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Influence of liming on the yield and uptake of calcium, magnesium, potassium, and phosphorus by soybeans grown on two different soils

Mahadevappa Basappa Yeligar

To the Graduate Council:

I am submitting herewith a thesis written by Mahadevappa Basappa Yeligar entitled "Influence of liming on the yield and uptake of calcium, magnesium, potassium, and phosphorus by soybeans grown on two different soils." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in .

, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 10, 1961

To the Graduate Council:

I am submitting herewith a thesis written by Mahadevappa Basappa Yeligar entitled "Influence of Liming on the Yield and Uptake of Calcium, Magnesium, Potassium and Phosphorus by Soybeans Grown on Two Different Soils." 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.

Lloyd F. Seatz
Major Professor

We have read this thesis
and recommend its acceptance:

Horace C. Smith Jr.

H. R. DeSelm

Accepted for the Council:

W. E. Spivey
Dean of the Graduate School

INFLUENCE OF LIMING ON THE YIELD AND UPTAKE OF CALCIUM, MAGNESIUM, POTASSIUM, AND PHOSPHORUS BY SOYBEANS GROWN ON TWO DIFFERENT SOILS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements of the Degree

Master of Science

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by

Mahadevappa Basappa Yeligar

August 1961

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CHAPTER I

INTRODUCTION

Recent developments in the field of agricultural science, has helped in understanding many of the soil fertility problems. Soil fertility problems are not concerned with one or two interacting factors but concerned with many. The living plant is a complex system that responds continually to the environmental conditions. The soil in which the plant grows is a heterogenous medium and plants respond by effecting a sort of physiological integration of the various factors concerned with growth. The specific study on the nutritional requirement for a particular crop depends mainly on the species, to which the crop belongs and the nutritional status of the soil.

The soybean--a legume--has assumed great importance in recent years because of its varied usefulness and offers far reaching possibilities in the agriculture of the future. The problem of raising the soybean yields is not simple because it is a plant of great genetic and morphological diversity. It varies in height from less than a foot to more than six feet and in habit of growth from stiffly erect to prostrate. The seed varies greatly in size, shape, color and in its chemical composition. Because of its distinct and variable growth characteristics, research workers are heading towards solving some of the perplexing problems of soybean nutrition.

Because of the fact that the proper nutrition requirement for different crops varies with the fertility status of soil, a close study for a particular crop is required. In order to control the environmental factors, other than the one being studied, a controlled study is required. To accomplish this the present study was made under greenhouse conditions.

The present study was made in order to determine the effect of different rates of lime, phosphorus, potassium, and magnesium application on the soybean yield and nutrient uptake of calcium, phosphorus, potassium, and magnesium on two different soil types by soybeans. Two soils used for the study were Tunica clay loam and Loring silt loam. These soils occur in the areas where soybeans are grown in Tennessee.

CHAPTER II

REVIEW OF LITERATURE

Numerous studies under greenhouse, as well as under field conditions, have been and are being made in various parts of the world to investigate the effect of liming on the yield and uptake of major nutrients for different crops. In this review, only the pertinent literature concerned with the subject under study has been dealt with.

Albrecht (1) reported that the normal growth of soybeans is controlled by the quantity of available calcium and not by the hydrogen ion concentration. With low supplies of calcium per plant nodulation was not possible and with higher supplies both growth and nodulation resulted. Thus he emphasized the function of calcium as a nutrient in the growth of legumes as to its act of nutrient calcium which seems to be needed more than other elements for growth and normal development of legumes and not to change the soil reaction. Thus he elucidated the role of calcium in legumes. Horner (8) studied the relation of total calcium supply and of the degree of saturation of a colloidal clay by calcium to the growth, nodulation, nitrogen fixation, and calcium absorption were increased with higher calcium levels. The growth and nitrogen fixing activities of legumes are closely related to the calcium present in the plant. Moser (13) concluded that an increase in the calcium supply increases gradually the concentration of the element in soybeans reaching the maximum where ten milliequivalents per 100 g. of soil were supplied at pH 6.0-6.5. The magnesium content of the crops i.e. soybeans, lespedeza, and sorghum, increased proportionately to the calcium supplied in nutrient solution and appeared to be directly correlated with the calcium content of the crop. Further he reported that phosphorus concentration in plants gradually increased with calcium supply and maximum mobilization occurred at the more acid pH values. Soybeans, lespedeza, and sorghum gave the maximum concentration of potassium for the higher calcium increments supplied attaining the highest concentration for ten milliequivalents per 100 grams of soil, treatment at pH 6.0-6.5. Smith and Hester (21) reported that liming on acid Putnam silt loam which is low in calcium failed to increase the calcium content of soybeans but produced a significant increase in the nitrogen and phosphorus content. Hampton, et al. (7) emphasized the role of calcium and potassium in nitrogen fixation at high levels of potassium. He further reported that calcium additions increased magnesium uptake and further potassium additions decreased magnesium uptake. Ferguson and Albrecht (6) reported that the application of potassium to the clay colloids increased the nitrogen fixation, efficiency of phosphorus uptake, and decreased the absorption of magnesium in young soybean plants. Carolus (4) in his experiment on Norfolk sandy loam concluded that potassium uptake was decreased by liming, whereas an increased application of potassium increased the potassium uptake by soybeans. Hampton and Albrecht (7) reported that the concentration of potassium in plant material showed a direct relation to the amount of potassium supplied and the total quantity of potassium in the plant tissue was determined by the potassium supply in the soil and it was changed little by a high calcium level. Reed and York (18) have concluded that the potassium uptake by the soybean plant is the same from the unfertilized soil as from the fertilized soil and very little difference has been noticed in the absorption of potassium under high potassium levels where fertilizer has been applied. From these results it was also seen that the uptake of potassium from the soil sources decreased the amount of exchangeable potassium in the fertilized soil to an extent almost as great as the unfertilized soil.

MacIntire and Co-workers (11) have observed that liming an acid soil increased the uptake of potassium by plants which resulted indirectly by the suppressive effect on the leaching of potassium. Jenny and Ayres (9) have emphasized the potassium saturation of the soil and the complementary ions, as the two main factors that influence potassium uptake by plants.

Peech and Bradfield (16) conducted an experiment on the effect of calcium and magnesium on soil potassium and its uptake by plants. They reported that an increase in the degree of calcium saturation of clay favors the absorption of potassium from solution and its neutral salts. The influence of magnesium on the clay upon the absorption of potassium from potassium chloride is similar to that of calcium. Under conditions where addition of lime to an acid soil containing neutral salts appreciably increases the calcium concentration and decreases potassium concentration. The suppressive effects of lime is induced primarily by calcium-potassium interactions initiated in the soil.

They also state that moderate applications of lime to an acid soil in the absence of neutral salts should have comparatively little effect on the Ca/K ratios in the soil solution. In such a case, the absorption of potassium by the plants should remain unaffected or may be increased by the addition of lime.

Welch and Nelson (24) in an experiment on calcium and magnesium requirements of soybeans found that the calcitic lime increased the yields of soybeans. The first increment was generally sufficient. This resulted in calcium saturations of 19, 31, and 27 percent in Hyde, Craven, and Bladen soils series respectively. There was some indication, however, that a higher base saturation was required with dolomitic limestone and this was closely related to the calcium supply. Yield increases were obtained from magnesium sulfate in the treatment including the high rate of calcium. They concluded that the amount of calcium supplied is important and soybean yields are rather closely related to the degree of calcium saturation regardless of the source.

Webb, Ohlrogge and Barber (23) conducted an experiment to study the effect of magnesium upon the growth, phosphorus absorption and translocation, and cation content of soybean plants. Its absence during the earlier growth stages was more effective than in the late periods. The magnesium deficient plants were found to contain a higher percent of phosphorus in the vegetative organs and a lower percentage in the seeds than the normal plant. The omission of magnesium from the nutrient solution resulted in an increase in percent of phosphorus, potassium, and calcium in the mature soybean plants. They also found that a slightly larger accumulation of phosphorus, potassium, and calcium in general; and phosphorus and potassium in particular, were absorbed per unit of dry weight by the magnesium deficient plants than by the plants having received adequate quantities of magnesium.

Ohlrogge (14) in his review states that the high rate of phosphorus applications to soybeans under adequate calcium supply may result in locking up the added phosphorus resulting in a decrease in the grain yield. Lawton and Devis (10) studied the effects of liming two strongly acid Rifle peat soils on the growth and absorption of soil and fertilizer phosphorus by field beans. It was observed that the dry weight of field beans was markedly increased by lime applications up to 12 tons of calcium carbonate per acre. It was further noted that liming had a depressing effect on the phosphorus content of plants which was attributed to a decrease in the proportion of $H_2PO_4^-$ to $HPO_4^{=}$ ions in the soil solution.

Pearson (15) in his recent review states that liming acid soils had a beneficial effect on the utilization of phosphorus by plants both from fertilizer phosphorus as well as from the native soil supply.

CHAPTER III

MATERIAL AND METHODS

In this experiment, Tunica clay loam and Loring silt loam were the soils used. The chemical characteristics of these soils are given in Table 1. The liming material used was calcium hydroxide. Phosphorus, potassium, and magnesium were applied in the form of mono-calcium phosphate, potassium sulfate, and magnesium sulfate, respectively. The treated soils were placed in plastic lined No. 10 cans and soybeans were planted. Details of the procedure followed for the greenhouse experiment and for the laboratory studies are given below separately.

A. Greenhouse Experiment

Three rates of lime, and twelve combinations of phosphorus, potassium, and magnesium were used in this experiment in a factorial design with three replications on both the soils. Details about the treatments are given in Tables 2 through 9. The soil required for the three replicate cans and the fertilizer materials were mixed in a soil blender five minutes. Then this thoroughly mixed soil was divided equally among the three cans. Each can held 3.2 kg. of oven-dry soil.

About 8-10 soybean seeds were planted in each can on December 18, 1960. Two days prior to seeding one watering with demineralized water was added to all cans. On the day of seeding, and thereafter, demineralized water was added in order to maintain the moisture of the soil at approximately the field capacity. After a week, the stand was

Table 1.--Chemical characteristics of the soils.

Soil	C.E.C.	Milliequivalents of			Ca/K	Ca/Mg	pH	Average pH values after liming		
		K	Ca	Mg				2 tons	4 tons	6 tons
Tunica clay loam	31.90	0.86	14.71	2.35	171:1	6.25:1	5.2	5.9	6.4	6.8
Loring silt loam	7.68	0.54	4.90	1.64	9.1:1	3:1	5.6	6.1	6.9	7.2

thinned to 5-6 plants per can. Harvesting was done in the third week of February. Harvested materials were kept separately and were oven-dried at 70° C. for six days and weights were recorded. Statistical analysis was determined on each of the soils separately. Results are given in Tables 2 and 3.

B. Laboratory Studies

For analysis of the plant tissue for its calcium, magnesium, potassium, and phosphorus content, the plant material from each treatment was oven-dried and ground in a Wiley mill. All the plant tissue samples from different replications were kept separate. One gram of the ground plant material from these samples where the yield was more than one gram and the whole yield from those samples where the yield was less than one gram was taken for wet digestion. The method used for digestion and determining calcium, magnesium, and potassium with the Model DU Beckman flame spectrophotometer is described by Shaw (20). Phosphorus was determined on an aliquot of the same digestate by the Vanadomolybo diphosphoric acid method and the percent transmittance determined by AC Fisher Electrophotometer.

CHAPTER IV

RESULTS

A. Yield

The average yields of oven-dry soybeans per can for various lime, phosphorus, potassium and magnesium treatments of the two soils are presented in Tables 2 and 3. The original data were subjected to statistical analysis as outlined by Snedecor (22).

There is a marked difference in the yield between the two soils and in yield response to lime applications. The highest average yields of 9.10 grams per can and 6.44 grams per can were obtained at the four tons lime rate on Tunica clay loam and Loring silt loam, respectively. The lowest average yields of 8.26 grams per can and 5.48 grams per can were recorded on both the soils at the six ton lime rate.

Application of 60 pounds of P_2O_5 only on Tunica clay loam and Loring silt loam did not give significant differences in the yields over the unfertilized treatment. The yields for these two treatments were 8.65 and 8.60 grams per can on Tunica clay loam and 5.67 and 5.22 grams per can for Loring silt loam respectively. Application of 120 pounds of P_2O_5 gave a significant difference over the no fertilizer treatment only on Loring silt loam. The yield values were 6.13 and 5.22 respectively.

On both the soils significant yield differences were not obtained for the application of 60 pounds of K_2O alone over the no potassium treatment. The yields recorded for these two treatments

Table 2.--Average yield of oven-dry soybeans on Loring silt loam at different lime, phosphorus, potassium, and magnesium levels.

Sub treatments				Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				grams/can	grams/can	grams/can	
1	0	0	0	4.59	6.00	5.08	5.22
2	60	0	0	5.31	6.09	5.62	5.67
3	0	60	0	5.16	6.21	4.49	5.25
4	0	0	50	5.60	6.26	4.69	5.51
5	60	60	0	5.26	6.17	4.66	5.36
6	60	0	50	5.85	6.16	5.24	5.75
7	60	60	50	6.45	6.41	5.61	6.16
8	120	0	0	5.93	6.53	5.95	6.13
9	120	60	0	5.99	6.49	6.28	6.25
10	120	0	50	6.98	6.81	5.77	6.52
11	120	120	0	6.68	6.97	6.59	6.75
12	120	120	50	6.06	7.18	5.85	6.54
Mean				5.85	6.44	5.48	

L. S. D. for Lime:
95 percent level: 0.38
99 percent level: 0.50

Phosphorus, potassium and magnesium:
95 percent level: 0.76
99 percent level: 1.00

Lime x phosphorus, potassium, and magnesium:
95 percent level: 1.34
99 percent level: 1.77

Table 3.--Average yield of oven-dry soybeans on Tunica clay loam at different lime, phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				grams/can	grams/can	grams/can	
1	0	0	0	8.34	9.24	8.23	8.60
2	60	0	0	8.00	9.53	8.43	8.65
3	0	60	0	8.55	9.35	8.91	8.93
4	0	0	50	8.63	9.10	8.80	8.84
5	60	60	0	9.01	8.89	6.96	8.29
6	60	0	50	8.93	8.64	7.92	8.50
7	60	60	50	8.77	9.29	7.56	8.54
8	120	0	0	9.38	9.40	8.75	9.17
9	120	60	0	8.78	8.83	8.08	8.56
10	120	0	50	8.79	8.99	8.60	8.79
11	120	120	0	9.97	9.37	9.43	9.59
12	120	120	50	9.24	8.59	7.51	8.44
Mean				8.86	9.10	8.26	

L. S. D. for Lime:
95 percent level: 0.38
99 percent level: 0.50

Phosphorus, potassium and magnesium:
95 percent level: 0.76
99 percent level: 1.00

Lime x phosphorus, potassium, and magnesium:
95 percent level: 1.34
99 percent level: 1.77

were 8.93 and 8.60 grams per can for Tunica clay loam and 5.25 and 5.22 grams per can for Loring silt loam.

On Loring silt loam significant differences were found between the treatments. The treatment 120 pounds of P_2O_5 plus 60 pounds of K_2O and 60 pounds of each P_2O_5 and K_2O, and yields recorded were 6.25 and 5.36 grams per can respectively. On Tunica clay loam for the same treatments difference was nonsignificant.

Application of 120 pounds each of P_2O_5 and K_2O gave highly significant increases in the yields on Tunica clay loam over the treatment 120 pounds of P_2O_5 along with 60 pounds of K_2O. The yields recorded for the treatments mentioned were 9.59 and 8.56 grams per can respectively. But on Loring silt loam for the same treatments differences were nonsignificant. The yields for the treatments were 6.75 and 6.25 grams per can respectively. Highly significant differences in yields were obtained for 120 pounds each of P_2O_5 and K_2O over the treatment 60 pounds of each P_2O_5 and K_2O on both the soils. The yields for the treatments mentioned were 9.59 and 8.29 grams per can for Tunica clay loam and 6.75 and 5.36 grams per can for Loring silt loam.

On Tunica clay loam no significant yield responses were obtained for the application of 120 pounds of P_2O_5 plus 50 pounds of Mg over 60 pounds of P_2O_5 plus 50 pounds of Mg. The values were 8.79 and 8.50. On Loring silt loam the difference in the yields for the same treatments were statistically significant. The values were 6.52 and 5.75 respectively.

On Loring silt loam, significant increase in the yield was observed due to the application of 120 pounds each of P_2O_5 and K_2O plus 50 pounds of Mg over the treatment 60 pounds each of P_2O_5 and K_2O plus 50 pounds of Mg. The yields recorded were 6.54 and 6.16 grams per can respectively. But the differences found were statistically nonsignificant. The results obtained were 8.54 grams per can with 50 pounds of Mg and 8.29 grams per can without 50 pounds of Mg with the highest rates of P_2O_5 and K_2O for Tunica clay loam and 6.16 and 5.36 for Loring silt loam respectively. On Tunica clay loam differences were nonsignificant whereas on Loring silt loam differences were significant.

Application of 50 pounds of Mg at the higher rate of P_2O_5 and K_2O had a depressing effect on yield. The yields were 6.75 without Mg on Loring silt loam and 6.54 with Mg and 9.59 and 8.44 for the same treatment on Tunica clay loam. These differences were significant on Tunica clay loam but were nonsignificant on Loring silt loam.

B. Mineral Compositions

Calcium

The summary of calcium content (expressed in percentage) of the soybean plants for different treatments of lime, phosphorus, potassium, and magnesium is given in Tables 4 and 5.

There was a significant increase in percent calcium content of soybeans for an increase in lime rates for 2, 4, and 6 tons per acre on both the soils. The values were 2.03, 2.10, and 2.28 percent for Tunica clay loam and 1.97, 2.09, and 2.26 percent for Loring silt loam.

Table 4.--Percentage of calcium in soybeans on Loring silt loam at different lime, phosphorus, potassium, and magnesium levels.

Sub treatments				Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	1.89	1.96	2.21	2.02
2	60	0	0	2.02	1.98	2.31	2.10
3	0	60	0	2.14	1.96	2.24	2.11
4	0	0	50	2.04	2.04	2.22	2.10
5	60	60	0	1.97	2.10	2.22	2.10
6	60	0	50	1.94	2.21	2.24	2.13
7	60	60	50	1.91	2.23	2.30	2.15
8	120	0	0	2.05	2.14	2.35	2.18
9	120	60	0	1.85	2.13	2.31	2.10
10	120	0	50	1.83	2.08	2.23	2.04
11	120	120	0	2.07	2.14	2.26	2.15
12	120	120	50	1.97	2.11	2.25	2.11
Mean				1.97	2.09	2.26	

L. S. D. for lime:
95 percent level: 0.018
99 percent level: 0.023

Phosphorus, potassium and magnesium:
95 percent level: 0.040
99 percent level: 0.053

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.070
99 percent level: 0.092

Table 5.--Percentage of calcium in soybeans on Tunica clay loam at different lime, phosphorus, potassium, and magnesium levels.

Sub treatments				Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	1.88	2.21	2.40	2.16
2	60	0	0	2.01	2.23	2.36	2.20
3	0	60	0	1.99	2.14	2.28	2.14
4	0	0	50	1.98	2.22	2.31	2.17
5	60	60	0	1.97	2.17	2.18	2.10
6	60	0	50	1.83	2.12	2.25	2.07
7	60	60	50	1.87	1.11	2.37	2.12
8	120	0	0	1.84	1.97	2.31	2.04
9	120	60	0	2.21	1.91	2.36	2.16
10	120	0	50	2.27	2.01	2.24	2.18
11	120	120	0	2.23	2.06	2.20	2.16
12	120	120	50	2.24	2.07	2.21	2.17
Mean				2.03	2.10	2.28	

L. S. D. for Lime:
95 percent level: 0.026
99 percent level: 0.034

Phosphorus, potassium and magnesium:
95 percent level: 0.050
99 percent level: 0.066

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.088
99 percent level: 0.116

Application of 120 pounds of P_2O_5 increased significantly the percent calcium content over the application of 60 pounds of P_2O_5 and no fertilizer treatment on Loring silt loam. The values were 2.18, 2.10, and 2.02 respectively. On the other hand on Tunica clay loam there was a significant decrease in percent calcium content from 2.20 to 2.04, for 120 pounds and 60 pounds P_2O_5 applications, though there was a significant increase in percent calcium content from 2.16 to 2.20 for the application of 60 pounds of P_2O_5 over no fertilizer treatment.

Application of 50 pounds of Mg. did not affect significantly the calcium content of soybeans on Tunica clay loam. On Loring silt loam a significant difference was found between the 50 pound Mg. and the unfertilized treatments. The values for percent calcium content were 2.10 and 2.02 respectively.

On Tunica clay loam significant differences in calcium content were observed between the treatments 120 pounds of P_2O_5 plus 60 pounds K_2O and 60 pounds P_2O_5 plus 60 pounds K_2O. The values recorded were 2.16 and 2.10 respectively. On the other hand no difference was found for the same treatments on Loring silt loam.

Highly significant differences were obtained between the treatments 120 pounds of P_2O_5 plus 50 pounds of Mg. and 60 pounds of P_2O_5 plus 50 pounds of Mg. on both the soils. The values for the treatments mentioned were 2.18 and 2.07 for Tunica clay loam and 2.04 and 2.13 for Loring silt loam respectively.

On Tunica clay loam there is a significant increase in percent calcium content when magnesium was applied at the high P_2O_5 and K_2O rates over the values when Mg. was applied at the low rates. The values were 2.17 and 2.12. On Loring silt loam for the same treatments, a significant decrease in percent calcium content was observed. The values were 2.11 and 2.15 respectively.

Magnesium

The summary of percent magnesium in soybean plants for different treatments of lime, phosphorus, potassium, and magnesium is given in Tables 6 and 7. Considerable difference in the percent magnesium of soybeans grown on the two soils was found. The average percent magnesium was 0.46 for Tunica clay loam and 0.52 for Loring silt loam.

The magnesium content increased significantly from 0.51 to 0.53 and 0.43 to 0.47 due to the increase in lime rates from 2 to 4 tons on Tunica clay loam and Loring silt loam respectively. On Loring silt loam a significant increase was observed with the application of 6 ton over 4 tons of lime. The values were 0.50 and 0.47. On Tunica clay loam the differences due to lime rate were not significant.

Addition of 60 pounds of P_2O_5 to both the soils decreased percent magnesium of soybeans. The values were 0.46 for the unfertilized treatment and 0.42 for the 60 pounds of P_2O_5 treatment. Differences obtained on Tunica clay loam for the same treatments were nonsignificant. There is a significant increase in the percent magnesium due to the applications of 120 pounds of P_2O_5 alone over the 60 pounds P_2O_5 and unfertilized treatments on Tunica clay loam. The values obtained were 0.53, 0.49, and 0.50 on Tunica clay loam and

Table 6.--Percentage of magnesium in soybeans on Loring silt loam at different lime, phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime Treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	0.52	0.39	0.46	0.46
2	60	0	0	0.40	0.38	0.47	0.42
3	0	60	0	0.34	0.39	0.47	0.40
4	0	0	50	0.32	0.44	0.51	0.42
5	60	60	0	0.29	0.49	0.47	0.41
6	60	0	50	0.39	0.54	0.52	0.48
7	60	60	50	0.41	0.58	0.53	0.51
8	120	0	0	0.46	0.49	0.50	0.48
9	120	60	0	0.51	0.46	0.55	0.51
10	120	0	50	0.55	0.48	0.59	0.54
11	120	120	0	0.54	0.45	0.49	0.48
12	120	120	50	0.46	0.57	0.48	0.50
Mean				0.43	0.47	0.50	0.46

L. S. D. for Lime:
95 percent level: 0.018
99 percent level: 0.023

Phosphorus, potassium and magnesium:
95 percent level: 0.036
99 percent level: 0.047

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.064
99 percent level: 0.084

Table 7.--Percentage of magnesium in soybeans on Tunica clay loam at different lime, phosphorus, potassium, and magnesium levels.

Sub treatments	P	K	Mg	Lime treatments 2 tons/acre	4 tons/acre	6 tons/acre	Means Average
				%	%	%	%
1	0	0	0	0.49	0.49	0.53	0.50
2	60	0	0	0.46	0.52	0.50	0.49
3	0	60	0	0.51	0.51	0.52	0.51
4	0	0	50	0.53	0.52	0.59	0.54
5	60	60	0	0.53	0.49	0.52	0.51
6	60	0	50	0.57	0.53	0.55	0.55
7	60	60	50	0.58	0.52	0.56	0.55
8	120	0	0	0.52	0.53	0.54	0.53
9	120	60	0	0.49	0.53	0.51	0.51
10	120	0	50	0.52	0.55	0.56	0.54
11	120	120	0	0.45	0.52	0.51	0.49
12	120	120	50	0.52	0.60	0.57	0.56
Mean				0.51	0.53	0.54	0.52

L. S.D. for Lime:
95 percent level: 0.015
99 percent level: 0.020

Phosphorus, potassium and magnesium:
95 percent level: 0.028
99 percent level: 0.037

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.054
99 percent level: 0.071

0.48, 0.42, and 0.46 percent magnesium on Loring silt loam for the same treatments, but the differences between the values 0.48 and 0.46 was not statistically significant.

On Tunica clay loam addition of 60 pounds of K_2O did not increase the percent magnesium over the unfertilized treatment. On Loring silt loam there was a significant decrease in the percent magnesium for the same treatments. The values were 0.46 and 0.40 percent magnesium.

Addition of 50 pounds of Mg. alone increased the percent magnesium over the unfertilized treatment. Values were 0.50 and 0.54 on Tunica clay loam. But on Loring silt loam there was a significant decrease for the same treatments, from 0.46 for the unfertilized treatment to 0.42 for 50 pounds of Mg. applications.

On Loring silt loam highly significant differences were obtained from the application of 120 pounds of P_2O_5 plus 60 pounds of K_2O which increased the percent magnesium significantly over 60 pounds each of P_2O_5 and K_2O from 0.41 to 0.51. Application of 120 pounds each of P_2O_5 and K_2O decreased significantly the percent magnesium from 0.51 to 0.48.

On Tunica clay loam no significant difference was observed between the treatment with 60 pounds of P_2O_5 plus 50 pounds of Mg. and 120 pounds of P_2O_5 plus 50 pounds of Mg. The values obtained were 0.55 and 0.54. On the other hand there was a significant increase in the percent magnesium content for the same treatments on Loring silt loam with values of 0.48 and 0.54.

No significant differences in percent magnesium were found between the high and low phosphorus and potassium treatments when magnesium was added to both soils.

On Tunica clay loam addition of 50 pounds of Mg to 60 pounds each of P_2O_5 and K_2O increased significantly the percent magnesium content from 0.51 to 0.55 over the similar treatment without magnesium. The same trends were found when 50 pounds of magnesium was added to 120 pounds each of P_2O_5 and K_2O. The values recorded for these treatments were 0.49 and 0.56 percent magnesium. This increase was also significant.

On Loring silt loam the addition of 50 pounds of Mg along with 60 pounds each of P_2O_5 and K_2O increased significantly the percent magnesium from 0.41 to 0.51. The addition of 50 pounds of Mg to 120 pounds each of P_2O_5 and K_2O increased the percent magnesium only slightly.

Potassium

The summary of the percent potassium of soybean plants for different treatments of lime, phosphorus, potassium, and magnesium is given in Tables 8 and 9.

No marked difference was observed in the two different soils for the effects of lime applications on the percent potassium. The average percent potassium was 1.11 for Tunica clay loam and 1.04 for Loring silt loam. There was a significant decrease in the potassium content of soybeans for an increase in the lime rates for 2, 4, and 6 tons on Loring silt loam only with values of 1.08, 1.04, and 0.99 percent potassium respectively. The average potassium content on

Table 8.--Percentage of potassium in soybeans on Loring silt loam at different lime, phosphorus, potassium, and magnesium levels.

Sub treatments				Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	1.15	0.98	0.91	1.05
2	60	0	0	0.93	1.00	1.05	0.99
3	0	60	0	1.15	1.07	1.06	1.09
4	0	0	50	1.02	0.99	0.99	1.03
5	60	60	0	1.10	1.04	0.95	1.03
6	60	0	50	1.07	1.04	1.04	1.05
7	60	60	50	1.10	1.01	1.06	1.06
8	120	0	0	1.02	1.04	0.91	0.99
9	120	60	0	1.03	1.04	0.99	1.02
10	120	0	50	1.05	0.96	0.96	0.99
11	120	120	0	1.22	1.18	1.04	1.15
12	120	120	50	1.12	1.12	0.98	1.07
Mean				1.08	1.04	0.99	

L. S. D. for Lime:
95 percent level: 0.017
99 percent level: 0.023

Phosphorus, potassium and magnesium:
95 percent level: 0.038
99 percent level: 0.050

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.080
99 percent level: 0.100

Table 9.--Percentage of potassium in soybeans on Tunica clay loam at different lime, phosphorus, potassium and magnesium levels.

	Sub treatments			Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	1.01	1.07	1.02	1.03
2	60	0	0	1.10	1.11	1.07	1.09
3	0	60	0	1.12	1.19	1.19	1.16
4	0	0	50	1.13	1.12	1.11	1.12
5	60	60	0	1.05	1.17	1.13	1.12
6	60	0	50	1.08	1.14	1.08	1.10
7	60	60	50	1.03	1.09	1.12	1.08
8	120	0	0	1.14	1.04	1.07	1.08
9	120	60	0	1.13	1.08	1.08	1.10
10	120	0	50	1.12	1.09	1.15	1.12
11	120	120	0	1.22	1.09	1.14	1.15
12	120	120	50	1.20	1.10	1.18	1.15
Mean				1.11	1.11	1.11	

L. S. D. for Lime:
95 percent level: 0.014
99 percent level: 0.018

Phosphorus, potassium and magnesium:
95 percent level: 0.032
99 percent level: 0.042

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.056
99 percent level: 0.074

Tunica clay loam was 1.11 percent for all three rates of lime.

On Loring silt loam a significant decrease in percent potassium was found for the application of 60 pounds of P_2O_5 over the unfertilized treatment. The values were 0.99 and 1.05 respectively. On Tunica clay loam there is a highly significant increase in the percent potassium content when the same treatments are compared. The values were 1.03 and 1.09 percent potassium. On Loring silt loam the potassium content was the same for the 120 and 60 pounds of P_2O_5 treatments. But on Tunica clay loam the difference was not statistically significant. The values were 1.08 and 1.09 respectively.

Application of 60 pounds of K_2O increased significantly the percent potassium of soybeans on both soils. Values were 1.05 for unfertilized treatment and 1.09 for 60 pounds of K_2O on Loring silt loam and on Tunica clay loam 1.03 and 1.12 for the same treatments.

There was a decreasing effect from the application of 50 pounds of Mg over the unfertilized treatment in percent potassium in soybeans grown on Loring silt loam, but the difference was not statistically significant. On Tunica clay loam a highly significant increase from 1.03 to 1.12 percent potassium was obtained from the 50 pounds Mg application when compared with the unfertilized treatment.

Application of 60 pounds of K_2O in combination with either 60 pounds of P_2O_5 or 120 pounds of P_2O_5 did not decrease the potassium content significantly on either soil.

On the other hand, on both soils a significant increase in the percent potassium was found with the application of 120 pounds of K_2O

over 60 pounds of K_2O at the high phosphorus level. The values for the treatments mentioned were 1.15 and 1.02 on Loring silt loam and 1.15 and 1.10 on Tunica clay loam. On Tunica clay loam, however, magnesium application had no effect on the potassium content at either phosphorus or potassium level. On Loring silt loam the percent potassium did increase from 1.08 to 1.12 for the application of 50 pounds of Mg along with 120 pounds each of P_2O_5 and K_2O over the treatment 50 pounds of Mg in combination with 60 pounds each of P_2O_5 and K_2O.

Addition of 50 pounds of Mg with 60 pounds each of P_2O_5 and K_2O increased the percent potassium over 60 pounds of P_2O_5 and 60 pounds of K_2O from 1.03 to 1.06 on Loring silt loam. But on Tunica clay loam for the same treatments there was a significant decrease in the percent potassium content from 1.12 to 1.08. On the other hand on Loring silt loam addition of 50 pounds of Mg along with 120 pounds of each P_2O_5 and K_2O decreased significantly the percent potassium over 120 pounds each of P_2O_5 and K_2O from 1.15 to 1.07. For the same treatments on Tunica clay loam no difference in potassium content was found.

Phosphorus

The summary of phosphorus content of the soybean plants for different treatments of lime, phosphorus, potassium, and magnesium is given in Tables 10 and 11.

A striking difference was observed for the two different soils in their responses to lime applications in the uptake of phosphorus by soybeans. The average percent phosphorus was 0.25 and 0.15 for Tunica clay loam and Loring silt loam respectively.

Table 10.--Percentage of phosphorus in soybeans on Loring silt loam at different lime, phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	0.13	0.13	0.12	0.13
2	60	0	0	0.15	0.16	0.14	0.15
3	0	60	0	0.15	0.16	0.14	0.15
4	0	0	50	0.11	0.14	0.13	0.13
5	60	60	0	0.15	0.14	0.12	0.14
6	60	0	50	0.17	0.15	0.15	0.16
7	60	60	50	0.16	0.17	0.14	0.15
8	120	0	0	0.16	0.18	0.13	0.16
9	120	60	0	0.18	0.17	0.15	0.16
10	120	0	50	0.16	0.19	0.14	0.16
11	120	120	0	0.18	0.19	0.15	0.17
12	120	120	50	0.17	0.18	0.16	0.17
Mean				0.15	0.16	0.14	

L. S. D. for Lime:
95 percent level: 0.002
99 percent level: 0.003

Phosphorus, potassium and magnesium:
95 percent level: 0.0062
99 percent level: 0.0082

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.0102
99 percent level: 0.0130

Table 11.--Percentage of phosphorus in soybeans on Tunica clay loam at different lime, phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			Means
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Average
				%	%	%	%
1	0	0	0	0.20	0.25	0.27	0.24
2	60	0	0	0.22	0.26	0.27	0.25
3	0	60	0	0.20	0.24	0.27	0.24
4	0	0	50	0.22	0.22	0.27	0.24
5	60	60	0	0.22	0.26	0.26	0.25
6	60	0	50	0.22	0.27	0.26	0.25
7	60	60	50	0.24	0.27	0.26	0.26
8	120	0	0	0.22	0.24	0.25	0.24
9	120	60	0	0.24	0.25	0.24	0.24
10	120	0	50	0.23	0.27	0.23	0.24
11	120	120	0	0.26	0.27	0.24	0.26
12	120	120	50	0.24	0.29	0.25	0.26
Mean				0.23	0.26	0.25	

L. S. D. for Lime:
95 percent level: 0.008
99 percent level: 0.010

Phosphorus, potassium and magnesium:
95 percent level: 0.015
99 percent level: 0.020

Lime x phosphorus, potassium, and magnesium:
95 percent level: 0.028
99 percent level: 0.037

A significant increase in the percent phosphorus in soybeans for an increase in the lime rate from 2 tons to 4 tons of 0.23 to 0.26 on Tunica clay loam and 0.15 to 0.16 on Loring silt loam was found. On the other hand, there was a decrease in the phosphorus content of the soybeans from the 4 to 6 tons lime rate on both the soils. The results were 0.25 and 0.14 for Tunica clay loam and Loring silt loam respectively.

From the Tables 10 and 11 it can be seen that the phosphorus content of soybeans was least affected by the different treatments of phosphorus, potassium, and magnesium on Tunica clay loam with values ranging from 0.24 and 0.26. On Loring silt loam the values range from 0.13 to 0.17. It could be further noticed that the phosphorus content of treatments grown on Tunica clay loam is as much as twice that of similar treatments grown on Loring silt loam.

On Tunica clay loam application of 60 pounds of K_2O along with the high rates of phosphorus has a decreasing effect on the percent phosphorus content over the application of 60 pounds each of P_2O_5 and K_2O. The results obtained for the treatments were 0.25 and 0.24, and the difference was also found statistically significant. But for the same treatments on Loring silt loam there was a significant increase in the percent phosphorus content from 0.14 to 0.16 respectively.

Significant increases in the phosphorus content of soybeans were obtained on both the soils for the application of the high rate of phosphorus and potassium over the higher rate of phosphorus and the lower rate of potassium. The percent values obtained were 0.26, 0.24 on Tunica clay loam and 0.17 and 0.16 on Loring silt loam respectively.

There is a significant increase in the percent phosphorus content for the application of 60 pounds of K_2O alone (0.15) over the control (0.13) on Loring silt loam. But on Tunica clay loam there was no difference.

On Tunica clay loam only a very slight increase in phosphorus content of soybeans was obtained from either the application of 60 or 120 pounds of P_2O_5.

Application of 120 pounds of K_2O along with 120 pounds of P_2O_5 and 50 pounds of Mg has increased significantly the percent phosphorus content from 0.24 to 0.26 on Tunica clay loam and 0.16 to 0.17 on Loring silt loam over the treatment without potassium with the same levels of phosphorus and magnesium.

C. Cation Equivalence in Soybeans

The cation content of the plants expressed as milliequivalents per 100 grams of the plant material is presented in Tables 12 and 19. The total number of milliequivalents of cations per 100 gram of plant material has increase in all the three rates of liming on Loring silt loam only. The total cation concentration was greater on Tunica clay loam than in Loring silt loam. The relative change in cation equivalence was not consistent for the three rates of liming.

The average values of cation equivalence for the various treatments were 171.0 for Loring silt loam with a range from 163.5 to 177.1 milliequivalents per 100 grams of soil and with 9 of 12 values lying between 165 and 175. For Tunica clay loam 178.8 milliequivalents per 100 grams was the average value with values ranging from 173.7 to 184.5

Table 12.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Loring silt loam at different phosphorus, potassium, and magnesium levels (irrespective of lime treatments).

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	101.0	38.4	26.9	166.3
2	60	0	0	105.0	35.0	25.3	163.5
3	0	60	0	105.5	33.5	27.9	166.9
4	0	0	50	105.0	35.0	26.4	166.4
5	60	60	0	105.0	34.1	26.4	165.4
6	60	0	50	106.5	40.0	26.9	173.4
7	60	60	50	107.5	42.5	27.1	177.1
8	120	0	0	109.4	40.0	25.3	174.3
9	120	60	0	105.0	42.5	26.1	173.6
10	120	0	50	102.0	45.0	25.3	172.3
11	120	120	0	107.5	40.0	29.4	176.9
12	120	120	50	105.5	41.6	29.4	174.5
Mean				105.3	38.9	26.8	171.0

Table 13.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Loring silt loam at the 2 ton lime level and different phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	94.5	43.3	29.4	167.2
2	60	0	0	101.0	33.3	23.8	158.1
3	0	60	0	107.0	28.3	29.4	164.7
4	0	0	50	102.0	26.5	26.1	154.6
5	60	60	0	98.5	24.0	28.2	150.7
6	60	0	50	97.0	32.5	27.4	156.9
7	60	60	50	95.5	34.5	28.2	158.2
8	120	0	0	102.5	38.3	26.1	166.9
9	120	60	0	92.5	42.5	26.4	161.4
10	120	0	50	91.5	45.8	26.9	168.2
11	120	120	0	103.5	45.0	31.2	179.7
12	120	120	50	98.5	38.3	28.7	165.5
Mean				98.6	36.3	27.6	162.5

Table 14.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Loring silt loam at the 4 ton lime level and different phosphorus, potassium, and magnesium levels.

Sub treatments				Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	98.0	32.5	25.1	155.6
2	60	0	0	99.0	31.6	25.6	156.2
3	0	60	0	98.0	32.5	27.4	157.9
4	0	0	50	102.0	36.6	25.3	163.9
5	60	60	0	105.0	40.8	26.6	172.9
6	60	0	50	110.5	45.0	26.6	182.1
7	60	60	50	111.5	48.3	25.8	185.6
8	120	0	0	107.0	40.8	26.6	174.4
9	120	60	0	106.5	38.3	26.6	171.4
10	120	0	50	104.0	40.0	24.6	168.6
11	120	120	0	107.0	37.5	30.2	174.7
12	120	120	50	105.5	47.5	28.7	181.7
Mean				104.5	39.2	26.6	170.4

Table 15.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Loring silt loam at the 6 ton lime level and different phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	110.5	38.3	23.3	172.1
2	60	0	0	115.5	39.1	26.9	181.5
3	0	60	0	112.0	39.1	27.1	178.2
4	0	0	50	111.0	42.5	25.3	178.8
5	60	60	0	111.0	39.1	24.3	174.4
6	60	0	50	112.0	43.3	26.6	181.9
7	60	60	50	115.0	44.1	27.1	186.2
8	120	0	0	117.5	41.6	23.3	182.4
9	120	60	0	115.5	45.8	25.3	186.6
10	120	0	50	111.5	49.1	24.6	185.2
11	120	120	0	113.0	40.8	26.6	180.4
12	120	120	50	112.5	40.0	25.1	180.6
Mean				113.0	42.7	25.4	180.6

Table 16.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Tunica clay loam at different phosphorus, potassium, and magnesium levels (irrespective of lime treatments)

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	108.0	41.6	26.4	176.0
2	60	0	0	110.0	40.8	27.9	178.7
3	0	60	0	107.0	42.5	29.7	179.2
4	0	0	50	108.5	45.0	28.7	182.2
5	60	60	0	105.0	42.5	28.7	176.2
6	60	0	50	103.5	45.8	28.2	177.5
7	60	60	50	106.0	45.8	27.6	179.4
8	120	0	0	102.0	44.1	27.6	173.7
9	120	60	0	108.0	42.5	28.2	178.7
10	120	0	50	109.0	45.0	28.7	182.7
11	120	120	0	108.0	40.0	29.4	177.4
12	120	120	50	108.5	46.6	29.4	184.5
Mean				107.0	43.5	28.3	178.8

Table 17.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Tunica clay loam at the 2 ton lime level and different phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	94.0	40.8	25.8	160.6
2	60	0	0	105.0	38.3	27.4	170.7
3	0	60	0	99.5	42.5	28.7	170.2
4	0	0	50	99.0	44.1	28.9	172.0
5	60	60	0	98.5	34.1	26.9	172.5
6	60	0	50	91.5	47.5	27.6	166.6
7	60	60	50	93.5	48.3	26.4	167.7
8	120	0	0	92.0	43.3	29.2	164.5
9	120	60	0	110.0	40.8	28.9	179.7
10	120	0	50	113.5	43.3	28.7	185.5
11	120	120	0	115.0	37.5	31.2	183.7
12	120	120	50	112.0	43.3	30.7	186.0
Mean				101.9	42.8	28.3	173.8

Table 18.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Tunica clay loam at the 4 ton lime level and different phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	110.0	40.8	27.4	178.2
2	60	0	0	111.5	43.3	28.4	183.2
3	0	60	0	107.0	42.5	30.5	180.0
4	0	0	50	111.0	43.3	28.7	183.0
5	60	60	0	108.5	40.8	30.4	179.3
6	60	0	50	106.0	44.1	39.2	179.3
7	60	60	50	55.5	43.3	27.9	126.7
8	120	0	0	98.5	44.1	26.6	169.2
9	120	60	0	95.5	44.1	27.6	167.2
10	120	0	50	100.5	45.8	27.9	174.2
11	120	120	0	103.0	43.3	27.9	174.2
12	120	120	50	103.5	50.0	28.2	181.7
Mean				100.8	43.7	28.3	173.0

Table 19.--Cation contents of soybeans expressed in milliequivalents per 100 grams of plant material on Tunica clay loam at the 6 ton lime level and different phosphorus, potassium, and magnesium levels.

	Sub treatments			Lime treatments			
	P	K	Mg	2 tons/acre	4 tons/acre	6 tons/acre	Total
				Ca	Mg	K	
1	0	0	0	120.0	44.1	26.1	190.2
2	60	0	0	118.0	41.6	27.4	187.0
3	0	60	0	114.0	43.3	30.5	187.2
4	0	0	50	115.5	49.1	28.5	193.1
5	60	60	0	109.0	43.3	28.9	171.2
6	60	0	50	112.5	45.8	27.6	185.9
7	60	60	50	118.5	46.6	28.7	193.8
8	120	0	0	115.5	45.0	27.4	187.9
9	120	60	0	118.0	42.5	27.6	188.1
10	120	0	50	112.0	46.6	29.4	188.0
11	120	120	0	110.0	42.5	29.2	181.7
12	120	120	50	110.5	47.5	30.2	188.2
Mean				114.4	44.8	28.4	186.8

and with 9 of the 12 values lying between 172 and 180.

On Loring silt loam the application of 2, 4, and 6 tons of lime consistently changed the cation equivalence value. These were 162.5, 170.4, and 180.6 for the 2, 4, and 6 tons of lime rates.

On Tunica clay loam the cation equivalence values were not changed by application of 2 or 4 tons of lime. A sudden increase in the cation equivalence values at the 6 tons lime rate was observed. The values recorded were 173.8, 173.0 for the 2 and 4 tons lime rate and 186.8 for the 6 tons lime rate.

CHAPTER V

DISCUSSION

Yield

Results of this investigation show that the highest total yields of 9.10 and 6.44:8.86 and 5.85; 8.26 and 5.48 grams per can were obtained at the 4, 2, and 6 tons per acre lime rate on Tunica clay loam and Loring silt loam respectively. The differences in the yields may be attributed to the difference in the chemical properties of the two soils. The total cation exchange capacity and exchangeable calcium, magnesium and potassium contents on Tunica clay loam are 3, 2.5, 3 and 2.5 times greater than the corresponding values of Loring silt loam. The lowest average yields of 8.26 grams per can and 5.48 grams per can were obtained on both the soils at 6 ton lime rate. The difference may be due to the favorable conditions rendered by the 4 tons lime applications in changing the soil reaction from 5.2 to 6.4 on Tunica clay loam and 5.6 to 6.9 on Loring silt loam respectively.

Results for all the three rates of lime showed that 50 pounds of Mg in combination with highest rates of phosphorus and potassium decreased the yields whereas applications of highest rates of P_2O_5 and K_2O only gave the comparable highest yields, except for the 4 ton lime rate on Loring silt loam. The reduction in the yields on Loring silt loam for the application of 50 pounds of Mg along with high rates of P_2O_5 and K_2O may be due to its depressive effect on the potassium uptake by the soybean plants, Table , which might have indirectly affected the carbohydrate and nitrogen metabolisms in the plant resulting in the reduction of dry matter production as suggested by Black (3).

On Tunica clay loam though the application of Mg did not affect the potassium uptake by soybeans, the reduction in the yields may be due to its increased uptake of magnesium, Table 7, which might have indirectly affected the physiological processes in the plants and thus resulted in the consequential reduction in the dry matter production of soybeans.

The difference in the yields on Tunica clay loam for the application of 60 pounds of P_2O_5, 60 pounds of K_2O and 50 pounds of Mg, and 120 pounds of P_2O_5 alone may be due to the decreased uptake of calcium, magnesium, potassium and phosphorus, by soybeans Tables 5, 7, 9, and 11. This may be due to high exchangeable calcium, magnesium, potassium contents of Tunica clay loam. But on Loring silt loam which is poorer in nutrient contents, results indicate that high rates of phosphorus applications decreased the yields to a very small content.

Mineral Composition

Results of the present investigation provide useful information regarding fertilizer practices on two acid soils of Tennessee where soybeans are grown, and give some significant indications about the nature of certain fundamental soil-plant relationships.

The major effects of liming on nutrient uptake by soybeans are brought out clearly on both the soils. The lime requirement of soils vary depending on several interacting factors such as texture and nature of the soil colloidal complex. Tunica clay loam has a higher cation exchange capacity and calcium, magnesium, and potassium contents than Loring silt loam. Lime requirement of Tunica clay loam was more than that of Loring silt loam because of its high cation exchange capacity, which is almost three times that of Loring silt loam. The proper rate of lime application is a major factor in enhancing the uptake of other nutrients, which also depends on the other properties of the soils.

The depressing effect of lime on the absorption of added phosphorus by plants is generally attributed to the reversion of readily soluble phosphates to less soluble phosphates in the presence of excess calcium. This may be due to the fact that under excess lime conditions the phosphorus is precipitated as insoluble calcium and compounds which are not readily available for plant consumption.

In the present study results indicate that increased application of lime increased significantly the magnesium uptake by the plants on both the soils. Decrease in the magnesium uptake by the application of 60 and 120 pounds of potassium may be explained as due to the complementary ion effect. Mehlich and Coleman (12) state that increasing the potassium saturation of soil or other ion exchange substrate lowers the calcium and magnesium contents of plants. The effect of large potassium saturations in inhibiting the uptake of calcium and magnesium by plants is a reflection of exchange equilibrium involved. Similar results were obtained on both the soils.

On Tunica clay loam three different rates of liming did not affect the potassium content of soybeans. Potassium may be absorbed on the colloid with so much less force than some other nutrients that the presence or the absence of hydrogen does not significantly alter its relative place in the hyotropic series. This would leave the potassium undisturbed by the degree of soil acidity.

Increased applications of potassium have increased the percent potassium content irrespective of different rates of liming on Tunica clay loam. Application of 4 and 6 tons of lime with 60 pounds of K_2O alone increased the potassium uptake significantly. These two observations may be explained as due to the increase in the degree of calcium saturation which might have favored the absorption of potassium from solution. Peech and Bradfield (16) state that moderate applications of lime to an acid soil in the absence of neutral salts should have comparatively little effect on the Ca:K ratio in the soil solution. In such a case the absorption of potassium by the plants should remain uneffected or may be increased by the addition of lime.

On Loring silt loam results have shown that increase in the lime rates have a depressive effect on the percent potassium content. This is due to calcium and potassium interactions, i.e. the antagonistic effect of calcium upon potassium. On both the soils results have shown that application of potassium favored the percent phosphorus content of soybeans.

A striking cation equivalence of about 171.0 and 178.0 were found for Loring silt loam and Tunica clay loam respectively. This difference in the cation equivalence may be attributed to the chemical characteristics of the soil which indicate that the total cation exchange capacity is three times higher for Tunica clay loam than for Loring silt loam.

Additions of cations to the soil cause considerable variation in calcium, potassium, and magnesium contents. Though there is a considerable variation in the individual ions, the sum of the three cations remain approximately constant. In the present study an increased calcium content occurred in the treatments where the magnesium had been included and decreased absorption of potassium in the presence of higher levels of calcium and magnesium. It is also seen that for each lime treatment the maintenance of the reciprocal relationship between calcium and magnesium on one side and calcium and potassium on the other. These values run almost parallel for different rates of liming. These results support with the view expressed by Bear and Prince (2) that every element will have two or more functions in the plant, one of which is specific for that element and the other or others capable of being performed interchangeably by all elements. Once a minimum available amount of each of these elements is assured to meet the specific needs, there can be a wide range over which the relative proportions of these ions vary.

On the other hand on Tunica clay loam the cation equivalence values have not been changed for application of 2 tons and 4 tons of lime. There is a sudden increase in the cation equivalence values for 6 tons of lime rate. This may be due to the unexpected potassium behaviour in that soil. Under 2 and 4 tons of lime application calcium decreased in 4 tons lime rate and magnesium was found to increase whereas the potassium was not affected at all. These interactions might have maintained cation equivalence for 2 and 4 tons of lime applications.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A greenhouse study of influence of three rates of lime and different levels of phosphorus, potassium and magnesium on the yield, and composition of soybeans grown on two soil types has been made. The soil types used were Tunica clay loam and Loring silt loam.

1. Four tons of lime per acre produced the highest yield on both the soils and 6 tons rate of lime produced the lowest yield. With the addition of each increment of lime, the percentage of Ca and Mg in the soybeans was increased significantly on both the soils. The percentage of potassium was significantly decreased on Loring silt loam, but on Tunica clay loam each increment of lime did not affect the percentage of potassium.

2. On Tunica clay loam the 4 tons lime rate with 60 pounds of P_2O_5 gave the highest yields whereas on Loring silt loam the 4 tons lime rate with 120 pounds each of P_2O_5 and K_2O along with 50 pounds of magnesium treatment gave the highest yield.

3. A significant increase in the percentage of phosphorus in soybeans for an increase in the lime rate from 2 tons to 4 tons was found on both the soils. On the other hand there was a decrease in the phosphorus content of the soybeans from the 4 to 6 ton lime rate on both the soils. The differences in yields due to each increment of lime ran almost parallel to the percentage phosphorus of soybeans

on both the soils.

4. The average values of cation equivalence for the various treatments were found to be 171.0 and 178.0 me./100 g. of plant material for Loring silt loam and Tunica clay loam respectively. These constancy values were maintained by the reciprocal relationship between Ca and Mg on one hand and K on the other, and by an inverse relationship between Ca and Mg.

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