed.

K2234, a Kansas white hybrid, was planted on the Carnahan and Kelsey farms, and a yellow commercial hybrid was planted on the Lind-Mullen farm. The seed was drilled in the row at all three locations so that the spacing was 18 to 20 inches between plants.

Ammonium nitrate containing 32.5 per cent of total nitrogen was applied at the rate of 45 pounds per acre of total nitrogen. Treble superphosphate carrying 43 per cent of available P_2O_5 was applied at the rate of 45 pounds per acre of available P_2O_5 .

The plow sole treatments were applied on the Lind-Mullen farm March 14 and the row treatments at seeding time April 30. The side dressing of nitrogen was put on July 4, which was 65 days after the planting date. The corn averaged from 36 to 42 inches in height at this date.

The plow sole treatments on the Carnahan farm were applied April 4 and the row treatment applications at seeding time were made May 20. The side dressing of nitrogen was made on this farm July 13, 54 days after planting. The corn on these plots averaged 36 to 40 inches in height.

On the Kelsey farm the fertilizer was distributed on the plow sole April 28 and in bands beside the seed on May 7. The nitrogen side dressing was applied July 3, 57 days after planting. On this date, the corn averaged 42 to 48 inches in height.

On each plot the two center rows were harvested, with the two outside rows serving as border or guard rows. One two-hundredth of an acre was harvested in each subplot and the weight of the ear corn was taken as the yield. The stand count was determined by counting the total number of stalks in the harvested area.

On July 24, tissue tests were made one replication of all plow sole and row treatments on the Carnahan farm and on the Lind-Mullen farm. The method used was the Purdue test for available nutrients as described by Thornton, Conner and Fraser (23). These tests were made on the Lind-Mullen farm one week after tasseling and on the Carnahan farm as the first tassels were emerging. It is believed that any deficiencies of nutrients at this stage of growth will be limiting factors in the yield of grain. Studies at the Ohio Agricultural Experiment Station (24) show that less than five per cent of the total nitrogen used by the corn plant was taken up during the first month of growth, but, during the fast period of growth in July and August, 68 pounds per acre of nitrogen each month were required to produce maximum yields.

Season and Growing Conditions

The early portion of the growth period during the months of April, May and June was very favorable for corn. Although the average monthly rainfall totals were below the normal, according to weather bureau reports (25), soil moisture was sufficient for rapid growth.

A droughty period occurred during July and August as the corn reached its maximum growth and entered the tasseling stage on the Carnahan and Lind-Mullen farms. No rainfall records are available for the Kelsey farm, but these plots received a greater amount of rainfall during this critical period.

EXPERIMENTAL RESULTS AND DISCUSSION

The total number of stalks per plot for each location is given in Tables 4, 6 and 8, and the average number of stalks per plot is given in Table 10. The average number of stalks per acre for each treatment is shown in Table 11.

Yields for each location are presented in Tables 5, 7 and 9 as pounds of ear corn per plot, and the averages of these yields are given in Table 12. A summary of the yields converted to bushels of ear corn per acre is given in Table 13.

A summary of average ear weights computed as pounds per ear is contained in Table 14.

Results presented in these tables are shown graphically in

Plates 1, 2 and 3.

The F-ratios obtained by calculation of the analysis of variance for stand count and yield for each location together with the F-values required for significance at the five and one per cent levels are presented in Table 15.

Lind-Mullen Farm

The stand counts for each plow sole treatment on the Lind-Mullen farm, as presented in Table 4, show that plowing under ammonium nitrate and a mixture of ammonium nitrate and 43 per cent treble superphosphate resulted in a significant increase in the number of stalks as shown by the F-ratios given in Table 15. The F-ratios for both of these treatments exceed the critical F-value required at the five per cent level. The increase in the number of stalks was due to the stimulation of suckering by the added nitrogen. Plowing under superphosphate alone had no effect on the number of stalks on this farm.

The row treatments produced increases in the number of stalks when these treatments included fertilizers containing nitrogen. Ammonium nitrate placed in the row at seeding time gave the largest increase and the determination of the fiducial limits shows that it is significantly greater than the untreated plots at the five per cent level. There were consistent differences between the replications of the row treatments for which no satisfactory explanation can be given.

There was no appreciable difference between the plow sole treatments in their effect on average ear weights. Superphosphate applied in the row at seeding time had no effect on the average ear weight. The ammonium nitrate applications in the row seemed to give a slight increase in the average ear weight.

Plowing under fertilizers had no significant effect on the yield of ear corn. Superphosphate, either with or without ammonium nitrate, gave a slight indication toward decreased yields.

Ammonium nitrate added at last cultivation gave a yield increase of 8.52 bushels of ear corn per acre over the untreated plot. This difference exceeded that value required for significance at the five per cent level. Ammonium nitrate applied in the row at seeding time produced slight increases in yields while the superphosphate treatment in the row at seeding time resulted in a slight decrease in yield.

Plant tissue tests were made on one replication at silking time to determine the relative abundance of nitrates, available phosphate and available potash in the plants. Corn on all plots where no fertilizer was plowed under was deficient in nitrates except where ammonium nitrate had been applied alone in the row at seeding time. Low tissue tests were obtained on those plots where superphosphate was plowed under except where ammonium nitrate had been placed in the row at seeding time, and as a side dressing at last cultivation. The application of ammonium nitrate on the plow sole resulted in an abundance of nitrate in the plants when there was also a row treatment of ammonium nitrate. Plant tissue tests showed nitrate deficiencies on this plow sole treatment where the row treatment contained no ammonium nitrate. Placing ammonium nitrate-superphosphate on the plow sole produced an abundance of

Table 4. Stand counts of corn-fertility experiment on Lind-Mullen farm, 1946, showing number of stalks per 1/200 acre plot.

Plow sole treatment	Replication	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	37	36	39	41	37	190
	2	35	39	36	41	39	190
	3	35	40	38	51	38	202
	4	41	32	35	40	49	197
	Total	148	147	148	173	163	779
43% treble superphosphate	1	37	43	32	41	46	199
	2	44	37	43	35	42	201
	3	46	39	37	46	38	206
	4	35	34	34	38	29	170
	Total	162	153	146	160	155	776
NH_4NO_3	1	45	42	41	35	47	210
	2	40	44	41	48	41	214
	3	49	46	43	49	54	241
	4	39	42	42	55	41	219
	Total	173	174	167	187	183	884
NP mix	1	36	47	42	50	50	225
	2	38	43	38	53	57	229
	3	42	45	47	43	49	226
	4	39	42	45	46	47	219
	Total	155	177	172	192	203	899
Sum of totals		638	651	633	712	704	3338

Table 5. Yields of corn-fertility experiment on Lind-Mullen farm, 1946, showing pounds of ear corn per 1/200 acre plot.

Plow sole treatment	Replication	Row treatment					
		Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	15.3	12.1	16.9	19.7	18.2	82.2
	2	11.5	11.9	17.1	20.0	19.5	80.0
	3	13.3	9.0	19.4	14.5	19.0	75.2
	4	9.5	9.1	11.6	12.5	12.1	54.8
	Total	49.6	42.1	65.0	66.7	68.8	292.2
43% treble superphosphate	1	10.5	12.3	18.2	18.4	10.4	69.8
	2	17.6	18.9	9.3	14.5	19.3	79.6
	3	12.5	10.9	15.5	14.5	13.8	67.2
	4	13.9	11.6	10.0	13.0	8.8	57.3
	Total	54.5	53.7	53.0	60.4	52.3	273.9
NH_4NO_3	1	17.9	9.4	20.3	11.5	19.4	78.5
	2	15.6	16.3	19.9	15.0	11.2	78.0
	3	17.2	18.8	20.1	18.2	15.3	89.6
	4	10.6	16.0	16.1	12.4	10.5	65.6
	Total	61.3	60.5	76.4	57.1	56.4	311.7
NP mix	1	12.2	17.0	21.5	14.7	16.6	82.0
	2	14.7	17.2	16.6	18.8	17.4	84.7
	3	13.9	12.4	15.5	13.5	11.5	66.8
	4	10.4	8.4	16.3	15.1	10.0	60.2
	Total	51.2	55.0	69.9	62.1	55.5	293.7
Sum of totals		216.6	211.3	264.3	246.3	233.0	1171.5

nitrate in the plant tissues where a row treatment was also applied. Corn on this plot that had no fertilizer added in the row at seeding time showed a deficiency of nitrate in the tissue.

There were no plots showing plants with serious deficiencies of available phosphate, and the corn from all plots tested high in available potash.

Nitrogen was the limiting nutrient element on this location, but the effect of the fertilizers added was overshadowed by moisture deficiency during the critical period of rapid growth just prior to tasseling.

The addition of nitrogen produced an excess of this element in the available form during the early growth period of the corn, but as soil moisture became more deficient the nitrogen became unavailable to the plant during the time when the ears were forming. Searseth (4) observed that these conditions may cut corn yields below those where no fertilizer was used.

Carnahan Farm

The plow sole treatment on this location resulted in no significant differences in the stand count, although there was an indication that nitrogen increased the number of stalks, as shown in Table 6. There were no increases in stand count due to any row treatment. Superphosphate applied in the row at seeding time resulted in a decrease in the number of stalks.

Yield data as presented in Table 7 show no significant effects due to plowing under fertilizer. However, the application of superphosphate showed an apparent trend toward a decrease in

Table 6. Stand counts of corn-fertility experiment on Carnahan farm, 1946, showing number of stalks per 1/200 acre plot.

Plow sole treatment	Replication	Row treatment					
		Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	50	50	53	54	52	259
	2	47	49	52	44	45	237
	3	42	40	42	45	47	216
	4	60	44	60	44	51	259
	Total	199	183	207	187	195	971
43% treble superphosphate	1	53	43	52	50	46	244
	2	40	46	45	45	55	231
	3	43	42	47	46	46	224
	4	55	49	49	49	53	255
	Total	191	180	193	190	200	954
NH_4NO_3	1	56	47	59	52	51	265
	2	56	50	59	61	43	269
	3	59	51	59	49	54	272
	4	60	51	57	50	48	266
	Total	231	199	234	212	196	1072
NP mix	1	53	53	46	56	37	244
	2	58	46	57	65	54	280
	3	54	44	50	60	59	267
	4	51	47	54	53	48	253
	Total	216	190	207	233	198	1044
Sum of totals		837	752	841	822	789	4041

Table 7. Yields of corn-fertility experiment on Carnahan farm, 1946, showing pounds of ear corn per 1/200 acre plot.

Plow sole treatment	Row treatment						
	Replication	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	22.6	15.5	28.2	24.0	21.4	111.7
	2	20.8	13.3	23.3	24.9	20.9	103.2
	3	19.9	11.9	24.1	22.4	19.7	98.0
	4	18.0	11.0	27.1	18.2	13.9	88.2
	Total	81.3	51.7	102.7	89.5	75.9	401.1
43% treble superphosphate	1	22.1	14.5	26.3	23.0	19.8	105.7
	2	17.0	23.3	13.4	16.4	18.4	88.5
	3	17.5	11.7	23.1	18.7	17.4	88.4
	4	16.7	8.4	20.5	16.5	11.3	73.4
	Total	73.3	57.9	83.3	74.6	66.9	356.0
NH_4NO_3	1	24.3	22.3	23.1	25.0	20.9	115.6
	2	26.3	22.0	28.1	29.7	18.3	124.4
	3	22.0	14.5	24.4	21.0	17.5	99.4
	4	22.1	11.2	12.6	12.4	10.0	68.3
	Total	94.7	70.0	88.2	88.1	66.7	407.7
NP mix	1	20.7	19.6	21.8	25.4	13.0	100.5
	2	24.2	14.8	26.9	22.2	19.8	107.9
	3	19.5	13.6	20.1	15.5	12.5	81.2
	4	18.5	9.6	15.2	11.8	9.4	64.5
	Total	82.9	57.6	84.0	74.9	54.7	354.1
Sum of totals		332.2	237.2	358.2	327.1	264.2	1518.9

yield whenever it was used. The superphosphate plow sole treatment yielded 6.44 bushels per acre less than the untreated plot. The side dressing of ammonium nitrate at last cultivation was the only row treatment to produce greater yields than the untreated plots, but the increase was not enough to reach the value required for significance as shown in Table 15. The calculation of the fiducial limits for each treatment reveals that the superphosphate and ammonium nitrate-superphosphate treatments in the row resulted in lower yields than the untreated plots.

No satisfactory explanation can be given for the differences in yield between replications of the row treatments.

Table 14 shows the effect of fertilizer treatments on the average ear weight. Superphosphate on the plow sole decreased ear weights from 0.48 pound to 0.44 pound per ear and when placed in the row superphosphate decreased ear weights still further to 0.39 pound per ear. Ammonium nitrate on the plow sole or in the row had little effect on ear weight, but ammonium nitrate with superphosphate decreased the average ear weight 0.05 pound per ear on both plow sole and row treatment plots. Ammonium nitrate side dressing at last cultivation increased the average ear weight from 0.48 pound to 0.51 pound per ear.

Plant tissue tests for available nutrients were made on one replication at this location. Available nitrates in the plants were found to be very low on the untreated plow sole plots where superphosphate had been placed in the row at seeding time.

A condition of multiple, barren ears similar to that described by Weidemann (8) was observed. In some cases from three to five ears started to form on one shank but no grain developed. These occurred most frequently on those plots which had superphosphate as the only treatment. They were rarely found on plots to which ammonium nitrate had been added. Weidemann (8) contends that these are normally dormant buds on the ear shank that have been stimulated by available nutrient elements near the plant but that they seldom produce kernels.

It was observed during the droughty period in late July and early August, which extended into the tasseling period, that severe nitrogen deficiencies were showing up on the untreated plots and on those plots where superphosphate had been applied alone either on the plow sole or in the row at seeding time. The addition of ammonium nitrate in the row at seeding time to those plots with superphosphate on the plow sole remedied the condition slightly. Ammonium nitrate in the row at seeding time, in addition to being placed on the plow sole, delayed firing of the lower leaves from 7 to 10 days. The stalks were thicker and stronger on these plots and the leaves were darker green in color.

On those plots where superphosphate was the plow sole treatment, available nitrates in the plant were found in large amounts on those plots where ammonium nitrate was applied in the row at seeding time. Ammonium nitrate applied as a side dressing at last cultivation was able to supply only a medium amount of nitrates to the plant. This can be explained as a result of the droughty conditions whereby there was not enough moisture to move the fertilizer material down to the root zone. Scarseth (4) found that shallow placement of fertilizers is ineffective in dry periods. Prince and

Blood (17) obtained increased yields of sweet corn from side dressing with complete fertilizer only in those years of ample rainfall throughout the growing season.

All of the ammonium nitrate plow sole treatments gave high readings of available nitrates in the plants with the exception of the superphosphate row treatment which tested very low in this nutrient. Superphosphate applied in the row on the ammonium nitrate-superphosphate plow sole plots resulted in a medium amount of nitrates being supplied to the plant. All the other row treatments on these plow sole plots showed a high amount of nitrates in the plants.

Plants on all plots in this replication showed a low amount of available phosphate. Corn on those plots with ammonium nitrate-superphosphate on the plow sole and superphosphate and ammonium nitrate-superphosphate in the row at seeding time showed a medium amount of available phosphate in the tissue. Tissue tests of plants on all plots showed an abundant supply of available potash.

Nitrogen and phosphorus were both limiting factors of maximum corn yields on this farm. Results of soil sample analyses presented in Table 1 indicate a deficiency in the supply of available phosphates in the soil. Tests of the growing crop showed that the corn plants were not able to maintain a supply of available phosphates on any of the plots. The addition of a phosphorus fertilizer to the soil may remedy the phosphorus deficiency but probably would accentuate the symptoms of nitrogen deficiency which were observed on this farm. This experiment indicated that maximum results from the application of either nitrogen or phosphate fertil-

Table 8. Stand counts of corn-fertility experiment on Kelsey farm, Rossville, 1946, showing number of stalks per 1/200 acre plot.

Plow sole treatment	Replication	Row treatment: Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	46	40	44	56	59	245
	2	50	33	36	56	70	245
	3	41	35	35	55	57	223
	4	45	39	44	57	70	255
	Total	182	147	159	224	256	968
43% treble superphosphate	1	44	45	48	45	63	245
	2	48	49	37	38	50	222
	3	49	52	51	51	54	257
	4	51	49	44	47	61	252
	Total	192	195	180	181	228	976
NH_4NO_3	1	56	57	56	50	50	269
	2	50	54	56	50	62	272
	3	55	55	42	67	52	271
	4	59	58	46	51	55	269
	Total	220	224	200	218	219	1081
NP mix	1	58	53	51	60	65	287
	2	49	70	64	53	75	311
	3	53	58	40	74	66	291
	4	60	58	54	53	65	290
	Total	220	239	209	240	271	1179
Sum of totals		814	805	748	863	974	4204

Table 9. Yields of corn-fertility experiment on Kelsey farm, Rossville, 1946, showing pounds of ear corn per 1/200 acre plot.

Plow sole treatment	Replication	Row treatment: Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Total
Untreated	1	26.3	26.6	30.7	31.8	27.5	142.9
	2	32.2	20.7	20.8	35.8	30.2	139.7
	3	30.5	24.2	26.5	20.3	34.6	136.1
	4	22.5	25.0	26.5	24.7	28.5	127.2
	Total	111.5	96.5	104.5	112.6	120.8	545.9
43% treble superphosphate	1	24.8	24.0	21.0	27.2	18.2	115.2
	2	20.5	31.9	26.2	21.7	29.1	129.4
	3	27.3	31.5	34.0	34.6	31.3	158.7
	4	26.4	25.0	23.7	24.7	27.4	127.2
	Total	99.0	112.4	104.9	108.2	106.0	530.5
NH_4NO_3	1	25.9	24.0	26.7	16.5	18.8	111.9
	2	29.5	32.7	32.5	28.3	22.0	145.0
	3	29.8	34.8	30.8	32.3	29.8	157.5
	4	25.8	24.2	22.8	25.5	29.8	128.1
	Total	111.0	115.7	112.8	102.6	100.4	542.5
NP mix	1	23.5	24.1	25.5	19.0	23.2	115.3
	2	21.8	26.4	28.5	25.2	37.2	139.1
	3	32.5	31.3	28.3	31.9	31.2	155.2
	4	23.0	24.1	25.0	20.5	21.3	113.9
	Total	100.8	105.9	107.3	96.6	112.9	523.5
Sum of totals		422.3	430.5	429.5	420.0	440.1	2142.4

izer cannot be achieved so long as one remains deficient in the soil. Caldwell (26) has shown in fertilizer trials with corn on soils where phosphate was primarily deficient that nitrogen was needed to correct deficiencies which became apparent only when yields had been increased by the use of phosphates. The addition of nitrogen fertilizers did not remedy the nitrogen deficiencies of the plants except where 90 pounds of nitrogen per acre were applied. Droughty conditions tended to cause much of the nitrogen to become unavailable for plant use. Scarseth (4) has explained this lack of availability by the movement of the nitrate ion with the soil moisture to the surface of the soil in dry periods, where it accumulates out of reach of the roots.

Kelsey Farm

Plow sole treatment with ammonium nitrate increased the number of stalks at this location as shown in Table 8. Superphosphate had no appreciable effect on the stand count but the increases obtained from the ammonium nitrate and the ammonium nitrate-superphosphate treatments were highly significant.

The ammonium nitrate-superphosphate applied in the row resulted in a highly significant increase in the number of stalks. The increase in stand count due to ammonium nitrate alone did not quite approach significance at the five per cent level when tested by calculation of its fiducial limits. The difference between replications of the row treatments was highly significant, for which no cause can be shown.

Plow sole or row treatments had no significant effect on the yield of ear corn.

Data for average ear weights on this location, as shown in Table 14, indicate that fertilizers have had very little effect. There is a slight indication that ammonium nitrate decreased the average weight when placed either in the row at seeding time or on the plow sole.

No nutrient deficiency symptoms were observed on these plots, and moisture was not a limiting factor in growth or yield. Table 14 shows average ear weights from 0.59 pound to 0.63 pound per ear.

Reed and Salter (12) have obtained significant increases in yield from fertilizer treatments on soils of high fertility level, but to obtain the maximum returns from large applications of fertilizer, it is necessary to maintain a planting rate of 12,000 to 14,000 plants per acre with adequate soil moisture.

It appears evident that the planting rate on this location was not thick enough to obtain the maximum yield. Table 11 shows that the average number of stalks per acre on the untreated plot was 9,200. Increases in yields from the application of fertilizers cannot be expected with thin planting rates that give high average ear weights.

Table 10. Average stand counts of corn-fertility experiments showing number of stalks per 1/200 acre plot in 1946.

Lind-Mullen Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	37	37	37	43	41	39
43% Super	41	38	37	40	39	39
NH_4NO_3	43	44	42	47	46	44
NP mix	39	44	43	48	51	45
Average	40	41	40	45	44	42

Carnahan Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	50	46	52	47	49	49
43% Super	48	45	48	48	50	48
NH_4NO_3	58	50	59	53	49	54
NP mix	54	48	52	58	50	52
Average	52	47	53	51	49	51

Kelsey Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	46	37	40	56	64	48
43% Super	48	49	45	45	57	49
NH_4NO_3	55	56	50	55	55	54
NP mix	55	60	53	60	68	59
Average	51	50	47	54	61	53

Table 11. Average stand counts of corn-fertility experiments showing number of stalks per acre in 1946.

Lind-Mullen Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	7,400	7,400	7,400	8,600	8,200	7,800
43% Super	8,200	7,600	7,400	8,000	7,800	7,800
NH_4NO_3	8,600	8,800	8,400	9,400	9,200	8,800
NP mix	7,800	8,800	8,600	9,600	10,200	9,000
Average	8,000	8,200	8,000	9,000	8,800	8,400

Carnahan Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	10,000	9,200	10,400	9,400	9,800	9,800
43% Super	9,600	9,000	9,600	9,600	10,000	9,600
NH_4NO_3	11,600	10,000	11,800	10,600	9,800	10,800
NP mix	10,800	9,600	10.400	11,600	10,000	10,400
Average	10,400	9,400	10,600	10,200	9,800	10,200

Kelsey Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	9,200	7,400	8,000	11,200	12,800	9,600
43% Super	9,600	9,800	9,000	9,000	11,400	9,800
NH_4NO_3	11,000	11,200	10,000	11,000	11,000	10,800
NP mix	11,000	12,000	10,600	12,000	13,400	11,800
Average	10,200	10,000	9,400	10,800	12,200	10,600

Table 12. Average yields of corn-fertility experiments showing pounds of ear corn per 1/200 acre plot in 1946.

Lind-Mullen Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	12.4	10.5	16.3	16.7	17.2	14.6
43% Super	13.6	13.4	13.3	15.1	13.1	13.7
NH_4NO_3	15.3	15.1	19.1	14.3	14.1	15.6
NP mix	12.8	13.8	17.5	15.6	13.9	14.7
Average	13.5	13.2	16.5	15.4	14.6	14.6

Carnahan Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	20.3	12.9	25.7	22.4	19.0	20.1
43% Super	18.3	14.5	20.8	18.7	16.7	17.8
NH_4NO_3	23.7	17.5	22.1	22.0	16.7	20.4
NP mix	20.8	14.4	21.0	18.5	13.7	17.7
Average	20.8	14.8	22.4	20.4	16.5	19.0

Kelsey Farm

Plow sole treatment	Row treatment					
	Untreated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	27.9	24.1	26.1	28.2	30.2	27.3
43% Super	24.9	28.1	26.2	27.1	26.5	26.5
NH_4NO_3	27.7	29.4	28.2	25.7	25.1	27.1
NP mix	25.2	26.5	26.8	19.2	28.2	26.2
Average	26.4	26.9	26.8	26.3	27.5	26.8

Table 13. Summary tables of yields of corn-fertility experiments showing bushels per acre in 1946.

Lind-Mullen Farm

Plow sole treatment	Row treatment					
	Un- treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	35.43	30.07	46.43	47.64	49.14	41.73
43% Super	38.93	38.36	37.86	43.14	37.36	39.11
NH_4NO_3	43.79	43.22	54.57	40.79	40.29	44.51
NP mix	36.57	39.29	49.93	44.36	39.64	41.94
Average	38.68	37.74	47.20	43.99	41.61	41.83

Carnahan Farm

Plow sole treatment	Row treatment					
	Un- treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	58.07	36.93	73.36	63.93	54.22	57.28
43% Super	52.36	41.36	59.50	53.29	47.79	50.84
NH_4NO_3	67.64	50.00	63.00	62.93	47.64	58.22
NP mix	59.22	41.14	60.00	53.50	39.07	50.57
Average	59.33	42.36	63.97	58.42	47.19	54.24

Kelsey Farm

Plow sole treatment	Row treatment					
	Un- treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	79.64	68.93	74.64	80.43	86.29	77.95
43% Super	70.72	80.29	74.93	77.29	75.72	75.76
NH_4NO_3	79.29	82.64	80.57	73.29	71.72	77.47
NP mix	72.00	75.64	76.64	69.00	80.64	74.76
Average	75.42	76.89	76.71	75.01	78.60	76.54

Table 14. Average ear weights of corn-fertility experiments showing weight in pounds per ear in 1946.

Lind-Mullen Farm

Plow sole treatment	Row treatment: Un-treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	0.42	0.41	0.51	0.54	0.51	0.48
43% Super	0.47	0.47	0.47	0.45	0.49	0.47
NH_4NO_3	0.48	0.47	0.54	0.44	0.44	0.47
NP mix	0.45	0.47	0.49	0.45	0.50	0.47
Average	0.46	0.46	0.50	0.47	0.49	

Carnahan Farm

Plow sole treatment	Row treatment: Un-treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	0.45	0.36	0.54	0.56	0.49	0.48
43% Super	0.46	0.39	0.49	0.46	0.42	0.44
NH_4NO_3	0.54	0.42	0.51	0.51	0.42	0.48
NP mix	0.46	0.38	0.50	0.46	0.37	0.43
Average	0.48	0.39	0.51	0.50	0.43	

Kelsey Farm

Plow sole treatment	Row treatment: Un-treated	43% Super	NH_4NO_3 (LC)	NH_4NO_3 (ST)	NP mix	Average
Untreated	0.63	0.63	0.65	0.63	0.61	0.63
43% Super	0.62	0.65	0.63	0.60	0.63	0.63
NH_4NO_3	0.59	0.62	0.62	0.62	0.57	0.60
NP mix	0.60	0.59	0.60	0.57	0.60	0.59
Average	0.61	0.62	0.63	0.61	0.60	

Table 15. Summary table of analysis of variance F-ratios of stand counts and yields of corn-fertility experiment at three locations in 1946.

Stand Count

Treatment	DF	Lind-Mullen	Car-nahan	Kelsey	Critical F-values 5%	1%
Complete plots						
Plow sole	3	11.33	3.23	14.41**	3.86	6.99
Replications	3	2.86	----	-----	3.86	6.99
Subplots						
Row	4	3.65*	4.52**	15.48**	2.64	3.89
Plow sole x row treatment Interaction	12	-----	1.62	3.73**	2.04	2.73
Replication x row treatment Interaction	12	-----	----	1.89	2.04	2.73

Yield

Treatment	DF	Lind-Mullen	Car-nahan	Kelsey	Critical F-values 5%	1%
Complete plots						
Plow sole	3	1.52	2.57	----	3.86	6.99
Replications	3	9.16**	12.84**	6.01*	3.86	6.99
Subplots						
Row	4	3.60*	17.51**	----	2.64	3.89
Plow sole x row treatment Interaction	12	1.57	1.33	----	2.04	2.73
Replication x row treatment Interaction	12	----	----	----	2.04	2.73

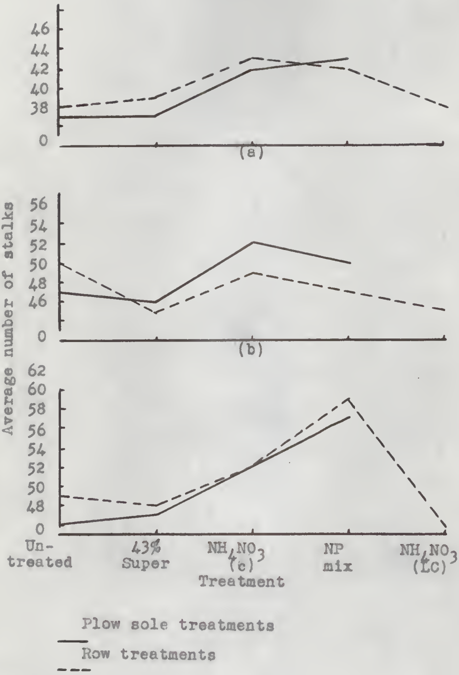
* Significant
**Highly significant

EXPLANATION OF PLATE I

Effect of plow sole and row treatments on the number of stalks per 1/200 acre plot in 1946.

(a) Lind-Mullen farm
(b) Carnahan farm
(c) Kelsey farm

PLATE I

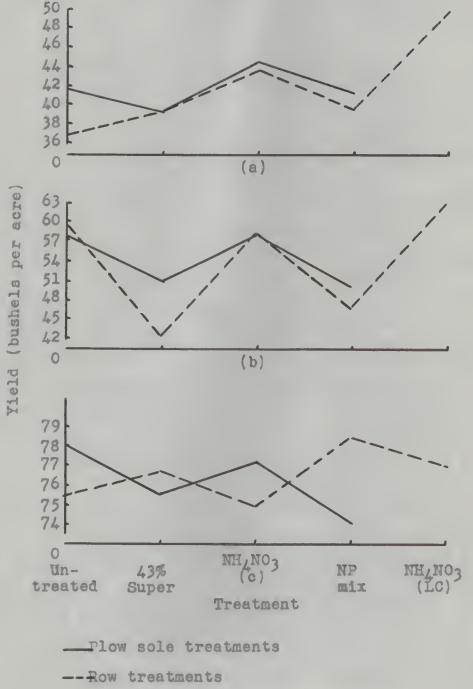

46
44
42
40
38
0
(a)
56
54
52
50
48
46
0
(b)
Average number of stalks
62
60
58
56
54
52
50
48
0
Un-
treated
43%
Super
NH_4NO_3
(c)
NP
mix
NH_4NO_3
(LC)
Treatment
Plow sole treatments
Row treatments

EXPLANATION OF PLATE II

Effect of plow sole and row treatments on the yield of ear corn in 1946.

(a) Lind-Mullen farm
(b) Carnahan farm
(c) Kelsey farm

PLATE II

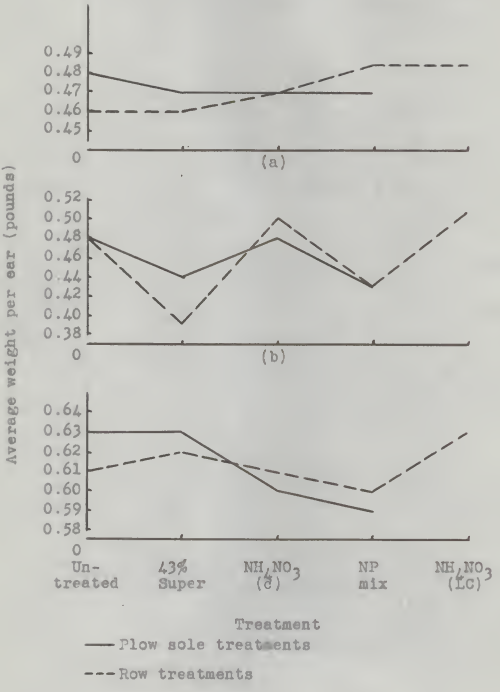

50
48
46
44
42
40
38
36
0
(a)
63
60
57
54
51
48
45
42
0
(b)
Yield (bushels per acre)
79
78
77
76
75
74
0
Un-
treated
43%
Super
NH4NO3
(c)
NP
mix
NH4NO3
(LC)
Treatment
Plow sole treatments
Row treatments

EXPLANATION OF PLATE III

Effect of plow sole and row treatments on ear weights in 1946.

(a) Lind-Mullen farm
(b) Carnahan farm
(c) Kelsey farm

PLATE III


Average weight per ear (pounds)
0.49
0.48
0.47
0.46
0.45
0
(a)
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0
(b)
0.64
0.63
0.62
0.61
0.60
0.59
0.58
0
Un-treated
43% Super
NH4NO3 (C)
NP mix
NH4NO3 (LC)
Treatment
Plow sole treatments
Row treatments

SUMMARY

An experiment on the effect of time and method of placement of fertilizer on the yield of corn was carried out on three locations in the growing season of 1946, and the following observations were made.

1. A droughty period occurred during the critical stage of rapid growth at tasseling time which overshadowed the response of the corn to the fertilizer application.

2. The application of nitrogen fertilizer on the plow sole and in the row at seeding time increased the yield of forage by stimulating the growth of suckers.

3. Plowing under fertilizers had no effect on the yield of corn under the conditions of this experiment.

4. A side dressing of ammonium nitrate at last cultivation increased the yield of corn on two locations.

5. The application of superphosphate either on the plow sole or in the row gave no increases in stand count, yield or ear weight on any location.

6. The addition of superphosphate accentuated the nitrogen deficiencies of the corn plant where the soil was deficient in both phosphorus and nitrogen.

7. A total application of nitrogen at the rate of 90 pounds per acre by both row and plow sole treatments was sufficient to supply nitrates to the corn plants for a period of 7 to 10 days longer than on those plots that were untreated or had superphosphate treatments.

8. Placing ammonium nitrate in the row at seeding time stimu-

lated a heavy growth of weeds.

9. Forty-five pounds of nitrogen per acre produced an early increase in forage on the Carnahan farm, but the plants became deficient in nitrates during the tasseling stage, which resulted in the formation of multiple barren ears.

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