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To the Graduate Council:

I am submitting herewith a thesis written by James C. Kramer entitled "Crop Yield and Chemical Composition as Affected by Zinc Fertilization at Different Soil pH and Phosphorus Levels." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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CROP YIELD AND CHEMICAL COMPOSITION AS AFFECTED BY ZINC FERTILIZATION AT DIFFERENT SOIL pH AND PHOSPHORUS LEVELS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

---

by

James C. Kramer

March, 1959

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CHAPTER I

INTRODUCTION

Zinc deficiency, though not widespread in Tennessee soils, has been observed in the Central Basin, Highland Rim, and Cumberland Plateau areas of the state. At the present time Zn deficiency is not considered a major problem, although many farmers would benefit appreciably by the use of Zn as a fertilizer material. It was the purpose of this investigation to study some of the factors that influence the availability of Zn to plants. The two main objectives of this study were: (1) to determine the effect of various lime and phosphate levels on Zn deficiency of corn, small grain, and grain sorghum; and, (2) to determine the chemical composition and yield of the three crops at two Zn levels of fertilization.

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CHAPTER II

REVIEW OF LITERATURE

The value of Zn as a plant nutrient and its toxic effects on plants are not new discoveries, though the extensive use of Zn salts for nutrient purposes on crops in the field dates from about 1931.

According to Camp (7)[1] some of the earliest references to the value of Zn as a nutrient occur in the literature on Aspergillus spp. about 1900. Javiller started about 1907, enlarged this work, and by 1912 had been so successful in extending it to green plants that he recommended the use of Zn as fertilizer material for corn and some other crops. Maze working at the same time determined by water culture methods that Zn was necessary for the growth of corn, though his work like that of Javiller was not well accepted. Not until the work of Sommer and Lipman (38) and Sommer (39) was Zn widely accepted as a plant nutrient.

The first widespread commercial use of Zn salts as a fertilizer was on tung trees in Florida in 1932 and 1933 when several thousand acres were treated. In the period 1931 to 1936 Zn became established both as a plant nutrient and a valuable fertilizer and as spray material. Zinc deficiency symptoms were described for deciduous fruits (8), pecans (1), corn (2, 3), and numerous other crops.

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[1]Figures in parentheses refer to literature cited.

Zinc is a necessary component of several enzyme systems which regulate various metabolic activities within plants. It is a part of the enzyme carbonic anhydrase, which regulates the equilibrium between carbon dioxide, water, and carbonic acid. It also functions as a part of two enzymes, dehydropeptidase; and glycylglycine dipeptidase, which have a part in specific aspects of protein metabolism (34).

Zinc also is needed for the formation of auxins. Skoog (37) has shown a decrease in auxin preceeding the appearance of Zn-deficiency symptoms in tomato and sunflower plants.

Millikan (21) found that Zn deficiency on flax was more severe in the winter than in the spring which was influenced by the higher light intensity in the winter. Skoog (37) reported that excessive illumination of Zn-deficient plants leads to excessive destruction (probably oxidation) of auxin which in turn causes growth retardation and abnormalities.

In Tennessee, Winters and Parks (44) observed that in cold wet seasons Zn-deficiency of corn was more extensive and severe.

In general there is reduced absorption of Zn by plants as the pH of the soil rises. The critical point lies somewhere between pH 5.5 and 6.5 (7).

Gall (10) in 1936 found that the toxicity of large applications of $ZnSO_4$ was reduced by the application of $CaCO_3$ or $Ca(H_2PO_4)_2$. Lett (20) reported that the injurious effects of over-application of Zn stated that injurious effects are more pronounced as the pH of the soil is decreased.

Gall and Barnette (11) in 1940, showed that $CaCO_3$ applications raised the toxic limit of Zn on corn and cowpeas in all soils tested. Peech (26) showed that the availability of Cu and Zn in sandy soils is affected by soil reaction. The amount of Zn and Cu removed by a single extraction with 1N NaCl solution from 3 acid soils decreased rapidly with increase in pH of the soil.

Viets (41) reported that Zn-deficiency of corn and beans in newly irrigated areas in central Washington was associated with a shallow depth to the horizon of lime accumulation (2-6% $CaCO_3$).

Wear (43) designed experiments to separate Ca effects from pH effects with regard to Zn uptake by sorghum, and demonstrated that Ca was not a factor but that reduced absorption was related to alkalinity.

Nelson and Melsted (23) reported that as the Ca saturation increased, especially above 50%, the quantity of Zn in the acid-soluble (fixed Zn) forms increased considerably.

It seems that as the pH rises above 7.5 Zn again becomes slightly more available and this is thought to be due to Zn being in a more soluble zincate form (7). Jurinak and Thorne (17) showed that the increase in soluble Zn over the alkaline range was attributed mainly to the formation of the bizincate ($HZnO_2^-$) and zincate ($ZnO_2^{=}$) ions forming soluble sodium and potassium zincates. Calcium zincate is relatively insoluble over the alkaline range. Potassium zincate is the most soluble over the alkaline range and sodium zincate is slightly less soluble than potassium zincate.

The presence of $CaCO_3$ in the soil does not necessarily indicate that a Zn-deficiency hazard exists. On the contrary calcareous soils in Utah (18) for example, seldom suffer from Zn-deficiency. Jurinak and Bauer (18) made a study to determine why Zn is available in some calcareous soils. Minerals found in calcareous soils of arid and semiarid regions are calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and magnesite ($MgCO_3$). These three minerals were used to study the influence of temperature on Zn adsorption over the pH range 4 to 11. The greatest Zn adsorption occurred in the magnesite phase, the dolomitic phase was second and the least amount of Zn was adsorbed on the calcite phase. The modification of interionic distances in the crystal lattice by the introduction of Mg^{++} into the calcite lattice was considered to be the source of the differences in adsorptive properties among the minerals studied.

Sanik, Perkins and Schrenk (30) working on the effect of the Ca-Mg ratio on the solubility and availability of plant nutrients showed that a high Mg soil favors the uptake of Mn and Zn in sorghum and K, B, and Mn by wheat.

In the last 20 years numerous reports have indicated that Zn-deficiency was associated with or could be induced by heavy applications of phosphate.

West (42) was the first to report on phosphate induced Zn-deficiency in 1938 at the Commonwealth Experiment Station in New South Wales. Zinc fertilizer cured mottle leaf of citrus occurring on the superphosphate plots of the fertilizer field. Mottling was reduced by a $ZnSO_4$ spray.

Millikan (21) in 1940 reported the effect of superphosphate on the Zn requirement of wheat. He showed that the application of superphosphate in the field not only increased the P content of the plant, but also the Zn content. His explanation was that the application of superphosphate increased the Zn requirement of the plant. It would therefore be more responsive to Zn applications particularly if the amount of available Zn in the soil were limited.

In soils containing excessive Zn, Gall and Barnette (11) reported that although phosphate apparently did not change the toxic limits of replaceable Zn, it stimulated the growth of corn and cowpeas on a sandy loam and on a clay loam while no effect was noted on a sand.

Millikan (21) also reported on the effect of phosphates on the development of Zn-deficiency symptoms in flax. Heavy dressings of phosphate both with and without $ZnSO_4 \cdot 7H_2O$ induced significant increases in the severity of Zn-deficiency symptoms in flax.

Winters and Parks (44) in Tennessee reported that soil tests on many of the fields on which Zn-deficiency of corn was observed showed high to medium-high available phosphate, and a pH of 6.3 or above.

More quantitative data showing a decrease in total Zn content of plant tops as a result of applying phosphate was presented by Rogers and Wu (29) in 1948 working with oats and by Loneragan (19) in 1951 working with flax. Rogers and Wu conducted a pot experiment with virgin Lakeland fine sand and Florida 167 oats. Results showed that the Zn content of the plants decreased to an almost constant value with increasing rates of application of phosphate, while the P content increased regularly

in direct ratio to that applied. Higher rates of application of phosphate resulted in significant increases in plant weights at the second cutting. The Zn content decreased with increasing rates of lime application, but increased regularly with increasing rates of Zn.

Loneragan (19) using flax as the indicator plant grown in Zn-deficient sand at different amounts of added phosphate showed that the phosphate concentration of the flax increased and the Zn content was reduced at all harvests with increasing phosphate application. The reduction in relative Zn content of the tops was sufficient to account for the effect of phosphate on Zn-deficiency symptoms and a response to Zn treatment.

Boawn, Viets, and Crawford (6) in 1954 reported on the effects of phosphate fertilizers and Zn nutrition of field beans. They reported that, regardless of the mechanism of phosphate induced Zn-deficiency, the bean plant, though extremely sensitive to Zn-deficiency does not appear to be influenced by a high concentration of phosphate either in the soil or in the plant tissues. Several attempts to induce deficiency symptoms failed even though the P content of the plant tissue was raised to approximately twice the normal concentration.

Woltz, Toth and Bear (45) reported on tests made in New Jersey to determine the relative degree of fixation of Zn resulting from application of lime and superphosphate to soil. Soybeans were used as the test crop, and radioactive Zn^{65} as the tracer. Increasing the rates of application of limestone resulted in progressively reduced Zn^{65} uptake. For example, without phosphate, activity per gram of tissue was 335 and 40

counts per minute as the limestone level was raised from 2,000 pounds to 10,000 pounds per acre. At the 2,000 pound level, increasing rates of application of phosphate generally reduced Zn^{65} uptake in all but the 100 pound rate. Little difference existed between Zn^{65} uptake at the 5,000 and 10,000 pound rates of limestone as P_2O_5 application was increased from 50-800 pounds per acre. Effects of increasing phosphate applications on Zn^{65} had disappeared by the second harvest.

Limestone, under conditions of this test, played a more important role in Zn fixation than did phosphate, although phosphate did effect Zn availability at the low level of limestone and in the first harvest. It is believed from this study that the order of addition of limestone, phosphate, and Zn salts has much to do with determining whether phosphate or liming material plays the major role in Zn fixation. Barnette, et al., (3) report a mutual interference of the response of the corn plant to P and Zn when superphosphate and $ZnSO_4$ are mixed before application in the row.

Viets, et al., (41) found that phosphate application to corn did not decrease the Zn concentrations of corn leaves grown on Zn deficient soils, nor was there a relationship between the incidence of Zn-deficiency symptoms in corn and the $NaHCO_3$ soluble phosphate in the soil. Also Seatz (33) found that phosphate applications up to 1,000 pounds of P_2O_5 per acre failed to reduce flax yield on a Hartsells soil.

It seems that in certain cases phosphate has an adverse effect on Zn absorption and utilization. There is little evidence to indicate how and under what conditions such a phenomenon occurs. Several mechanisms

have been postulated: (I) the immobilization of Zn by precipitation as an insoluble phosphate ($Zn_3(PO_4)_2$). Jamison (15) working with lysimeters in Florida showed that superphosphate applications increased the mobility of Zn and Cu in the soil. This is due to the replacing action of Ca and to the fact that the phosphates of Zn and Cu are somewhat more soluble than the corresponding humates. On the effect of phosphates upon fixation of Zn and Cu in Florida soils in the presence and absence of superphosphate, Jamison (16) found that more Zn and Cu were fixed when superphosphate was not applied. The Ca applied in superphosphate not only tends to displace Zn and Cu from the soil but it displaces acidity (H^+) into solution, lowering the pH, and in many cases mobilizing significant amounts of Zn and copper. Moderate and practical amounts of superphosphate do not reduce the solubility or exchangeability of Zn and Cu in the soil. Reuther, et al., (28) showed that phosphate fertilization over a seven year period resulted in the accumulation of phosphate in the soil. However, the accumulation of cations was not greatly affected. Copper, Mn and Zn applied to the soil were retained near the surface regardless of phosphate treatment. Bingham, et al., (5) reported that excessive P fertilization brought about a reduction in Zn uptake by citrus only when exceedingly large amounts of P had been added. Bingham also found that although soil reaction may greatly affect the total absorption of trace elements by plants it does not appear to be the major factor. Additions of $Ca(H_2PO_4)_2$ up to 1,800 pounds P per acre tended to lower the pH value of five soils yet Ca,

B, and Zn absorption was decreased. The wide range of soil pH values (4.4 to 7.4) represented by the soils tend to discount soil reaction as the primary factor involved. Their evidence favors the concept of P immobilizing Cu and Zn as relatively insoluble phosphates probably external to the root.

Boawn, et al., (6) has shown that the supernatant liquid over $Zn3(PO_4)_2$ at 25° C. and pH 6.7 contains between 1,000 and 2,300 ug.Zn per liter. Similar values have been reported by Jamison (16). Even though the common ion effect of large superphosphate applications would tend to reduce the Zn concentration it is doubtful that this concentration would ever become less than that used in normal nutrient solutions. A greenhouse experiment conducted by Boawn, et al., (6) showed that the uptake of Zn from $Zn_3(PO_4)_2$ (applied at the rate of 2 ppm Zn) by grain sorghum was 739 ug. for each pot as compared with 348 ug. for the checks. Respective Zn concentrations in the plants were 36 and 14 ppm. According to Boawn it is unlikely that Zn would ever become a limiting nutrient while a free precipitate of $Zn_3(PO_4)_2$ existed in the soil.

(II) The second postulation is that Ca from superphosphate may have an inhibiting effect on Zn in the absorption process. Jamison's (16) work has already been mentioned in which he stated that in some cases the effect of Ca from superphosphate tended to make Zn and Cu more available. Pearson (25) found that Zn absorption by barley root segments was not decreased by the phosphate ion except at a solution of pH 9, but the Ca ion had a pronounced depressing effect on Zn absorption

which he thinks may account for the effect of superphosphate on Zn absorption. Jurinak and Thorne (17) found that $CaZnO_2$ (calcium zincate) is less soluble in the alkaline range than sodium and potassium zincates. The low solubility of Zn in the Ca system is considered to be the combination of Zn absorption on the clay and the precipitation of $Zn(OH)_2$ and $CaZnO_2$.

(III) Precipitation of $Zn_3(PO_4)_2$ or other Zn complexes on root surfaces, in roots, and in conducting tissues. Biddulph (4) showed that deposition of nutrients e.g. Fe and Zn, as phosphates in xylem extremities may be responsible for inadequate leaf nutrition as demonstrated by Fe^{55} and Zn^{65}. Viets (39) showed that acid washed bean and corn roots have been found to contain up to 10 times greater Zn concentrations than do aerial parts.

Many workers disagree on the effect of phosphate application and availability of soil Zn (16, 19, 28) probably because effects of soil pH have not been adequately considered. Primary and secondary Zn phosphates that are formed at low pH levels (9) are relatively soluble in comparison with tertiary phosphates formed at high pH levels. Fixation of Zn by phosphates should be more marked at high than at low pH levels. Ammoniated phosphates are often very insoluble (9) especially when two H^+ ions are replaced by a heavy metal. Insoluble soil phosphates of Zn may possibly be of this type.

Nikitin and Rainey (24) studied the chemical reactions between trace element salts of Mn, Fe, Cu, and Zn, and N-P-K fertilizer-type compounds. They found that commercial superphosphates have only a

slight diminishing effect on trace element solubility. Usually the precipitating action of N-P-K carriers on trace elements can be traced to high alkalinity of the fertilizer.

A deficiency of Zn in plants may affect its content of other elements. Seatz (33) using flax as the indicator plant found that Zn-deficient plants contained twice as much P as Zn-fertilized plants. Calcium and Mg were affected less by Zn than phosphorus.

Viets (41) found that the total nutrient absorption of plant nutrients by Zn deficient corn plants was much higher than for normal plants. Zinc deficient plants were much higher in K and P, but differences in concentration of Ca and Mg were not consistent. According to Viets the accumulation of these elements in the corn plant interferred with the metabolism of zinc.

CHAPTER III

METHODS AND PROCEDURE

Various amounts of lime and phosphate were added to soils in East, Middle, and West Tennessee. Three different crops were grown which varied in their capacity to utilize native soil zinc. Corn which is included in the very sensitive group was planted first, followed by small grain, a rather insensitive plant, and grain sorghum which is included in the mildly sensitive group. Grain, forage yields and chemical composition of the different crops were determined at two rates of Zn-fertilization.

Location of Plot Areas

Suitable areas were selected with average pH and soil fertility levels at the Plateau, Middle, and West Tennessee Experiment Stations on Hartsells, Maury, and Olivier soils. Hartsells fine sandy loam was chosen for this study because of its low native fertility and previous history of lime induced Zn-deficiency. Maury silt loam is naturally high in phosphate and is the soil on which Zn-deficiency has been most frequently observed in Tennessee. Olivier silt loam in West Tennessee was selected to see if Zn-deficiency could be induced by liming and phosphate applications on a soil which had no previous Zn-deficiency history. Initial pH values, extractable cations, cation exchange capacity and total Zn and P content of the three soils are shown in Table I.

TABLE I

INITIAL SOIL pH VALUES, EXTRACTABLE CATIONS, CATION EXCHANGE CAPACITY AT pH 7.0 AND TOTAL ZINC AND PHOSPHORUS CONTENT OF THE THREE SOILS USED IN ZINC STUDY

Soil	pH	me/100g. soil				Total Pounds/Acre	
		Ca	Mg	K	C.E.C.	Zn	P
Hartsells fine sandy loam	5.8a/	2.80	1.40	0.22	7.1	51	269
Maury silt loam	6.6	9.60	1.40	0.31	12.0	70	3,366
Olivier silt loam	5.7	4.29	0.67	0.29	6.8	67	427

a/ Values represent an average of four replications.

Experimental Design

A split-split-plot, experimental design was used and replicated four times. Total number of harvested plots at the Plateau Station was 96, in Middle Tennessee 72, and at the West Tennessee Station 48.

Fertilization

Lime was added to the three soils four months in advance of planting to allow sufficient time for it to react with the soil. Lime was applied at the rate of 0, 2, 4, and 6 tons per acre to Hartsells soil; 0, 2, and 4 tons per acre to Maury soil; and 2, 4, and 8 tons per acre to Olivier soil. Concentrated superphosphate ($48\%P_2O_5$) was added to the Hartsells soil at the rate of 500, 1,000 and 2,000 pounds P_2O_5 per acre, 100, 300, and 500 pounds per acre to Maury soil, and 1,000 and 2,000 pounds P_2O_5 per acre to the Olivier soil. Phosphate applications on the Hartsells and Olivier soils were broadcast and disked in prior to planting, and that in the Maury soil applied in the row at planting time. Zinc was applied at the rate of 0 and 20 pounds $ZnSO_4 \cdot H_2O$ per acre in the row at planting.

Corn

Corn of the variety, Dixie 22, was planted in the three soils in May, 1957. An application of 60 pounds K_2O per acre as KCl, and 30 pounds N per acre as NH_4NO_3 was added in the row at planting time on all three soils. On the Olivier and Hartsells soils which received broadcast applications of concentrated superphosphate, 100 pounds of P_2O_5 was also added in the row at planting. Approximately seven weeks after

planting the corn on all three soils was side-dressed with 200 pounds of NH_4NO_3 per acre.

The corn was harvested in October, 1957, at the three locations. The two center rows of a four row plot on Hartsells and Maury soils and the three center rows of a five row plot on Olivier soil were harvested, weighed, moisture samples taken, and yield determined. Harvested plot areas were 1/200 acre on the Hartsells soil, 1/186 acre on the Olivier soil, and 1/234 acre on the Maury soil.

Small Grain

After the corn was harvested the plot areas were prepared for a seeding of small grain. The only additional fertilization was 100 pounds per acre of NH_4NO_3 broadcast in the spring of 1958. This was to determine if the lime and phosphate additions and residual Zn would affect the forage and grain yield. Forkedeer oats followed corn on the Olivier soil, and Seneca wheat followed corn on the Maury soil. A fall seeding of small grain was not possible on the Hartsells soil because of excessive rainfall.

The Zn and no-Zn plots were split for harvesting. One-half was harvested for forage and one-half for grain. The small grain forage was harvested in the boot-stage of development, moisture samples taken, and yield in dry weight determined. The grain was harvested in June, 1958, at maturity.

Grain Sorghum

DeKalb E-56A grain sorghum was planted in the Hartsells soil on June 24, 1958. Two weeks later the Olivier soil was also planted. No

planting was made in Maury soil because of wet weather.

Twenty pounds of N as NH_4NO_3, 40 pounds of P_2O_5 as concentrated superphosphate, and 40 pounds of K_2O as KCl were added in the row at planting. Zinc sulfate monohydrate was applied at the rate of 0 and 20 pounds per acre in the row.

The grain sorghum was harvested in the soft dough stage of maturity to prevent grain loss by bird damage, moisture samples taken, and dry forage weight calculated.

Sampling

Corn tissue samples were taken at the end of the third, sixth, and ninth week after planting. In the first sampling the whole above-ground portion was harvested from plants selected randomly in the row. The second sampling at the sixth week consisted of a random selection of the first leaf out of the whorl of the plant. The third sampling was the selection of the first leaf below the ear.

Small grain forage samples were taken at the boot-stage of development only.

Grain sorghum samples were taken four weeks after planting. The whole above-ground portion of the plant was used. This was the only sample taken.

After the samples were collected they were oven dried at 70° C, ground in a Wiley mill, mixed thoroughly, and stored in bottles for analysis. A modification of the wet oxidation procedure of Gieseking, Snider, and Getz (13) was used for ashing all samples. The K, Ca, and

Mg content of the tissue was determined by a Beckman "DU" flame spectrophotometer equipped with a photomultiplier attachment. Phosphorus was determined by a modification of the method developed by Gee and Deitz (12).

Soil Analysis

The pH of the soil was determined using the Beckman model "G" pH meter.

The soil extractable cations were determined by the method of Shaw and Veal (35). Cation exchange capacity was determined by the procedure of Peech, et al., (27). The total Zn content of the three soils was determined by the method of Holmes (14), and total P by the procedure developed by Sherman (36).

CHAPTER IV

RESULTS

Yield and Chemical Composition of Corn and Grain Sorghum Grown on Hartsells Fine Sandy Loam

Corn Yield

Results of the various lime, phosphate and Zn treatments on corn yield are shown in Table III. The Zn versus no-Zn means were 89.4 and 89.1 bushels per acre showing no significant Zn response. Response to phosphate fertilization between the 500 and 1,000 pound rates was over five bushels per acre with the difference being highly significant. Yield increase between the 500 and 2,000 pound rates was significant at the 0.05 level. No significant difference in yield could be attributed to lime application although there was a yield increase of 10.6 bushels per acre between the 0 and 6 ton rates. The pH of the various lime treatments at the beginning and end of the experiment is found in Table II.

Corn Ear Number

Ear number per plot was also significantly affected by phosphate fertilization. The ear number means for the 500, 1,000 and 2,000 pound phosphate rates were 84, 88, and 86 ears per plot respectively, with a difference of three ears being highly significant. The increase between the 500 and 2,000 pound rates and the decrease between the 1,000 and 2,000 pound rates were significant at the 0.05 level of probability.

TABLE II

SOIL pH VALUES AND EXTRACTABLE CATIONS AT DIFFERENT LIME LEVELS ON HARTSELLS FINE SANDY LOAM

Lime Tons/Acre	Beginning of Expt.* pH	End of Experiment pH	me/100g. soil Ca	Mg	K
0	5.5a/	6.1	4.39	0.73	0.19
2	6.3	6.9	8.02	0.63	0.21
4	6.5	7.3	9.02	0.52	0.19
6	6.8	7.5	13.46	0.41	0.21

a/ Values represent an average of four replications.

* Beginning pH was taken May, 1957. pH at end of experiment was taken September, 1958.

TABLE III

YIELD OF CORN ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Bushels Per Acre: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	77.4a/	90.9	88.1	87.4	86.0	85.8
20	500	77.6	84.3	92.5	87.9	85.6	
0	1000	85.0	92.6	95.8	96.5	92.5	91.5
20	1000	85.5	85.6	93.6	97.7	90.6	
0	2000	86.1	88.6	88.3	91.9	88.7	90.4
20	2000	84.6	88.8	95.8	98.3	91.9	
Lime Rate Ave.		82.7	88.5	92.4	93.3		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	3.5 bu.
L.S.D. (.01) between phosphorus means	4.7 bu.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	27%
C.V. for sub-plots	8%
C.V. for sub-sub-plots	6%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

Ear number results are shown in Table IV.

Lime and Zn rates did not significantly affect the ear number although there was a significant zinc x lime interaction.

Corn Chemical Composition

Summaries of the effect of lime, phosphate, and Zn treatments on the Ca, Mg, P, and K content of corn at each sampling date are presented in Tables V through XVI. Data presented are expressed as per cent composition of oven dry material on a weight basis, and represent the mean of four replications. (Samples were collected at the end of the third, sixth, and ninth week after planting.)

Calcium. The Ca means of the third, sixth, and ninth week samples were 0.68, 0.31, and 0.61 per cent, respectively. At the first sampling, lime additions caused a highly significant increase in Ca content between the 0 and 2 ton rates, and the 2 and 4 ton rates, while no significant difference was found between the four and six ton lime levels. Calcium composition at the ninth week sampling also showed a highly significant increase when comparing the 0, 2, and 4 ton rates, but showed non-significant change in Ca content at the sixth week sampling.

Phosphate fertilization caused a significant increase in Ca composition between the 1,000 and 2,000 pound rates at the sixth week sampling while no significant change was found between the 500 and 1,000 pound levels. The third and ninth week samples were not significantly affected by the phosphate additions.

TABLE IV

CORN EAR NUMBER PER PLOT ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Ears Per Plot: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	77a/	95	84	85	85	84
20	500	80	85	80	85	82	
0	1000	86	94	92	89	90	88
20	1000	88	90	82	86	86	
0	2000	83	86	85	87	85	86
20	2000	85	85	85	88	86	
Lime Rate Ave.		83	89	85	87		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - 2.0 ears
L.S.D. (.01) between phosphorus means - - - - - - - - - - - - - - 3.0 ears
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 14%
C.V. for sub-plots - 4%
C.V. for sub-sub-plots - 5%
C.V. for entire experiment - 6%

a/ Values represent an average of three replications.

TABLE V

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.58a/	0.63	0.74	0.71	0.66	0.68
20	500	0.61	0.68	0.71	0.76	0.69	
0	1000	0.50	0.60	0.66	0.83	0.65	0.67
20	1000	0.53	0.69	0.85	0.74	0.70	
0	2000	0.58	0.64	0.79	0.75	0.69	0.69
20	2000	0.63	0.65	0.74	0.76	0.70	
Lime Rate Ave.		0.57	0.64	0.75	0.76		

L.S.D. (.05) between lime means - 0.02%
L.S.D. (.01) between lime means - 0.03%
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 16%
C.V. for sub-plots - 7%
C.V. for sub-sub-plots - 13%
C.V. for entire experiment - 12%

a/ Values represent an average of four replications.

TABLE VI

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.27a/	0.36	0.30	0.33	0.32	0.31
20	500	0.28	0.29	0.33	0.32	0.30	
0	1000	0.22	0.28	0.33	0.33	0.29	0.29
20	1000	0.26	0.27	0.35	0.32	0.30	
0	2000	0.32	0.35	0.33	0.32	0.33	0.32
20	2000	0.29	0.35	0.32	0.34	0.32	
Lime Rate Ave.		0.27	0.31	0.32	0.32		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.02%
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	23%
C.V. for sub-plots	15%
C.V. for sub-sub-plots	17%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

TABLE VII

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent					
		Lime Tons/Acre				Zinc	Phosphorus
		0	2	4	6	Rate Ave.	Rate Ave.
0	500	0.50a/	0.60	0.66	0.62	0.60	0.61
20	500	0.54	0.64	0.66	0.62	0.62	
0	1000	0.57	0.60	0.61	0.66	0.61	0.61
20	1000	0.54	0.64	0.68	0.61	0.62	
0	2000	0.58	0.60	0.68	0.60	0.62	0.61
20	2000	0.57	0.61	0.63	0.63	0.61	
Lime Rate Ave.		0.55	0.61	0.65	0.62		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - - 0.027%
L.S.D. (.01) between lime means - - - - - - - - - - - - - - - - - - - 0.039%
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 7%
C.V. for sub-plots - 13%
C.V. for sub-sub-plots - 7%
C.V. for entire experiment - 9%

a/ Values represent an average of four replications.

TABLE VIII

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.25a/	0.23	0.25	0.31	0.26	0.25
20	500	0.22	0.26	0.24	0.23	0.24	
0	1000	0.26	0.33	0.33	0.33	0.31	0.29
20	1000	0.22	0.30	0.31	0.28	0.28	
0	2000	0.26	0.31	0.30	0.33	0.30	0.28
20	2000	0.21	0.28	0.30	0.26	0.26	
Lime Rate Ave.		0.24	0.28	0.29	0.29		

L.S.D. (.05) between lime means	0.025%
L.S.D. (.01) between lime means	0.036%
L.S.D. (.05) between phosphorus means	0.022%
L.S.D. (.01) between phosphorus means	0.030%
L.S.D. (.05) between zinc means	0.024%
L.S.D. (.01) between zinc means	0.032%
C.V. for main plots	14%
C.V. for sub-plots	16%
C.V. for sub-sub-plots	22%
C.V. for entire experiment	19%

a/ Values represent an average of four replications.

TABLE IX

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.20a/	0.30	0.25	0.27	0.26	0.25
20	500	0.23	0.25	0.25	0.24	0.24	
0	1000	0.21	0.31	0.26	0.31	0.27	0.24
20	1000	0.22	0.23	0.22	0.26	0.23	
0	2000	0.26	0.29	0.31	0.29	0.29	0.27
20	2000	0.21	0.27	0.26	0.27	0.25	
Lime Rate Ave.		0.22	0.27	0.26	0.26		

L.S.D. (.05) between lime means	0.025%
L.S.D. (.01) between lime means	0.036%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.016%
L.S.D. (.01) between zinc means	0.021%
C.V. for main plots	15%
C.V. for sub-plots	22%
C.V. for sub-sub-plots	15%
C.V. for entire experiment	18%

a/ Values represent an average of four replications.

TABLE X

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.35a/	0.39	0.40	0.48	0.40	0.39
20	500	0.30	0.45	0.34	0.38	0.37	
0	1000	0.40	0.44	0.44	0.44	0.43	0.40
20	1000	0.28	0.40	0.35	0.40	0.36	
0	2000	0.44	0.38	0.48	0.43	0.43	0.40
20	2000	0.26	0.38	0.41	0.38	0.36	
Lime Rate Ave.		0.34	0.41	0.41	0.42		

L.S.D. (.05) between lime means - 0.053%
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - 0.029%
L.S.D. (.01) between zinc means - 0.039%

C.V. for main plots - 21%
C.V. for sub-plots - 20%
C.V. for sub-sub-plots - 18%
C.V. for entire experiment - 19%

a/ Values represent an average of four replications.

TABLE XI

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.56a/	0.50	0.49	0.47	0.50	0.51
20	500	0.57	0.51	0.48	0.51	0.52	
0	1000	0.63	0.54	0.54	0.52	0.56	0.55
20	1000	0.63	0.54	0.52	0.51	0.55	
0	2000	0.75	0.68	0.62	0.61	0.66	0.65
20	2000	0.73	0.65	0.61	0.57	0.64	
Lime Rate Ave.		0.64	0.57	0.54	0.53		

L.S.D. (.05) between lime means	0.046%
L.S.D. (.01) between lime means	0.067%
L.S.D. (.05) between phosphorus means	0.030%
L.S.D. (.01) between phosphorus means	0.041%
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	13%
C.V. for sub-plots	10%
C.V. for sub-sub-plots	8%
C.V. for entire experiment	9%

a/ Values represent an average of four replications.

TABLE XII

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.35a/	0.36	0.37	0.35	0.36	0.34
20	500	0.32	0.35	0.34	0.30	0.33	
0	1000	0.35	0.37	0.37	0.37	0.36	0.35
20	1000	0.31	0.36	0.34	0.36	0.34	
0	2000	0.36	0.37	0.38	0.37	0.37	0.36
20	2000	0.34	0.34	0.35	0.35	0.34	
Lime Rate Ave.		0.34	0.36	0.36	0.35		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.0058%
L.S.D. (.01) between phosphorus means	0.0079%
L.S.D. (.05) between zinc means	0.0020%
L.S.D. (.01) between zinc means	0.0054%
C.V. for main plots	9%
C.V. for sub-plots	10%
C.V. for sub-sub-plots	9%
C.V. for entire experiment	8%

a/ Values represent an average of four replications.

TABLE XIII

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.25a/	0.28	0.31	0.30	0.28	0.28
20	500	0.25	0.28	0.32	0.28	0.28	
0	1000	0.29	0.30	0.31	0.31	0.30	0.29
20	1000	0.25	0.30	0.30	0.30	0.29	
0	2000	0.30	0.30	0.32	0.34	0.32	0.31
20	2000	0.28	0.31	0.32	0.33	0.31	
Lime Rate Ave.		0.27	0.30	0.31	0.31		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.013%
L.S.D. (.01) between phosphorus means	0.018%
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	17%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	9%
C.V. for entire experiment	10%

a/ Values represent an average of four replications.

TABLE XIV

PER CENT POTASSIUM IN CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	4.06a/	4.15	3.58	4.15	3.98	4.13
20	500	4.15	4.04	4.43	4.46	4.27	
0	1000	4.40	4.25	4.39	4.18	4.30	4.12
20	1000	3.86	3.91	3.59	4.40	3.94	
0	2000	4.36	4.10	4.51	4.41	4.34	4.14
20	2000	4.40	4.21	3.28	3.85	3.94	
Lime Rate Ave.		4.21	4.11	3.96	4.24		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 15%
C.V. for sub-plots - 14%
C.V. for sub-sub-plots - 12%
C.V. for entire experiment - 13%

a/ Values represent an average of four replications.

TABLE XV

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent					
		Lime Tons/Acre				Zinc Rate Ave.	Phosphorus Rate Ave.
		0	2	4	6		
0	500	2.30a/	1.83	1.94	1.75	1.96	1.91
20	500	1.93	1.82	1.97	1.75	1.87	
0	1000	2.07	1.93	1.97	1.78	1.93	1.86
20	1000	1.77	1.77	1.90	1.70	1.78	
0	2000	1.88	1.70	1.80	1.82	1.80	1.76
20	2000	1.76	1.69	1.76	1.63	1.71	
Lime Rate Ave.		1.95	1.79	1.89	1.74		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.091%
L.S.D. (.01) between phosphorus means	0.124%
L.S.D. (.05) between zinc means	0.073%
L.S.D. (.01) between zinc means	0.098%
C.V. for main plots	17%
C.V. for sub-plots	10%
C.V. for sub-sub-plots	10%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

TABLE XVI

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent					
		Lime Tons/Acre				Zinc Rate Ave.	Phosphorus Rate Ave.
		0	2	4	6		
0	500	1.80a/	1.64	1.61	1.47	1.63	1.67
20	500	1.86	1.51	1.78	1.70	1.71	
0	1000	1.69	1.64	1.67	1.76	1.69	1.67
20	1000	1.80	1.62	1.62	1.58	1.66	
0	2000	1.58	1.72	1.48	1.42	1.55	1.61
20	2000	1.61	1.52	1.68	1.58	1.60	
Lime Rate Ave.		1.72	1.61	1.64	1.63		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	14%
C.V. for sub-plots	10%
C.V. for sub-sub-plots	10%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

Inspection of Tables V, VI, and VII shows that Zn-fertilization caused little or no change in Ca composition, but a significant zinc x lime interaction was found at the third week sampling.

Magnesium. The third, sixth, and ninth week Mg means were 0.27, 0.25, and 0.39 per cent. Zinc rates affected Mg content at each of the three sampling dates. The Zn versus no-Zn Mg means were 0.26 and 0.29 per cent at the third week, 0.24 and 0.26 at the sixth week, and 0.36 and 0.42 per cent at the final sampling. In each instance the difference was highly significant.

Lime application caused a highly significant increase in Mg content between the 0 and 2 ton rates at each sampling date. No significant difference was found among the 2, 4, and 6 ton rates. There was a highly significant zinc x lime interaction at the second sampling and a significant zinc x lime interaction in the final sampling.

Phosphate applications influenced Mg content at the 0.01 level of probability in the third week samples. The difference was highly significant between the 500 and 1,000 pound P_2O_5 rates while no significant difference was found between the 1,000 and 2,000 pound additions. There was no significant change in Mg composition due to phosphate fertilization in the sixth and ninth week samples.

Phosphorus. Phosphorus composition increased with increased phosphate application at each sampling date. The per cent P means for the 500, 1,000, and 2,000 pound P_2O_5 rates were: 0.51, 0.55, and 0.65 for the first samples, 0.34, 0.35, 0.36 for the second, and 0.28, 0.29, and 0.31 per cent for the final samples. The difference in P content due to

phosphate rates was highly significant at the third and sixth week samples, but in the ninth week samples a significance at the 0.01 level was found between the 500 and 2,000, and 1,000 and 2,000 pound rates only. The difference between the 500 and 1,000 pound rates was significant at the 0.05 level.

Lime significantly affected P content at the first sampling only. The difference was highly significant between the 0 and 2 ton rates as the P fell from 0.64 to 0.57 per cent. The difference among the 2, 4, and 6 ton rates was not significant.

Zinc fertilization did not significantly affect P composition at the third and ninth week samples, but showed a highly significant effect on the samples taken at the end of the sixth week. The Zn versus no-Zn means were 0.34 and 0.36 per cent, respectively, at that sampling.

The P means for the three sampling dates were 0.57, 0.35, and 0.30 per cent for the third, sixth, and ninth samples, respectively.

Potassium. The mean per cent K composition was 4.13 per cent at the first sampling, 1.84 per cent at the second sampling, and decreased again to 1.64 per cent in the last samples.

Lime treatments failed to cause a significant change in K content. Potassium content was also unaffected by P-fertilization at the first and final samplings. In the second sampling K content was decreased with increased phosphate fertilization. The per cent K means were: 1.91, 1.86, and 1.76 per cent, respectively, for the 500, 1,000, and 2,000 pound P_2O_5 rates. The difference between the 500 and 2,000 pound rates was highly significant, and between the 1,000 and 2,000 pound rates significant

at the 0.05 level. The difference between the 500 and 1,000 pound rates was not significant.

Zinc, like phosphate, affected K content at the sixth week sampling only. The Zn versus no-Zn means were 1.79 and 1.90 per cent, respectively, the difference being highly significant.

Grain Sorghum Forage Yield

Grain sorghum forage yield response to increased lime application was highly significant. Increases in yield between the 0 and 4, and 0 and 6 ton lime rates were significant at the 0.01 level. Increase in forage yield between the 2 and 4 ton rate was significant at the 0.05 level of probability. No significant difference in yield could be attributed to phosphate and Zn fertilization. A summary of the effect of the various treatments on forage yield is shown in Table XVII.

Grain Sorghum Chemical Composition

Summaries of the effect of lime, phosphate, and Zn-fertilization on Ca, Mg, P, and K content of sorghum are presented in Tables XVIII through XXI. Samples were collected four weeks after planting.

Calcium. Lime rates caused significant changes in Ca composition. The Ca means were 0.55, 0.66, 0.74, 0.77 per cent for the 0, 2, 4, and 6 ton rates, respectively. The difference between the 0 and 4 tons, and 0 and 6 ton rates was highly significant. A significant change was found between the 0 and 2 tons, and 2 and 4 ton rates. Neither phosphate nor Zn-fertilization significantly affected Ca composition. The Ca mean for this sampling was 0.68 per cent.

TABLE XVII

YIELD OF OVEN DRY GRAIN SORGHUM FORAGE ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Pounds Forage/Acre: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	3,540a/	3,840	4,600	4,800	4,200	4,180
20	500	3,200	3,840	4,780	4,820	4,160	
0	1000	3,520	4,160	4,440	4,760	4,220	4,260
20	1000	3,480	4,240	4,500	4,940	4,280	
0	2000	3,960	4,160	4,420	4,680	4,300	4,280
20	2000	3,400	3,980	4,840	4,780	4,240	
Lime Rate Ave.		3,520	4,040	4,600	4,800		

L.S.D. (.05) between lime means	580 pounds
L.S.D. (.01) between lime means	840 pounds
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	21%
C.V. for sub-plots	12%
C.V. for sub-sub-plots	10%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

TABLE XVIII

PER CENT CALCIUM IN OVEN DRY GRAIN SORGHUM PLANT TISSUE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.52a/	0.70	0.71	0.77	0.68	0.67
20	500	0.61	0.55	0.72	0.76	0.66	
0	1000	0.50	0.70	0.70	0.74	0.66	0.68
20	1000	0.57	0.68	0.74	0.84	0.71	
0	2000	0.56	0.63	0.84	0.70	0.68	0.69
20	2000	0.53	0.71	0.71	0.82	0.69	
Lime Rate Ave.		0.55	0.66	0.74	0.77		

L.S.D. (.05) between lime means	0.095%
L.S.D. (.01) between lime means	0.137%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	21%
C.V. for sub-plots	22%
C.V. for sub-sub-plots	11%
C.V. for entire experiment	16%

a/ Values represent an average of four replications.

TABLE XIX

PER CENT MAGNESIUM IN OVEN DRY GRAIN SORGHUM PLANT TISSUE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.32a/	0.43	0.39	0.38	0.38	0.36
20	500	0.32	0.41	0.30	0.28	0.33	
0	1000	0.32	0.41	0.37	0.32	0.36	0.35
20	1000	0.30	0.36	0.32	0.40	0.34	
0	2000	0.34	0.38	0.46	0.40	0.40	0.37
20	2000	0.32	0.36	0.36	0.33	0.34	
Lime Rate Ave.		0.32	0.39	0.37	0.35		

L.S.D. (.05) between lime means	0.035%
L.S.D. (.01) between lime means	0.051%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.025%
L.S.D. (.01) between zinc means	0.033%
C.V. for main plots	5%
C.V. for sub-plots	22%
C.V. for sub-sub-plots	16%
C.V. for entire experiment	18%

a/ Values represent an average of four replications.

TABLE XX

PER CENT PHOSPHORUS IN OVEN DRY GRAIN SORGHUM PLANT TISSUE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	0.52a/	0.48	0.52	0.52	0.51	0.50
20	500	0.46	0.48	0.49	0.48	0.48	
0	1000	0.53	0.52	0.53	0.55	0.53	0.52
20	1000	0.50	0.51	0.50	0.48	0.50	
0	2000	0.57	0.61	0.58	0.60	0.59	0.57
20	2000	0.57	0.57	0.54	0.55	0.56	
Lime Rate Ave.		0.52	0.53	0.53	0.53		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.025%
L.S.D. (.01) between phosphorus means	0.034%
L.S.D. (.05) between zinc means	0.009%
L.S.D. (.01) between zinc means	0.012%
C.V. for main plots	9%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	5%
C.V. for entire experiment	7%

a/ Values represent an average of four replications.

TABLE XXI

PER CENT POTASSIUM IN OVEN DRY GRAIN SORGHUM PLANT TISSUE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON HARTSELLS FINE SANDY LOAM GROWN WITH FOUR LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	6	Zinc Rate Ave.	Phosphorus Rate Ave.
0	500	4.66a/	4.07	4.04	3.99	4.19	4.18
20	500	4.49	4.22	4.04	3.95	4.18	
0	1000	4.93	3.96	4.02	4.02	4.23	4.16
20	1000	4.65	3.96	3.96	3.76	4.08	
0	2000	4.39	4.47	3.82	3.88	4.14	4.20
20	2000	4.48	4.28	4.07	4.17	4.25	
Lime Rate Ave.		4.60	4.16	3.99	3.96		

L.S.D. (.05) between lime means	0.20%
L.S.D. (.01) between lime means	0.29%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	7%
C.V. for sub-plots	8%
C.V. for sub-sub-plots	7%
C.V. for entire experiment	6%

a/ Values represent an average of four replications.

Magnesium. The Mg means for the four lime rates were 0.32, 0.39, 0.37, and 0.35 per cent in order of increased lime application. The increase in Mg content between the 0 and 2, and 0 and 4 ton rates was highly significant. The decrease in Mg composition between the 2 and 6 ton rates was significant at the 0.05 level.

The difference in Mg content between the 0 and 20 pound Zn rates was highly significant. The Zn versus no-Zn means were 0.34 and 0.38 per cent, respectively.

Phosphate rates failed to cause a significant change in Mg content in the grain sorghum forage samples.

Phosphorus. Phosphate and Zn rates caused significant changes in P content. The differences between the 500 and 2,000 and 1,000 and 2,000 pound P_2O_5 rates were highly significant. The Zn versus no-Zn means were 0.51 and 0.55 per cent P, respectively, with the difference also being highly significant.

Lime treatments caused no significant change in P composition.

Potassium. Potassium composition of grain sorghum was affected by lime treatments only. Phosphate and Zn-fertilization did not significantly change the K content. The K means were 4.60, 4.16, 3.99, and 3.96 per cent for the 0, 2, 4, and 6 ton lime rates, respectively. A difference among the K means of 0.30 per cent is significant at the 0.01 level, while a difference of 0.20 per cent or greater is significant at the 0.05 level.

TABLE XXII

SOIL pH VALUES AND EXTRACTABLE CATIONS AT DIFFERENT LIME LEVELS ON MAURY SILT LOAM

Lime Tons/Acre	Beginning of Expt.* pH	End of Experiment pH	me/100g. soil Ca	Mg	K
0	6.6a/	7.1a/	11.0	0.76	0.14
2	6.7	7.0	10.0	0.87	0.18
4	6.8	7.0	10.7	0.92	0.22

a/ Values represent an average of four replications.

* Beginning pH was taken May, 1957. pH at end of experiment was taken in September, 1958.

Yield and Chemical Composition of Corn and Wheat Grown on Maury Silt Loam

Corn Yield

Lime and phosphate rates had no significant effect on yield of corn grown on Maury silt loam. Yield increase due to Zn-fertilization was highly significant. The Zn versus no-Zn means were 81.8 and 67.5 bushels per acre, respectively. The effect of the various treatments on yield are shown in Table XXIII.

Corn Ear Number

Corn ear number per plot also showed a highly significant increase due to Zn-fertilization. Corn ear number yields for the 0 and 20 pound Zn rates were respectively, 70 and 74 ears per plot. Lime and phosphate applications failed to cause a significant change in ear number. Ear number results are summarized in Table XXIV.

Corn Chemical Composition

Summaries of the effect of lime, phosphate and Zn treatments on the Ca, Mg, P and K content at each sampling date are presented in Tables XXIV through XXXVI, respectively. Data presented are expressed as per cent composition of oven dry material on a weight basis, and represent the mean of four replications. Samples were collected at the end of the third, sixth, and ninth week after planting.

Calcium. The Ca means of the third, sixth, and ninth week samples were: 0.58, 0.38, and 0.74 per cent, respectively. Analysis of the third week samples showed that the Ca content decreased from 0.65 to 0.51

TABLE XXIII

YIELD OF CORN ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Bushels Per Acre: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	68.6a/	66.9	72.8	69.4	74.9
20	100	79.8	81.8	80.4	80.4	
0	300	69.0	62.6	64.2	65.3	74.3
20	300	83.3	81.8	85.1	83.4	
0	500	69.8	67.8	66.2	67.9	74.7
20	500	78.1	81.4	85.2	81.6	
Lime Rate Ave.		74.7	73.6	75.7		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	2.5 bu.
L.S.D. (.01) between zinc means	3.4 bu.
C.V. for main plots	13%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	7%
C.V. for entire experiment	9%

a/ Values represent an average of four replications.

TABLE XXIV

CORN EAR NUMBER PER PLOT ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Ears Per Plot: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	70a/	70	74	71	72
20	100	70	74	72	72	
0	300	70	68	68	69	72
20	300	74	74	78	75	
0	500	68	70	68	69	72
20	500	71	73	78	74	
Lime Rate Ave.		70	72	73		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - - 2 ears
L.S.D. (.01) between zinc means - - - - - - - - - - - - - - - - - - - 3 ears

C.V. for main plots - 6%
C.V. for sub-plots - 6%
C.V. for sub-sub-plots - 7%
C.V. for entire experiment - 6%

a/ Values represent an average of four replications.

TABLE XXV

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.68a/	0.60	0.78	0.69	0.65
20	100	0.65	0.60	0.62	0.62	
0	300	0.50	0.64	0.66	0.60	0.58
20	300	0.56	0.59	0.51	0.55	
0	500	0.54	0.51	0.46	0.50	0.51
20	500	0.54	0.55	0.49	0.53	
Lime Rate Ave.		0.58	0.58	0.59		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.032%
L.S.D. (.01) between phosphorus means	0.049%
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	31%
C.V. for sub-plots	8%
C.V. for sub-sub-plots	21%
C.V. for entire experiment	18%

a/ Values represent an average of four replications.

TABLE XXVI

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.40a/	0.38	0.41	0.40	0.38
20	100	0.38	0.38	0.34	0.37	
0	300	0.36	0.38	0.40	0.38	0.39
20	300	0.40	0.40	0.40	0.40	
0	500	0.40	0.35	0.38	0.38	0.38
20	500	0.36	0.40	0.38	0.38	
Lime Rate Ave.		0.38	0.38	0.39		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 10%
C.V. for sub-plots - 13%
C.V. for sub-sub-plots - 18%
C.V. for entire experiment - 15%

a/ Values represent an average of four replications.

TABLE XXVII

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.72a/	0.67	0.73	0.71	0.74
20	100	0.74	0.78	0.80	0.77	
0	300	0.69	0.62	0.67	0.66	0.74
20	300	0.76	0.86	0.85	0.82	
0	500	0.72	0.67	0.72	0.70	0.75
20	500	0.80	0.78	0.85	0.81	
Lime Rate Ave.		0.74	0.73	0.77		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.052%
L.S.D. (.01) between zinc means	0.070%
C.V. for main plots	17%
C.V. for sub-plots	14%
C.V. for sub-sub-plots	14%
C.V. for entire experiment	15%

a/ Values represent an average of four replications.

TABLE XXVIII

PER CENT MAGNESIUM IN CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.22a/	0.20	0.29	0.24	0.21
20	100	0.20	0.19	0.17	0.19	
0	300	0.19	0.31	0.24	0.25	0.21
20	300	0.20	0.17	0.14	0.17	
0	500	0.22	0.22	0.16	0.20	0.20
20	500	0.24	0.17	0.19	0.20	
Lime Rate Ave.		0.21	0.21	0.20		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - 0.041%

C.V. for main plots - 26%
C.V. for sub-plots - 30%
C.V. for sub-sub-plots - 41%
C.V. for entire experiment - - - - - - - - - - - - - - - - - - - 35%

a/ Values represent an average of four replications.

TABLE XXIX

PER CENT MAGNESIUM IN CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.21a/	0.30	0.28	0.26	0.24
20	100	0.20	0.22	0.22	0.21	
0	300	0.21	0.26	0.28	0.25	0.22
20	300	0.19	0.20	0.22	0.20	
0	500	0.21	0.22	0.24	0.22	0.22
20	500	0.20	0.21	0.20	0.20	
Lime Rate Ave.		0.20	0.24	0.23		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - 0.029%

C.V. for main plots - 20%
C.V. for sub-plots - 20%
C.V. for sub-sub-plots - 26%
C.V. for entire experiment - - - - - - - - - - - - - - - - - - 23%

a/ Values represent an average of four replications.

TABLE XXX

PER CENT MAGNESIUM IN CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.28a/	0.27	0.34	0.30	0.27
20	100	0.20	0.26	0.27	0.24	
0	300	0.26	0.26	0.29	0.27	0.27
20	300	0.20	0.33	0.28	0.27	
0	500	0.21	0.25	0.33	0.26	0.25
20	500	0.26	0.26	0.24	0.25	
Lime Rate Ave.		0.24	0.26	0.29		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	28%
C.V. for sub-plots	26%
C.V. for sub-sub-plots	29%
C.V. for entire experiment	27%

a/ Values represent an average of four replications.

TABLE XXXI

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.65a/	0.72	0.70	0.69	0.58
20	100	0.47	0.45	0.49	0.47	
0	300	1.09	0.88	0.85	0.94	0.77
20	300	0.52	0.62	0.66	0.60	
0	500	1.11	1.15	1.27	1.18	0.93
20	500	0.68	0.64	0.72	0.68	
Lime Rate Ave.		0.75	0.74	0.78		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.056%
L.S.D. (.01) between phosphorus means	0.076%
L.S.D. (.05) between zinc means	0.086%
L.S.D. (.01) between zinc means	0.117%
C.V. for main plots	8%
C.V. for sub-plots	10%
C.V. for sub-sub-plots	23%
C.V. for entire experiment	17%

a/ Values represent an average of four replications.

TABLE XXXII

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.52a/	0.55	0.58	0.55	0.48
20	100	0.42	0.41	0.41	0.41	
0	300	0.50	0.58	0.64	0.57	0.50
20	300	0.42	0.43	0.45	0.43	
0	500	0.54	0.52	0.63	0.56	0.49
20	500	0.42	0.42	0.43	0.42	
Lime Rate Ave.		0.47	0.48	0.52		

L.S.D. (.05) between lime means	0.035%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.028%
L.S.D. (.01) between zinc means	0.039%
C.V. for main plots	10%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	12%
C.V. for entire experiment	11%

a/ Values represent an average of four replications.

TABLE XXXIII

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	0.61a/	0.59	0.65	0.62	0.56
20	100	0.48	0.47	0.54	0.50	
0	300	0.61	0.64	0.67	0.64	0.59
20	300	0.50	0.52	0.58	0.53	
0	500	0.62	0.63	0.74	0.66	0.58
20	500	0.47	0.50	0.56	0.51	
Lime Rate Ave.		0.55	0.56	0.62		

L.S.D. (.05) between lime means	0.058%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.077%
L.S.D. (.01) between zinc means	0.105%
C.V. for main plots	14%
C.V. for sub-plots	13%
C.V. for sub-sub-plots	28%
C.V. for entire experiment	20%

a/ Values represent an average of four replications.

TABLE XXXIV

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	4.41a/	5.11	4.20	4.57	4.45
20	100	4.10	4.30	4.58	4.33	
0	300	5.25	5.16	4.55	4.99	4.53
20	300	4.25	3.79	4.20	4.08	
0	500	5.30	4.81	5.59	5.23	4.80
20	500	4.05	4.55	4.51	4.37	
Lime Rate Ave.		4.56	4.62	4.60		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.31%
L.S.D. (.01) between zinc means	0.43%
C.V. for main plots	10%
C.V. for sub-plots	13%
C.V. for sub-sub-plots	14%
C.V. for entire experiment	13%

a/ Values represent an average of four replications.

TABLE XXXV

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	1.92a/	1.85	2.06	1.94	1.90
20	100	1.88	1.81	1.91	1.87	
0	300	2.06	1.97	2.08	2.04	1.96
20	300	1.97	1.77	1.92	1.89	
0	500	2.06	2.10	2.08	2.08	2.03
20	500	2.05	1.92	1.96	1.98	
Lime Rate Ave.		1.99	1.90	2.00		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.043%
L.S.D. (.01) between zinc means	0.058%
C.V. for main plots	16%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	4%
C.V. for entire experiment	9%

a/ Values represent an average of four replications.

TABLE XXXVI

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	1.63a/	1.74	1.52	1.63	1.62
20	100	1.47	1.51	1.54	1.51	
0	300	1.80	1.81	1.70	1.77	1.61
20	300	1.52	1.44	1.58	1.51	
0	500	1.77	1.67	1.88	1.77	1.62
20	500	1.54	1.48	1.52	1.51	
Lime Rate Ave.		1.57	1.64	1.64		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	0.11%
L.S.D. (.01) between zinc means	0.15%
C.V. for main plots	6%
C.V. for sub-plots	11%
C.V. for sub-sub-plots	14%
C.V. for entire experiment	12%

a/ Values represent an average of four replications.

per cent as the P rate was increased from 100 to 500 pounds P_2O_5 per acre. The difference among P rates was highly significant. There was also a highly significant phosphorus x lime interaction at the first sampling. Phosphorus rates failed to significantly change Ca content at the sixth and ninth week samples.

Lime application did not cause a significant change in Ca composition at the three sampling dates.

Zinc rates affected Ca content at the final sampling only. At that sampling the 20 pound Zn rate mean was 0.11 per cent greater than the no-Zn mean. This difference was significant at the 0.01 level.

Magnesium. The Mg means were 0.21, 0.23 and 0.26 per cent for the three sampling dates.

The effect of the various lime and phosphate treatments on Mg content of the three samplings was not significant. Differences between Zn rate means was significant at the third and sixth week samples while no significant difference was found in the ninth week samples.

A highly significant zinc x phosphorus interaction was found in the first sampling.

Phosphorus. The per cent P means for the third, sixth, and ninth week samples were: 0.76, 0.49, and 0.58 per cent, respectively. Lime rates did not significantly affect P content in the first sampling, but in the sixth and ninth week samples increase in P content due to increased lime application was significant.

The difference in P content among P rates was highly significant in the third week samples while no significant difference was found in the sixth and ninth week samples. In the first sampling the P composition was

increased from 0.58 to 0.93 per cent as the phosphate rate was increased from 100 to 500 pounds P_2O_5 per acre.

Zinc additions caused highly significant differences in P content at each of the three sampling dates. The Zn versus no-Zn per cent P means were: 0.58 and 0.93 for the first sampling, 0.42 and 0.56 for the second sampling, and 0.51 and 0.64 per cent for the final sampling, respectively.

A significant zinc x phosphorus interaction was found in the third week samples. The sixth week samples showed a zinc x lime interaction that was highly significant.

Potassium. Lime and P rates failed to cause a significant change in K content.

The Zn versus no-Zn per cent K means were 4.26 and 4.93 for the first sampling, 1.91 and 2.02 for the second, and 1.51 and 1.72 per cent for the third sampling, respectively. In each instance the difference was significant at the 0.01 level of probability.

The per cent K means for the three sampling dates were: 4.60, 1.96, and 1.62 per cent for the third, sixth, and ninth week samples, respectively.

Wheat Forage Yield

Wheat forage yield was not significantly affected by the lime, P, or Zn treatments. Mean yield was 3,130 pounds per acre. Wheat forage yield is summarized in Table XXXVII.

Wheat Grain Yield

Wheat grain yield was not significantly affected by the lime, P,

TABLE XXXVII

WHEAT FORAGE YIELD ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Pounds/Acre: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	3,310a/	3,040	3,530	3,260	3,170
20	100	2,850	3,420	2,890	3,060	
0	300	2,750	3,270	2,890	2,970	3,040
20	300	3,180	3,090	3,080	3,110	
0	500	3,180	3,130	3,060	3,120	3,170
20	500	3,200	3,030	3,170	3,130	
Lime Rate Ave.		3,080	3,200	3,100		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	11%
C.V. for sub-plots	12%
C.V. for sub-sub-plots	14%
C.V. for entire experiment	13%

a/ Values represent an average of four replications.

or Zn treatments. Mean yield was 27.0 bushels per acre. Wheat grain yield is summarized in Table XXXVIII.

Yield and Chemical Composition of Corn, Oats, and Grain Sorghum Grown on Olivier Silt Loam

Corn Yield

Statistical analysis of the corn yield results on Olivier silt loam showed no significant difference due to the various lime, phosphate and Zn treatments. The mean corn yield was 117.3 bushels per acre. The results are shown in Table XL.

Corn Ear Number

The lime, phosphate and Zn additions did not significantly affect corn ear number. The results are shown in Table XLI.

Corn Chemical Composition

Summaries of the effect of lime, phosphate and Zn treatments on the Ca, Mg, P and K content at each sampling date are presented in Tables XLII through LIII, respectively. Data presented are expressed as per cent composition of oven dry forage on a weight basis, and represent the mean of four replications. Samples were collected at the end of the third, sixth and ninth week after planting.

Calcium. The Ca means were 0.71, 0.39 and 0.56 per cent for the third, sixth and ninth week samples, respectively.

Lime and Zn rates did not cause a significant difference in Ca content. Phosphate additions cause a significant increase in Ca content in

TABLE XXXVIII

YIELD OF WHEAT ON MAURY SILT LOAM GROWN WITH THREE LIME LEVELS, THREE PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Bushels/Acre: Lime Tons/Acre 0	2	4	Zinc Rate Ave.	Phosphorus Rate Ave.
0	100	29.4a/	24.8	21.8	25.3	25.8
20	100	29.0	25.1	24.6	26.2	
0	300	27.2	29.5	26.0	27.6	27.2
20	300	26.1	27.5	26.6	26.7	
0	500	25.9	27.2	29.7	27.6	28.1
20	500	28.1	28.4	29.4	28.6	
Lime Rate Ave.		27.6	27.1	26.4		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 11%
C.V. for sub-plots - 14%
C.V. for sub-sub-plots - 12%
C.V. for entire experiment - 13%

a/ Values represent an average of four replications.

TABLE XXXIX

SOIL pH VALUES AND EXTRACTABLE CATIONS AT DIFFERENT LIME LEVELS ON OLIVIER SILT LOAM

Lime Tons/Acre	Beginning of Expt.* pH P_2O_5 Pounds/Acre 1000	2000	End of Experiment pH	me/100g. soil Ca	Mg	K
2	6.3 a/	6.2	6.7	6.62	0.55	0.22
4	6.6	6.4	6.8	7.38	0.59	0.25
8	7.3	6.7	7.0	8.32	0.64	0.24

a/ Values represent an average of four replications.

* pH taken October, 1957 after harvesting of corn crop. pH at end of experiment was taken in October, 1958.

TABLE XL

YIELD OF CORN ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Bushels Per Acre				
		Lime Tons/Acre			Zinc Rate Ave.	Phosphorus Rate Ave.
		2	4	8		
0	1000	110.4a/	118.5	119.5	116.1	116.4
20	1000	112.4	120.3	117.6	116.8	
0	2000	119.0	118.4	114.5	117.3	118.1
20	2000	113.2	120.6	123.2	119.0	
Lime Rate Ave.		113.8	119.4	118.7		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 12%
C.V. for sub-plots - 11%
C.V. for sub-sub-plots - 6%
C.V. for entire experiment - 8%

a/ Values represent an average of four replications.

TABLE XLI

CORN EAR NUMBER PER PLOT ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Ears Per Plot: Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	88a/	95	95	93	96
20	1000	96	103	98	99	
0	2000	98	98	95	97	96
20	2000	89	95	101	95	
Lime Rate Ave.		93	98	97		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 7%
C.V. for sub-plots - 8%
C.V. for sub-sub-plots - 6%
C.V. for entire experiment - 7%

a/ Values represent an average of four replications.

TABLE XLII

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent: Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.62a/	0.65	0.73	0.67	0.71
20	1000	0.77	0.70	0.80	0.76	
0	2000	0.71	0.70	0.70	0.70	0.72
20	2000	0.68	0.65	0.85	0.73	
Lime Rate Ave.		0.69	0.68	0.77		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 14%
C.V. for sub-plots - 15%
C.V. for sub-sub-plots - 15%
C.V. for entire experiment - 14%

a/ Values represent an average of four replications.

TABLE XLIII

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.42a/	0.42	0.39	0.41	0.40
20	1000	0.35	0.40	0.38	0.38	
0	2000	0.33	0.38	0.37	0.36	0.38
20	2000	0.40	0.38	0.42	0.40	
Lime Rate Ave.		0.38	0.40	0.39		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	23%
C.V. for sub-plots	16%
C.V. for sub-sub-plots	14%
C.V. for entire experiment	17%

a/ Values represent an average of four replications.

TABLE XLIV

PER CENT CALCIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.56a/	0.52	0.54	0.54	0.54
20	1000	0.56	0.55	0.54	0.55	
0	2000	0.58	0.58	0.54	0.57	0.56
20	2000	0.58	0.52	0.59	0.56	
Lime Rate Ave.		0.57	0.54	0.55		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.017%
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	20%
C.V. for sub-plots	5%
C.V. for sub-sub-plots	20%
C.V. for entire experiment	17%

a/ Values represent an average of four replications.

TABLE XLV

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.18a/	0.20	0.18	0.16	0.19
20	1000	0.22	0.22	0.23	0.22	
0	2000	0.20	0.20	0.17	0.19	0.19
20	2000	0.22	0.18	0.20	0.20	
Lime Rate Ave.		0.19	0.20	0.18		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 24%
C.V. for sub-plots - 53%
C.V. for sub-sub-plots - 45%
C.V. for entire experiment - 45%

a/ Values represent an average of four replications.

TABLE XLVI

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent				
		Lime Tons/Acre			Zinc	Phosphorus
		2	4	8	Rate Ave.	Rate Ave.
0	1000	0.08a/	0.08	0.12	0.09	0.10
20	1000	0.09	0.15	0.11	0.12	
0	2000	0.14	0.10	0.10	0.11	0.12
20	2000	0.14	0.10	0.15	0.13	
Lime Rate Ave.		0.11	0.11	0.12		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 41%
C.V. for sub-plots - 28%
C.V. for sub-sub-plots - 44%
C.V. for entire experiment - 40%

a/ Values represent an average of four replications.

TABLE XLVII

PER CENT MAGNESIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.18a/	0.17	0.22	0.19	0.19
20	1000	0.18	0.20	0.20	0.19	
0	2000	0.18	0.20	0.21	0.20	0.20
20	2000	0.22	0.18	0.19	0.20	
Lime Rate Ave.		0.19	0.18	0.20		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 23%
C.V. for sub-plots - 20%
C.V. for sub-sub-plots - 25%
C.V. for entire experiment - 24%

a/ Values represent an average of four replications.

TABLE XLVIII

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	1.00a/	0.90	0.94	0.95	0.92
20	1000	0.92	0.89	0.86	0.89	
0	2000	1.00	1.17	1.06	1.08	1.03
20	2000	0.95	1.02	0.99	0.99	
Lime Rate Ave.		0.97	1.00	0.96		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.026%
L.S.D. (.01) between phosphorus means	0.037%
L.S.D. (.05) between zinc means	0.050%
L.S.D. (.01) between zinc means	0.068%
C.V. for main plots	8%
C.V. for sub-plots	5%
C.V. for sub-sub-plots	8%
C.V. for entire experiment	8%

a/ Values represent an average of four replications.

TABLE XLIX

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.46a/	0.47	0.46	0.46	0.44
20	1000	0.42	0.42	0.42	0.42	
0	2000	0.51	0.59	0.56	0.55	0.50
20	2000	0.46	0.44	0.47	0.46	
Lime Rate Ave.		0.46	0.48	0.48		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.013%
L.S.D. (.01) between phosphorus means	0.018%
L.S.D. (.05) between zinc means	0.042%
L.S.D. (.01) between zinc means	0.057%
C.V. for main plots	7%
C.V. for sub-plots	4%
C.V. for sub-sub-plots	15%
C.V. for entire experiment	12%

a/ Values represent an average of four replications.

TABLE L

PER CENT PHOSPHORUS IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.46a/	0.50	0.45	0.47	0.46
20	1000	0.45	0.45	0.45	0.45	
0	2000	0.58	0.66	0.62	0.62	0.57
20	2000	0.51	0.47	0.56	0.51	
Lime Rate Ave.		0.50	0.52	0.52		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.062%
L.S.D. (.01) between phosphorus means	0.090%
L.S.D. (.05) between zinc means	0.059%
C.V. for main plots	6%
C.V. for sub-plots	19%
C.V. for sub-sub-plots	19%
C.V. for entire experiment	18%

a/ Values represent an average of four replications.

TABLE LI

PER CENT POTASSIUM IN CORN PLANT TISSUE SAMPLES TAKEN THREE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	4.94a/	4.60	4.79	4.78	4.70
20	1000	4.68	4.50	4.71	4.63	
0	2000	4.70	4.35	4.78	4.61	4.70
20	2000	4.90	4.98	4.52	4.80	
Lime Rate Ave.		4.80	4.61	4.70		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	5%
C.V. for sub-plots	9%
C.V. for sub-sub-plots	8%
C.V. for entire experiment	8%

a/ Values represent an average of four replications.

TABLE LII

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN SIX WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	2.51a/	2.62	2.51	2.55	2.54
20	1000	2.42	2.48	2.71	2.54	
0	2000	2.15	2.34	2.46	2.32	2.28
20	2000	2.50	2.16	2.10	2.25	
Lime Rate Ave.		2.40	2.40	2.45		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - 0.23%
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 17%
C.V. for sub-plots - 15%
C.V. for sub-sub-plots - 15%
C.V. for entire experiment - 15%

a/ Values represent an average of four replications.

TABLE LIII

PER CENT POTASSIUM IN OVEN DRY CORN PLANT TISSUE SAMPLES TAKEN NINE WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	2.10a/	2.22	2.13	2.15	2.12
20	1000	2.14	2.13	2.02	2.10	
0	2000	1.97	1.87	2.12	1.99	2.05
20	2000	1.96	2.27	2.09	2.11	
Lime Rate Ave.		2.04	2.12	2.09		

L.S.D. (.05) between lime means - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - N.S.

C.V. for main plots - 13%
C.V. for sub-plots - 38%
C.V. for sub-sub-plots - 10%
C.V. for entire experiment - 11%

a/ Values represent an average of four replications.

the final sampling changing the composition from 0.54 to 0.56 per cent. An interaction between Zn and P was significant at the 0.05 level in the sixth week samples.

Magnesium. Statistical analysis of the results from the corn plant tissue samples showed no significant difference in Mg content due to lime, phosphate and Zn treatment at the three sampling dates. The per cent Mg means for the three sampling dates were 0.19, 0.11 and 0.19 per cent for the third, sixth and ninth week samples respectively.

Phosphorus. Lime rates did not cause a significant change in P content at the three sampling dates.

Per cent P composition was increased with increased phosphate application. The P means for the 1,000 and 2,000 pound rates were 0.92 and 1.03, 0.44 and 0.50, and 0.46 and 0.57 per cent for the first, second, and third sampling dates, respectively. A highly significant phosphorus x lime interaction was found in the third and sixth week samples. Difference between phosphorus x lime means in the ninth week samples was not significant.

The Zn versus no-Zn per cent P means were 1.01 and 0.94, 0.51 and 0.44, and 0.55 and 0.46 per cent for the third, sixth, and ninth week samples, respectively. The difference between Zn treatment means was highly significant in the third and sixth week samples while in the final sampling the difference was significant at the 0.05 level.

The per cent P means were 0.98, 0.47, and 0.51 per cent for the first, second, and third sampling, respectively.

Potassium. No significant difference in per cent K could be attributed to lime and Zn rates. A significant decrease in K content due

to increased phosphate application was found in the sixth week samples. The third and ninth week samples were not significantly affected by phosphate application.

Oat Forage Yield

Lime rates were the only treatments to cause a significant change in oat forage yield. Inspection of Table LIV shows a significant decrease in oat forage yield between the 2 and 4 ton lime means, and a significant increase between the 4 and 8 ton rates. Mean yield was 3,060 pounds per acre.

Oat Grain Yield

Statistical analysis of the oat grain yield results showed no significant difference due to the various lime, phosphate and Zn treatments. Mean yield was 70.6 bushels per acre. Results are shown in Table LV.

Oat Chemical Composition

Summaries of the effect of lime, phosphate and Zn treatments on the Ca, Mg, P and K content are presented in Tables LVI through LIX, respectively. Data presented are expressed as per cent composition of oven dry forage on a weight basis, and represent the mean of four replications. Samples were collected at the boot stage of maturity.

Calcium. No significant difference was found among the various Ca means due to lime, phosphate and Zn application.

Magnesium. Magnesium composition was not significantly affected by either lime or phosphate treatment. Application of 20 pounds $ZnSO_4 \cdot H_2O$ per acre caused a significant increase in Mg uptake as compared to the no-Zn treatment mean.

TABLE LIV

OAT FORAGE YIELD ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Pounds Per Acre: Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	3,510	2,840	2,900	3,080	3,090
20	1000	2,570	2,880	3,800	3,090	
0	2000	2,430	3,160	3,110	2,900	3,040
20	2000	3,770	3,060	2,730	3,190	
Lime Rate Ave.		3,080	2,990	3,140		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - 64 pounds
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 24%
C.V. for sub-plots - 30%
C.V. for sub-sub-plots - 40%
C.V. for entire experiment - - - - - - - - - - - - - - - - - - - 35%

a/ Values represent an average of four replications.

TABLE LV

OAT GRAIN YIELD ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Bushels Per Acre: Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	73.2a/	69.3	70.4	71.0	70.1
20	1000	64.5	69.0	74.3	69.3	
0	2000	72.6	68.7	68.3	69.9	71.2
20	2000	80.6	66.2	70.7	72.5	
Lime Rate Ave.		72.7	68.3	70.9		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 26%
C.V. for sub-plots - 23%
C.V. for sub-sub-plots - 11%
C.V. for entire experiment - 18%

a/ Values represent an average of four replications.

TABLE LVI

PER CENT CALCIUM IN OVEN DRY OAT FORAGE SAMPLES TAKEN AT BOOT STAGE OF MATURITY ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent				
		Lime Tons/Acre			Zinc	Phosphorus
		2	4	8	Rate Ave.	Rate Ave.
0	1000	0.27a/	0.29	0.35	0.30	0.30
20	1000	0.29	0.28	0.36	0.31	
0	2000	0.27	0.34	0.31	0.31	0.31
20	2000	0.34	0.32	0.28	0.31	
Lime Rate Ave.		0.29	0.31	0.32		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	24%
C.V. for sub-plots	28%
C.V. for sub-sub-plots	13%
C.V. for entire experiment	20%

a/ Values represent an average of four replications.

TABLE LVII

PER CENT MAGNESIUM IN OAT FORAGE SAMPLES TAKEN AT BOOT STAGE OF MATURITY ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.13a/	0.13	0.14	0.13	0.15
20	1000	0.16	0.14	0.20	0.17	
0	2000	0.18	0.16	0.14	0.16	0.16
20	2000	0.17	0.18	0.14	0.16	
Lime Rate Ave.		0.16	0.15	0.15		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - 0.017%

C.V. for main plots - 37%
C.V. for sub-plots - 39%
C.V. for sub-sub-plots - 18%
C.V. for entire experiment - 29%

a/ Values represent an average of four replications.

TABLE LVIII

PER CENT PHOSPHORUS IN OVEN DRY OAT FORAGE SAMPLES TAKEN AT BOOT STAGE OF MATURITY ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.38a/	0.38	0.40	0.39	0.38
20	1000	0.38	0.39	0.39	0.39	
0	2000	0.40	0.40	0.41	0.40	0.41
20	2000	0.42	0.40	0.41	0.41	
Lime Rate Ave.		0.39	0.40	0.40		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - 0.016%
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 7%
C.V. for sub-plots - 6%
C.V. for sub-sub-plots - 8%
C.V. for entire experiment - 8%

a/ Values represent an average of four replications.

TABLE LIX

PER CENT POTASSIUM IN OVEN DRY OAT FORAGE SAMPLES TAKEN AT BOOT STAGE OF MATURITY ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	3.25a/	3.18	3.22	3.22	3.28
20	1000	3.33	3.37	3.33	3.34	
0	2000	3.48	3.39	3.39	3.42	3.46
20	2000	3.46	3.71	3.32	3.50	
Lime Rate Ave.		3.38	3.41	3.32		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - - 0.16%
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 4%
C.V. for sub-plots - 7%
C.V. for sub-sub-plots - 10%
C.V. for entire experiment - 9%

a/ Values represent an average of four replications.

Phosphorus. Increased phosphate application resulted in a significant increase in P composition. Phosphorus content was not significantly changed by lime and Zn-fertilization.

Potassium. Phosphate rates caused a significant change in K content. The per cent K means for the 1,000 and 2,000 pound P_2O_5 rates was 3.28 and 3.46 per cent, respectively. No significant difference in K content could be attributed to the lime and Zn additions.

Grain Sorghum Forage Yield

No significant difference in grain sorghum forage yield could be attributed to the various lime, phosphate and Zn additions, but an interaction between Zn and lime was significant at the 0.05 level. The mean forage yield for the entire experiment was 4,180 pounds per acre. The effect of the lime, phosphate and Zn treatments on grain sorghum forage yield are shown in Table LX.

Grain Sorghum Chemical Composition

Summaries of the effect of lime, phosphate and Zn treatments on the Ca, Mg, P and K content are presented in Tables LXI through LXIV, respectively. Samples were collected four weeks after planting.

Calcium. The difference in Ca content due to lime, phosphate and Zn fertilization was not significant. The per cent Ca mean for this sampling was 0.65 per cent.

Magnesium. Magnesium composition decreased with increased lime application. The difference between the 2 and 8 ton rates was significant at the 0.05 level. The per cent Mg means for the 2, 4 and 8 ton rates were 0.35, 0.32 and 0.27 per cent, respectively. Zinc and phosphate applications did not cause a significant difference in Mg content.

TABLE LX

YIELD OF GRAIN SORGHUM FORAGE ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES, AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Pounds Forage/Acre				
		Lime Tons/Acre			Zinc Rate Ave.	Phosphorus Rate Ave.
		2	4	8		
0	1000	4,500a/	4,130	4,280	4,300	4,200
20	1000	3,450	4,580	4,260	4,110	
0	2000	4,630	4,650	2,900	4,060	4,090
20	2000	4,090	3,870	4,440	4,140	
Lime Rate Ave.		4,180	4,320	3,960		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 13%
C.V. for sub-plots - 19%
C.V. for sub-sub-plots - 14%
C.V. for entire experiment - 16%

a/ Values represent an average of four replications.

TABLE LXI

PER CENT CALCIUM IN OVEN DRY GRAIN SORGHUM FORAGE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.66a/	0.62	0.66	0.65	0.65
20	1000	0.63	0.70	0.61	0.65	
0	2000	0.66	0.70	0.65	0.67	0.65
20	2000	0.61	0.60	0.68	0.63	
Lime Rate Ave.		0.64	0.65	0.65		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 10%
C.V. for sub-plots - 14%
C.V. for sub-sub-plots - 14%
C.V. for entire experiment - - - - - - - - - - - - - - - - - - - 13%

a/ Values represent an average of four replications.

TABLE LXII

PER CENT MAGNESIUM IN OVEN DRY GRAIN SORGHUM FORAGE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

		Per Cent				
		Lime Tons/Acre				
$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.36a/	0.29	0.29	0.31	0.31
20	1000	0.32	0.33	0.28	0.31	
0	2000	0.40	0.35	0.26	0.34	0.32
20	2000	0.34	0.32	0.25	0.30	
Lime Rate Ave.		0.35	0.32	0.27		

L.S.D. (.05) between lime means	0.06%
L.S.D. (.05) between phosphorus means	N.S.
L.S.D. (.05) between zinc means	N.S.
C.V. for main plots	22%
C.V. for sub-plots	22%
C.V. for sub-sub-plots	25%
C.V. for entire experiment	24%

a/ Values represent an average of four replications.

TABLE LXIII

PER CENT PHOSPHORUS IN OVEN DRY GRAIN SORGHUM FORAGE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	0.50a/	0.46	0.47	0.48	0.45
20	1000	0.39	0.46	0.40	0.42	
0	2000	0.57	0.56	0.58	0.57	0.53
20	2000	0.47	0.49	0.50	0.49	
Lime Rate Ave.		0.48	0.49	0.49		

L.S.D. (.05) between lime means	N.S.
L.S.D. (.05) between phosphorus means	0.039%
L.S.D. (.01) between phosphorus means	0.057%
L.S.D. (.05) between zinc means	0.038%
L.S.D. (.01) between zinc means	0.052%
C.V. for main plots	4%
C.V. for sub-plots	12%
C.V. for sub-sub-plots	13%
C.V. for entire experiment	12%

a/ Values represent an average of four replications.

TABLE LXIV

PER CENT POTASSIUM IN OVEN DRY GRAIN SORGHUM FORAGE SAMPLES TAKEN FOUR WEEKS AFTER PLANTING ON OLIVIER SILT LOAM GROWN WITH THREE LIME LEVELS, TWO PHOSPHORUS RATES AND TWO RATES OF ZINC FERTILIZATION.

$ZnSO_4 \cdot H_2O$ Pounds/Acre	P_2O_5 Pounds/Acre	Per Cent Lime Tons/Acre 2	4	8	Zinc Rate Ave.	Phosphorus Rate Ave.
0	1000	4.45a/	4.61	4.52	4.53	4.46
20	1000	4.47	4.59	4.15	4.40	
0	2000	4.35	4.26	4.58	4.40	4.39
20	2000	4.29	4.54	4.34	4.39	
Lime Rate Ave.		4.39	4.50	4.40		

L.S.D. (.05) between lime means - - - - - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between phosphorus means - - - - - - - - - - - - - - N.S.
L.S.D. (.05) between zinc means - - - - - - - - - - - - - - - - - N.S.

C.V. for main plots - 8%
C.V. for sub-plots - 7%
C.V. for sub-sub-plots - 9%
C.V. for entire experiment - - - - - - - - - - - - - - - - - - - 8%

a/ Values represent an average of four replications.

Phosphorus. The difference in per cent P composition between the 1,000 and 2,000 pound P_2O_5 rates was highly significant. Phosphorus composition was increased from 0.45 to 0.53 per cent with increased phosphate application.

The addition of 20 pounds of $ZnSO_4 \cdot H_2O$ caused a highly significant decrease in P content. The per cent P means for the 0 and 20 pound Zn rates were 0.52 and 0.45 per cent, respectively.

Lime failed to cause a significant change in P composition.

Potassium. No significant difference in K content could be attributed to lime, phosphate and Zn-fertilization.

CHAPTER V

DISCUSSION

Corn Grain Yield and Ear Number

Lime, under conditions of these tests, did not significantly affect corn yield and ear number on the three soils used in this study. Comparison of the lime means on the Hartsells soil showed an increase of nearly 11 bushels per acre between the two and six ton lime rates. This increase was not significant, probably due to the large C.V. value for the main plots. Ear number also showed a large difference between lime means on Hartsells soil but this, too, was not significant due to a high C. V. value and a significant zinc x lime interaction. Although the differences between lime rates on Maury and Olivier soils were not as great as on the Hartsells the trend was toward increased grain yield and ear number production with increased lime application. The small difference in pH between the various lime rates on Maury silt loam was probably due to considerable soil mixing brought about by water erosion. Soil mixing due to three seedbed preparations probably accounts for the small change in pH between the lime treatments on Olivier silt loam at the end of the experiment.

Hartsells fine sandy loam was the only soil to show a significant increase in grain yield and ear number due to phosphate application. The increase in grain yield and ear number was highly significant between the 500 and 1,000 pound P_2O_5 rates. Increase in grain yield between the 500 and 2,000 pound rates was significant at the 0.05 level indicating a slight yield depression. This depression was more evident on ear number

showing a significant decrease between the 1,000 and 2,000 pound phosphate rates. No significant differences in corn yield and ear number was obtained on Maury and Olivier silt loams. However, the 2,000 pound P_2O_5 rate on Olivier soil lowered the pH at each lime rate. Difference between the 1,000 and 2,000 P_2O_5 additions at the 8 ton lime rate was 0.6 pH unit. This is in agreement with Jamison (16) who found that the Ca applied in superphosphate displaces acidity (H^+) into solution, lowering the pH, and in many cases mobilizing significant amounts of Zn and copper.

Corn plants showed a significant yield response to Zn-fertilization only on the naturally high phosphate Maury soil. This is in agreement with Winters and Parks (44) who found that Zn-deficiency of corn in Tennessee was observed most frequently on soils high to medium-high in available phosphate. The Zn versus no-Zn corn yield means were 81.8 and 67.5 bushels per acre. Maury silt loam was also the only soil to show a significant increase in ear number due to Zn-fertilization. The increase in ear number due to Zn-fertilization was significant at the 0.01 level.

The sequence of development of Zn-deficiency symptoms on corn varied on the three soils. Visual observation of the corn plants on Maury silt loam at the end of the third week after planting showed moderate to severe chlorosis and purple coloring of the lower leaves on the untreated Zn plots, while the corn receiving 20 pounds of $ZnSO_4 \cdot H_2O$ were normal to slightly chloratic in appearance. These symptoms appeared to be the same over the entire plot area and were not enhanced by the higher lime and

phosphate treatments. In contrast to the third week observation on the Maury soil the no-Zn treated corn on Hartsells showed a very slight chlorotic condition only on the four and six ton lime rates of the fertilizer field. On Olivier silt loam this condition was evident only at the eight ton lime rate.

At the end of the sixth week the no-Zn treated corn on Maury silt loam still showed some chlorosis of the lower leaves but considerable white striping of the upper leaves appeared and the plots were stunted in growth as compared to the Zn treated corn. On the Hartsells soil corn on the no-Zn treated plots of the six ton lime rate showed a slight decrease in growth and striping of the leaves as compared to the Zn treated plots, although not nearly as severe as on the Maury soil. Some striping but no difference in growth was found on the corn grown on Olivier soil at the eight ton lime rate. At this date all of the corn receiving 20 pounds of $ZnSO_4 \cdot H_2O$ at the three soil sites showed good color and normal growth.

Only corn grown on Maury silt loam showed Zn-deficiency symptoms at the end of the ninth week. White striping of the leaves was still evident on plots receiving no-Zn and the plants were smaller in size than those on the Zn treated plots. The Zn fertilized corn was also more mature showing larger plant size, larger ear development, and a greater number of ears per plant.

No visual evidence of Zn-deficiency could be seen on corn grown on Hartsells and Olivier soils nine weeks after planting. This agrees with the findings of Winters and Parks (44) that in Tennessee corn grown under conditions of mild deficiency tends to grow out of Zn-deficiency.

In general the sequence of Zn-deficiency symptoms on corn paralleled very closely with those described by Winters and Parks (44) in 1955.

Moisture conditions were very good throughout the growing season on the Maury and Olivier soils, but on the Hartsells soil, plants suffered from lack of moisture by the end of the ninth week. A good rain three days later corrected this condition.

It is difficult to determine what was the major cause of Zn-deficiency on Maury silt loam. The initially high pH, soil mixing by erosion, little change in pH between lime treatments, and the lack of significant differences in yield between lime means makes it very hard to correlate Zn-deficiency with soil reaction. Also, since Maury silt loam is initially high in available phosphate, and no difference was found due to row applications up to 500 pounds per acre P_2O_5, it is difficult to establish P as the principle cause of Zn-deficiency. Phosphate, however, may be a contributing cause.

Lime and phosphate treatments did not significantly affect corn yield on Hartsells and Olivier soils. The tendency was for increased grain yield with increased lime and phosphate application, although the 2,000 pound P_2O_5 addition on Hartsells soil brought about a slight, but not significant, depression in yield. Data in Table III show the increased difference between Zn versus no-Zn yield means when 2,000 pounds P_2O_5 was added to the four and six ton lime rates. It appears that as the P_2O_5 rate is increased above 2,000 pounds per acre at high lime levels on Hartsells soil the incidence of Zn-deficiency will increase. Apparently Zn-deficiency is caused by a combination of high pH and phosphate additions (5).

Small Grain Forage and Grain Yield

Wheat forage and grain yield on Maury soil, and oat forage and grain yield on Olivier soil were not significantly affected by the various lime, phosphate and Zn treatments.

Grain Sorghum Forage Yield

Grain sorghum forage on Hartsells soil showed a highly significant increase in yield due to lime treatment. Forage yield on Olivier soil did not show a significant difference among lime means, but showed a highly significant zinc x lime interaction. Phosphate and Zn treatment did not cause a significant change in forage yield on the two soils.

Corn Chemical Composition

Effects of Lime Application. Calcium content of corn increased with increased lime application on Hartsells soil. The difference between lime means was highly significant in the third and ninth week samples. This is in close correlation with increased corn yield and ear number due to lime treatment. Increasing the lime rates failed to cause a significant change in Ca content of corn on Maury and Olivier soils. Soil mixing as previously described may account for this non-significant change on Maury soil but no explanation is available for this condition on Olivier soil.

Magnesium composition also increased with increased lime application on Hartsells soil. The difference was highly significant in the third and sixth week samples, and significant at the 0.05 level at the ninth week. Lime did not significantly affect Mg composition of corn grown on Maury and Olivier soils.

The P content of corn was decreased at the 0.01 level with increased lime application in the third week samples on Hartsells soil. Analysis of the sixth and ninth week samples on Maury soil shows a significant increase in P content with increased lime addition. Lime application did not significantly affect the P content of corn grown on Olivier soil. There was, however, a significant phosphorus x lime interaction on P content of the samples taken at the end of the third and sixth week.

The effect of lime additions on K content of corn on the three soils was non-significant.

The accumulation of Ca, Mg, P and K in leaf samples of the corn plant on the three soils followed the pattern shown by Sayre (31, 32). Calcium and P content of corn leaves increased with increasing age of the plant while K content of the leaf began to decrease six weeks after planting.

Effect of Phosphate Application. The effect of phosphate fertilization on Ca content of corn varied with the different soils and sampling dates.

Calcium content of corn on Hartsells soil at the end of the sixth week showed a significant decrease between the 500 and 1,000 pound P_2O_5 rates and a significant increase between the 1,000 and 2,000 pound rates. In contrast to the results on Hartsells soil the Ca content of corn grown on Maury soil at the end of three weeks was decreased at the 0.01 level with increased phosphate fertilization. The third week samples also showed a highly significant phosphorus x lime interaction on Ca

content. On Olivier soil chemical analysis of the corn leaves at the end of nine weeks showed a significant increase in Ca content as the P_2O_5 rate was raised from 1,000 to 2,000 pounds per acre.

Other than causing a highly significant increase in Mg content of corn on Hartsells soil at the third week, phosphate had very little effect on Mg composition.

Phosphorus composition of corn on Hartsells and Olivier soils increased with increased phosphate fertilization. The difference between phosphate rates at each sampling date on the two soils was highly significant. The corn on the naturally high phosphate Maury soil showed a highly significant increase in P content due to phosphate fertilization at the third week, but this effect had disappeared by the end of the sixth week on this soil.

Phosphorus fertilization brought about a significant decrease in K content at the sixth week sampling on Hartsells and Olivier soils. The difference in K content due to phosphate rates on Hartsells soil was highly significant while the difference due to rates on Olivier soil was significant at the 0.05 level. Potassium content of corn on Maury soil was not significantly affected by phosphate application.

In general, excessive phosphate application did not greatly affect corn mineral composition other than increasing P content. Composition of corn grown on the naturally high phosphate Maury soil was not affected at all by the phosphate additions except in the early stages of growth. The effect of excessive phosphate on Ca uptake was inconsistent. Magnesium uptake was also not greatly affected by phosphate. Potassium content, however, was decreased on Hartsells and Olivier soils at the sixth week.

The changes in absorption of Ca, Mg, P and K by corn plants due to excessive phosphate fertilization were much greater on the Hartsells and Olivier soils than on the naturally high phosphate Maury soil.

No information could be found in the literature on the effect of high rates of phosphate on absorption of the major elements by corn plants. Bingham, et al. (5), however, working with citrus found that phosphate fertilization up to 1,800 pounds P per acre had no effect on leaf Ca content. On the other hand, Mg absorption was 40-50% greater at the high rates of P and K leaf concentration was decreased by increased phosphate fertilization. Phosphorus increased in direct ratio to that applied.

Effects of Zinc Application. In general the Zn treated corn was lower in Ca, Mg, P, and K content than the corn receiving no-Zn. The differences among Zn treatments varied with the particular element, sampling date and soil. Comparison of the results from each sampling date indicates that the ninth week samples are the most important. It was at this date that visual Zn-deficiency symptoms of corn had disappeared on Hartsells and Olivier soils, and were still evident on the corn not receiving Zn on Maury soil. Maury was also the only soil to show a yield response to Zn-fertilization.

Corn grown on the Zn deficient Maury soil showed the greatest differences due to Zn-fertilization especially in regard to the elements P and potassium. The difference in K and P content between Zn deficient and normal plants was highly significant at each sampling date. The difference between Zn versus no-Zn per cent Ca means at the ninth week was also highly significant. These results are in agreement with the

findings of Seatz (33) and Viets (41).

Analyses of the samples taken at the third and sixth week on Hartsells and Olivier soils show that although corn without Zn-fertilization may have a greater percentage of Ca, P and K in the early stages of growth than the Zn treated corn, these differences tended to disappear by the end of the ninth week. An exception was on Olivier soil at the ninth week where the no-Zn plants were significantly greater in P content than the Zn fertilized plants.

Under conditions of these tests Mg acted in an opposite manner to Ca, P and potassium. Magnesium composition of Zn deficient corn on Maury soil was significantly greater in the early stages of growth than the normal plants but by the end of the ninth week no significant difference was found. The no-Zn corn on Hartsells soil was higher in Mg at the 0.01 level than the Zn fertilized corn at each sampling date. No difference was found on Olivier soil. The results on Hartsells soil may be due to the fact that the initial soil analysis showed it to be relatively high in magnesium. Sanik, et al., (30) found that a high Mg soil favors Zn uptake. Viets (41) found that the accumulation of Mg in Zn deficient and normal plants was not consistent but tended to be greater in Zn deficient plants. A highly significant zinc x lime interaction at the end of the sixth week and a significant zinc x lime interaction at the ninth week may account for the differences in Mg content between Zn treated plants on Hartsells soil.

Oat Forage Chemical Composition

The various lime, phosphate and Zn treatments showed several

significant effects on the chemical composition of oats which does not exhibit Zn-deficiency as readily as some other crops.

Lime did not significantly affect the chemical composition of oats grown on Olivier soil.

The P and K content showed a significant increase due to phosphate application.

Zinc-fertilization showed the most striking results. The Mg content of the forage from Zn treated plots was significantly greater than from the untreated plots. This is opposite to the results found for corn and grain sorghum where the untreated plants were higher in Mg than the Zn fertilized plants. Calcium, P and K content of oats was not significantly affected by Zn-fertilization.

Grain Sorghum Chemical Composition

Effects of Lime Application. The Ca content of grain sorghum on Hartsells soil increased with increased lime application. Differences between lime rates was highly significant and closely parallels the increase in forage yield attributed to lime on this soil. The Ca content of grain sorghum on Olivier soil was not significantly affected by lime application. Inspection of Table XXXIX shows little change in pH between lime treatments on Olivier soil.

Magnesium content of grain sorghum on Hartsells soil showed a highly significant increase due to lime application. A significant decrease in per cent Mg was also found between the lower and higher lime levels. Magnesium content of grain sorghum on Olivier soil also showed a significant decrease due to lime application. The decrease in Mg content was probably due to the antagonistic effects of Ca at the higher lime levels.

Differences in P content due to lime application was non-significant on the two soils.

The decrease in K content due to lime additions on Hartsells soil was highly significant. This, too, was probably due to the antagonistic effects of Ca on potassium. Lime rates did not significantly affect K content of grain sorghum on Olivier soil.

Effects of Phosphate Application. Phosphorus content increased with increased phosphate application. Differences among phosphate rates on each soil was highly significant. Calcium, Mg and K content was not significantly affected by phosphate application. These results show that the residual P in the soil resulting from the high applications a year before still had a pronounced effect on plant P content.

Effects of Zinc Application. In most instances the effect of Zn-fertilization on nutrient content of grain sorghum closely resembles that of corn grown on the two soils.

Calcium and K content were not significantly affected by Zn application on the two soils.

Magnesium content was lowered by Zn-fertilization on Hartsells soil. The difference between Zn means was highly significant. No significant difference was found between the treated and untreated plants on Olivier soil.

Zinc-fertilization also lowered the P content of the sorghum on the two soils and in each instance the difference was highly significant.

CHAPTER VI

CONCLUSIONS

The results of this investigation did not establish the primary cause of Zn-deficiency. Whether it is due to high pH, high phosphate, or a combination of the two is not known.

Maury silt loam was the only soil to show a yield response to Zn-fertilization. Inspection of Table I shows that Maury silt loam contained the highest amount of total Zn and P of the three soils. The total Zn content of Maury soil is approximately equal to Olivier soil, but was twenty-seven per cent greater than Hartsells soil. The total P content of Maury soil was eight times greater than Olivier soil and twelve times greater than Hartsells soil. This indicates that phosphate must be inhibiting Zn uptake in Maury soil. However, lack of a wide range of pH values prevents separation of phosphate and pH effects.

Yield of corn on Hartsells fine sandy loam began to decline when 2,000 pounds P_2O_5 was added to the four and six ton lime rates. The application of approximately 7,700 pounds P_2O_5 per acre and the addition of sufficient lime to keep the pH near the neutral point would make the total phosphate level of hartsells soil equal to Maury soil. If a combination of various high phosphate applications and wide range of pH values were used on Hartsells soil, the question of phosphate induced Zn-deficiency in the field may be answered.

The fact that Zn deficient corn plants contain more total P and K than normal plants may serve as a tool in determining if corn plants in

the field are suffering from lack of zinc. In Middle Tennessee corn suffering from Zn-deficiency in many cases does not cover the entire field but occurs in small localized areas within a field. Analysis of corn leaf samples from the normal and deficient areas for K and P may show if the plant is Zn deficient. An average difference in per cent P of 0.14 to 0.36 per cent, depending on the stage of growth, would indicate a Zn-deficiency hazard exists. The average difference in per cent K, according to the results of this study, would run from 0.11 to 0.67 per cent potassium.

CHAPTER VII

SUMMARY

The effects of various lime, phosphate and Zn additions on Zn uptake by corn, small grain and grain sorghum were determined on Maury, Hartsells and Olivier soils. Yield and chemical composition of the plants at different stages of growth were also determined.

These determinations showed:

1. A significant corn yield response to Zn-fertilization on Maury silt loam. Corn on Olivier silt loam and Hartsells fine sandy loam did not respond to Zn treatment.
2. Lime application up to eight tons per acre did not significantly affect corn yield on the three soils.
3. Hartsells fine sandy loam was the only soil to show a significant increase in corn yield due to very high phosphate fertilization. Application of concentrated superphosphate up to 2,000 pounds P_2O_5 per acre failed to reduce corn yields in the three soils.
4. Small grain forage and grain yields were not affected by phosphate and Zn-fertilization. Oat forage yield increased with increased lime additions on Olivier silt loam.
5. Grain sorghum forage yield increased with increased lime application on Hartsells fine sandy loam. Forage yield was not affected by phosphate and Zn additions on Hartsells and Olivier soils.

6. Chemical analysis of corn plant tissue samples indicated the ninth week sampling to be the most important in determining chemical changes due to Zn-fertilization.
7. Corn showing mild Zn-deficiency symptoms in early stages of growth tended to grow out of Zn-deficiency by the end of the ninth week.
8. Corn plants receiving $ZnSO_4 \cdot H_2O$ contained less P and K than Zn deficient plants. Results on Ca and Mg were inconsistent.
9. Phosphorus content of corn, small grain and grain sorghum increased with increased phosphate applications on Hartsells and Olivier soils. Corn on Maury silt loam showed an increase only in the early stages of growth.
10. Calcium, Mg, P and K composition of grain sorghum forage was similar to that of corn grown on the two soils.
11. Chemical composition of oats showed little change due to lime and Zn treatment.

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