

THE EFFECT OF FERTILIZER APPLICATIONS ON YIELD AND
NUTRIENT COMPOSITION OF THE LEAF AND GRAIN
OF CORN GROWN ON A WISNER LOAM SOIL

By
Tatsuo Fujimoto

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State
University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Soil Science

Year 1958

Approved

Lynn Robertson

ABSTRACT

Fifty-six samples of grain and leaf of corn which had been fertilized with various combinations and rates of nitrogen, phosphoric acid and potash were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Yield determinations were made for each plot. The treatment levels in pounds per acre of the various nutrients used on the individual plots were as follows:

N:	0	20	40	80	160	240	320
P ₂ O ₅ :	0	40	80	160	320	480	640
K ₂ O:	0	20	40	80	160	240	320

Nitrogen and phosphorus fertilizer applications increased the grain yield whereas potash fertilization had no effect.

Yield was significantly correlated with the combined nutrient elements of nitrogen, phosphorus, potassium, calcium, magnesium and sodium in the grain. Positive relationships existed between yield and phosphorus and sodium contents of the leaf.

Applications of nitrogen and phosphorus fertilizers increased the nitrogen and phosphorus contents in the grain. In the leaf, however, phosphorus and potassium contents were significantly affected by their respective fertilizer applications.

Several interrelationships between various elements were present in the grain. Phosphorus was positively correlated with nitrogen, potassium, and magnesium. Magnesium was also directly related to nitrogen and potassium. In the corn leaf, significant correlations existed between nitrogen and phosphorus, potassium and sodium, and magnesium and calcium.

Significant relationships between the nutrient elements in the grain and leaf were found with phosphorus and magnesium. A positive correlation existed between the phosphorus contents of the grain and leaf, and a negative correlation existed between the magnesium contents of the grain and leaf.

THE EFFECT OF FERTILIZER APPLICATIONS ON YIELD AND
NUTRIENT COMPOSITION OF THE LEAF AND GRAIN
OF CORN GROWN ON A WISNER LOAM SOIL

By
Tatsuo Fujimoto

A THESIS

Submitted to the College of Agriculture of Michigan State
University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Soil Science

Year 1958

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. L. S. Robertson under whose supervision this investigation was undertaken.

He is greatly indebted to Dr. W. B. Sundquist of the Agricultural Research Service, U. S. D. A., for the invaluable service rendered in facilitating the statistical analysis.

He is also indebted to Dr. R. L. Cook for the patient guidance offered in his graduate study.

The author also wishes to acknowledge his fellow graduate students of the Soil Science Department for their willing assistance in this project.

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
REVIEW OF LITERATURE	3
MATERIALS AND METHODS	13
Field Plot Design	13
Fertilizer Materials	14
Management of Plots	14
Samples	14
Chemical Analysis of Samples	15
Total Nitrogen Determination	15
Wet Ashing	15
Phosphorus Determination	16
Potassium, Calcium and Sodium Determinations ..	16
Magnesium Determination	17
RESULTS AND DISCUSSION	18
Yield Relationships	18
Effect of Fertilizers on the Composition of Grain.	19
Effect of Fertilizers on the Composition of Leaf..	28
Relationships of Nutrient Elements in Leaf and Grain	32
SUMMARY	36
BIBLIOGRAPHY	38
APPENDIX	42

LIST OF TABLES

TABLE	PAGE
1. Significant Correlation Coefficients Calculated between Several Factors.....	20
2. The Effect of Applied Nitrogen, Phosphate and Potash on the Chemical Composition of Corn Grain	23
3. The Effect of Applied Nitrogen, Phosphate and Potash on the Chemical Composition of Corn Leaf	28
4. Field Diagram for Continuous Corn Experiment, Tuscola County	43
5. Selected Samples for Chemical Analysis	44
6. Adjustment of the Beckman Spectrophotometer for the Determination of Calcium, Potassium and Sodium	45
7. Yield and Chemical Analysis of Corn Grain as Affected by Various Fertilizer Treatments	46
8. Chemical Analysis of Corn Leaves as Affected by Various Fertilizer Treatments	49

LIST OF FIGURES

FIGURES	PAGE
1. The relationship between yield and the phosphorus contents of the leaves	21
2. The relationship between yield and the sodium contents of the leaves	22
3. The effect of applied nitrogen in the nitrogen contents of the grain	24
4. The effect of applied phosphate on the phosphorus contents of the grain	24
5. The relationship between nitrogen and magnesium contents of the grain	26
6. The relationship between phosphorus and nitrogen contents of the grain	26
7. The relationship between phosphorus and potassium contents of the grain	27
8. The relationship between magnesium and phosphorus contents of the grain	27
9. The relationship between magnesium and potassium contents of the grain	30
10. The effect of applied phosphate on the phosphorus contents of the leaves	31
11. The effect of applied potash on the potassium contents of the leaves	31
12. The relationship between phosphorus and nitrogen contents of the leaves	31
13. The relationship between sodium and potassium contents of the leaves	33
14. The relationship between magnesium and calcium contents of the leaves	33
15. Relationship between phosphorus contents of grain and phosphorus contents of the leaves	35
16. Relationship between magnesium contents of grain and magnesium contents of the leaves	35

INTRODUCTION

The use of chemical fertilizer probably dates from 1665, when Sir Kenelur Digly wrote that he had increased crop yield through the application of saltpeter. Little was understood concerning the principles of fertilization until 1804, when Nicholas Theodore de Saussure of Switzerland first directed the attention of the scientific world to the fact that the ash ingredients of plants were taken from the soil and that they were essential for plant growth.

Fifty years later (1855 and 1856), Justus von Liebig, German chemist of the University of Giessen, emphasized the necessity of supplying plants with phosphoric acid and potash. In 1840 Liebig delivered his historic address before the British Association of Science on the role of minerals on plant nutrition. He later demonstrated during 1845 the essential nature of potash. Since that time, extensive investigations have been carried out on the importance of mixed fertilizers in the production of crops.

In early days, mixed fertilizers were composed of low analysis carriers and the total content of nitrogen phosphoric acid and potash was necessarily low. At the same time, a number of secondary and trace plant-nutrient elements were commonly present as incidental constituents. In recent years, there has been a steady increase in the nutrient content of the average grade of mixed fertilizers sold in the United

States. In addition, the consumption of mixed fertilizer has increased very rapidly. The great increase in consumption was due in part to the following reasons: 1)increased farm income 2)education and demonstration 3)changes in crop varieties 4)nutrient depletion of the soil and 5)improved cultural practices.

Many investigations have shown the effects of nitrogen, phosphorus and potassium fertilizers on yield, quality and chemical composition of corn.

Efficient fertilizer use by the crop can result when each element is used to its fullest advantage. If an element is applied in too small an amount to meet the needs of the crop, it may prevent efficient utilization of other elements, or, if the presence of one element interferes with the uptake or utilization of another, the growth of the plant may be inhibited. Therefore, nutrient balance is of importance in determining sound fertilizer usage.

The present study, a part of a nutrient level and balance project, was designed to determine the effect of various levels and combinations of nitrogen, phosphorus and potassium fertilizers on yield and chemical composition of corn grain and leaves.

REVIEW OF LITERATURE

Although fertilizers play an important role in corn production in the United States, an increase in fertilizer consumption could result in greater corn production. Relatively large amounts of nitrogen, phosphorus and potassium are required to produce high yielding crops. For example, in Michigan, to obtain corn yields of 85 bushels per acre on a Wisner soil which, according to soil tests, is low in phosphorus and potassium, 80 pounds of phosphoric acid and 40 pounds of potash is recommended (10).

Many investigators (5,15,17,26) found that large applications of nitrogen fertilizer markedly increase yield of corn. Yield responses to increasing increments usually follow the Mitscherlich-type curve, providing the levels of other nutrients and moisture are not limiting and that other factors do not adversely affect plant growth.

Krantz (17) reported that yield increased from 19 bushels per acre without nitrogen to 107 bushels of corn where 120 pounds per acre of nitrogen was applied on a Norfolk sandy loam.

Cummings (5), summarizing three years results of 38 fertilizer tests in North Carolina, reported average yields of 28, 50, 68 and 78 bushels per acre from plots receiving 0, 40, 80 and 120 pounds of nitrogen respectively. All plots received adequate amounts of phosphorus and potassium fertili-

zers.

Lack of phosphorus is most apparent during early growth when the root system is small. The percentage of phosphorus in a plant derived from fertilizer is influenced by the position of the fertilizer in respect to the seed. On phosphorus deficient soils, large applications of phosphorus fertilizer are required. Krantz (18) and others obtained significant yield response from phosphorus applications where soils were low in phosphorus. Under conditions of low phosphorus supply, starter fertilizer of 20 to 50 pounds of P_2O_5 per acre cannot be depended upon to supply the major requirements of the crop, since the plant recovers less than 15 percent of applied fertilizer phosphorus (25,31).

Nelson et al (25) found that corn absorbed high proportions of fertilizer phosphorus during early growth and small amounts in the later portion of its growing period. They further observed that the percent of fertilizer phosphorus absorbed by corn decreased as the amount of native soil phosphorus increased.

Several investigators have shown that yield of corn increased with application of potassium to potassium deficient soils but no effect on yield on soils well supplied with potassium.

According to Krantz and Chandler (19), yields were increased by an application up to 80 pounds of potash on potassium deficient soils. However, additional increments

of potassium had no effect on yield. Potash application did not affect yield on soils which contained enough soil potassium so that no visual deficiency symptoms were noted.

In another study Krantz observed similar results. The yield increased 0.31 bushels per acre where 40 pounds of K_2O per acre was applied but no response was obtained from higher applications of potash on Coxville fine sandy loam which was low in potassium (18).

Boswell and Parks (3) in working with soils low in exchangeable potassium obtained a significant yield increase from the first increment of potash but no further increase in yield from additional increments.

The effectiveness of a nutrient applied to corn is reduced when the supply of other plant nutrients is inadequate. Krantz (18) pointed out the need for nutrient balance, although in most tests nitrogen was the key to high yields. For example, on a Dunbar sandy loam, an increase of 24 bushels per acre was obtained from potash where high rates of nitrogen were used but no response to potash without nitrogen. Conversely, a striking response to nitrogen was obtained when potash was supplied but no nitrogen response occurred without potash.

Viets et al (36) showed that when nitrogen fertilizer was applied to soils which were low in available nitrogen, the phosphorus content of the leaf increased. They concluded

that this effect may be due to the development of more extensive root systems that contacted more soil phosphorus.

Bennett et al (2) observed that the percent of phosphorus in corn leaf ranged from 0.173 - 0.320 percent where no nitrogen was applied and 0.206 - 0.331 percent when 80 pounds of nitrogen was applied. He found that the percent phosphorus in corn leaves was significantly increased over those obtained from plots that had not received nitrogen. The reverse of this occurred in the grain.

Investigations on the effect of the addition of phosphorus and nitrogen to crops on their absorption of potassium generally indicated that a reduction occurs, especially if the soil potassium supply is limited. Lawton et al (21) found that the percent of potassium in legume hay was reduced from 1.52 - 1.35 when superphosphate was applied to soils treated with potash.

Nitrogen accumulates rather rapidly in the grain until maturity. This is accomplished in large part through the movement and depletion from other plant parts such as the leaves, stems and husks (16, 29). Nitrogen, according to Sayre (29), continued to accumulate in the grain as long as the plants were sampled. This indicated that nitrogen moved out of the cob, husks, stems and leaves. The greatest amount of nitrogen had accumulated in the plant tissues, with the exception of the grain, by the first of August. In addition, the grain continued to increase in nitrogen and the husks

lost a great deal of nitrogen after the grain began to form.

Phosphorus accumulates in the whole plant at a fairly continuous rate until maturity (14,16,29). Earley and DeTurk (9) showed that the greatest rate of phosphorus accumulation usually paralleled the period of most rapid dry matter production. As pollination approached, phosphorus started to migrate into the developing but yet seedless ear and then accumulated rapidly in the grain until maturity. The leaves, stalks, husks and cobs lost phosphorus to the grain. Jordan et al (16) found that as with nitrogen, phosphorus uptake by the whole plant was continuous throughout the season and increased generally with applied nitrogen.

Potassium accumulation and translocation differ in several respects from nitrogen and phosphorus. Most striking is the actual loss of potassium from the corn plant as maturity approached. This loss occurs chiefly from the leaves, stalks and husks and is not surprising inasmuch as most of the potassium in the plant is in water soluble form (24,37).

Sayre (29) reported that the grain does not accumulate much potassium. There was a small but consistent increase in the amount of potassium in the grain and a rather marked loss of potassium from the other plant tissues, especially the stem.

The nutrient composition of a crop provides information regarding the physiology of the plant and in conjunction

with the yield, serves as a measure of the recovery of applied nutrients.

Determination of nutrient composition in corn leaves has received considerable emphasis in recent years. Following Tyner's work (34), investigators have more or less standardized upon the selection of the sixth leaf from the base taken during the period of full silk for leaf analysis. Tyner listed four reasons for his selection: 1) the stage is easily recognized and described, 2) all varieties mature in about the same number of days once silking and tasseling occur, 3) the weight of vegetative parts is at or near its peak at this time, and 4) this is a period when nutrient demand by the plant is very high. According to Tyner (34), the critical nitrogen, phosphorus and potassium concentrations of the sixth leaf were 2.9 percent nitrogen, 0.295 percent phosphorus and 1.3 percent potassium. At N-P-K concentration above these levels, doubtful or rapidly decreasing response to further applications of these nutrients occurred. At nutrient levels in excess of the critical concentrations, extraneous factors appeared to exert greater influence on yields than nutrient content variations.

Most investigators have found high positive correlations between the level of the nutrient element in the leaf, the rate of nutrient application or its available level in the soil and the yield of the corn grain (2,19,35,36).

Tyner (34) in West Virginia found for each change of 0.1 percent of nitrogen, phosphorus and potassium in the sixth leaf at silk, grain yields varied 4.43, 25.3 and 2.05 bushels per acre respectively.

Nitrogen content, according to Bennett et al (2), increased by increasing the nitrogen application. The percent nitrogen in the leaf ranged from 1.52 - 2.77, 1.97 - 2.95, and 2.68 - 3.17, from plots where 0, 20, 40, and 80 pounds of nitrogen were applied, respectively. The percent of nitrogen in the grain also increased as the application of nitrogen increased, ranging from 0.96 - 1.43. They reported that the percent of phosphorus ranged from 0.173 - 0.320 in the absence of applied nitrogen.

These investigators point out that because of many uncontrollable and variable factors which influence final yields caution should be used in interpretations of such results.

Krantz and Chandler (19) found that potassium uptake, as reflected by leaf composition, was increased progressively up to 320 pounds of potash application. However, this luxury composition did not affect plant performances, yield or composition of the corn grain. They found that phosphorus content of corn leaves and grain was not appreciably increased by phosphorus application, but it was markedly affected by the level of soil phosphorus. Nitrogen applications, according to them, increased the nitrogen composi-

tion of corn leaves and corn grain. It also increased phosphorus and potassium uptake especially in soils which were high in these minerals. In high phosphorus soils there was a direct correlation between the nitrogen and phosphorus content of corn leaves.

A number of ion relationships affecting the absorption of nutrients have been demonstrated with corn. Beckenbach et al (1) showed that the nitrate ion concentration in the nutrient solution directly affected the calcium content of the corn tissue. High calcium in the tissues was associated with high nitrates in the nutrient solution.

Phosphorus absorption appeared to be relatively unaffected by variations in the concentration of other ions in the substrate (1,14,35).

Potassium interferes competitively with the absorption of a number of ions. Wadleigh and Shive (37) found that high potassium absorption by the corn plant depressed the absorption of calcium and magnesium. Stanford et al (30) added potassium to a soil high in calcium and magnesium carbonates and observed lowered calcium and magnesium uptake by the corn.

Ohlrogge (26) noted that potassium additions intensified nitrogen deficiency symptoms on corn growing on nitrogen deficient soils. Conversely, Tyner and Webb (35) reported that potassium had little significant depressive effect on

nitrogen when 30 pounds or more of potassium was added. Glover (13), on the other hand, found no interference between potassium and nitrogen nutrition in sand cultures with potassium levels varying from 5 - 45 ppm.

Magnesium content of corn tissues was directly related to variations in the nitrate and calcium ion concentration in the nutrient solution. High magnesium content corresponded to high nitrate and high calcium ion concentration, and low magnesium content corresponded to low concentration of these ions. Magnesium content of corn tissues was affected in the opposite way by variations in potassium ion concentration and phosphorus ion concentration did not affect magnesium content (1).

According to Taylor (32), there was a consistent increase in leaf concentration of magnesium in corn when this element was increased in the nutrient culture from low level (3ppm) to the medium level (75ppm) and to high level (300ppm). Uptake of nitrogen, phosphorus, potassium and sulphur was significantly depressed as a result of high magnesium level.

Foy and Barber (12) reported that occurrence of magnesium deficiency symptoms was not accompanied by a reduction in corn yield. Addition of magnesium prevented development of magnesium deficiency symptoms, significantly increased the percentage of magnesium and decreased the percentage of potassium in leaves, but did not affect yields.

Webb et al (38), investigating the effect of different magnesium treatments upon the absorption and translocation of phosphorus by the soybean plant, found that a positive relationship existed between the magnesium and phosphorus content of the seed and a negative relationship existed between the content of these two elements in the leaflets.

Studies by Leonard and Bear (22), Truog et al (33), Larson and Pierre (20) and Cope et al (4) showed that corn absorbs very little sodium even when this element is present in the substrate in appreciable quantities. According to these investigators, as a general rule, sodium salts do not materially increase the growth of corn, nor does there appear to be any notable substitution of sodium for potassium within the plant. Sodium applications on some soils may result in small growth increases but this probably results from the sodium replacing potassium in the soil through cation exchange which increases the concentration of potassium in the soil solution.

Larson and Pierre (20) found that increasing the potassium level in the soil produced increased growth at all sodium levels in the soil. It also resulted in increased uptake of potassium and decreased uptake of calcium and magnesium by the corn plants.

MATERIALS AND METHODS

In order to study the effects of various fertilizer combinations on yield and the nutrient composition of corn leaf and grain, a continuous corn experiment was conducted on Joe and Charles Wells farm four miles north of Vassar in Section 26 of Denmark Township in Tuscola County. This was the first of the continuous corn experiments conducted on this farm. The soil was mapped as Wisner loam (41).

This is a ~~fine~~ textured, poorly drained soil with free lime occurring in A and B horizons. The A horizon has a brownish gray, weakly developed, subangular blocky to granular structure. The silty clay loam B horizon is moderately developed with a medium angular blocky structure. This soil was developed on a calcareous clay loam till. Mottling occurs throughout the horizons. The field is now well drained as a result of open ditches and recently installed tile.

Field Plot Design

Two hundred and ten individual plots, measuring 14 x 55 feet, were planted to corn in May of 1956. The plots were randomized individually within a factorial design, as shown in Table 4 (Appendix). The treatment levels in pounds per acre of the various nutrients used on the individual plots were as follows:

N:	0	20	40	80	160	240	320
P ₂ O ₅ :	0	40	80	160	320	480	640
K ₂ O:	0	20	40	80	160	240	320

Fifty-six of the 210 plots were selected to be sampled for chemical analysis (Table 5(Appendix)). These sampled plots included eight samples of each treatment level of nitrogen, phosphoric acid and potash and their combinations.

Fertilizer Materials

The fertilizer carriers of the three major plant nutrients were ammonium nitrate (33.5% nitrogen), triple superphosphate (45% P₂O₅) and potassium chloride (60% K₂O).

All the nitrogen and potash were applied broadcast and plowed down. On those plots receiving triple superphosphate, all but 40 pounds of phosphoric acid were broadcast and plowed down. The 40 pounds not broadcast were used as a starter fertilizer at planting time.

Management of Plots

Minimum tillage methods were used. This included plowing and pulling a rotating spade tiller behind the plow. Corn was planted immediately after plowing. On May 28, 1956 certified seed of Michigan "480" corn was planted in four rows per plot, each row 42 inches apart.

Samples

Ten leaf samples per plot were taken on August 14, 1956.

The corn crop was in the last stage of pollination and the leaf just below the developing ear was sampled. These conditions are most favorable for leaf analysis since they presumably represent the optimum chemical status in the plant (34). The leaf samples were dried, ground and stored in cardboard containers for chemical analysis.

The grain samples were taken at harvest time, October 25, 1956. Twenty ears were taken from each plot, dried and shelled. The shelled corn grain samples were then ground and stored in glass jars for chemical analysis.

Chemical Analysis of Samples

The leaf and grain samples were analyzed for total nitrogen, phosphorus, potassium, calcium, sodium and magnesium.

Total Nitrogen Determination

A modification by Prince (43) of the Kjeldahl method was followed. A mixture consisting of CaSO_4 , HgO , and K_2SO_4 was used as a catalyst. The indicator selected consisted of a mixture of 10 milliliters of 0.1 percent bromocresol green in 95 percent alcohol and 2 milliliters of 0.1 percent methyl red in 95 percent alcohol.

Wet Ashing

The plant samples were wet ashed by the perchloric acid method of Piper (42).

A two-gram sample was placed in a 125-milliliter tall

form beaker and 25 milliliters of concentrated nitric acid were added to it. The sample was digested on an electric hot plate until all the organic matter was destroyed. Ten milliliters of 70 percent perchloric acid was then added to the solution. The digestion was continued until the oxidation was complete, as indicated by the clear, colorless solution. The solution was evaporated almost to dryness, cooled, and the volume was made up to 50 milliliters with 0.1 N HCl. The solution was then filtered through Whatman No. 42 filter paper and the filtrate was collected in sample bottles for different nutrient determinations.

Phosphorus Determination

The phosphorus in solution was determined colorimetrically by the ammonium molybdate method. One milliliter of the solution was diluted to 10 milliliters with 0.1 N HCl. Six drops of ammonium molybdate-sulfuric acid reagent were added, followed by the same amount of Fiske-Subarrow reagent (4D). The solution was shaken and after twenty minutes the transmittance of blue color that developed was measured in a Coleman spectrophotometer, using a red filter (650 mu). A standard curve was obtained by using standards of known concentration of phosphorus.

Potassium, Calcium and Sodium Determinations

The potassium, calcium and sodium contents of the plant samples were determined on the Beckman spectrophotometer model DU with a flame attachment. The cations in the

solutions were determined directly. The adjustment of the Beckman DU for the specific nutrients are shown in Table 6 (Appendix).

Magnesium Determination

Magnesium was determined colorimetrically using the thiazole yellow method(39).

One milliliter of the solution was placed in a 50-milliliter volumetric flask. Distilled water was added to make up to 25 milliliters. To this mixture one milliliter of 5 percent hydroxylamine hydroxhloride, 5 milliliters of an equal mixture of 2 percent starch solution and compensating solution, one milliliter of thiazole yellow and 5 milliliters of 2.5 N sodium hydroxide solution were added and made up to volume. After 10 minutes the development of a yellow color was measured in a Coleman spectrophotometer, using a green filter (560 mu).

RESULTS AND DISCUSSION

Yield Relationships

Results of the grain yields shown in Table 7 (Appendix) indicate that the soil was productive, producing an average yield of 109.3 bushels per acre. The yields ranged between 80.9 to 143.9 bushels per acre. The four "no fertilizer" plots had an average yield of 96.0 bushels per acre. This was almost double the yield of 50.4 bushels per acre obtained in similar studies carried out on Kalamazoo sandy loam (6). Response in yield due to application of phosphoric acid and nitrogen was significant at the 1% level of probability, whereas potash applications did not significantly increase yields.

Multiple correlation analysis was conducted between yield and the nutrient elements of nitrogen, phosphorus, potassium, magnesium, calcium and sodium in the grain in order to determine whether any significant relationships existed between yield and the nutrient elements combined. A coefficient of multiple correlation of 0.241 was obtained, which was significant at the 5% level of probability.

In order to determine which of the nutrient elements had the greatest effect on yield, simple correlations between yield and each of the nutrient elements in the grain were analyzed statistically. Significant correlation coefficients of yield and of the six nutrient elements of the grain

and leaf are summarized in Table 1. No significant relationships existed between yield and any of the nutrient elements in the grain. This indicates that although significance of 5 percent was obtained between yield and the nutrient elements combined, this was due more to the combinations or interactions of the nutrients instead of each independently affecting yield.

When simple correlations were conducted between yield and the nutrient contents of the leaf, significant positive correlations existed between phosphorus and sodium contents of the leaf and yield. Phosphorus relationships were significant at the 1% level of probability and sodium at the 5% level. Figures 1 and 2 show the direct relationships of these nutrients in the leaf to the yield of corn. The straight line in each figure represents a line of best fit for the data or a line which minimizes the sum of squared deviations from regressions.

Effect of Fertilizers on the Composition of Grain

As shown in Table 7 (Appendix), the nutrient compositions of corn grain did not reflect great differences in composition and did not vary greatly with fertilizer treatments.

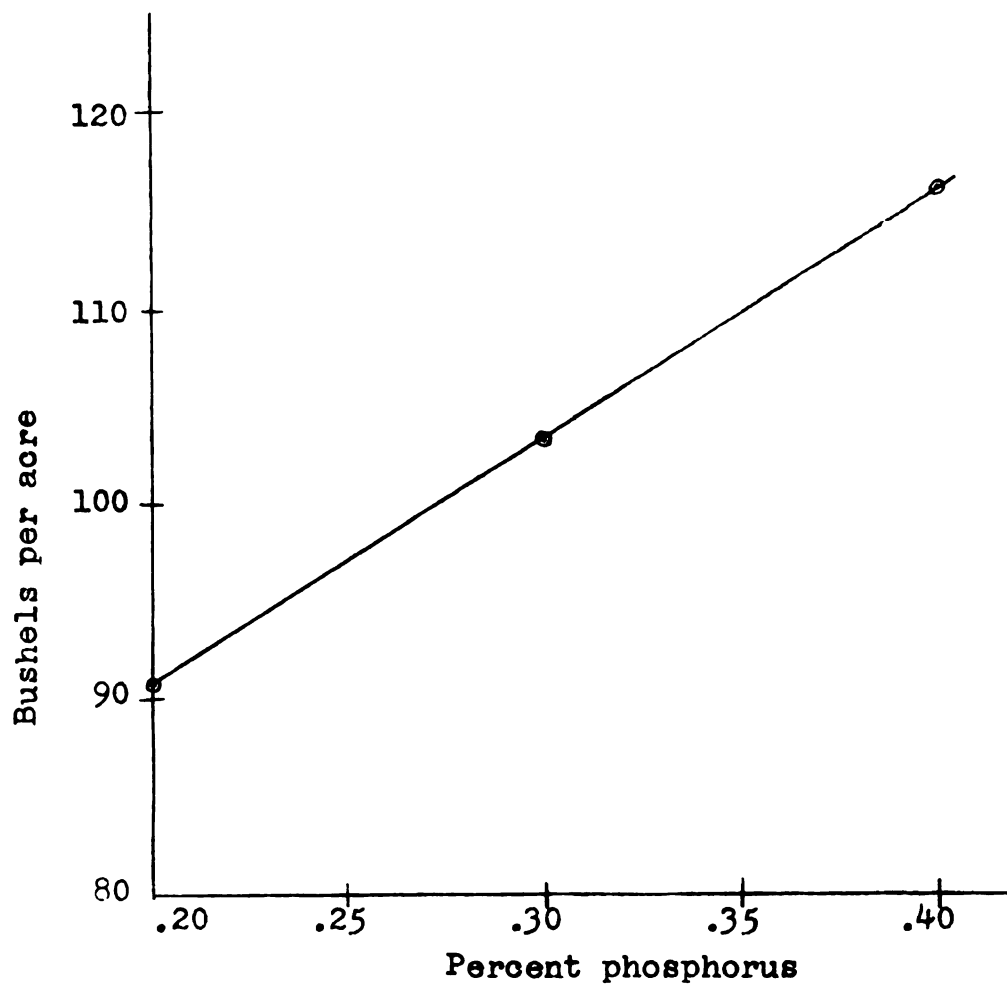
Table 2 shows the overall averages and the ranges of the percent mineral composition of the corn grain.

Table 1. Significant correlation coefficients calculated between several factors.

	<u>Grain</u>						<u>Leaf</u>					
	N	P	K	Ca	Mg	Na	N	P	K	Ca	Mg	Na
N	1.0	.267*			.337**		1.0	.209*				
P	.267*	1.0	.520**		.417**		.209*	1.0				
K		.520**	1.0		.361**				1.0			.242*
Ca										1.0	.707**	
Mg	.337**	.417**	.361**		1.0					.707**	1.0	
Na						1.0			.242*			1.0
Yield								.378**				.273*

* significant at 5% level of probability.

** Significant at 1% level of probability.



$$\hat{y} = 65.002 + 128.331x \quad S_e = 12.789^{**}$$

$$(42.36)^* \quad r = 0.378^{\nearrow}$$

Fig. 1. The relationship between yield and the phosphorus contents of the leaves.

* Standard error of the regression coefficient

** Standard error of estimate

$\nearrow$ Correlation coefficient

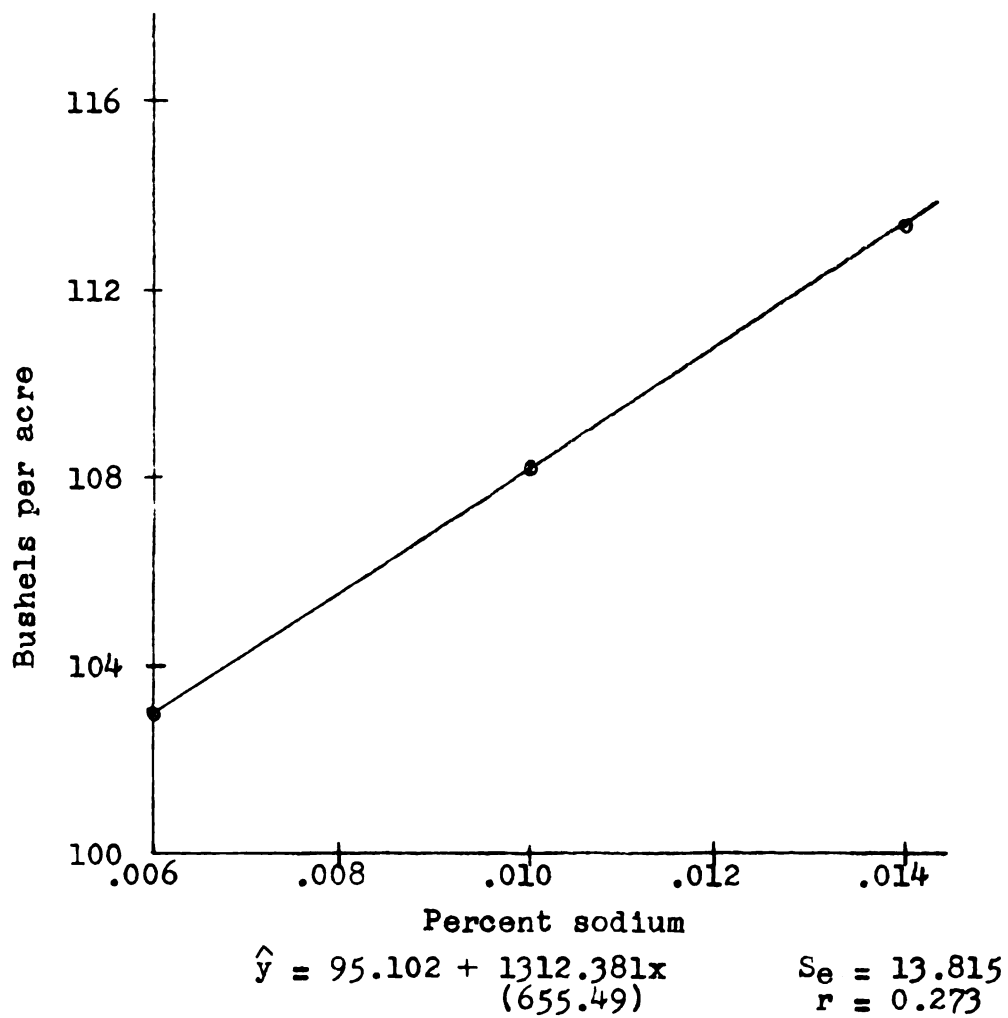


Fig. 2. The relationship between yield and the sodium contents of the leaves.

Table 2. The effect of applied nitrogen, phosphate and potash on the chemical composition of corn grain.

Percent (oven dry basis)		
	Range	Average
Nitrogen	1.130 - 1.500	1.33
Phosphorus	0.2750 - 0.4375	0.3307
Potassium	0.3425 - 0.5000	0.4066
Calcium	0.0013 - 0.0200	0.0074
Magnesium	0.0750 - 0.2500	0.1737
Sodium	0.0038 - 0.0150	0.0085

Many investigators have shown that applications of nitrogen and phosphorus fertilizers increase the nitrogen and phosphorus contents of the grain but potassium fertilizer applications do not affect the potassium content of the grain. The results in this study also indicated that nitrogen and phosphorus fertilizers were significantly correlated with nitrogen and phosphorus contents of the grain (Figures 3 and 4), and the potassium content of the grain was not significantly affected by the various increments of potassium fertilizers. Correlation coefficients of 0.498 and 0.433 for nitrogen and phosphorus with their respective fertilizer applications were both significant at the 1% level of probability.

Several significant correlations were noted between the various elements in the grain. As shown in Figure 5,

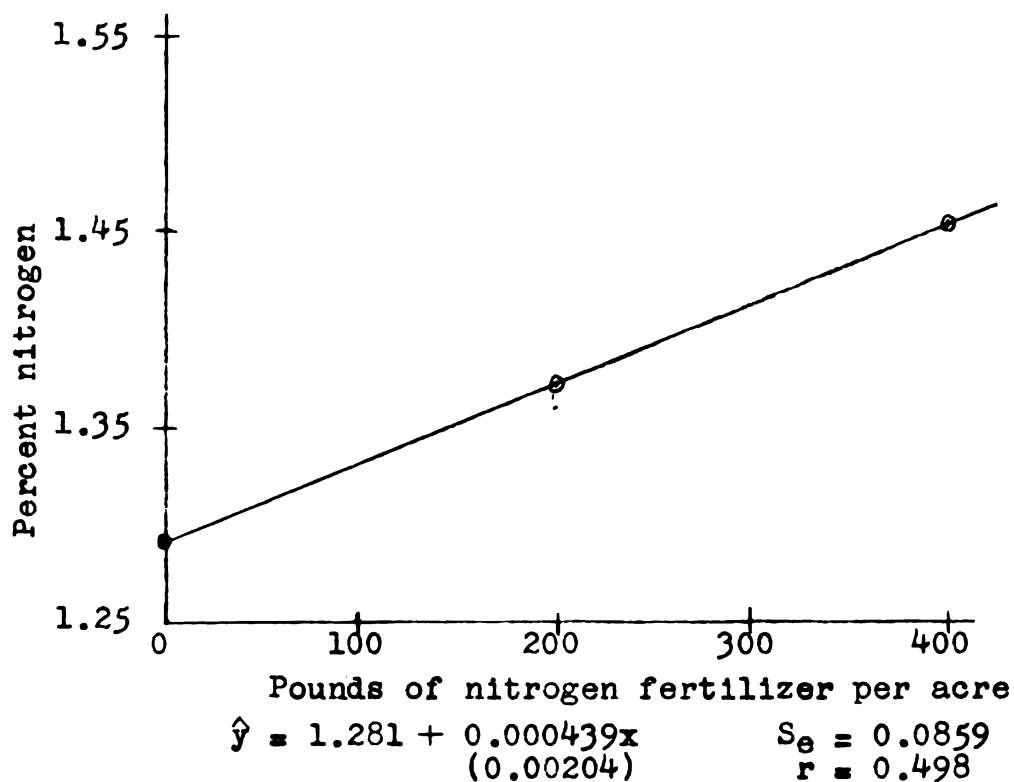


Fig. 3. The effect of applied nitrogen on the nitrogen contents of the grain.

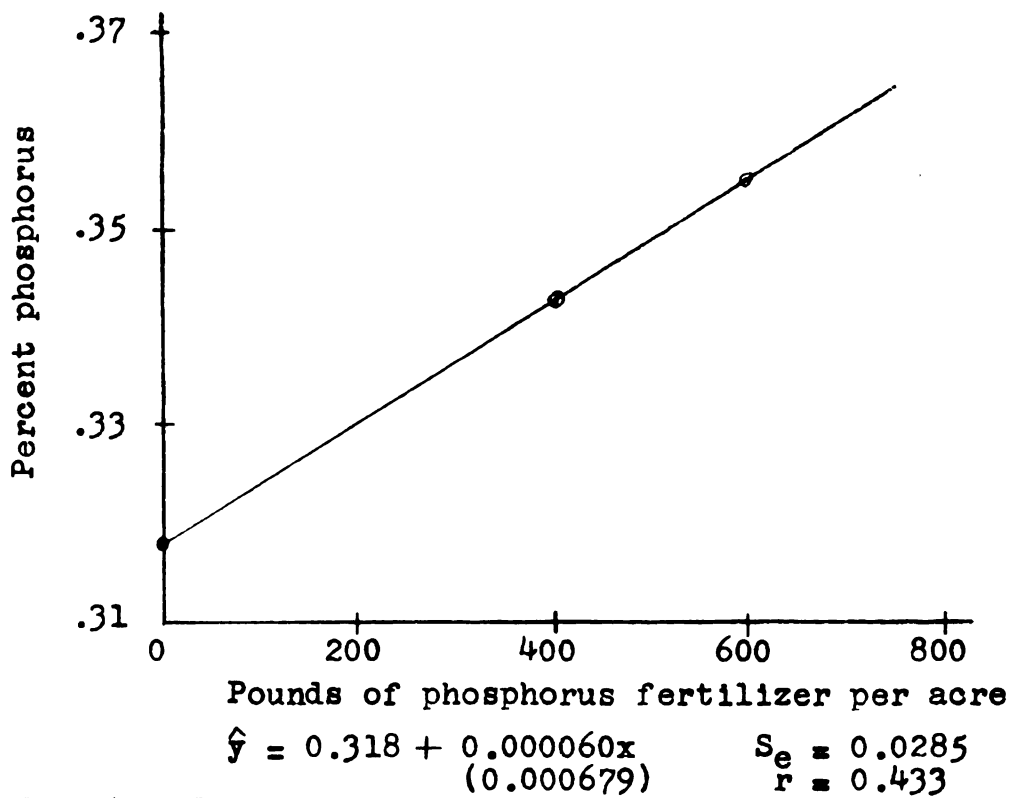
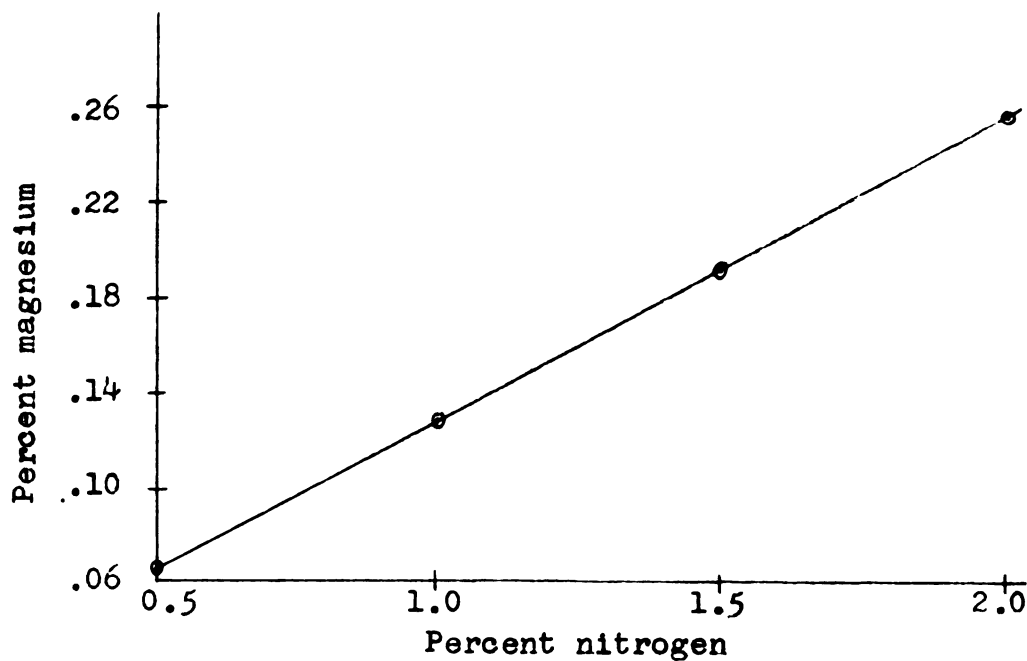


Fig. 4. The effect of applied phosphate on the phosphorus contents of the grain.

nitrogen was directly related to magnesium. The correlation coefficient of 0.337 was significant at the 1% level of probability. Nitrogen in the grain ranged from 1.13 to 1.50 percent and magnesium from 0.1125 to 0.2500 percent. The grain with the lowest nitrogen content of 1.13 percent had a low magnesium content of 0.125 and the grain with the highest nitrogen content of 1.50 percent contained 0.2313 percent of magnesium. This positive correlation was in agreement with the findings of Beckenbach et al (2), however, similar studies on Kalamazoo sandy loam showed a negative correlation between nitrogen and magnesium (6).

Many investigators found that phosphorus absorption is relatively unaffected by the presence of the other ions. However, in this study, an increase in phosphorus content of the grain was accomplished by an increase of nitrogen, potassium and magnesium contents (Figures 6, 7, 8). The correlation coefficients of phosphorus with nitrogen, potassium and magnesium were 0.267, 0.520 and 0.417 respectively. The correlation coefficient between phosphorus and nitrogen was significant at the 5% level. The correlation coefficients between phosphorus and potassium and between phosphorus and magnesium were significant at the 1% level of probability.

In addition to phosphorus the potassium contents of the grain were also significantly related to magnesium contents (Figure 9). The correlation coefficient of 0.361 was significant at the 1% level of probability.



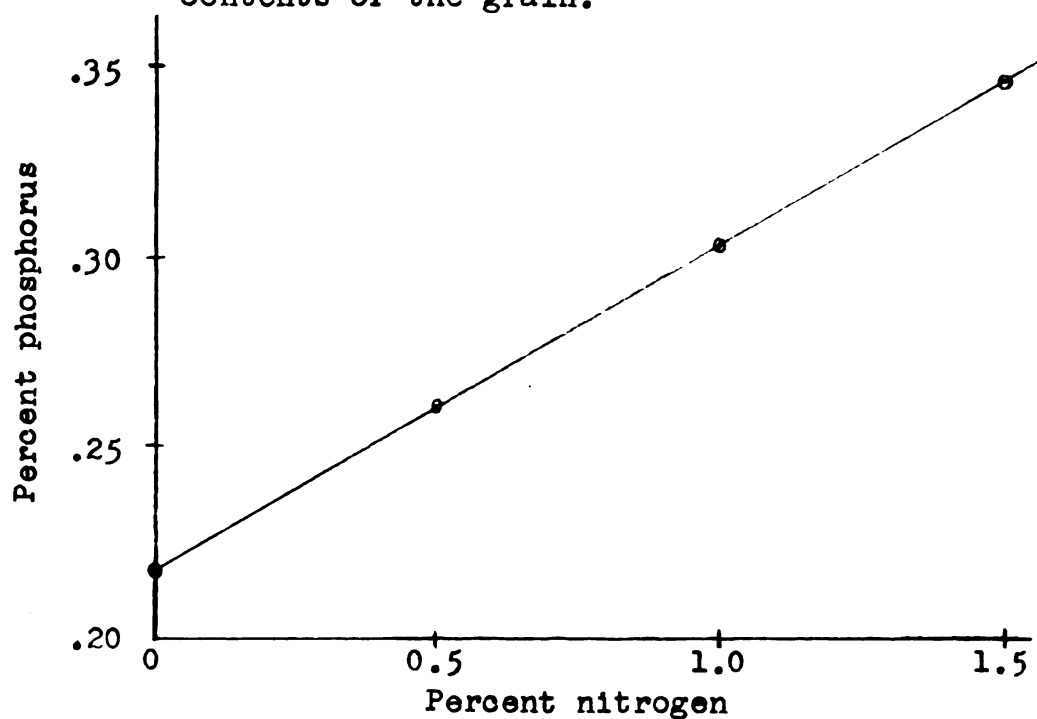
$$\hat{y} = 0.002157 + 0.1285x$$

(0.0479)

$$S_e = 0.0356$$

$$r = 0.337$$

Fig. 5. The relationship between nitrogen and magnesium contents of the grain.



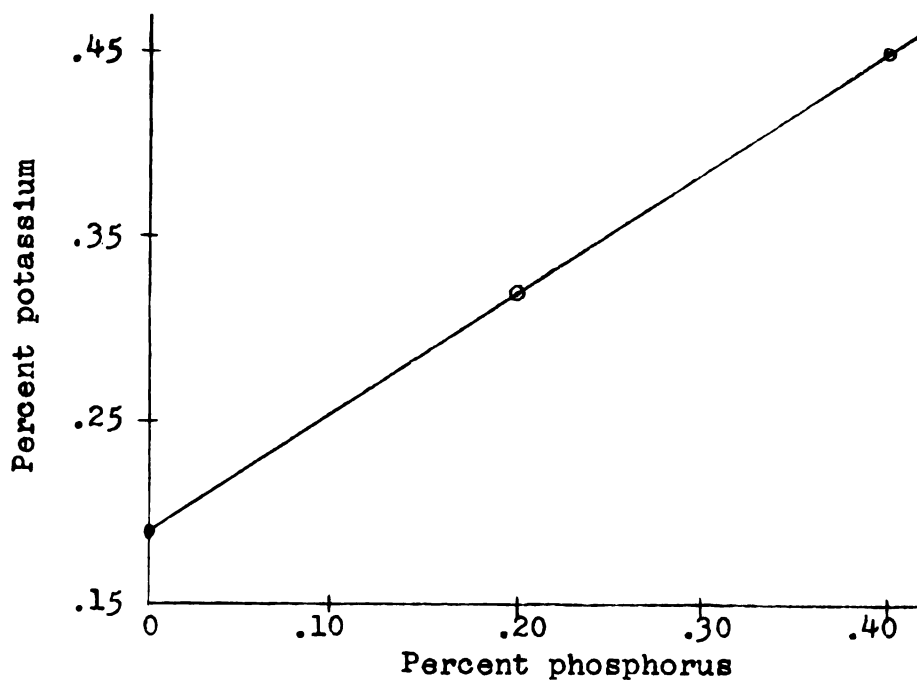
$$\hat{y} = 0.2191 + 0.0858x$$

(0.0411)

$$S_e = 0.0305$$

$$r = 0.267$$

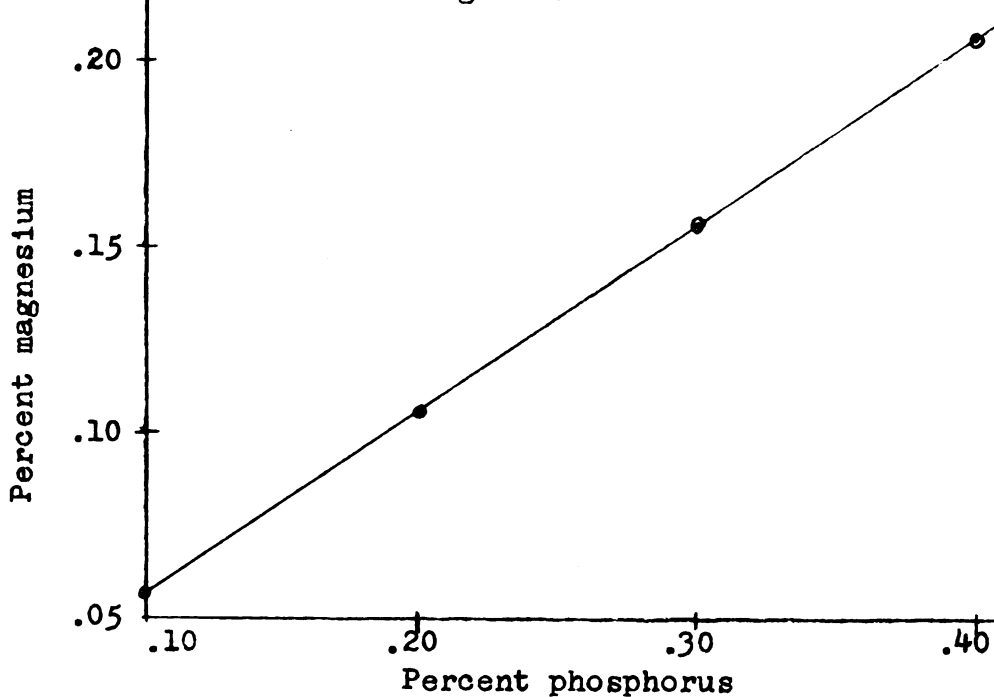
Fig. 6. The relationship between phosphorus and nitrogen contents in the grain.



$$\hat{y} = 0.1859 + 0.6625x \quad S_e = 0.0344$$

$$(0.1453) \quad r = 0.520$$

Fig 7. The relationship between phosphorus and potassium contents of the grain.



$$\hat{y} = 0.00767 + 0.4984x \quad S_e = 0.03436$$

$$(0.145) \quad r = 0.417$$

Fig. 8. The relationship between magnesium and phosphorus contents of the grain.

The interesting observation made on these interrelationships of nutrient contents in the grain was that magnesium had significant positive correlations with all three of the major nutrients, namely, nitrogen, phosphorus and potassium.

Effect of Fertilizers on the Composition of Leaf

Nutrient composition of the corn leaf varied more than the grain as shown in Table 8 (Appendix). In all cases except for phosphorus and sodium, the nutrient composition of the leaf was much greater than in the grain.

Table 3 shows the overall averages and the ranges of the percent mineral composition of the corn leaf.

Table 3. The effect of applied nitrogen, phosphate and potash on the chemical composition of corn leaf.

Percent (oven dry basis)		
	Range	Average
Nitrogen	2.240 - 3.280	2.740
Phosphorus	0.2656 - 0.4438	0.3416
Potassium	0.1880 - 2.2750	1.4270
Calcium	0.3875 - 0.8375	0.5677
Magnesium	0.1813 - 0.6750	0.4808
Sodium	0.0063 - 0.0188	0.0105

The phosphorus content of the leaf was related to the rates of applied phosphate. The correlation coefficient, 0.697, was significant at the 1% level of probability.

Figure 10 shows the positive relationship of phosphorus fertilizer levels to the phosphorus content of the leaf. The leaf with the highest phosphorus content of 0.4438 percent received 480 pounds per acre of phosphate whereas the lowest phosphorus content of the leaf, 0.2656 percent, received no phosphorus fertilizer.

The use of potassium fertilizer increased the potassium content of the leaf. Although it was not as significant as the phosphorus relationship, the potassium content of the leaf was significantly correlated to potash application at the 5% level of probability (Figure 11).

Although yield was significantly affected by the applications of nitrogen fertilizer, the nitrogen content of the leaf was not altered by the different rates of nitrogen fertilizer used. This can be verified by the relatively high content of total nitrogen of the leaf, averaging 2.41 percent in the leaf at the "no fertilizer" level.

There were several significant correlations within the nutrient contents of the corn leaf. Figure 12 shows the correlation of nitrogen and phosphorus contents of the leaf, which was significant at the 5% level of probability. This situation may have been due to the development of a more extensive root system with increased nitrogen uptake by the plant and hence, contacting more soil phosphorus and increasing the uptake of phosphorus into the leaf. Potassium

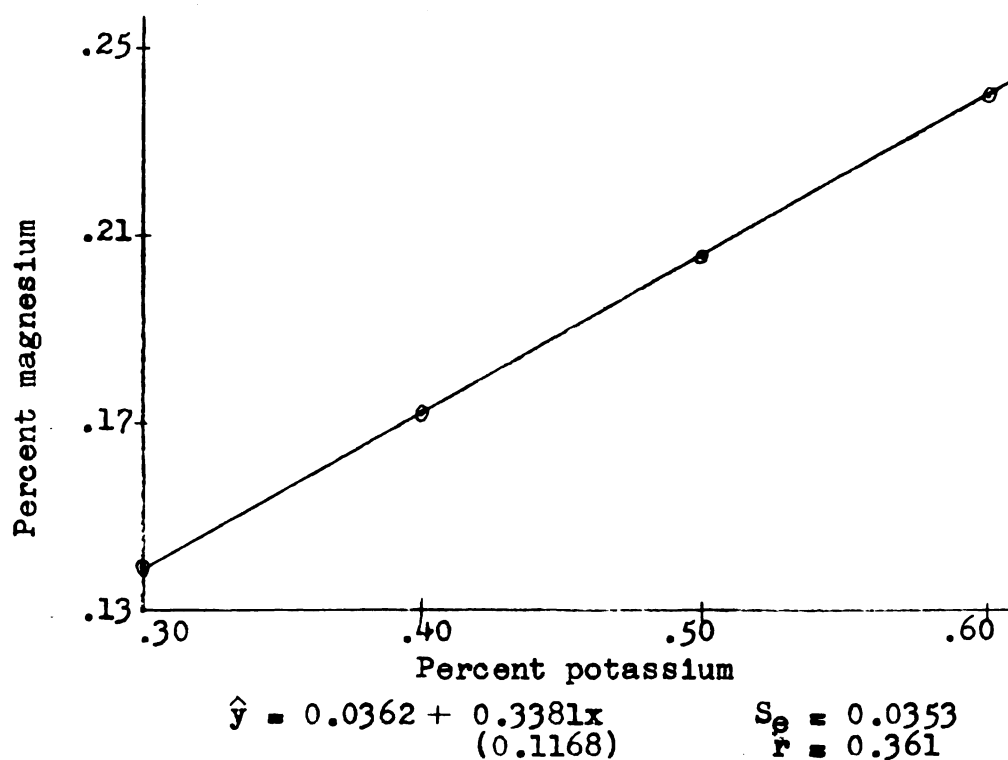


Fig. 9. The relationship between magnesium and potassium contents of the grain.

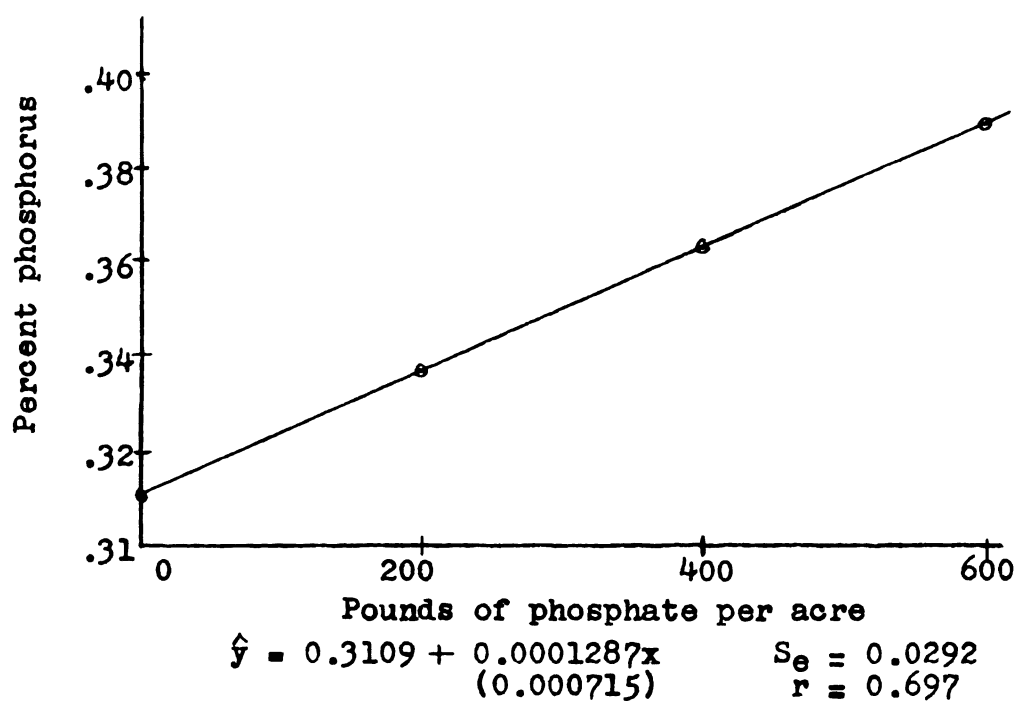


Fig. 10. The effect of applied phosphate on the phosphorus contents of the leaves.

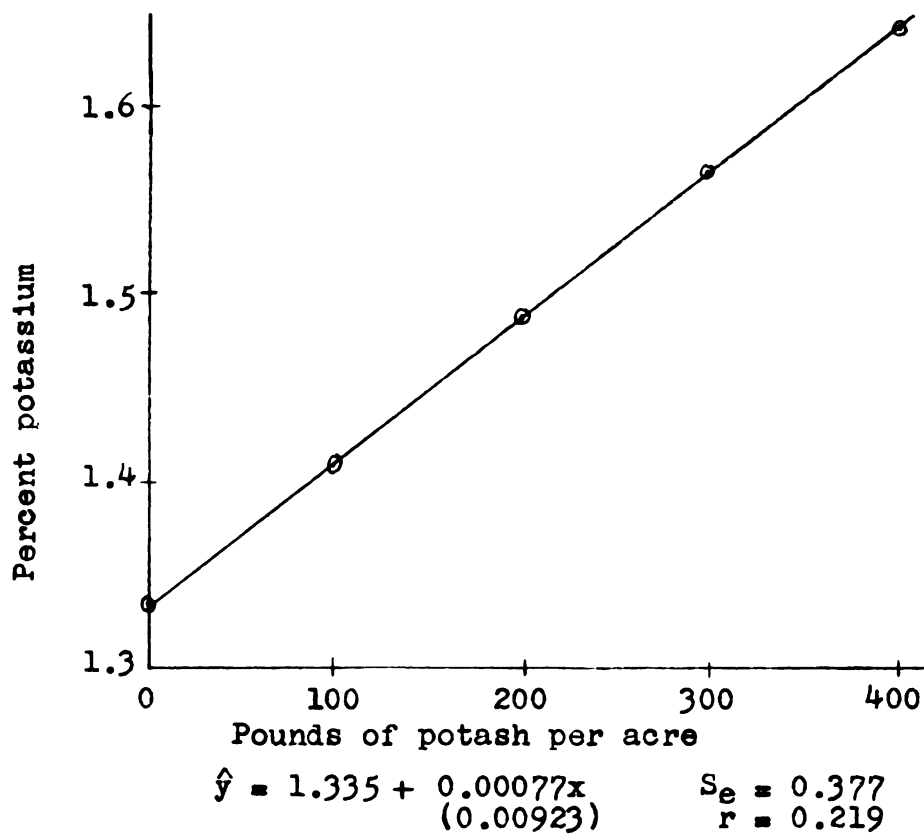


Fig. 11. The effect of applied potash on the potassium contents of the leaves.

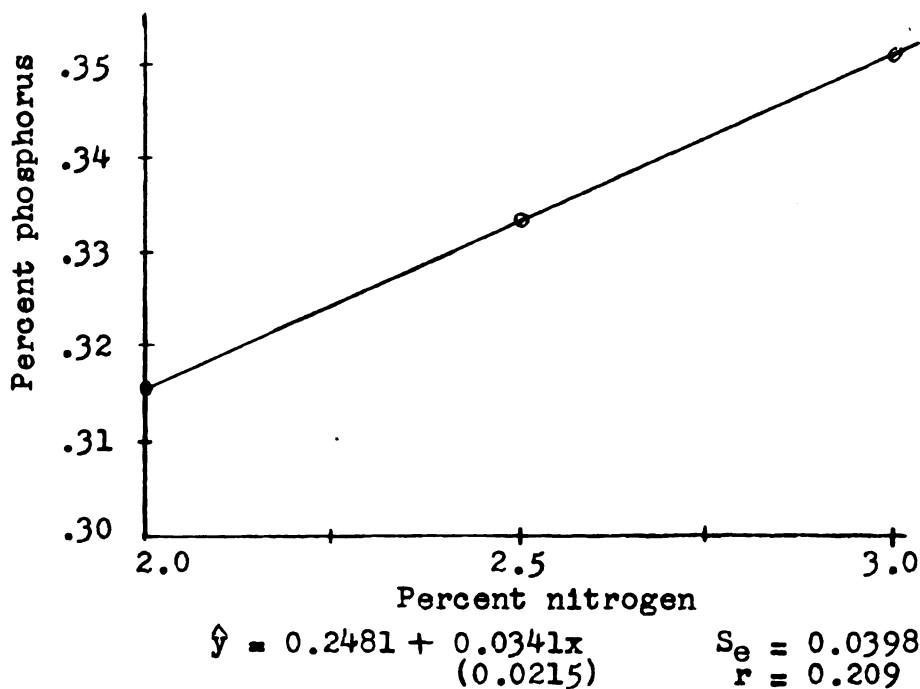


Fig. 12. The relationship between phosphorus and nitrogen contents of the leaves.

content was also significantly correlated with sodium content in the leaf (Figure 13). The correlation coefficient of 0.242 was significant at the 5% level.

The calcium and magnesium contents of the leaf were closely related (Figure 14). This is in agreement with other investigators. The coefficient of 0.707 was significant at the 1% level of probability. The leaf with the lowest calcium content, 0.3875 percent, had a low magnesium content of 0.3188 percent, whereas the leaf with the highest calcium content of 0.8375 percent had a high magnesium content of 0.5500 percent.

Relationships of Nutrient Elements in Leaf and Grain

To determine whether there were any relationships of the nutrient content of the leaf in respect to its content in the grain, the results were analyzed statistically. Phosphorus and magnesium were the only two nutrient elements that were significantly correlated.

Figure 15 shows the relationship of phosphorus in the leaf and grain. As the nutrient increased in the leaf, there was a corresponding increase in the grain. Many investigators have shown similar results. As the phosphorus uptake of the leaf increased, due to increase of soil phosphorus by fertilizer applications, more of this nutrient was able to be utilized in the grain. The correlation coefficient of 0.491 was significant at the 1% level of probability.

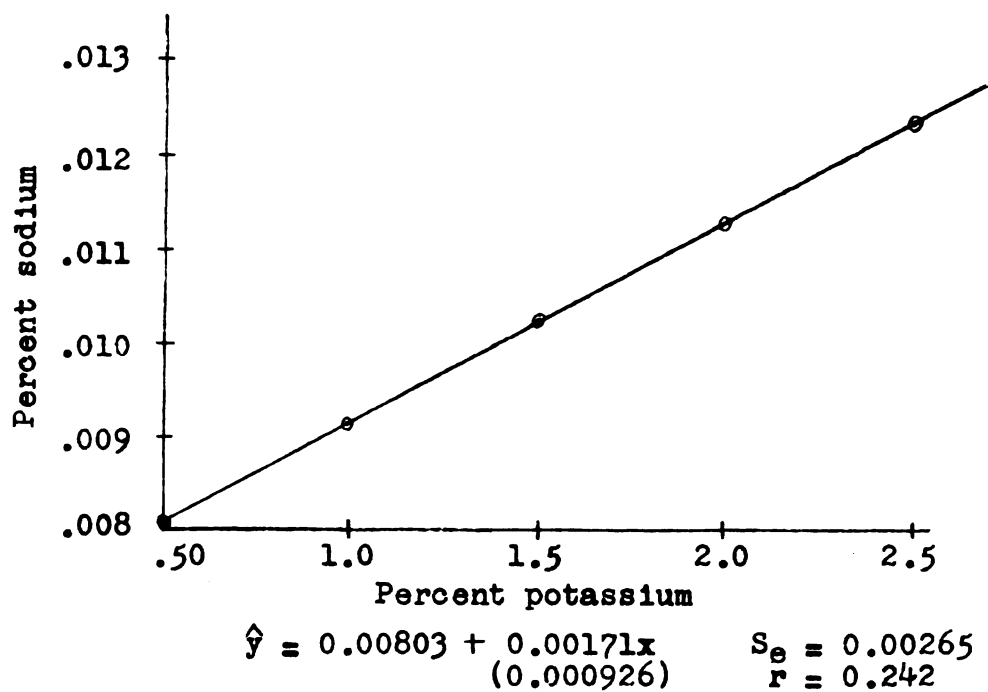


Fig. 13. The relationship between sodium and potassium contents of the leaves.

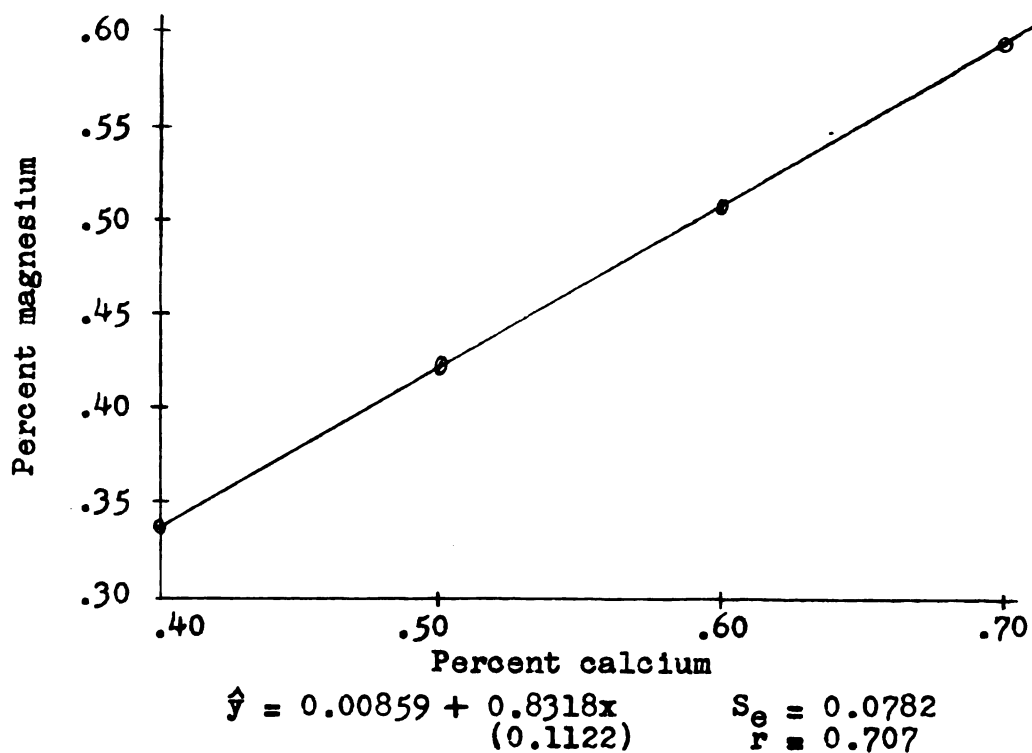


Fig. 14. The relationship between magnesium and calcium contents of the leaves.

As shown in Figure 16, there was a negative correlation between magnesium content of the leaf and grain, the correlation being significant at the 5% level of probability. As the magnesium content of the grain increased, the leaf decreased in magnesium. This indicates that the magnesium was translocated to the grain and depleted the leaf of magnesium. Noting that the phosphorus and magnesium were the only two nutrients that were significantly correlated and that a positive relationship existed between the phosphorus and magnesium contents of the grain, magnesium may function as the carrier of phosphorus into the grain.

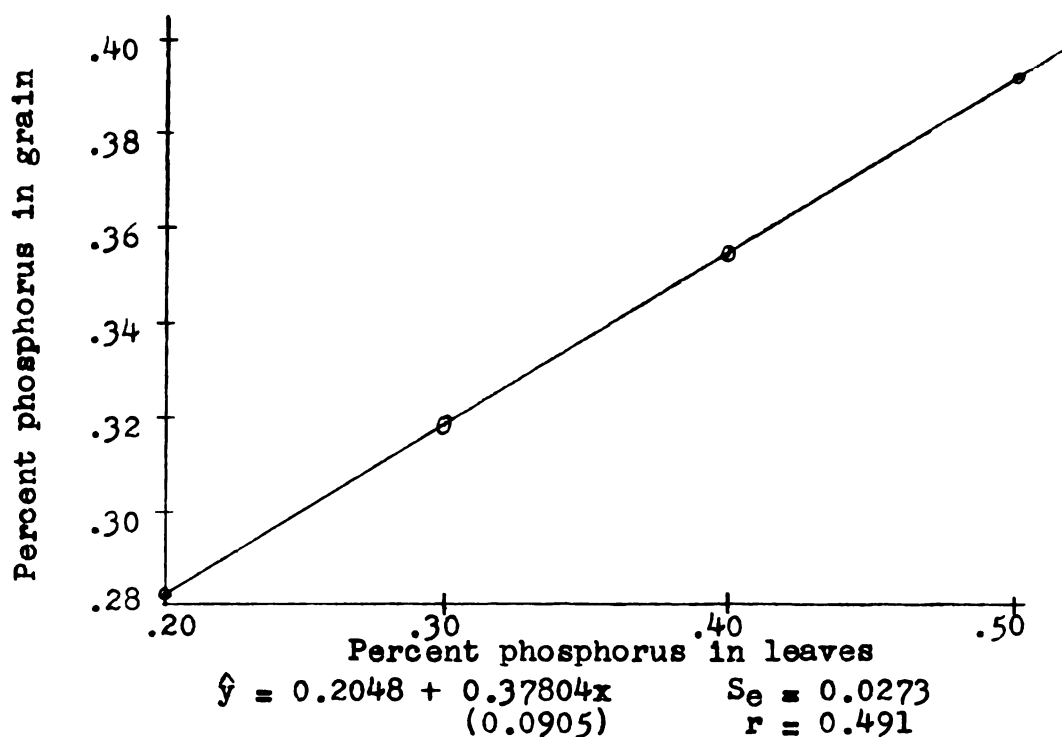


Fig. 15. Relationship between phosphorus contents of grain and phosphorus contents of the leaves.

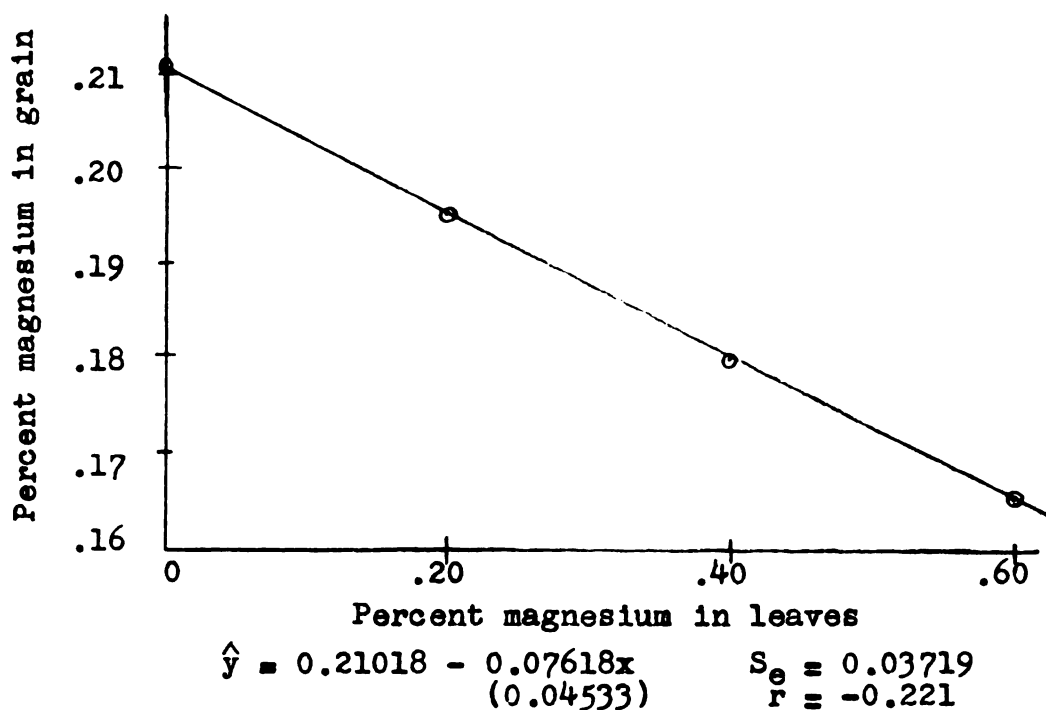


Fig. 16. Relationship between magnesium contents of grain and magnesium contents of the leaves.

SUMMARY

Field plots were established and corn was fertilized with various rates and combinations of nitrogen, phosphoric acid and potash. The highest rate included 320, 640 and 320 pounds per acre of nitrogen, phosphoric acid and potash respectively. Leaf and grain samples were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Yield determinations were made. Multiple and simple correlations were calculated to determine whether any significant correlations existed. The results are summarized as follows:

1. Corn yields ranged from 80.9 to 143.9 bushels per acre, averaging 109.3 bushels per acre. The high average yield of 96.0 bushels per acre from four of the "no fertilizer" plots indicated that this soil was productive.

2. Yield was increased by nitrogen and phosphorus fertilizer applications. However, potash fertilization did not affect corn yield.

3. Yield was significantly correlated with the combined variables of nitrogen, phosphorus, potassium, calcium, magnesium and sodium of the grain at the 5% level of probability but not significant with the nutrients taken individually.

4. Applications of nitrogen and phosphorus fertilizers increased the nitrogen and phosphorus concentrations in the grain.

5. Several interrelationships of nutrients were found

in the grain. Phosphorus was positively correlated with nitrogen, potassium and magnesium. Magnesium was also positively correlated to nitrogen and potassium.

6. A positive correlation existed between yield and the phosphorus and sodium contents of the leaf.

7. Phosphorus and potassium fertilizers increased the uptake of phosphorus and potassium in the leaf. This was not the case with nitrogen.

8. In the leaf nitrogen and phosphorus, potassium and sodium, and magnesium and calcium were positively correlated.

9. In the relationship between nutrient contents of grain and leaf, a positive correlation existed with phosphorus and a negative correlation with magnesium.

BIBLIOGRAPHY

1. Beckenbach, J. R., Robbins, W. R., Shive, J. W. Nutrient studies with corn: II A statistical interpretation of the relationship between the ionic concentration of the culture solutions and the elements content of the tissues. *Soil Sci.* 45:403-426, 1938.
2. Bennett, W. F., Stanford, G. and Dumenil, L. Nitrogen, phosphorus and potassium content of the corn leaf and grain as related to nitrogen fertilization and yield. *Soil Sci. Soc. Amer. Proc.* 17:252-258, 1953.
3. Boswell, F. C. and Parks, W. L. The effect of soil potassium levels on yield, lodging and mineral composition of corn. *Soil Sci. Soc. Amer. Proc.* 21:301-305, 1957.
4. Cope, J. T., Jr., Bradfield, R. and Peech, M. Effect of sodium fertilization on yield and cation content of some field crops. *Soil Sci.* 76:65-74, 1953.
5. Cummings, R. W. North Carolina makes progress toward doubling corn yield. *Plant Food Jour.* 1(1):4-7, 1947.
6. Dowdy, E. R. The effect of fertilizer rate and ratio on the composition of the leaves and grain of corn grown on a Kalamazoo sandy loam soil. Master of Science Thesis, Mich. State Univ., 1957.
7. Drosdoff, M. and Nearpass, D. C. Quantitative micro-determination of magnesium in plant tissues and soil extracts. *Anal. Chem.* 20:673-674, 1948.
8. Dumenil, L. and Nelson L. B. Nutrient balance and interaction in fertilizer experiments. *Soil Sci. Soc. Amer. Proc.* 13:335-341, 1948.
9. Earley, E. B. and DeTurk, E. E. Time and rate of synthesis of phytin in corn grain during the reproductive period. *Jour. Amer. Soc. Agr.* 36:803-814, 1944.
10. Fertilizer recommendations for Michigan crops. Extension Bulletin 159 (Revised), Mich. State Univ., Oct, 1957.
11. Fiske, G. H. and Subarrow, V. S. The colorimetric determination of phosphorus. *Jour. Biol. Chem.* 66:325, 1925.

12. Foy, C. D. and Barber, S. A. Magnesium deficiency and corn yield on two acid Indiana soils. Soil Sci. Soc. Amer. Proc. 22:145-148, 1958.
13. Glover, J. The nutrition of maize in sand culture. I. The balance of nutrition with particular reference to the level of supply of nitrogen and phosphorus. Jour. Agr. Sci. 43:154-159, 1953.
14. _____. The nutrition of maize in sand culture. II. The uptake of nitrogen and phosphorus and its relevance to plant analysis. Jour. Agr. Sci. 43:160-165, 1953.
15. Hunter, S. and Yunger, J. A. The influence of variations in fertility levels upon the yield and protein content of field corn in eastern Oregon. Soil Sci. Soc. Amer. Proc. 19:214-218, 1955.
16. Jordan, H. V., Laird, K. B., and Ferguson, B. B. Growth rates and nutrient uptake by corn in a fertilizer-spacing experiment. Agron. Jour. 42:261-268, 1950.
17. Krantz, B. A. Higher corn yields for North Carolina. Better Crops with Plant Food, XXXIX (3):19-22, 48-49, 1945.
18. _____. Research points the way for higher corn yields in North Carolina. Better Crops with Plant Food, XXXI (2):6-10, 45-47, 1947.
19. _____ and Chandler, W. V. Lodging, leaf composition and yield of corn as influenced by heavy applications of nitrogen and potassium. Agron. Jour. 43:547-552, 1951.
20. Larson, W. E. and Pierre, W. H. Interaction of sodium and potassium on yield and cation composition of selected crops. Soil Sci. 76:51-64, 1953.
21. Lawton, K. et al. Diagnostic techniques used in soil fertility studies. Mich. Agr. Exp. Sta. Quart. Bull. 34 (4):466-471, 1952.
22. Leonard, C. D. and Bear, F. E. Sodium as a fertilizer for New Jersey soils. New Jersey Agr. Expt. Sta. Bull. 752, 1950.

23. McKenzie, L. J., Engberg, C. A., and Whiteside, E. P. Soils of Denmark Township, Tuscola County, Michigan. Mich. State College Agr. Exp. Sta., 1955.
24. Morris, V. H. and Sayre, J. D. Solubility of potassium in corn tissues. Plant Physiology. 10:565-568, 1935.
25. Nelson, W. L. et al. Application of radioactive tracer technique to studies of phosphatic fertilizer utilization by crops. II. Field experiments. Soil Sci. Soc. Amer. Proc. 12:113-118, 1947.
26. Ohlrogge, A. J., Krantz, B. A., and Scarseth, G. D. The recovery of plowed-under ammonium sulfate by corn. Soil Sci. Soc. Amer. Proc. 8:196-200, 1943.
27. Piper, C. S. Soil and Plant Analysis. Interscience Publishers, Inc., N. Y., pp. 258-275, 1950.
28. Prince, A. L. Methods in soil analysis. Chemistry of the Soil, edited by Bear, F. E. ACS Mon. No. 126:328-362, 1955.
29. Sayre, J. D. Mineral accumulation in corn. Plant Physiology. 23:26-267, 1948.
30. Stanford, G., Kelly, J. B., and Pierre, W. H. Cation balance in corn grown on high-lime soils in relation to potassium deficiency. Soil Sci. Soc. Amer. Proc. 6:335-341, 1941.
31. _____ and Nelson, L. B. Utilization of phosphorus as affected by placement. I. Corn in Iowa. Soil Sci. 68:129-135, 1949.
32. Taylor, G. A. The effects of three levels of magnesium on the nutrient-element composition of two inbred lines of corn and on their susceptibility to helminthosporium maydis. Plant Physiology. 29:87-91, 1954.
33. Truog et al. Response of nine economic plants to fertilization with sodium. Soil Sci. 76:41-50, 1953.
34. Tyner, E. H. The relation of corn yields to leaf nitrogen, phosphorus, and potassium content. Soil Sci. Soc. Amer. Proc. 11:317-323, 1946.
35. _____ and Webb, J. R. The relation of corn yields to nutrient balance as revealed by leaf analysis. Jour. Amer. Soc. Agron. 38:173-185, 1946.

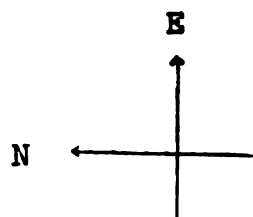
36. Viets, F. H., Jr., Nelson, C. E. and Crawford, C. D. The relationships among corn yields, leaf composition and fertilizers applied. Soil Sci. Soc. Amer. Proc. 18:297-301, 1954.
37. Wadleigh, C. W. and Shive, J. W. Base content of corn plants as influenced by pH of substrate and form of nitrogen supply. Soil Sci. 47:273-283, 1939.
38. Webb, J. R., Ohlrogge, A. J. and Barber, S. A. The effect of magnesium upon the growth and the phosphorus content of soybean plants. Soil Sci. Soc. Amer. Proc. 18:458-462, 1954.

APPENDIX

Table 4

Field Diagram for Continuous Corn Experiment, Tuscola County.

3-3-3	3-3-5	3-0-0							
6-4-5	3-5-5	6-6-3							
5-1-5	6-5-1	3-1-1							
5-1-1	6-3-2	3-5-1							
1-4-1	0-0-0	1-3-3							
1-5-5	1-1-3	0-6-3							
4-1-0	5-3-1	4-0-1							
4-4-4	4-4-3	5-5-1							
2-1-4	3-3-1	6-4-3	0-0-0	6-3-6	6-1-5	3-1-5	6-3-0	0-1-5	
6-2-4	2-2-2	5-3-3	3-6-3	6-6-2	0-0-0	6-6-5	0-0-2	1-3-1	
5-1-3	5-5-5	5-3-5	6-2-3	3-5-2	4-3-6	2-4-1	1-5-1	1-1-5	
3-2-5	4-0-3	2-1-3	1-3-5	5-5-3	3-1-3	1-5-3	2-4-6	4-2-2	
6-4-2	3-3-1	1-3-2	1-1-1	2-5-2	3-5-3	4-5-6	2-4-2	2-5-3	
6-2-6	3-0-4	5-2-4	6-2-2	6-1-1	3-4-0	5-1-3	2-5-5	6-6-6	
3-5-5	3-5-1	2-3-5	3-1-3	1-4-6	3-4-2	1-1-5	3-4-4	6-6-6	
5-6-6	3-3-3	3-1-1	1-3-5	1-2-3	4-5-1	3-2-4	4-6-3	5-5-1	
0-5-1	3-3-3	2-3-1	0-0-0	3-1-5	4-3-5	2-6-1	2-1-1	4-3-3	
1-1-4	1-1-1	5-2-2	5-3-5	5-3-3	4-2-4	5-3-1	0-2-0	2-2-5	
5-6-2	1-1-1	0-4-4	3-6-6	5-4-2	5-5-3	6-0-3	6-5-4	3-5-3	
5-1-1	3-3-5	0-6-6	1-4-4	4-3-1	0-0-0	5-5-5	1-3-3	1-1-3	
1-6-4	3-1-1	6-5-6	1-5-1	5-1-5	2-2-0	1-5-5	1-3-1	1-5-3	
4-4-4	3-3-5	2-1-2	4-6-5	5-2-6	2-4-3	5-0-0	3-3-3	0-2-2	
4-4-4	0-0-0	1-2-5	1-1-3	5-1-3	4-1-3	5-5-1	1-5-1	1-3-5	
0-3-6	3-3-6	5-3-3	1-3-3	5-3-5	5-1-1	2-6-4	1-5-2	3-5-5	
4-1-5	0-0-0	2-0-0	1-2-1	0-0-0	2-4-4	5-5-3	5-0-2	5-5-5	
5-2-0	1-1-5	2-1-6	4-5-3	3-5-1	3-1-5	1-3-1	1-6-6	4-4-2	
2-2-2	2-3-3	1-5-5	5-4-4	6-2-5	3-3-1	3-2-2	4-3-0	5-5-5	
2-2-2	6-4-4	6-6-6	2-0-2	2-3-4	5-3-1	4-3-4	3-1-3	5-1-5	
			5-4-6	5-6-4	1-1-1	3-5-3	1-5-3	2-6-6	

Key to Treatments

Levels	0	1	2	3	4	5	6
N	0	20	40	80	160	240	320
P ₂₀ ₅	0	40	80	160	320	480	640
K ₂₀	0	20	40	80	160	240	320

Plot size: 14' x 55'

Alleys: 20' between each tier of plots

Border: 7' on each end of each tier of plots

Table 5
Selected Samples for Chemical Analysis

<u>Plot Number</u>	<u>Treatment</u>	<u>Plot Number</u>	<u>Treatment</u>	<u>Plot Number</u>	<u>Treatment</u>
1	N ₂ P ₂ K ₂	68	N ₂ P ₃ K ₁	147	N ₆ P ₁ K ₅
3	N ₅ P ₂ K ₀	69	N ₃ P ₁ K ₁	150	N ₃ P ₂ K ₂
13	N ₅ P ₆ K ₆	72	N ₁ P ₃ K ₂	155	N ₅ P ₀ K ₀
19	N ₆ P ₂ K ₄	74	N ₅ P ₃ K ₅	160	N ₂ P ₆ K ₁
21	N ₄ P ₄ K ₄	76	N ₆ P ₄ K ₃	162	N ₁ P ₁ K ₅
28	N ₃ P ₃ K ₃	78	N ₄ P ₀ K ₁	171	N ₄ P ₃ K ₀
29	N ₆ P ₄ K ₄	94	N ₁ P ₄ K ₄	172	N ₁ P ₆ K ₆
32	N ₀ P ₀ K ₀	95	N ₃ P ₆ K ₆	179	N ₆ P ₅ K ₄
38	N ₁ P ₁ K ₁	97	N ₀ P ₀ K ₀	181	N ₂ P ₁ K ₁
44	N ₃ P ₃ K ₁	107	N ₂ P ₃ K ₄	182	N ₄ P ₆ K ₃
45	N ₄ P ₀ K ₃	108	N ₆ P ₂ K ₅	183	N ₃ P ₄ K ₄
46	N ₅ P ₅ K ₅	113	N ₅ P ₂ K ₆	188	N ₀ P ₀ K ₂
52	N ₀ P ₀ K ₀	120	N ₁ P ₄ K ₆	189	N ₆ P ₃ K ₀
55	N ₃ P ₅ K ₅	122	N ₂ P ₅ K ₂	190	N ₂ P ₆ K ₆
57	N ₆ P ₆ K ₆	124	N ₃ P ₅ K ₂	193	N ₄ P ₄ K ₂
65	N ₀ P ₆ K ₆	133	N ₄ P ₁ K ₃	198	N ₁ P ₅ K ₃
66	N ₀ P ₄ K ₄	137	N ₅ P ₅ K ₃	199	N ₁ P ₁ K ₃
67	N ₅ P ₂ K ₂	140	N ₄ P ₅ K ₁	201	N ₂ P ₂ K ₅
		146	N ₀ P ₀ K ₀	210	N ₀ P ₁ K ₅

Table 6

Adjustment of the Beckman Spectrophotometer
for the Determination of Calcium
Potassium and Sodium

	<u>Ca</u>	<u>K</u>	<u>Na</u>
Wave length	422.7	766.5	589.3
Photo tube resistor	#2	#1	#2
Photo tube filter	blue	red (lever out)	blue
Selector	0.1	0.1	0.1
Photo-multiplier sensitivity	4	off	2
Zero suppression	1.0	off	1.0
O ₂ pressure			
a) tank	40	40	40
b) instrument panel	12	12	12
H ₂ pressure			
a) tank	10	10	10
b) instrument panel	4	4	4
Slit width	.01	.01 -.02	.01

Table 7

Yield and Chemical Analysis of Corn Grain as Affected
by Various Fertilizer Treatments *

Treat.	Plot No.	N	P	Percent K	Total Ca	Na	Mg	Bu/A
N ₀ P ₀ K ₀	32	1.37	0.3188	0.4050	0.0050	0.0081	0.1500	85.3
N ₀ P ₀ K ₀	52	1.40	0.2969	0.3675	0.0013	0.0063	0.1500	106.6
N ₀ P ₀ K ₀	97	1.50	0.3438	0.4250	0.0125	0.0081	0.2313	100.3
N ₀ P ₀ K ₀	146	1.13	0.2969	0.3675	0.0113	0.0106	0.1250	91.6
N ₀ P ₀ K ₂	188	1.29	0.2813	0.3825	0.0013	0.0063	0.2000	91.3
N ₀ P ₁ K ₅	210	1.24	0.3344	0.3675	0.0050	0.0081	0.1125	92.5
N ₀ P ₄ K ₄	66	1.15	0.3438	0.3675	0.0088	0.0088	0.1500	95.7
N ₀ P ₆ K ₆	65	1.20	0.3344	0.3675	0.0075	0.0081	0.1688	105.5
N ₁ P ₁ K ₁	38	1.16	0.2969	0.3925	0.0025	0.0100	0.0750	118.2
N ₁ P ₁ K ₃	199	1.23	0.3344	0.4050	0.0063	0.0081	0.1688	113.0
N ₁ P ₁ K ₅	162	1.37	0.3563	0.4175	0.0063	0.0081	0.2000	94.8
N ₁ P ₃ K ₂	72	1.21	0.3469	0.3925	0.0100	0.0106	0.1125	124.0
N ₁ P ₄ K ₄	94	1.29	0.4000	0.4250	0.0113	0.0088	0.1813	99.4
N ₁ P ₄ K ₆	120	1.20	0.2750	0.3675	0.0038	0.0081	0.1813	120.8
N ₁ P ₅ K ₃	198	1.23	0.3781	0.4575	0.0113	0.0081	0.2313	123.4
N ₁ P ₆ K ₆	172	1.25	0.2875	0.3500	0.0075	0.0081	0.1813	135.3
N ₂ P ₁ K ₁	181	1.31	0.3344	0.3925	0.0038	0.0056	0.1813	106.1
N ₂ P ₂ K ₂	1	1.27	0.3031	0.3675	0.0138	0.0100	0.1813	108.4
N ₂ P ₂ K ₅	201	1.28	0.3313	0.4425	0.0088	0.0100	0.1500	115.6
N ₂ P ₃ K ₁	68	1.28	0.3313	0.4250	0.0038	0.0088	0.1813	124.6
N ₂ P ₃ K ₄	107	1.34	0.3344	0.3500	0.0063	0.0081	0.1125	118.5

Table 7 (Cont'd)

Treat.	Plot No.	Percent Total						
		N	P	K	Ca	Na	Mg	Bu/A
N ₂ P ₅ K ₂	122	1.23	0.3250	0.5000	0.0100	0.0100	0.1313	114.2
N ₂ P ₆ K ₁	160	1.24	0.3344	0.4575	0.0100	0.0063	0.1813	114.7
N ₂ P ₆ K ₆	190	1.41	0.3781	0.3925	0.0025	0.0056	0.2125	133.5
N ₃ P ₁ K ₁	69	1.26	0.2750	0.3925	0.0113	0.0088	0.1313	104.6
N ₃ P ₂ K ₂	150	1.37	0.3250	0.3675	0.0125	0.0063	0.1313	116.5
N ₃ P ₃ K ₁	44	1.39	0.3219	0.3825	0.0075	0.0075	0.1500	115.0
N ₃ P ₃ K ₃	28	1.44	0.3625	0.4875	0.0063	0.0081	0.2000	98.0
N ₃ P ₄ K ₄	183	1.40	0.3219	0.3825	0.0038	0.0100	0.2000	111.3
N ₃ P ₅ K ₂	124	1.40	0.3563	0.4250	0.0075	0.0075	0.2000	87.6
N ₃ P ₅ K ₅	55	1.37	0.3656	0.4425	0.0038	0.0113	0.1500	101.2
N ₃ P ₆ K ₆	95	1.33	0.3500	0.3425	0.0075	0.0088	0.2125	142.8
N ₄ P ₀ K ₁	78	1.30	0.3063	0.3925	0.0075	0.0038	0.1125	101.4
N ₄ P ₀ K ₃	45	1.34	0.3100	0.4250	0.0050	0.0081	0.1688	103.8
N ₄ P ₁ K ₃	133	1.40	0.3438	0.3675	0.0038	0.0088	0.2313	111.6
N ₄ P ₃ K ₀	171	1.29	0.3188	0.4425	0.0138	0.0063	0.2000	122.0
N ₄ P ₄ K ₂	193	1.38	0.3250	0.3675	0.0200	0.0100	0.1125	136.4
N ₄ P ₄ K ₄	21	1.14	0.3813	0.4250	0.0063	0.0081	0.2125	111.3
N ₄ P ₅ K ₁	140	1.34	0.3313	0.4175	0.0050	0.0150	0.2000	119.0
N ₄ P ₆ K ₃	182	1.47	0.4375	0.5000	0.0050	0.0088	0.2125	110.7
N ₅ P ₀ K ₀	155	1.45	0.3313	0.4250	0.0050	0.0125	0.2125	93.1
N ₅ P ₂ K ₀	3	1.44	0.3125	0.3675	0.0088	0.0081	0.2313	111.3
N ₅ P ₂ K ₂	67	1.42	0.3500	0.3825	0.0063	0.0063	0.1688	112.7
N ₅ P ₂ K ₆	113	1.44	0.3875	0.5125	0.0125	0.0088	0.2313	110.1

Table 7 (Cont'd)

Treat	Plot No.	Percent Total						
		N	P	K	Ca	Na	Mg	Bu/A
N ₅ P ₃ K ₅	74	1.49	0.3219	0.3925	0.0075	0.0100	0.1313	114.7
N ₅ P ₅ K ₃	137	1.46	0.3469	0.4050	0.0100	0.0100	0.1813	111.3
N ₅ P ₅ K ₅	46	1.41	0.3469	0.4750	0.0075	0.0081	0.2000	143.9
N ₅ P ₆ K ₆	13	1.38	0.3500	0.4575	0.0050	0.0088	0.2500	105.2
N ₆ P ₁ K ₅	147	1.20	0.3250	0.4250	0.0113	0.0100	0.1688	88.4
N ₆ P ₂ K ₄	19	1.44	0.3100	0.3825	0.0175	0.0081	0.1813	101.2
N ₆ P ₂ K ₅	108	1.43	0.2813	0.4250	0.0038	0.0081	0.1500	96.5
N ₆ P ₃ K ₀	189	1.26	0.2875	0.3925	0.0088	0.0081	0.1813	84.1
N ₆ P ₄ K ₃	76	1.40	0.3063	0.3500	0.0025	0.0063	0.1313	80.9
N ₆ P ₄ K ₄	29	1.48	0.3563	0.4250	0.0025	0.0081	0.1813	118.5
N ₆ P ₅ K ₄	179	1.38	0.3469	0.3825	0.0063	0.0113	0.1688	116.5
N ₆ P ₆ K ₆	57	1.48	0.3625	0.4250	0.0038	0.0088	0.1813	106.4

* Average of two replications

Table 8
Chemical Analysis of Corn Leaves as Affected
by Various Fertilizer Treatments *

Treat	Plot No.	Percent Total					
		N	P	K	Ca	Na	Mg
N ₀ P ₀ K ₀	32	2.56	0.2656	1.475	0.6125	0.0075	0.5500
N ₀ P ₀ K ₀	52	2.36	0.3000	0.875	0.6825	0.0113	0.6063
N ₀ P ₀ K ₀	97	2.43	0.3188	0.838	0.4375	0.0088	0.4188
N ₀ P ₀ K ₀	146	2.31	0.2750	1.650	0.6750	0.0088	0.5000
N ₀ P ₀ K ₂	188	2.20	0.3031	1.613	0.5000	0.0088	0.4438
N ₀ P ₁ K ₅	210	2.42	0.3375	1.575	0.4250	0.0088	0.3188
N ₀ P ₄ K ₄	66	2.41	0.3375	1.200	0.6000	0.0106	0.3938
N ₀ P ₆ K ₆	65	2.52	0.3313	1.375	0.5500	0.0125	0.4188
N ₁ P ₁ K ₁	38	3.02	0.3000	1.525	0.7000	0.0150	0.6563
N ₁ P ₁ K ₃	199	2.80	0.3313	1.750	0.4700	0.0106	0.4188
N ₁ P ₁ K ₅	162	2.86	0.3250	0.650	0.3875	0.0063	0.3188
N ₁ P ₃ K ₂	72	2.70	0.2938	1.000	0.8375	0.0088	0.5500
N ₁ P ₄ K ₄	94	2.35	0.3219	2.050	0.5300	0.0113	0.2625
N ₁ P ₄ K ₆	120	2.58	0.2938	2.000	0.5000	0.0131	0.4438
N ₁ P ₅ K ₃	198	2.61	0.3938	1.275	0.4750	0.0150	0.5000
N ₂ P ₁ K ₁	181	3.10	0.3250	1.300	0.6625	0.0100	0.5375
N ₂ P ₂ K ₂	1	2.79	0.3000	1.425	0.6625	0.0150	0.6250
N ₂ P ₂ K ₅	201	3.15	0.3313	1.163	0.4000	0.0100	0.1813
N ₂ P ₃ K ₁	68	2.58	0.3344	1.450	0.7125	0.0100	0.6063
N ₂ P ₃ K ₄	107	2.83	0.3344	0.838	0.5500	0.0106	0.4875

Table 8 (Cont'd)

Treat	Plot No.	Percent Total					
		N	P	K	Ca	Na	Mg
N ₂ P ₅ K ₂	122	2.64	0.3688	0.425	0.6250	0.0063	0.6563
N ₂ P ₆ K ₁	160	3.19	0.4188	1.275	0.5300	0.0063	0.4625
N ₂ P ₆ K ₆	190	2.81	0.3375	1.850	0.4500	0.0163	0.4375
N ₃ P ₁ K ₁	69	3.13	0.3000	1.675	0.6250	0.0075	0.5000
N ₃ P ₂ K ₂	150	3.08	0.3031	2.100	0.4625	0.0088	0.4625
N ₃ P ₃ K ₁	44	2.80	0.3750	1.613	0.5625	0.0125	0.6063
N ₃ P ₃ K ₃	28	3.03	0.3625	1.025	0.5375	0.0088	0.4875
N ₃ P ₄ K ₄	183	3.28	0.3875	1.525	0.4125	0.0125	0.3750
N ₃ P ₅ K ₂	124	2.95	0.3688	1.338	0.5950	0.0100	0.5250
N ₃ P ₅ K ₅	55	2.91	0.3875	1.750	0.5250	0.0063	0.3750
N ₃ P ₆ K ₆	95	2.94	0.4156	2.275	0.4700	0.0125	0.2000
N ₄ P ₀ K ₁	78	3.25	0.3188	1.200	0.6375	0.0075	0.6375
N ₄ P ₀ K ₃	45	2.83	0.3375	1.713	0.6750	0.0100	0.5875
N ₄ P ₁ K ₃	133	2.61	0.3469	1.500	0.5000	0.0081	0.3938
N ₄ P ₃ K ₀	171	2.57	0.3031	1.625	0.6875	0.0106	0.6750
N ₄ P ₄ K ₂	193	2.62	0.3469	1.075	0.5950	0.0081	0.6063
N ₄ P ₄ K ₄	21	2.81	0.3813	1.050	0.5125	0.0081	0.5250
N ₄ P ₅ K ₁	140	2.72	0.4000	0.925	0.5950	0.0081	0.5875
N ₄ P ₆ K ₃	182	2.66	0.3938	1.675	0.5000	0.0125	0.4188
N ₅ P ₀ K ₀	155	2.94	0.3219	1.200	0.6375	0.0144	0.4625
N ₅ P ₂ K ₀	3	2.55	0.3375	1.475	0.6625	0.0131	0.6750
N ₅ P ₂ K ₂	67	2.64	0.3250	1.100	0.6625	0.0100	0.5375

Table 8 (Cont'd)

Treat	Plot No.	Percent Total					
		N	P	K	Ca	Na	Mg
N ₅ P ₂ K ₆	113	3.03	0.3438	1.750	0.4450	0.0063	0.3188
N ₅ P ₃ K ₅	74	2.67	0.3750	1.163	0.6125	0.0081	0.5063
N ₅ P ₅ K ₃	137	2.69	0.4188	1.113	0.6625	0.0100	0.4750
N ₅ P ₅ K ₅	46	2.77	0.4438	1.775	0.5625	0.0100	0.5063
N ₅ P ₆ K ₆	13	2.54	0.3688	0.425	0.5250	0.0113	0.5000
N ₆ P ₁ K ₅	147	2.24	0.3100	0.188	0.5000	0.0100	0.3438
N ₆ P ₂ K ₄	19	2.85	0.3031	1.825	0.5750	0.0100	0.4375
N ₆ P ₂ K ₅	108	2.86	0.3125	1.900	0.5750	0.0125	0.5063
N ₆ P ₃ K ₀	189	2.76	0.2688	1.075	0.4500	0.0081	0.5000
N ₆ P ₄ K ₃	76	2.78	0.3875	1.275	0.6625	0.0100	0.5063
N ₆ P ₄ K ₄	29	2.74	0.3100	1.713	0.6625	0.0188	0.5063
N ₆ P ₅ K ₄	179	2.88	0.3656	1.613	0.5875	0.0163	0.4063
N ₆ P ₆ K ₆	57	2.57	0.3875	1.250	0.5750	0.0131	0.5000

* Average of two replications

ROOM USE ONLY

ROOM USE ONLY

10/20/11 11:11 AM

11/29/00 JK

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03056 7436