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The effect of fertilization and spacing on the yield and composition of soybeans

Subramaniyan Chandrasekaran

To the Graduate Council:

I am submitting herewith a thesis written by Subramaniyan Chandrasekaran entitled "The effect of fertilization and spacing on the yield and composition of soybeans." 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 Agronomy.

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Vice Provost and Dean of the Graduate School

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May 27, 1961

To the Graduate Council:

I am submitting herewith a thesis written by Subramaniyan Chandrasekaran entitled "The Effect of Fertilization and Spacing on the Yield and Composition of Soybeans." 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.

Horace C. Smith Jr.

Major Professor

We have read this thesis
and recommend its acceptance:

Charles L. Cleland

M. E. Springer

Accepted for the Council:

H. E. Spivey

Acting Dean of the Graduate School

THE EFFECT OF FERTILIZATION AND SPACING ON THE YIELD AND COMPOSITION OF SOYBEANS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Subramaniyan Chandrasekaran

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CHAPTER I

INTRODUCTION

Among the agricultural crops of the United States soybeans, Glycine max, rank fourth in value. The response of this crop to direct fertilization and spacing between rows is inconsistent. The reasons for the lack of response are frequently not known. It has been suggested that one of the important phases of research on soybean nutrition might be to study the relationships between spacing and the nutrient needs of the crop. One phase of this study pertained to the response of soybean yield components to varying fertilizer application and different spacings between rows.

Soybeans generally respond to lime applied to acid soils. These responses are in part related to the availability and uptake of other nutrients. A greenhouse experiment to determine the influence of lime and potash on the growth and composition of soybean plants was conducted.

CHAPTER II

REVIEW OF LITERATURE

Umbreit and Fred (45) observed that under optimum conditions, the soybean plant favored free nitrogen rather than fertilizer nitrogen. Norman and Krampitz (35) in 1946 and Thornton (44) in 1947 by the use of isotope studies corraborated the earlier view that nitrogen fixation by the soybean plant was inversely proportional to the amount of nitrogen added. Fred et al (16) reported that even the inoculated soybean crop might undergo a nitrogen hunger period in the seedling stage.

Krantz et al (28) observed that phosphorus applications increased soybean yield only on a soil low in phosphorus. Welch et al (51) and Bureaue et al (5) reported that plant uptake of fertilizer phosphorus was inversely related to the level of soil phosphorus and directly related to the rate of phosphorus application, and the total phosphorus uptake was greater from the high phosphorus soil. Cartter (9) in 1940, Colwell (12) in 1944, and Collins et al (10) in 1947 reported yield responses to phosphate alone have been less than to potassium alone.

Hammond et al (17) observed that this crop caused heavy depletion of soil potassium, since the beans contain about twice the amount of potassium as the grain of an equivalent corn crop. They emphasized the need for supplying adequate amounts of potassium for high bean yields. On potassium deficient soils, direct applications of potassium frequently resulted in increased yields. Striking yield responses to potassium applications were reported by Collins et al (10) and Nelson and Hartwig (34) on loamy fine sand and fine sandy loam, and by Colwell (12) on silt loams. Increases in yield of beans and improvements in seed quality due to applications of potassium on very fine sandy loam was reported by Nelson et al (34). Adams et al (1) and Colwell (12) reported an increase in the oil content of beans as a consequence of potassium fertilization. Viljoen (47) made a similar observation in South Africa.

Vittum and Mulvey (48) found that the supply of phosphorus and potassium in combination not only increased the yield of beans but also resulted in marked early maturity. According to them the components of yield increased by fertilization included number of pods per plant, number of seeds per pod and size of seeds. Beacher (3) in 1953, and Collins et al (11) in 1955 obtained profitable increases in yield by the application of phosphorus and potassium to soils that were low in the availability of these nutrients. According to Beacher (3) potassium without phosphorus was more effective than phosphorus without potassium in increasing yields on certain alkaline soils.

Nelson and Hartwig (34) and Hartwig (21) found that the response of soybean to phosphorus and potassium fertilization was dependent not only on the level of these nutrients in the soil but also on other environmental factors. They found liming the soil along with phosphorus and potassium greatly increased the yield and the quality of the beans. Kamprath (27) obtained more than a five bushel increase in yield per acre due to the addition of phosphorusand potassium only in soils low in phosphorus and potassium.

Nutrient studies in sand cultures with two varieties of soybeans by Allen (2) revealed differential growth response of these varieties.

Ehrenberg (13) suggested a lime-potash law according to which potassium uptake by plants decreases with an increase in calcium uptake. MacIntire and Coworkers (30) observed that liming an acid soil could decrease the leaching of potassium which might increase potassium uptake by plants. According to Jenny and Ayres (26) potassium saturation of the soil and the kind of complementary ions are two important factors that influence the potassium uptake by plants. Peach and Bradfield (37) assumed soluble potassium as the major source for plants, and reported that liming a soil free of neutral salts might increase soluble potassium and increase the uptake of potassium by plants. Carolus (8) observed that potassium uptake by bean plants was not increased by calcium application in Norfolk sandy loam but it did increase with the increasing application of potassium. Van Itallie (46) observed that the uptake of potassium by oats was influenced by potassium application but not by calcium except at very low pH levels. Potassium uptake by plants is so efficient that the luxury consumption of this element might cause a deficiency of magnesium or calcium. Walsh and Clarke (50) reported magnesium deficiency in tomato was induced by high uptake of potassium. Thus widely differing views are held between the soil calcium - potassium relationship and the plant composition with reference to these elements.

While the above review relates to crops in general, similar observations were made on soybeans also. According to Horner (25) an increase in calcium level in the soil resulted in greater growth, nodulation and nitrogen fixation by soybeans. Studies on nutrient solution made by Hamner (18) indicated that the concent ration of potassium to be more critical than calcium and magnesium for the soybean growth. Ferguson and Albrecht (14) reported that potassium application to clay colloids resulted in greater nitrogen fixation, increased efficiency of phosphorus uptake and less absorption of magnesium by young soybean plants. Hampton and Albrecht (19) reported that the concentration of potassium in the plant materials 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.

McCleland (31) observed row planting of soybeans to be superior to the drill and broadcast planting methods especially under droughty conditions. Zahnley (53) obtained a lower yield from drilled planting than from row planting but suggested that drill planting could be followed with advantage in weed-free fields. Burlison et al (6) reported that the use of 24-inch rows gave higher yields than seeding in 8-inch rows. However, Wiggans (52) reported that yields increased as the distance between rows decreased even in drilled plantings. According to Wiggans, when row widths of 8, 12, 16, 24 and 32 inches were compared for four years in plots kept weed-free by hand cultivation, net yields of 38, 35, 34, 33 and 30 bushels per acre respectively were obtained. Smith (43) studied the drill and the row planting methods. He reported that solid-drilled beans yielded best, but suggested that solid planting was not advisable because of difficulty of weed control, admixture of weed seeds necessitating a cleaning operation, increase in lodging and increase in cost of seeding. Hildebrand et al (24) also held similar views on solid planting.

There are numerous reports to indicate that an increase in seed yield is obtained as spacing between intertilled rows is decreased. In a number of experiments conducted over a period of years, Weber and Weiss (49) reported that consistently highest yields could be obtained with the intertilled rows spaced 21 inches apart, slightly lower yields with 28 inch rows and greatly decreased yields with a further increase in row widths. In a canvass of 4200 growers in 48 principal soybean producing counties in Illinois, Indiana, and Ohio, Calland (7) found on the average that narrow rows, spaced 18 to 28 inches, gave the highest yields; medium width rows, 30 to 36 inches, yielded slightly less, and wide rows, 38 to 42 inches, gave the lowest yields. Hanway (20) reported that tests at Nebraska gave higher yields from 21 inch rows than from wider spacings.

Lehman and Lambert (29) found seed yields tended to be higher in the spacings with 20 inches between rows than spacing with 40 inches. The yield components studied by them were number of branches perplant and number of pods per plant, and the number of seeds in per pod. According to them, weight per 100 seeds and seeds per pod were not substantially affected by changes in spacing. However, the pods per plant and branches per plant increased as the row spacing increased. Pendelton et al (38) observed higher yield response for 24 inch rows over 40 inch rows, irrespective of latitude, soil type, favorable or unfavorable moisture and early or late planting. Schotten (40) advised Ohio farmers to adopt narrow rows, from 21 to 32 inches rather than 42 inch rows. Beeson and Probst (4) advocated 24 inch rows for early maturing and erect growing varieties to obtain highest yields in Indiana. Hilderbrand et al (23) reported highest yield with early varieties when a 28 inch row spacing was adopted in Michigan.

Experimental results in the North Central States generally show a yield advantage for narrow rows while many results in the South show no advantage for narrow rows. According to

Hartwig (23) much of the difference in response to spacing between regions can be explained by the fact that adapted varieties grown in the South have much heavier foliage and will normally fill the row middles in 36 to 40-inch rows. In a review of row width studies in Virginia, North Carolina and Mississippi Hartwig (23) reported that narrow rows had not yield advantage over wide rows for the Ogden variety. He stated that until more satisfactory chemicals for weed control in soybeans are available, narrow rows increase the growers' cultivation problem. Hartwig also reported more lodging with narrow row spacing.

Rogers (40) reported higher yields in Alabama from close spacing if the beans were planted late, weeds controlled, and the seeding rate per acre was not increased. Beeson and Probst (4) observed that varieties with a spreading type of growth yielded best in wide row spacings. Fraus (15) reported lower yields with narrow spacing on soils with shallow clay pans.

CHAPTER III

MATERIALS AND METHODS

I. FIELD EXPERIMENT

Soybeans were planted on Huntington fine sandy loam at two spacings between rows, and fertilized with various amounts of phosphorus and potassium. The yield and different components of the yield were determined.

Soil core samples obtained from 6-inch depth of soil were analyzed for exchangeable Ca, K and Mg, and available phosphorus. Exchangeable Ca, K and Mg, were determined using a Beckman flame photometer. In the estimation of phosphorus, 1, 2, 4-Amino napthol sulfonic acid - reduced molybdo-phosphoric blue color method was used by measuring light transmission with a Beckman Spectrophotometer. The pH of the soil samples was determined in a soil-water paste by using the Beckman pH meter. Details of these procedures are given in Appendix A. The soil analysis data are given in table 1. The values in this table are the averages for three soil samples.

A 3 x 3 x 2 factorial with a randomized block design of four replications was used in the experiment. The three levels of phosphorus and potash additions were 0, 40 and 80 pounds of P_2O_5 and K_2O per acre. The two spacings between rows were 18 and 36 inches. Each plot measured 12 feet by 12 feet with either 4 or 8 rows per plot depending on the spacing

Table 1-Initial pH, exchangeable cations, and available phosphorus of Huntington fine sandy loam

	Exchangeable cations me/100 gm. of soil			Available P
pH	K	Ca	Mg	pounds/acre [a]
6.0	0.25	4.65	1.25	34

a/2 million pounds of soil.

between rows. Nitrogen was also applied to all plots at the rate of 10 pounds per acre.

The experimental area was plowed, disced, and harrowed. Row furrows 18 and 36 inches apart were made with a tractor-mounted marker. Ammonium nitrate, superphosphate, and muriate of potash were mixed and applied by hand in the furrow, and covered with about two inches of soil with a hand plow.

Ogden soybean seeds were inoculated by mixing the seeds in a slurry of _Rhizobium_ inoculum and water for two minutes. The seeds were planted by hand in the center of the furrow to the side of the fertilizer band at the rate of approximately 10 seeds per foot of row. The seeds were covered with about one inch of soil. This planting was made on July 20, 1960. The stand was improved by planting in gaps with a hand planter about one week later.

The beans were cultivated once when they were about 12 inches in height to control weeds. Later cultivation was unnecessary because of a rapid development of a canopy which shaded out most of the weeds.

Before harvest 10 plants were removed from the central two or four rows of each plot depending on the number of rows per plot. Yield components including pods per plant, branches per plant and average number of seeds per pod, were obtained from the 10 plant samples. The remaining plants were harvested and threshed on November 14 and 15. The data for seed yield were obtained by adding the weight of the seeds obtained from the 10 plants to the weight of the seeds from the remainder of the plot.

II. GREENHOUSE EXPERIMENT

Samples of Huntington fine sandy loam obtained from the experimental area were mixed with varying quantities of lime and potash. The treated soils were placed in cans and soybeans were planted. The tops were harvested, dried and weighed. Plants were analyzed to determine the uptake of phosphorus, potassium, calcium and magnesium.

A 4 x 4 factorial with a randomized block design of six replications was used. The four levels of lime were 0, 2, 4 and 8 tons of $CaCO_3$ per acre. The potassium levels were 0, 40, 80, and 120 pounds K_2O per acre. The soil was air dried, pulverized and brought to about 5 percent moisture. The required amount of lime and potash for each treatment were blended with 3.6 kilograms of soil for 4 minutes to obtain uniform mixing. The soil was placed in cans with polyethyelene liners.

Soil in the cans was brought to field capacity with demineralized water. Soybean seeds were inoculated by mixing the seeds in a slurry of *Rhizobium* inoculum. The seeds were planted at a depth of 3/4 inch and at the rate of 8 seeds per can. The moisture content of the soil was maintained at approximately field capacity by weighing and watering every day. After a week, the stand was thinned to 3 plants per can in one set of three replications and to 4 plants per can in another set of three replications.

Three replications were harvested at the end of 30 days and three replications were harvested at the end of 45 days. The plant material was dried in an oven at 70° C. and weighed. For analysis of plant tissue for Ca, Mg, K and P content, the material from each can was ground in a Wiley mill. One gram of the ground plant tissue from these samples was taken for wet digestion. The method used for digestion and determining Ca, Mg and K with the Model DU Beckman Spectrophotometer is described by Shaw (42). Phosphorus was estimated on an aliquot of the same digestate by the 1, 2, 4-Amino Napthol Sulfonic Acid-reduced Molybdophosphoric blue color method with the use of a Beckman Spectrophotometer. Details of procedures are given in Appendix B.

CHAPTER IV

RESULTS AND DISCUSSION

Field Experiment

Soybean yields, number of pods per plant, number of branches per plant, and number of seed per pod at various fertilization rates and spacings are given in tables 2, 3, 4 and 5.

The average yield of beans obtained in the experiment was 54.6 bushels per acre. This high yield can be attributed to the favorable environmental conditions. The Huntington fine sandy loam on which the crop was grown is a level, deep soil with a high available water capacity. The soil is fertile as indicated by the soil test values shown in table 1. During the cropping season the rainfall was well distributed and no prolonged period of drought occurred (Appendix C).

The yield of soybeans at the 18-inch row spacing ranged from 52.3 to 58.5 bushels and averaged 55.6 bu. The yield at the 36-inch spacing ranged from 50.7 to 57.4 bushels and averaged 53.7 bushels. In 7 of the 9 fertilizer treatments of the yield of beans was higher at the 18-inch spacing. The difference in yield between spacings of 1.9 bushels was small but significant. The average number of pods per plant was 45.1 for the close spacing compared to 89.6 for the wide spacing. The average number of seed per pod for plants at both spacings was 2.5. Data not reported here showed that

Table 2--Yield of soybeans at various spacings and fertilization levels

Treatment		Yield, bu./acre		
P_2O_5 lb./acre	K_2O lb./acre	18-inch spacing	36-inch spacing	Fertilizer means
0	0	52.4	56.0	54.2
0	40	58.5	54.6	56.6
0	80	57.9	57.4	57.7
40	0	52.3	54.4	53.4
40	40	55.1	50.7	52.9
40	80	57.1	51.2	54.2
80	0	56.2	54.3	55.3
80	40	57.1	54.5	55.8
80	80	53.8	51.5	52.7
	Spacing Means	55.6	53.7	
L.S.D.	Between fertilizer means	4.4	4.2	N.S.
(.05)	Between spacing means	1.5		

Table 3--Pods per plant at various spacings and fertilization levels

Treatment		Number of pods/plant		
P_2O_5 lbs./acre	K_2O lbs./acre	18-inch spacing	36-inch spacing	Fertilizer means
0	0	35.8	82.6	59.2
0	40	46.1	96.2	71.1
0	80	52.8	98.8	75.8
40	0	40.0	68.5	54.3
40	40	38.1	99.8	69.0
40	80	50.3	91.6	71.0
80	0	48.2	59.4	53.8
80	40	44.1	100.8	72.5
80	80	50.9	100.4	79.7
Spacing Means		45.1	89.6	
L.S.D.	Between fertilizer means	8.4	10.1	
(.05)	Between spacing means	7.3		

Table 4--Branches per plant at various spacings and fertilizer levels

Treatment		Number of branches/plant		
P_2O_5 lbs./acre	K_2O lbs./acre	18-inch spacing	36-inch spacing	Fertilizer means
0	0	6.5	8.6	7.5
0	40	6.9	10.7	8.8
0	80	7.3	10.1	8.7
40	0	6.2	8.1	7.2
40	40	5.8	9.2	7.5
40	80	6.2	9.3	7.8
80	0	6.5	7.9	7.2
80	40	6.5	9.6	8.1
80	80	7.4	10.3	8.9
Spacing Means		6.6	9.3	
L.S.D. Between fertilizer means		0.3	0.5	
(.05) Between spacing means		0.3		

Table 5--Seeds per pod at various spacings and fertilization levels

Treatment		Number of seeds per pod		
P_2O_5 lb./acre	K_2O lb./acre	18-inch spacing	36-inch spacing	Fertilizer mean
0	0	2.4	2.4	2.4
0	40	2.5	2.5	2.5
0	80	2.5	2.6	2.6
40	0	2.4	2.5	2.5
40	40	2.4	2.5	2.5
40	80	2.6	2.5	2.6
80	0	2.4	2.4	2.4
80	40	2.4	2.6	2.5
80	80	2.5	2.5	2.5
Spacing Mean		2.5	2.5	

spacing did not influence the test weight per bushel or weight of 100 seed. Since neither the size of the seed nor the number of seed per pod was influenced by spacing, doubling the number of pods per plant on the 36-inch rows was sufficient to give almost the same yield as the 18-inch rows with approximately one-half the number of plants per pod.

Decreasing the distance between rows also decreased the number of branches per plant. The average number of branches was 6.6 for the narrow spacing and 9.3 for the wide spacing. The pods per branch averaged 6.8 and 9.6 for the 18 and 36-inch spacings. The decrease in the number of pods and branches with a decrease in inter-row spacing is in agreement with the findings of Lehman et al. (29). The absence of an effect of spacing on seed size and seed per pod is also in agreement with the data reported by these workers.

The absence of a large yield advantage for the narrow rows over wide rows is in agreement with the observations of Hartwig (23) for the Ogden variety, and with those of Beeson and Probst (4) for other spreading type varieties. Rogers (40) found that close spacing gave higher yields for spreading type varieties if the seeding rate per area was not increased. The seeding rate per area was doubled for the close spacing in this experiment.

A high incidence of lodging has frequently been associated with close spacing. The amount of lodging was high in all plots and did not seem to be related to spacing.

The data in table 2 indicate that available potassium and phosphorus were not greatly limiting soybean yields. Potash at both the 40 and 80-pound rates significantly increased the yield at the 18-inch spacing when phosphate was not applied. The yield at the 80-pound rate was not significantly different from the 40-pound rate. Potash gave smaller increases in yield when 40 pounds of phosphate was applied and had little effect at the 80-pound phosphate level. Potash did not significantly affect yields at the 36-inch spacing.

The application of potash alone or with phosphate gave a significant increase in the number of pods per plant and number of branches per plant. However, the high coefficient of variation (20.2%) for the number of pods and the lack of correlation between yield and number of pods in some treatments suggests that the 10-plant samples may not have been representative of the plots.

Phosphorus applied alone did not significantly affect the soybean yields. The use of phosphate tended to decrease the yield of beans and the number of pods per plant. Pierre (39) and Miller (32) reported reductions in soybean yields when phosphate was applied and suggested that phosphate reduced the potassium uptake by plants.

Fertilization did not influence the number of seed per pod or the size of the seed.

<u>Greenhouse</u> <u>Experiment</u>

The dry matter yields of soybean plants grown in the greenhouse at various lime and potash levels are given in table 6. The addition of lime significantly increased the dry weight of the plants with the exception of the 2-ton rate of lime without the addition of potash for the 30-day harvest time. The yields on the unlimed soils were 0.57g. and 0.87g. for the 30 and 45-day harvest time compared to 0.86g. and 1.45g. for the 2-ton rate of lime, 1.11g. and 1.82g. for the 4-ton rate, and 1.25g. and 2.01g for the 8-ton rate.

Examination of the root systems showed that the roots in the limed soil were larger and more numerous than those in the unlimed soil. The nodules on the roots were also larger and more numerous in the limed soil. Horner (25) observed similar effects of lime on soybean roots. The promotion of nodulation and root development may have been the factors contributing to the increase in yields from liming. The reason or reasons for the small yields on the unlimed soil and that receiving 2 tons per acre without potash are not known. The initial soil pH and exchangeable potassium were sufficiently high to have expected better plant growth.

Potash fertilization gave significant increases in soybean yields. The average yields when potash was not applied were 0.71g and 1.26g for the 30 and 45-day harvests. The yields at the two harvests for the 40, 80, and 120-pound potash rates were 1.03g. and 1.60g., 1.11g. and 1.84g. and 0.94g

Table 6--Yield of soybean plants at various levels of lime and potash

Treatments		Yield g./can	
Lime T./acre	K_2O lb./acre	30 days [a]	45 days [b]
0	0	0.18	0.21
0	40	0.66	1.05
0	80	0.71	1.09
0	120	0.73	1.13
2	0	0.19	0.40
2	40	0.93	1.18
2	80	1.20	1.62
2	120	1.13	1.98
4	0	1.19	1.68
4	40	1.14	1.78
4	80	1.07	2.69
4	120	1.02	1.13
8	0	1.28	2.16
8	40	1.40	2.40
8	80	1.44	1.95
8	120	0.87	1.52
L.S.D. (.05)		0.5	0.6

a/3 plants per can: b/4 plants per can

and 1.44g. Although the yield was greater at the 80-pound rate than the 40-pound rate, the 120-pound rate gave somewhat lower yields at both harvests than the lower rates.

The chemical composition of the soybean plants is given in table 7. The potassium content increased with increases in the amount of potash applied. The increase in potassium absorption from potash applications was less when lime was also applied. When lime alone was added the potassium content of the plants was reduced. The high calcium ion activity would be expected to reduce the relative concentration of potassium in the soil solution and, therefore, reduce the potassium absorption by plant roots.

The application of lime gave small but consistent reductions in the concentration of calcium in the plants. This reduction could have been a dilution effect resulting from a relatively greater rate of dry matter accumulation than the rate of calcium absorption. Potash additions decreased the uptake of calcium with the greatest decrease occurring when lime was not applied.

The magnesium content was reduced when potash was applied alone. Potash also reduced the magnesium content at the two lower rates of lime. Increases in potassium concentration in soybeans with a simultaneous decrease in magnesium has been reported by Hampton and Albrecht (19). The 2-ton rate of lime without the addition of potash, increased the magnesium content

Table 7--Percent P, K, Ca and Mg in soybean plants at various lime and potash levels

Treatments		Percentage content of elements			
Lime T./acre	K_2O lb./A.	P	K	Ca	Mg
0	0	0.36	1.34	1.59	0.80
0	40	0.33	1.49	1.44	0.65
0	80	0.29	1.53	1.34	0.56
0	120	0.30	1.80	1.25	0.59
2	0	0.29	1.07	1.39	0.91
2	40	0.28	1.30	1.32	0.84
2	80	0.28	1.43	1.34	0.59
2	120	0.28	1.84	1.25	0.59
4	0	0.26	0.88	1.23	0.64
4	40	0.25	0.97	1.11	0.57
4	80	0.25	1.18	1.22	0.56
4	120	0.24	1.41	1.18	0.59
8	0	0.25	0.93	1.45	0.71
8	40	0.25	0.94	1.17	0.74
8	80	0.23	1.39	1.36	0.72
8	120	0.24	1.67	1.40	0.74

whereas the higher lime rates decreased the magnesium uptake.

A certain amount of phosphorus, nitrogen and sulfur is necessary in synthesizing organic compounds in building plant structures. On the other hand, the cations are not used in large quantities in building organic compounds. However, there is a minimum amount of each cation necessary for plant growth once this minimum has been met. The additional amount of each cation taken up is largely for the purpose of maintaining cation-anion balance. Plants can show a great deal of variation between the ratios of different cations and still have normal growth. Although lime and potash application in this study influenced the uptake of the various cations the total cation concentration was relatively constant. The concentration of each cation for all treatments was in the favorable range reported by Ohlrogge (36).

The phosphorus content of the plants decreased with increases in the amount of lime applied. The pH of the unlimed soil was 6.1. The pH values for the soil treated with 2, 4, and 8 tons of lime were 7.2, 7.6 and 8.0 respectively. Low availability and plant uptake of soil phosphorus is often associated with high pH values. Lime increased the yield of the soybean plants, therefore, the lower phosphorus uptake for the limed treatments apparently was not a limiting factor in the growth of the plants.

CHAPTER V

SUMMARY

The influence of phosphate and potash fertilization on soybean yields under row spacings of 18 and 36-inches on Huntington fine sandy loam was studied. The effects of lime and potash applications to this soil on the dry matter yield and on the per cent composition of calcium, potassium, magnesium and phosphorus in soybeans were also studied under greenhouse conditions.

A high yield of beans obtained on all plots in the field experiment can be attributed to the high productive capacity of the soil and the favorable amount and distribution of the rainfall.

The response of the soybeans to spacing varied with fertilization with the average yield being somewhat higher for the 18-inch spacing. Close spacing decreased the number of pods per plant and branches per plant. Spacing had little influence on the seed size or seed per pod.

Phosphorus and potassium were not greatly limiting the yield of soybeans. However, potash alone gave significant increases in yield at the 18-inch spacing only. Potash increased the number of pods and branches per plant. Phosphate did not significantly affect yield or yield components.

In the greenhouse experiment, potash in most treatments increased the dry matter yield, increased the potassium content, reduced the calcium content and reduced the magnesium content. Lime increased the yield, decreased the potassium and had varying effects on the magnesium content of the plants.

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APPENDIXES

APPENDIX A

SOIL ANALYSIS

A 10 gram of soil sample obtained from the field was placed in 125 ml. flask. 50 ml. of 1 N. Ammonium acetate solution was added and the contents shaken for 30 minutes. The contents were allowed to stand overnight and filtered through Buchner funnel using Whatman filter paper No. 42. Soil was washed with another 50 ml. of 1 N. Ammonium acetate and the washings were collected in the filtrate. The flame photometer was used to determine exchangeable K, Ca and Mg in the extracts standard solutions of K, Ca and Mg containing potassium dihydrogen phosphate, magnesium acetate and calcium carbonate were prepared in the medium of 1 N. Ammonium acetate these were used determining the amounts of K, Ca and Mg in parts per million in the soil extract solution.

Into a 125 ml. flask, 6.5 grams of the soil was weighed. A small amount of activated carbon and 25 ml. of 0.05 N. H_2SO_4 containing 1 N. $(NH_4)_2SO_4$ was added. The sample was shaken for 5 minutes and filtered. To 10 ml. of the filtrate 1.0 ml. of molybdic acid and eight drops of 1-2-4 amino napthol sulfonic acid were added. After fifteen minutes the P content of the solution was determined.

The procedure suggested by Shaw (42) was followed in the preparation of K, Ca and Mg standard solutions used for the analysis of these elements in both plants and soils.

APPENDIX B

PLANT ANALYSIS

For analysis of plant tissue for Ca, Mg, K and P content, the dried plant material from each can was ground in a Wiley mill. All the plant tissue samples from different replications were kept separately. One gram of the ground plant tissue from these samples was taken for wet digestion. The method used for digestion and determining Ca, Mg and K with the Model DU Beckman Spectrophotometer is described by Shaw (42). Phosphorus was estimated on an aliquot of the same digestate by the 1, 2, 4-Amino Napthol Sulfonic Acid-reduced Molybdophosphoric blue color method with the use of a Beckman Spectrophotometer.

A 1.0 gram sample of plant material was digested in 1:1 mixture of conc. H_2SO_4 and $H\ ClO_4$ acids, filtered and the filtrate was made up to 50 ml. from which 5 ml. was removed for P determination. The remaining 45 ml. was evaporated to dryness and placed in muffle furnace at 200° C. for 10 minutes. The residue was dissolved in 5 ml. of 1:1 HCl, evaporated to dryness and this process was repeated with 5 ml. of 1.0 N HCl and 25 ml. of water. $Ba\ Cl_2$ solution was added and the contents of the beaker were digested for 1 hour. 10 ml. of ammonium acetate buffer, 5 ml. of $FeCl_3$ solution and $NH_4\ OH$ equivalent to neutralize 10 ml. of 1 N. HCl were added successively to the above solution. Contents of the beaker were digested at boiling for 15-20 minutes, transferred to 100 ml. volumetric flask, cooled quickly and made up to volume. This solution was filtered and the filtrate used for flame photometric analysis of Ca, Mg and K. Solutions of known concentrations containing K, Ca and Mg were prepared by dissolving potassium dihydrogen phosphate, magnesium acetate and calcium carbonate in 1N. Ammonium chloride solution were used as standards for determining the amounts of K, Ca and Mg in parts per million on the filtrate obtained above.

Five ml. of perchloric acid extract taken for phosphorus determination was poured in 50 ml. standard flask and made up to the mark. 10 ml. of this solution was mixed with 1.0 ml. of molybdic acid and 5 drops of reducing agent, 1, 2, 4-amino napthol sulfonic acid. After 15 minutes blue color developed in these solutions. Spectrophotometer was used to determine the light absorbancy in these solutions. Solutions of known concentrations containing potassium dihydrogen phosphate were prepared in water and used as standards for estimating the amount of phosphorus in parts per million in the unknown solutions asobtained above.

APPENDIX C

Daily rainfall, inches, 1960.

University of Tennessee Farm.

July	3	0.20	Sept.	11	1.85
	10	1.08		16	0.55
	11	0.88		17	0.11
	30	2.16		27	0.14
				28	0.14
July total		4.32		29	0.65
				30	0.15
			Sept. total		3.59
Aug.	5	0.79			
	8	0.56			
	9	0.62	Oct.	4	1.75
	10	0.79		6	0.39
	12	0.43		7	0.02
	19	0.18		8	0.24
	21	0.38		9	1.48
	22	0.67		16	0.05
	23	0.25		20	1.65
	29	0.15		27	0.24
				31	0.32
Aug. total		4.82			
			Oct. total		6.14

Nov.	2	0.02
	5	0.13
	10	0.63
	16	0.11
	23	0.48
	29	0.72
Nov. total		2.09