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I am submitting herewith a thesis written by William Virgil Anderson entitled "The Boron and Calcium Content and Yield of Three Crops Receiving Various Boron and Lime Treatments." 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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THE BORON AND CALCIUM CONTENT AND YIELD OF THREE CROPS
RECEIVING VARIOUS BORON AND LIME TREATMENTS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
William Virgil Anderson

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ABSTRACT

Experiments were conducted to study the effects of additions of B and limestone on the yields of three crops and their B and Ca contents. A corn (Zea mays L.), cotton (Gossypium hirsutum), and soybean (Glycine max) cultivar was grown on a Loring silt loam from 1969 through 1971. Plant and soil samples were taken to determine the Ca and B contents of the plants and the available soil B levels.

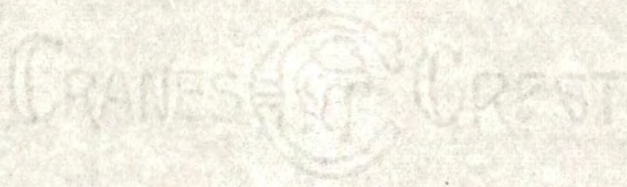
Fertilizer B applications significantly increased corn yields in two of the three years. The yields of cotton and soybeans were not affected by fertilizer B. Cotton and soybean yields were significantly increased by liming.

In general, the Ca and B leaf content of both crops increased with increasing lime and B levels respectively, although the stage of growth influenced the degree of change. The B content increased with maturity in soybeans, while as cotton matured the leaf B decreased. Soybeans contained greater B than cotton or corn while cotton contained more Ca than the other crops. The leaf Ca level of soybeans and cotton varied with the climatic differences of the years.

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CHAPTER I

INTRODUCTION

A shortage of information exists in Tennessee concerning the effects of a wide range of boron and lime application rates to the major row crops of the state. The original experiments in 1969 were conducted to determine the effects of B and lime applications on the yields of corn, cotton and soybeans. The experiments were expanded in 1970 and 1971 to provide more information related to the Ca and B content of cotton and soybeans at different physiological growth stages. It is believed that with the information provided by this three year study, inferences can be drawn regarding the future need for B applications to the soils of West Tennessee.

CHAPTER II

REVIEW OF LITERATURE

There is perhaps a greater volume of literature on B in plants and soils than for any of the other micronutrients. The majority of research with B deals with the following topics: (1) B in soils; (2) the functions of B in plants; (3) the effects of B on crop yields; (4) plant tissue B relations; and (5) Ca-B nutrient balance. These major topics will be reviewed in the above order.

I. BORON IN SOILS

Tourmaline, $\text{H}_2\text{MgNa}_9\text{Al}_3(\text{BO})_2\text{Si}_4\text{O}_{20}$, is the major borosilicate mineral found in the humid regions while Ca, K, and Na borates and tourmaline occur frequently in the arid regions (Berger and Pratt, 4). Wear (60) reported that due to the extreme insolubility of tourmaline, the total B present in the soil is of little value as an index of availability.

Russel (50) proposed that the total B content of a common soil may range from 20 to 200 pounds per acre furrow slice, of which, less than five percent is available to the plant.

Efforts have been made to determine the range of available B found in soils. Deturk and Olson (10), in determining the ranges of available B in soils, found that soils of Georgia range from 0.01 to 0.65 ppm while the soils of Illinois contain from 0.20 to 1.25 ppm water soluble B.

Jordon and Powers (29), using field beans as an indicator crop, found soils which were deficient in B. They judged values less than 0.5 ppm available B as deficient. By these standards many soils of the humid regions may be classified as deficient in water soluble B.

The question of the fixation of B in soils has been researched for several years. Hodgson (24) suggested that the chemical fixation of B with soils occurs by chemical precipitation, anion exchange and molecular adsorption. He also believed B will fit into the crystal lattice of the aluminosilicates. Wetting and drying favors this source of B fixation.

Berger (2), after studying chemical precipitation of B compounds, concluded that B does not precipitate as an insoluble silicate,

The drying and resultant fixation in the lattice, according to Parks (43), seems to allow more fixation of B in sandy soils than chemical precipitation, adsorption by clay, organic matter or microbial fixation.

Recent work by Sims and Bingham (53) on the retention of B by layer silicates and sesquioxides showed that the presence and extent of hydroxy iron and aluminum forms dominate over clay mineral species in determining B retention.

Another source of B fixation commonly studied in the soil chemistry of B is that of organic matter. Gupta (21) in his studies on the B content of Podzol soils, found that organic matter retains more B than do clays. Hanna and Purvis (22) studied the effects of borax on the activity of microorganisms in a sandy soil. They concluded that borax

increased microbial activity at several pH values, among them 5.1 and 7.7 and that the influence was greater at the higher pH level. They reasoned that microbial activity and thus organic matter had a share in B fixation.

Berger (2) reported the availability of native B in soils correlates with the organic matter present, such that soils high in organic matter have greater available B.

Olson and Berger (40) studied the effect of the oxidation of organic matter. They reported that organic matter oxidation releases B and causes a decrease in B fixation. They reasoned that organic matter plays a small part in B fixation. Sims and Bingham (53) substantiated the claim that organic matter does not fix B when they reported a negative correlation between B retention (of added B) and organic matter.

The soil pH is the factor with which most people associate B availability. Jackson (27) reported that the amount of water soluble B in cultivated soils appears to be influenced more by the pH level than by any other factor. He reported greater water soluble B at acid pH values, with less water soluble B as the pH approaches neutrality.

Organic matter and pH effects on B fixation have been studied by Olson and Berger (40). They proposed that the pH level has a greater influence in decreasing the availability of B than organic matter has on maintaining availability. They noticed B fixation increased rapidly as pH values rose above 7.0 while below 7.0 there was little or no correlation between pH and B fixation.

Both Jackson (27) and Hodgson (24) reported the fixation of B is independent of the activity of the Ca ion but is dependent upon the rise in soil pH.

Katalymov (30) attempted to find the cause of the decreased availability of B to plants after liming a soil. He theorized that B may unite with favorable diols which are gradually released by microbial activity. The esters of boric acid and polyhydric alcohols are more stable in neutral and alkaline media than acid media.

II. FUNCTIONS OF BORON IN PLANTS

The functions of B in plant tissue have been studied for many years and, like most other micronutrients, many of the functions are not completely understood.

Gauch and Dugger (17) suggested the three major functions of B in plants as (1) the role of the borate ion in the complexing of hydroxyl rich compounds thereby reducing their polarity and allowing easier transportation across membranes; (2) the role of B in salt absorption such that a decrease in B uptake resulted in a net decrease in salt uptake; (3) the role of B in pectic substances.

Russell (50) reported that B has a major influence on: (1) cell division; (2) flowering and fruiting processes; (3) active salt absorption; (4) the metabolism of pectic substances; and (5) pollen germination. The trend along this line continued such that Skok (54) found that cell maturation and cell differentiation through the role of B in pectin development, were major functions of B in plants.

Reed (48) correlated the accumulation of phenolic compounds in plants with a deficiency of tissue B, while Perkins and Aronoff (45) found that caffeic and chlorogenic acids (biogenetically close to lignin)

accumulated in a B deficient plant. This led them to suggest that B was necessary for lignin polymerization. In working with oil palm, Rajaratnam et al. (47) investigated this theory and a possible association between flavonoid and lignin production. Their results showed the role of B may be more closely associated with the biosynthesis of flavonoids.

III. BORON ON YIELDS

Generally, in the field, B has been applied to rectify symptoms of B deficiency. However some workers have found responses to B where deficiency symptoms could not be recognized, while others have found no response to B application. Much of the B work has been done in conjunction with lime studies.

In their work with soybeans grown on a Loring silt loam, Long et al. (34) found that yields were not affected by B applications, but lime rates did increase yields significantly.

Wear and Patterson (61) using several soils in greenhouse studies found no response in alfalfa yield with several B treatments at several pH values, but Norland and Starostka (39) reported a response in the yield of alfalfa with B additions applied on acid soils low in B.

The effects of B fertilizer rates on the yield of peanuts has been studied by Harris and Gilman (23). They received a significant yield response to B fertilizer treatments on a sandy soil.

Long (33) studied the effects of B on the yield of cotton at several lime levels on a Loring silt loam. He reported a significant yield increase due to one half pound B per acre on the unlimed check.

He also found a highly significant response to the same B increment on the two limed treatments.

In work on loessial soils, Keogh and Maples (31) had a significant response to B on seed cotton yield on several soils but they found no differences in B rates and soybean yields. They also reported no differences due to the method of application of B fertilizers.

Generally most of the yield responses to B have been associated with dicots. In their studies with corn however, Berger, Heikkinen, and Zube (3) reported that B additions increased yields in the field.

IV. PLANT TISSUE BORON

Several workers have reported ranges of tissue B found in plants. Chapman (7) classified monocots as low accumulators of B and dicots as high B accumulators. He also concluded that corn is semitolerant of B as are alfalfa, sorghum, tobacco, barley, and oats while cotton is tolerant of B.

Wolf (62) used tissue analysis to determine ranges of B for plants. He reported less than 25 ppm B in dicots and less than ten ppm B in monocots represents a deficiency. He also suggested if there is less than 75 ppm B in recently matured dried tissue of dicots, there is no toxicity. Eaton (13) has also studied deficiencies, toxicities, and the accumulation of B in plants. He determined less than 16 ppm B represents deficiency levels, 16 to 30 ppm of B is the intermediate range and greater than 200 ppm represents toxicity in cotton leaves.

The tissue B levels found in corn have been studied by Marsh and Shive (35). They report from five to eight ppm B in the tissue is an

intermediate range while if greater than 25 ppm are present in dried tissue, toxicity symptoms are evident. Peck, Walker, and Boone (44) found in corn tissue a range of 8 to 30 ppm B, while Berger, Heikkinen and Zube (3) believe the critical level of B in the upper leaves of corn to be between 8 and 13 ppm B.

Much of the recent study of B uptake by corn has been in relation to different genotypes. Major gene inheritance of nutrients by corn has been studied by Gorsline, Thomas, and Baker (19). They report that the concentrations of B and other major nutrients in the ear leaf are under genetic control. Sayre (51) reports that various inbred lines of corn contain different levels of B.

Soybean and tissue B levels have been studied by Walker, Peck, and Carmer (59). They report ranges of 24 to 108 ppm B while Evans, Lathwell, and Mederski (14) report an intermediate range of B in soybeans as 29 ppm. Stinson (56) believes that legumes require greater B than other dicots.

The fate of B applied to the soil or added to nutrient solutions has been studied extensively by many workers on various agronomic crops.

Berger and Truog (5) studied tissue B as revealed by plant and soil tests. They found greater B uptake by plants after B applications to soils. The B content of alfalfa tissue as influenced by B supply has been studied by Dible and Berger (11). They reported an increase in B uptake as B levels were raised in nutrient solutions. Wear and Patterson (61) studied the effects of several rates of B fertilizer at three pH levels on alfalfa. They concluded that the higher the levels

of applied B, the greater the tissue B content. They also found the leaf B content increased as the pH decreased. Norland and Starostka (39) found that applied B caused greater B uptake in alfalfa grown on calcareous soils.

Berger, Heikkinen, and Zube (3) found B applied in fertilizer resulted in greater B content of corn tissue. Marsh and Shive (35) found similar results with corn. Peanut nutrition and B has been studied by Cox and Reid (9). They found applied B increased the B content of stem tips.

The source or form of the applied B as related to the uptake has been studied by Colwell and Cummings (8). They studied aqueous solutions of boric acid and Ca, K and Na metaborates as sources of B. They found that the absorption of B does not depend upon the source if the water soluble concentration is the same.

V. CALCIUM-BORON NUTRIENT BALANCE

Nutrient balance is an important aspect of B studies, especially in relation to the functions and uptake of Ca. However, in order to understand the nutrient balance of Ca and B, the functions and ranges of tissue Ca must be explored.

The commonly accepted functions of Ca in plant tissue, according to Olson and Lucas (41) are: the regulation of the translocation of carbohydrates; the buffering of cell acidity; the integration into the cell wall; and essentiality for the growth of meristems. The functions of Ca are certainly similar to those of B in the plant. Berger (2)

believes the two function the same because the deficiency symptoms are very much alike.

The effects of Ca applications on the ranges of the element found in plant tissues have been studied in agronomic crops as in the case of B. Murphy (38) studied the Ca content of the cotton plant at various stages of growth. He concluded that Ca additions increase tissue Ca content and as maturity progresses Ca content increases.

Jones and Scarseth (28) found greater Ca in the plant tissue when Ca was applied to the soil. Swanback (57) reported that the addition of Ca to tobacco resulted in greater Ca uptake. Vanderford (58) reported similar results on soybeans and sweet clover. Hourigan et al. (26) found the more lime applied, the greater the percentage Ca recovered in barley and alfalfa tissue. Cox and Reid (9) found similar results in peanuts.

Many workers have observed ranges of Ca found in crop plants. Melich and Reed (36) studied Ca uptake at early bloom of cotton; they report the low range of tissue Ca as 0.80 to 1.02 percent while the intermediate range was 2.2 percent. Marsh and Shive (35) found less than 0.3 percent Ca on a dry weight basis of corn tissue showed deficiency while 0.76 to 0.80 percent was an intermediate range. Evans, Lathwell, and Mederski (14) report that soybeans with less than 0.57 percent Ca showed deficiency symptoms while 1.34 percent was an intermediate range.

Maximum growth and yields result only when the proper balance of nutrient elements occurs in combination with their optimum intensity. According to Shear, Crane, and Myers (52) under conditions of ideal

balance any critical change in the accumulation of any one or more elements, not accompanied by changes in all other nutrients will result in an imbalanced nutrition which will be reflected in decreased growth and if the imbalance is intensified, yields will fall and leaf symptoms will appear.

This theory is reflected in the work by Branchley and Warrington (6). These workers alluded to a Ca-B relationship such that without B, Ca is not fully utilized, and B enables the plant to absorb more Ca or utilize it more effectively.

Minark and Shive (37) on the other hand, postulated that if B does, in fact, influence Ca metabolism, its effect varies with the plant species. They also believed that the percentage of Ca in the soybean leaves was conditioned by the B in the nutrient solution.

The corn plant was studied by Marsh and Shive (35) in respect to B as a factor in Ca metabolism. They reported that adequate B in the corn plant tends to maintain Ca in an available condition throughout the plant. They found B content in the nutrient solution did not affect Ca content. This is one of several reported instances where B did not affect Ca uptake.

Jones and Scarseth (28) found if a plant has a low intake of Ca there will be a low tolerance for B, while on overlimed soils, plants require greater B.

Calcium and B relationships in plant nutrition were studied by Reeve and Shive (49). They concluded B toxicity, which occurred at high levels of available soil B, decreased with increasing Ca concentration.

They also found Ca uptake to be independent of B. The relation of Ca to the availability and absorption of trace elements in plant was studied by Purvis and Davidson (46). They described a Ca-B relationship such that a low intake of either causes the plant to require less of the other element. Berger (2) in nutrient solution studies concluded if Ca is increased in a nutrient solution, greater B is required to prevent B deficiency and greater B can be added without toxicity symptoms. He further postulates Ca uptake is independent of B. The soluble Ca in the plant, according to Gauch and Dugger (17) is determined not by the total Ca but by the level of B in the plant which in turn is regulated by available soil B. They further state that soil B does not affect the total Ca in plant tissues.

Duckweed was used by Fox and Albrecht (16) to determine what, if any, effect B had upon Ca uptake. They suggested greater Ca uptake with greater B uptake. They found B in duckweed increased with increasing Ca in substrate.

Cox and Reid (9) studied Ca-B nutrition as related to concealed damage in peanuts. They pointed to a Ca-B nutritional association since both reduced damage in peanuts and affected the level of damage. They also report no interaction between the Ca and B applications on the content of each other.

Some workers have tried to calculate Ca-B ratios which could be correlated with B deficiency, toxicity or optimum yield. The basis for these ratios has been the belief in a Ca-B nutritional association and a desire to be able to pinpoint plant conditions with a particular ratio.

The Ca-B balance was studied by Jones and Scarseth (28). They found in oats and alfalfa the Ca-B ratio decreased as applied B was increased. They also recognized Ca-B ratios varied with the crop specie.

Drake, Sieling, and Scarseth (12) reported that B starvation results when the Ca-B ratio becomes unfavorable. They further postulate a ratio of 1500:1 correlated with severe B deficiency of tobacco.

Fox and Albrecht (16) attempted to use the Ca-B ratio as an indicator of the toxicity of B in duckweed tissue. They concluded the Ca-B ratio is a poor indicator of B toxicity in duckweed.

CHAPTER III

METHODS AND PROCEDURES

Each year during the growing seasons of 1969 through 1971, a corn (Zea mays L.), cotton (Gossypium hirsutum), and a soybean (Glycine max) cultivar was grown on a Loring silt loam.

The Loring series are deep, medium acid to strongly acid, well to moderately well drained soils on the uplands. The series forms in thick loess. The surface is a brown silt loam with a reddish brown silty clay loam subsurface. In some places a weak fragipan is present. This soil series contains a moderate amount of potassium, a small amount of phosphorus and a low organic matter content (Flowers, 15).

The corn cultivars planted were Pioneer 511A, Tennessee 606, and Moews SM821W in 1969, 1970, and 1971 respectively. Pioneer 511A is a high yielding, full season white corn as is the Moews SM821W. Tennessee 606 is a high yielding yellow medium season cultivar (Graves, 20). The corn cultivars were not consistent from year to year due to seed availability.

The cotton cultivar seeded in each of the three years was Hancock. It is an early cultivar which yields very well and has excellent fiber quality. Stand establishment is good and Hancock has excellent seedling vigor (Hoskinson, 25).

The Lee cultivar of soybeans was seeded each of the three years. This is a high yielding soybean cultivar with good resistance to seed shatter but has a tendency to lodge under certain conditions. It is

recommended throughout the state of Tennessee except where cyst nematodes are a problem (Graves, 20).

I. FIELD METHODS

The experiments were conducted as a split plot factorial arrangement of treatments in randomized complete blocks. Each experiment had four replications yearly with the exception of the cotton experiment of 1970 which had only three replications.

Two rates of commercially available limestone and a check were used as the main treatments. The lime rates used were: zero, three and one half, and seven tons per acre which were applied in the spring of 1969. The main plots were not rerandomized in 1970 and 1971 due to the residual effect of the lime.

Three rates of Solubor and a check were assigned as the split treatments. The rates of B applied as Solubor broadcast annually were: zero, one half, one, and two pounds of B per acre. The split treatments were not rerandomized in the succeeding years so the residual soil B could be estimated for each rate of application.

Fertilizer applications were in accordance with recommendations for high yields, based on soil tests. All plots were prepared by mechanical means to provide a proper seedbed for crop establishment.

Each experimental unit had six rows in which the outside row of each unit was the guard row. All crops were planted on 40 inch row spacings.

Corn was seeded each year at the population of 15,000 plants per acre by a four row planter. The planting dates for the three years were:

May 1, 1969; May 5, 1970; and April 17, 1971. Weed control measures such as cultivation and herbicides were performed each year as needed. The four center rows of each plot were harvested in October of all years and the yields are reported in bushels per acre.

Corn leaf tissue was sampled each year in all plots. Corn tissue samples were taken when the other two crops were sampled. This occurred at or near the silking stage. The ear leaf was representatively sampled in each plot with a minimum of eight plants in each sample.

The cotton plots were planted each year by a four row planter and the plants were thinned to eight plants per foot. The planting dates were in the first week of May of each year. Weed control was attained by chemical means and cultivation as needed. The four center rows were harvested mechanically or by hand once or twice in October depending upon regrowth. The yields are expressed as pounds of seed cotton per acre.

Cotton leaf tissue samples were taken from all plots each year. The plots were representatively sampled at mid bloom stage in 1969 and both an early and late bloom stage in 1970 and 1971. All plots were representatively sampled by taking the uppermost mature leaf with a minimum of 15 leaves in each sample.

The soybean plots were planted each year by a four row planter and the plants were thinned to eight plants per foot. Each year the seed was treated with Mo at the recommended rate of 28 grams per bushel. The planting dates for the soybeans were: May 1, 1969; May 26, 1970; and June 1, 1971. Weeds were controlled by both mechanical and chemical

means. The four center rows were harvested and the resultant yields are reported in bushels per acre.

The soybean plots were sampled each year as were the other crops. In 1969 the plots were sampled only at the pod fill stage, but in 1970 and 1971 they were sampled at both the early bloom and pod fill stage. The upper most mature leaf was removed from a minimum of 12 plants in each plot.

All plant tissue samples were collected in paper bags, dried in a forced air oven at 60° C, ground in a Wiley mill and stored in plastic bags for subsequent analysis.

At the first tissue sampling of the three crops, representative soil samples were also taken from the upper eight inches of each plot with a Hoffer aluminum soil sampling tube. The samples were collected in plastic bags, air dried, ground with an iron mortar and pestle and stored in plastic bags for later analysis.

II. LABORATORY METHODS

Leaf tissue samples were analyzed for B by the curcumin-oxalic acid method reported by Jackson (27) as outlined in Appendix A. The B content of the plant tissue is reported in parts per million on a dry weight basis.

Several workers report a greater degree of correlation between the hot water soluble B in soils and the B level in plant tissue. The other methods are believed less suitable because the source of B is not readily available to the plant (1,5,42). As a result of these findings,

soil B was determined by the hot water soluble method as outlined by Jackson (27) in Appendix B.

The leaf tissue samples were digested by the wet oxidation procedure (Appendix C), as modified by Giesecking, Snider, and Getz (18). The samples were analyzed for Ca, Mg, K, and P although only Ca is reported here. The Technicon procedures were modified from those of Steckel and Flannery (55). The modified procedure is found in Appendix D. Tissue Ca content is reported in percent on a dry weight basis.

Soil pH values were determined on a 1:1 soil-water suspension.

III. STATISTICAL PROCEDURES

Analyses of variance were calculated on the individual stages of all crops each year to determine the effect of lime and B rates on Ca and B content. A combined analysis of variance was then performed on two stages of each crop in each of the two years. The two stages of growth were considered as split-split plots and analyzed as such. The analysis of variance for each year with two sampling dates was calculated on cotton and soybeans to determine year effects. Samples taken in 1969 from each crop were not included in any combined analysis of variance because only one sample had been taken.

Yields were combined by years in the analysis of variance of cotton and soybeans to determine and effects of year-treatment interactions. Corn yields could not be combined because different genotypes were seeded each year.

Duncan's New Multiple Range Test was used to separate means found to be different in an analysis of variance (32).

CHAPTER IV

RESULTS

I. CORN

Soil Tests

The soil pH values of the check and the limed main treatments in each of the three years are shown in Table I. The average pH values ranged from 5.1 on the unlimed check in 1969 to 7.2 in 1970 on the seven ton per acre lime rate. The pH values reached a peak in 1970 and declined in 1971. The decline began two years after the application of lime.

TABLE I
MEAN SOIL pH VALUES FOR LIME TREATMENTS IN CORN
PLOTS IN 1969, 1970, AND 1971

Treatment Tons Lime/A	Soil pH Values		
	1969	1970	1971
0	5.1	5.2	5.1
3.5	6.2	6.9	6.0
7.0	6.7	7.2	6.6

Unless otherwise stated in the following chapters, all treatment differences will be assumed significant at the $\alpha \leq .05$ level.

In 1970, the plots treated with three three and one half ton lime rate contained significantly greater water soluble B than the other lime treatments (Table II). In 1971 the lime applications of 1969 did not affect the hot water soluble soil B. The soil B ranged from 0.39 to 0.47 ppm in 1970 and 0.62 to 0.70 ppm in 1971. The soil B increased from 1970 to 1971 due to the B additions of 1971.

In the combined analysis of 1970 and 1971, lime had no effect on the soil B over the two years studied (Table II). A significant lime-year interaction was noted, which shows lime did not act the same in 1970 as in 1971, relative to the hot water soluble B.

Fertilizer B had a significant effect upon the hot water soluble B in both years, such that each B treatment effect was different from all other B treatment effects in the same year (Table II). In 1970 the hot water soluble B ranged from 0.25 ppm for the check to 0.70 ppm at the two pound rate, while 0.19 to 1.24 ppm B was the range in 1971.

The combined analysis of variance for the two years showed increasing rates of fertilizer B resulted in greater hot water soluble soil B (Table II). Each B treatment effect was different from all others over the two years. A significant boron-year interaction was noted which indicates that the B treatments did not act the same on the soil B in both 1970 and 1971.

Yields

Corn yields attributable to the 1969 lime applications are shown in Table III. In 1969 and 1970, with Pioneer 511A and Tennessee 606

TABLE II

MEAN AVAILABLE SOIL BORON IN CORN PLOTS AS INFLUENCED
BY BORON AND LIME RATES IN 1970 AND 1971

Treatment	Soil Boron, ppm		Mean
	1970	1971	
<u>Tons Lime/A</u>			
0	.40a*	.66a	.53a
3.5	.47b	.62a	.54a
7.0	.39a	.70a	.55a
<u>Pounds B/A</u>			
0	.25a	.19a	.22a
0.5	.33b	.44b	.38b
1.0	.41c	.77c	.59c
2.0	.70d	1.24d	.97d

*Treatments means followed by the same letter in the same column are not different at the .05 level of probability.

TABLE III

MEAN CORN YIELDS FOR THREE CORN CULTIVARS AS INFLUENCED BY BORON
AND LIME TREATMENTS IN 1969, 1970, AND 1971

Treatment	Corn Yields, Bu/A		
	1969 Pioneer 511A	1970 Tennessee 606	1971 Moews SM821W
<u>Tons Lime/A</u>			
0	72.0a*	76.6a	127.1a
3.5	78.1a	81.1a	139.4b
7.0	78.0a	85.3a	138.3b
<u>Pounds B/A</u>			
0	70.6a	77.7ab	133.6a
0.5	74.4ab	76.7a	133.8a
1.0	78.7bc	85.1c	133.2a
2.0	80.4c	84.6bc	139.1a

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

respectively, lime had no effect on yields. In 1969 the yields due to the lime treatments ranged from 72.0 to 78.1 bu/A, while in 1970 the range was 76.6 to 85.3 bu/A. In 1971 with the Moews cultivar, the two lime treatments were different from the check (Table III). The range of yields for 1971 was 127.1 to 139.4 bu/A. In each of the three years studied, the lime treatments increased corn yields although the yields were only significantly different in 1971 with the Moews cultivar.

The effects of added B on the yield of Pioneer 511A, grown in 1969, can be seen in Table III. Both the one and two pound rate of fertilizer B resulted in significant increases in yield over the check. The two pound rate of B resulted in a 14 percent increase in yield over the check. The yields ranged from 70.6 to 80.4 bu/A.

In 1970 B also had an effect on the yield of the Tennessee 606 variety (Table III). Plots treated at the one and two pound B rate yielded higher than the check plots. The one pound rate of B per acre resulted in a 9.5 percent increase in yield over the check. The yields ranged from 76.7 to 85.1 bu/A.

Table III shows that B rates had no effect on the yield of Moews SM821W in 1971. Although not statistically different, the two pound B treatment gave a 5.5 bu/A response over the check. The range of yields in 1971 were 133.2 to 139.1 bu/A.

Tissue Boron

Table IV shows the influence of lime and B in each of the three years of the experiment and on the leaf B content of the corn leaves. Lime had no effect on the ear leaf B content in 1969 with Pioneer 511A.

TABLE IV

MEAN BORON CONTENT OF CORN LEAVES AS INFLUENCED BY BORON
AND LIME TREATMENTS IN 1969, 1970, AND 1971

Treatment	Leaf Boron, ppm		
	1969	1970	1971
<u>Tons Lime/A</u>			
0	11.4a*	8.3a	11.1a
3.5	10.9a	7.9a	9.8b
7.0	10.8a	7.7a	9.1b
<u>Pounds B/A</u>			
0	10.3a	7.2a	7.1a
0.5	10.2a	7.0a	9.1b
1.0	10.6a	8.7b	10.1b
2.0	12.9b	9.0b	14.0c

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

No effect was noticed again in 1970 with Tennessee 606, although the lime had its greatest effect on the soil pH of this year. However, in 1971 with the Moews SM821W cultivar and as the lime effect on pH declined, the B content of plants grown on the check plot were significantly greater than the other lime treatments (Table IV).

Boron rates had an effect on the B content of the ear leaves of Pioneer 511A in 1969 (Table IV). The B content at the two pound B rate was different from the other treatment effects while the other treatment effects were the same. The B content in the ear leaf ranged from 10.2 to 12.9 ppm.

In 1970 with Tennessee 606, added B also had an effect on the ear leaf B (Table IV). With this cultivar, the plots treated at the one and two pound B rates differed from the one half and check rates. The ear leaf B range was 7.0 to 9.0 ppm.

Moews SM821W planted in 1971, as with the other cultivars, had increasing B contents with increasing rates of fertilizer B. The two pound rate of B resulted in the highest B content of all treatments, while the check had the lowest B content. The B contents ranged from 7.1 ppm B for the check to 14.0 ppm B for the two pound B rate, almost a 100 percent increase.

No evidence of deficiency or toxicity symptoms appeared in any of the three years on any of the cultivars, despite the soil B levels reaching a low of 0.19 ppm in 1971 and a high of 1.24 ppm in 1971.

Tissue Calcium

Ear leaf Ca content was determined in 1970 and 1971 with Tennessee 606 and Moews SM821W respectively (Table V). Lime had no effect on tissue Ca content of Tennessee 606 in 1970. In 1971 corn treated with the three and one half ton lime rate was different from both the check and the seven ton rate. The Ca content due to lime rates ranged from 0.60 to 0.66 percent in 1970, to 0.71 to 0.78 percent in 1971.

Table V gives the ear leaf Ca content for the B treatments in 1970 and 1971. Boron rates had no effect on the tissue Ca content of Tennessee 606 or Moews SM821W. No recognizable trends were observed. The Ca content ranged from 0.61 to 0.66 percent in 1970, to 0.71 to 0.75 percent in 1971.

The Moews cultivar contained more ear leaf Ca than did Tennessee 606, independent of B and lime treatments. This was true although the soil probably contained less Ca in 1971, as evidenced by the decline in the soil pH.

II. COTTON

Soil Tests

Table VI shows the average pH values for the lime treatments in all years. As in the case of corn, the soil pH values of the plots limed at the three and one half and seven ton rates reached a peak in 1970 and then began to decline in 1971. The average pH values ranged from 5.0 to 6.7 in 1969, 5.1 to 7.2 in 1970 and 5.0 to 6.6 in 1971.

Lime rates had no effect upon the soil B determinations in 1970 or 1971 (Table VII). The soluble B ranged from 0.33 to 0.36 ppm B in

TABLE V

MEAN CALCIUM CONTENT OF CORN LEAVES AS INFLUENCED BY BORON
AND LIME TREATMENTS IN 1970 AND 1971

Treatment	Leaf Calcium, Percent	
	1970	1971
<u>Tons Lime/A</u>		
0	.60a*	.70a
3.5	.66a	.78b
7.0	.66a	.71a
<u>Pounds B/A</u>		
0	.65a	.72a
0.5	.64a	.71a
1.0	.66a	.74a
2.0	.61a	.75a

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

TABLE VI

MEAN SOIL pH VALUES FOR LIME TREATMENTS IN COTTON PLOTS
IN 1969, 1970, AND 1971

Treatment Tons Lime/A	Soil pH Values		
	1969	1970	1971
0	5.0	5.1	5.0
3.5	6.3	6.7	5.8
7.0	6.7	7.2	6.6

TABLE VII

MEAN AVAILABLE SOIL BORON IN COTTON PLOTS AS INFLUENCED
BY BORON AND LIME RATES IN 1970 AND 1971

Treatment	Soil Boron, ppm		
	1970	1971	Mean
<u>Tons Lime/A</u>			
0	.33a*	.58a	.53a
3.5	.36a	.69a	.60a
7.0	.33a	.66a	.57a
<u>Pounds B/A</u>			
0	.30a	.21a	.25a
0.5	.37ab	.55b	.48b
1.0	.43b	.72c	.60c
2.0	.73c	1.08d	.93d

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

1970 to 0.58 to 0.69 ppm B in 1971. The soil B increased due to the addition of B in 1971. The combined analysis of variance for 1970 and 1971 revealed that lime had no effect on the soluble B over the two years.

Boron treatments had a significant effect on the available soil in both years (Table VII). In 1970 the plots treated with the two pound B rate contained twice as much available soil B as the check plots. The ranges of soluble B in 1970 ranged from 0.30 ppm B in the check to 0.73 ppm B at the two pound rate. In 1971 all soluble soil B levels were different from each other. The range in 1971 was 0.21 ppm in the check to 1.08 ppm B at the two pound rate.

The combined analysis for the two years showed that the B rates and years had a significant effect on the hot water soluble B. In 1971 there was more soluble soil B than in 1970. The range over the two years was 0.25 ppm B for the check, to 0.93 ppm B at the two pound B rate.

In the combined analysis of 1970 and 1971 a highly significant boron-year interaction was noted. This interaction, as in the case of corn, shows that the B rates might have acted on the soluble B in different manners in 1970 and 1971.

Yields

Table VIII shows the effects of lime rates on the yield of seed cotton over the three years studied. Lime rates had no effect on yields in any of the three years. The yields due to lime rates ranged from 2672 to 2866 pounds/A in 1969, to 2987 to 3267 pounds/A in 1970 and from 3029 to 3643 pounds/A in 1971.

TABLE VIII
 MEAN COTTON YIELDS AS INFLUENCED BY BORON AND LIME
 TREATMENTS IN 1969, 1970, AND 1971

Treatment	Cotton Yields, Pounds/A			Mean
	1969	1970	1971	
<u>Tons Lime/A</u>				
0	2672a*	2987a	3029a	2896a
3.5	2755a	3267a	3459a	3160ab
7.0	2866a	3212a	3643a	3240b
<u>Pounds B/A</u>				
0	2839a	3218a	3289a	3115a
0.5	2687a	3158a	3395a	3080a
1.0	2787a	3093a	3328a	3087a
2.0	2743a	3151a	3497a	3130a

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

The combined analysis for the three years indicates that lime did have an overall effect on yield such that the seven ton rate had a higher average yield than did the check rate (Table VIII). The combined analysis also pointed out that 1971 was the best yielding year followed by 1970. The 1969 cotton yields were the lowest in the study.

The effect of B rates on seed cotton yields can also be seen in Table VIII. There was no response to B additions in any of the years or in the combined analysis. The yields of seed cotton attributable to B rates ranged from 2687 to 2839 pounds/A in 1969, from 3093 to 3218 pounds/A in 1970, and from 3289 to 3497 pounds/A in 1971. The combined analysis indicated that B rates had no influence on the yield of seed cotton over the years. The average yields for the three years ranged from 3080 pounds/A at the one half pound rate to 3130 pounds/A at the two pound rate. No distinct yield trends can be seen from the data.

Tissue Boron

The 1970 first stage (mid bloom) mean cotton leaf B content, attributable to lime rates, is shown in Table IX. Samples from both the three and one half and seven ton lime treatment contained less B at the first stage of 1970 than did the check. The B ranged from 18.7 ppm at the seven ton rate to 25.7 ppm in the check. The three and one half and seven ton rates did not differ in their ability to reduce leaf tissue B present at the first stage.

In the second stage of growth (late bloom) lime rates had no effect on the B content (Table IX). The ranges were 15.0 ppm B at the seven

TABLE IX
MEAN BORON CONTENT OF COTTON LEAVES AS INFLUENCED BY
GROWTH STAGE, YEAR, BORON AND LIME

Treatment	Leaf Boron, ppm						Two Year Average
	1970			1971			
	S1	S2	Mean	S1	S2	Mean	
<u>Tons Lime/A</u>							
0	25.7a*	20.1a	22.9a	35.3a	30.9a	33.1a	28.7a
3.5	19.6b	16.7a	18.1b	35.4a	30.7a	33.0a	26.7a
7.0	18.7b	15.0a	16.8b	29.1b	28.6a	28.8a	23.7b
<u>Pounds B/A</u>							
0	16.6a	10.2a	13.4a	22.6a	27.2a	24.9a	20.0a
0.5	19.6a	13.9b	16.7b	31.6b	29.7b	30.6b	24.7b
1.0	20.6a	18.4c	19.5b	35.9c	30.5b	33.2c	27.3c
2.0	28.5b	26.6d	27.5c	42.9d	32.8c	37.9d	33.4d
<u>Stage</u>							
1			21.3a			33.2a	28.2a
2			17.3b			30.1b	24.6b

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

Legend: S1 - stage 1 - mid bloom.
S2 - stage 2 - late bloom.

ton rate to 20.1 ppm in the check. The combined analysis for the two stages of 1970 shows the cotton grown on the check plots averaged more leaf B than the two limed treatments (Table IX). The ranges were from 16.8 to 22.2 ppm B.

Table IX also shows the B content by stages of growth in 1971. In the first stage the seven ton lime rate treatment contained less leaf B than the other treatments, while in the second stage added lime failed to have an effect on the B content. In the first stage the B ranged from 29.1 ppm to 35.4 ppm while in the second stage the range was 28.6 to 30.9 ppm B.

The combined analysis of the two stages revealed that added lime had no effect on the B content over the stages studied in 1971. Apparently the lime treatment effect became negligible as maturity progressed, because over the two stages lime had no effect on B content. The ranges were 28.8 to 33.1 ppm B.

The combined analysis of variance for 1970 and 1971 showed that the lime had an effect on the cotton leaf B content. Over the two years studied, the seven ton lime rate significantly reduced the leaf B by three to five ppm, relative to the other two treatments.

In the first stage in 1970, the two pound B treated plots contained significantly more leaf B than the other treatments (Table IX). The B ranged from 16.6 ppm in the check to 28.5 at the two pound B application.

At the second sampling stage all B treatments were significantly different from each other (Table IX). Plant B ranged from 10.2 in the

check plots to 26.6 ppm in the two pound B treatment plots, or 2.5 times the B found in the check. In 1970 as the plant matured the effects of the B rates on the leaf B increased.

The combined analysis of the two stages in 1970 revealed that the check and the two pound rate of fertilizer B plots were different from the other treatments at the noted probability level (Table IX). The averages ranged from 13.4 to 27.5 ppm B.

Boron treatments in the first stage of 1971 had such an effect on the B content, that all treatment effects were different. The range was 22.6 ppm in the check plots to 42.9 ppm B in the plots treated with the two pound B rate. The two pound rate resulted in nearly twice as much B content over the check rate of fertilizer B at the first stage.

The second stage failed to maintain the same differences in the B content due to B treatments as in the first stage. In the check and the two pound rate, leaf B differed from the B content of the other two treatments. The B content in the second stage ranged from 27.2 to 32.8 ppm, nowhere near twice as much as in the first stage of 1971.

Added B had an effect on the B content when the combined analysis of variance was computed by stages in 1971 (Table IX). Each B treatment effect was different from all others. The treatment effects ranged from 24.9 ppm in the check to 37.9 ppm B at the two pound rate.

The combined analysis for 1970 and 1971 indicated that B fertilizer rates over the two years had a significant effect on the cotton leaf B. All treatment effects were different from each other, having a range of 20.0 ppm to 33.4 ppm B (Table IX).

The B content of the two stages of growth studied in 1970 were found to differ significantly. In 1970 the first stage averaged 21.3 ppm B while the second stage averaged 17.3 ppm B. Thus as the plant matured the percentage of the dry weight occupied by B decreased about 18 percent.

The stages of 1971 produced results like those of 1970. The stage B contents were again different as in 1970. The first contained 33.2 ppm B while the second averaged 30.1 ppm B.

The combined analysis of stages in years yielded information very much like that of the individual years. Year and stage B contents were different. The average leaf B content was higher in 1971 than in 1970 and the first stage over the two years averaged 28.2 ppm B while the second contained 24.6 ppm B. The net decrease from first stage to the second stage was about 13 percent.

A significant stage-boron interaction was noted in the combined analysis of 1970 and 1971. The response to B fertilizer rates on the B content was modified over 1970 and 1971 by the stage of growth sampled. Over the two years B rates had a greater effect on the tissue B in the first stage than in the second stage.

No symptoms of B deficiency or toxicity appeared in the three year test although the hot water soluble soil B and the B content reached a high in 1971 of 1.08 ppm B and 42.9 ppm B respectively.

Tissue Calcium

In 1970 the lime treatments had no effect on the percentage of Ca recovered in the cotton plant at the first stage (Table X). However in

TABLE X
MEAN CALCIUM CONTENT OF COTTON LEAVES AS INFLUENCED BY
GROWTH STAGE, YEAR, BORON AND LIME

Treatment	Leaf Calcium, Percent						Two Year Average
	1970			1971			
	S1	S2	Mean	S1	S2	Mean	
<u>Tons Lime/A</u>							
0	3.24a**	2.98a	3.11a	2.69a	2.06a	2.38a	2.69a
3.5	3.40a	3.63b	3.52a	2.99a	2.36b	2.68b	3.04b
7.0	3.53a	3.38b	3.47a	3.03a	2.52b	2.78b	3.07b
<u>Pounds B/A</u>							
0	3.58a	3.17a	3.38a	2.90a	2.34a	2.62a	2.94ab*
0.5	3.73a	3.41a	3.57a	2.96a	2.48a	2.72a	3.09a
1.0	3.06a	3.26a	3.16a	2.90a	2.40a	2.65a	2.87b
2.0	3.12a	3.48a	3.34a	2.85a	2.06b	2.45a	2.83b
<u>Stage</u>							
1			3.39a			2.90a	3.11a
2			3.33a			2.32b	2.75b

*Treatment means followed by the same letter in the same column are not different at the .10 level of probability.

**Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

Legend: S1 - stage 1 - mid bloom.
S2 - stage 2 - late bloom.

the second stage, the plants treated with the three and one half and seven ton lime rates contained a greater percentage of Ca than did the check plants. The leaf Ca ranged in the first stage from 3.24 to 3.53 percent, to 2.98 to 3.63 in the second stage. As the plants matured the effects of the three lime rates on the Ca content were variable.

The combined analysis of the growth stages in 1970 revealed that lime had no effect on the Ca content. The ranges were 3.11 percent Ca in the check to 3.47 percent in the plants treated with seven tons of lime.

As in 1970, lime had no effect on the 1971 leaf Ca content in the first stage but in the second stage the plants from the limed plots contained more Ca than did the check. The Ca content in the first stage of 1971 was 2.69 to 3.03 percent while in the second stage the range was 2.06 to 2.52 percent Ca. In 1971 the Ca content, relative to the dry matter, decreased as the plant matured.

The combined analysis for the 1971 stages shows that lime did have an effect on the leaf Ca over the stages such that the check and limed plant samples were different (Table X). This relationship occurred even though the lime levels in the soil probably declined with time, as indicated by the decline in the soil pH values.

The check plants contained significantly less Ca over the two years than did the plants grown on the other lime treatments (Table X), when the combined analysis of variance by years was calculated. The ranges over the two years are also shown in Table X.

Table X also shows that B rates had no effect on the percent Ca found in the cotton plant at either stage in 1970. The Ca content due to

fertilizer B applications ranged from 3.06 to 3.73 percent in the first stage to 3.17 to 3.48 in the second. The combined analysis for the two stages showed that the B rates, over the 1970 stages had no significant effect on the Ca content.

The first stage of 1971 gave results similar to those found in the two stages of 1970. No differences in the leaf Ca content due to B fertilizer rates are apparent. However, the range in Ca content due to B treatments narrowed to 2.85 percent at the two pound rate of 2.96 percent at the one half pound rate.

The second stage of 1971 produced results unlike those found in 1970. In this stage, the plants from the two pound rate plots contained a significantly lower Ca content than did tissue samples from other experimental units (Table X). Plants which had been treated at the two pound B rate contained about 14 percent less Ca than those treated with other B rates.

The combined analysis for growth stages of 1971 showed that over the two stages, the two pound B treatment did not affect the percent Ca found in the cotton. The two pound B rate plots averaged 2.45 percent Ca while those treated at the one half pound B rate contained a high of 2.72 percent Ca.

The combined analysis of variance for the two years (1970 and 1971) revealed information unlike that found in the individual year combined analyses. It showed that over the two years studied, plants from the plots treated at the one half pound B rate contained more Ca than did those treated at the one and two pound B rates (Table X). The two year average tissue Ca contents ranged from 2.83 percent to 3.09 percent.

The Ca content by stages was also interpreted by the combined analyses of 1970 and 1971 (Table X, page 36). In 1970 there was no difference between the Ca content at the first and second stages of growth. In 1971 however, the second stage Ca content was significantly lower than the first stage content (Table X, page 36). The averages for the stages ranged from 3.39 percent in stage one of 1970 to 3.33 percent Ca in the second stage of 1970. The first stage of 1971 averaged 2.90 percent Ca while the second contained 2.32 percent Ca.

Average Ca content by years and stages over years were significantly different. In 1970 the leaf Ca content was higher than in 1971 while over the two years the first stage averaged 3.11 percent Ca while the second averaged 2.75 percent.

III. SOYBEANS

Soil Tests

The soil pH values for the soybean plots during the three years are shown in Table XI. The average pH values ranged from 5.2 to 6.7 in 1969, 5.1 to 7.1 in 1970, and 5.3 to 6.6 in 1971. As in the case of the other two crops the lime application had its greatest effect on the soil reaction in 1970, while the effects declined with time.

Table XII shows the mean soluble B found in the soybean plots in 1970 and 1971. Lime in 1970 had a direct influence on the available B, in that each treatment effect was different from all others. The three and one half ton lime rate plots had the highest available B, followed by the check and the seven ton rate respectively. In 1970 the soluble

TABLE XI

MEAN SOIL pH VALUES FOR LIME TREATMENTS IN SOYBEAN
PLOTS OF 1969, 1970, AND 1971

Treatment Tons Lime/A	Soil pH Values		
	1969	1970	1971
0	5.2	5.1	5.3
3.5	6.2	6.6	6.0
7.0	6.7	7.1	6.6

TABLE XII

MEAN AVAILABLE SOIL BORON IN SOYBEAN PLOTS AS INFLUENCED
BY BORON AND LIME RATES IN 1970 AND 1971

Treatment	Soil Boron, ppm		Mean
	1970	1971	
<u>Tons Lime/A</u>			
0	.46a*	.56a	.51a
3.5	.50b	.56a	.53a
7.0	.38c	.61a	.50a
<u>Pounds B/A</u>			
0	.26a	.22a	.24a
0.5	.35b	.41b	.38b
1.0	.43b	.72c	.58c
2.0	.71c	.95d	.84d

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

soil B averaged from 0.38 ppm at the seven ton rate to 0.50 ppm B in the three and one half ton lime treatment.

Additions of lime did not produce the same effects on the soil B in 1971. The lime applications of 1969 had no effect on the soluble B in 1971. The available soil B ranged from 0.56 to 0.61 ppm (Table XII).

Lime did not have an effect on the average soil B over the two years studied, when the combined analysis of variance was calculated (Table XII). The analysis did show a significant lime-year interaction, indicating that lime probably did not influence the soil B in the same manner in 1970 as in 1971.

Fertilizer B rates had a significant effect on the soil B in 1970 (Table XII). The check and two pound B treatment effects were different from each other and the one half and one pound B treatment effects. The soluble soil B averaged from 0.26 ppm in the check plots to 0.71 ppm in the two pound B plots.

In 1971 each B treatment effect was different from all other effects (Table XII). The check plots averaged 0.22 ppm B while the two pound B fertilizer plots contained 0.95 ppm B or more than four times as much available B.

The results of the combined analysis of variance for the two years data indicate that each B rate had a significant effect on the soluble B over the years (Table XII). The averages of the two years ranged from 0.24 ppm in the check plots to 0.84 ppm B in the two pound B application plots.

The combined analysis for the soil B data of 1970 and 1971 also disclosed a significant boron-year interaction. This indicates that B

rates did not cause the soil B levels to react the same in both 1970 and 1971.

Yields

The lime applications of 1969 had no effect on the yields of Lee soybeans in any of the three years (Table XIII). The yields, attributable to lime applications, were 55.8 to 56.6 bu/A in 1969, 41.7 to 44.2 bu/A in 1970 and 37.7 to 41.2 bu/A in 1971.

In each of the three years, the yield on the three and one half ton lime plots was higher than the other treatments, although nonsignificantly. The combined analysis did reveal this trend, such that the yields due to the three and one half ton lime rate were different from the yields due to the lime check treatment at the .10 level of probability (Table XIII).

Boron rates had no effect on soybean yields in any of the years studied (Table XIII). The yields attributable to fertilizer B applications ranged from 55.1 to 57.1 bu/A in 1969, 42.2 to 44.1 bu/A in 1970, and 38.5 to 40.1 bu/A in 1971. No recognizable trends appeared in the data.

The combined analysis for the three years showed similar results to those of the individual years. The annual fertilizer B applications had no effect on the yield of the Lee soybeans (Table XIII). The three year averages ranged from 45.6 to 46.5 bu/A.

Tissue Boron

At the first and second stages of 1970 the soybean leaves from the check plots contained more B than did the tissue from the two limed

TABLE XIII
 MEAN SOYBEAN YIELDS AS INFLUENCED BY BORON AND LIME
 TREATMENTS IN 1969, 1970, AND 1971

Treatment	Soybean Yields, Bu/A			Mean
	1969	1970	1971	
<u>Tons Lime/A</u>				
0	55.8a*	41.7a	37.7a	45.1a
3.5	56.6a	44.2a	41.2a	47.3b
7.0	56.1a	43.6a	38.7a	46.1ab
<u>Pounds B/A</u>				
0	55.1a	42.2a	39.6a	45.6a
0.5	56.3a	43.4a	38.6a	46.4a
1.0	57.1a	43.2a	40.1a	46.5a
2.0	56.1a	44.1a	38.5a	46.2a

*Treatment means followed by the same letter in the same column are not different at the .10 level of probability.

treatments (Table XIV). The B content ranged from 35.9 to 41.5 ppm at the first stage and from 39.7 to 44.9 ppm B at the second stage.

The combined analysis yielded similar information as that found in the individual stages. At both stages, the B content of the leaves from the check lime treatment contained more B than did the two limed plots. Mean leaf B for three lime treatments in 1970 can be found in Table XIV.

The lime treatments did not have the same effect on the leaf B content in 1971 as in 1970. Lime had no effect on the B content at either stage sampled in 1971. The combined analysis showed similar results (Table XIV). The B content in the first stage ranged from 43.6 to 44.3 ppm B, while in the second stage the range was 46.9 to 49.5 ppm B. The range over the stages was 45.5 to 46.9 ppm B (Table XIV).

Over the two years studied, added lime did have an effect on leaf B content. Plants grown on the check plots contained greater B than did the tissue from the two limed plots. The combined analysis of the two years also revealed that the lime-year interaction was significant. This interaction indicates that the lime rates probably did not have the same effect on the leaf B in 1970 as in 1971.

Annual fertilizer B additions had a positive effect on the leaf B content of the Lee soybean cultivar in both the first and second stages of 1970 (Table XIV). In the first stage of 1970 the leaf tissue from

TABLE XIV

MEAN BORON CONTENT OF SOYBEAN LEAVES AS INFLUENCED BY
GROWTH STAGE, YEAR, BORON AND LIME

Treatment	Leaf Boron, ppm						Two Year Average
	1970			1971			
	S1	S2	Mean	S1	S2	Mean	
<u>Tons Lime/A</u>							
0	41.5a*	44.9a	43.2a	44.2a	46.9a	45.5a	44.3a
3.5	36.8b	41.4b	39.1b	44.3a	49.5a	46.9a	43.0b
7.0	35.9b	39.7b	37.8b	43.6b	48.9a	46.2a	42.0b
<u>Pounds B/A</u>							
0	22.8a	25.4a	24.0a	32.1a	41.2a	36.6a	30.3a
0.5	35.7b	40.2b	37.9b	44.1b	45.6b	44.8b	41.4b
1.0	45.2c	48.2c	46.6c	45.0b	52.0c	49.0c	47.8c
2.0	48.5c	54.3d	51.4d	54.9c	53.9c	54.4d	52.9d
<u>Stage</u>							
1			38.0a			44.0a	41.0a
2			41.9b			48.4b	45.2b

*Treatment means followed by the same letter in the same column are not different at the .05 level of probability.

Legend: S1 - stage 1 - early bloom.
S2 - stage 2 - pod fill.

the check and the one half pound B plots were different from each other and the other two treatments. In the second stage each treatment effect was different from all other effects. The tissue B content ranged from 22.8 to 48.5 ppm in the first stage, to 25.4 to 54.3 ppm in the second stage.

The combined analysis of variance produced similar information as that reported for the second stage. Over both stages in 1970, annual B applications resulted in greater leaf B content (Table IV). Average leaf B content in the two stages ranged from 24.0 to 51.4 ppm B.

In both stages of the 1971 growing season, B fertilizer rates increased the leaf B content. In the first and second stages the check contained less B than all other effects (Table XIV). The two pound B treatment, relative to the check, increased the leaf B by 22.8 and 12.7 ppm, in the first and second stages respectively.

Leaf B averaged by the stages in 1971 was found to differ significantly. Leaf B was found to range from 36.6 to 54.4 ppm at the check and two pound B treatment respectively.

The combined analysis by years indicated that B rates had a significant effect on the leaf B content of soybeans. Over the two years, each treatment effect was different from all other effects. The B content ranges over the two year period were 30.3 to 52.9 ppm B (Table XIV).

The boron-year interaction was also found to be significant in the combined analysis. This indicates that the B applications probably did not act the same on the B content in 1970 as in 1971.

Table XIV shows the average B content found in the two stages in 1970 and 1971. In 1970 the first stage sampled contained an average of 38.0 ppm B while the second contained 41.9 ppm B, an increase of ten percent. In 1971 the first and second stage contained 44.0 ppm and 48.4 ppm, respectively, again a ten percent increase in B content as maturity progressed.

The combined analysis of the years revealed that significant differences existed between stages and years. The first stage over the two years was found to average 41.0 ppm B while the second contained 45.2 ppm. The soybean leaves contained more B in 1971 than in 1970.

As in the case of the other two crops, no evidence of deficiency or toxicity appeared in any of the plots within the years, irrespective of the fact that the soil and leaf values of B varied, due to B and lime treatments.

Tissue Calcium

In the first stage of 1970 lime treatments did not affect the Ca content found in the leaves. In the second stage of the same year the plots treated at the three and one half and seven ton lime rates contained more Ca than did the check plots (Table XV). The first stage Ca content ranged from 0.88 to 0.97 percent while the second ranged from 0.98 to 1.21 percent.

The combined analysis of variance for 1970 revealed that lime treatments significantly affected the leaf Ca content. The soybeans from the check plots contained less Ca than those from the limed plots.

TABLE XV

MEAN CALCIUM CONTENT OF SOYBEAN LEAVES AS INFLUENCED BY
GROWTH STAGE, YEAR, BORON AND LIME

Treatment	Leaf Calcium, Percent						Two Year Average
	1970			1971			
	S1	S2	Mean	S1	S2	Mean	
<u>Tons Lime/A</u>							
0	0.88a*	0.98a	0.93a	0.89a	0.88a	0.88a	0.90a
3.5	0.97a	1.16b	1.07b	0.99ab	0.91a	0.95ab	1.01b
7.0	0.92a	1.21b	1.07b	1.06b	0.90a	0.98b	1.02b
<u>Pounds B/A</u>							
0	0.99a	1.14a	1.06a	1.00a	0.90a	0.96a	1.01a
0.5	0.92a	1.11a	1.02a	0.96a	0.90a	0.94a	0.98a
1.0	0.90a	1.12a	1.01a	0.92a	0.90a	0.92a	0.97a
2.0	0.91a	1.10a	1.00a	1.00a	0.82a	0.92a	0.96a
<u>Stage</u>							
1			0.93a			0.98a	0.95a
2			1.12b			0.89b	1.04b

*Treatments followed by the same letter in the same column are not different at the .05 level of probability.

Legend: S1 - stage 1 - early bloom.
S2 - stage 2 - pod fill.

Lime treatments probably did not react in the same manner in affecting the leaf Ca content of the two stages, as evidenced by the significance of the stage-lime interaction in the combined analysis of 1970. In the first stage lime rates had no effect on the Ca content of the samples. In the second stage, the rates did affect the leaf Ca content.

In 1971 the lime treatments had a significant effect on the leaf Ca content in the first stage but not in the second (Table XV). Plant analysis of leaves from plots treated at the seven ton lime rate contained more Ca than plants treated at the check rate. In the second stage all treatment effects were the same. The leaf Ca content ranged from 0.89 to 1.06 percent and 0.88 to 0.91 percent in the first and second stages respectively. The combined analysis over the growth stages indicated that the lime treatments had an effect on the tissue Ca content (Table XV). The 1971 stage-lime interaction was also significant.

The plant samples from plots treated with the three and one half and seven ton lime rates contained more Ca than the check plots over the two years studied (Table XV).

Boron additions did not affect the leaf Ca content in either stage of 1970. The tissue Ca content ranged from 0.91 to 0.99 percent and 1.10 to 1.14 percent in the first and second growth stages respectively. Table XV does show an interesting trend. As the rate of B increased, in both stages and the combined stages, there was less Ca present in the leaf tissue.

At the first and second stages of 1971 the effects of B treatments on the Ca content were mixed. No trend was apparent at the first stage

and a weak trend appeared at the second (Table XV). At the second stage the plants treated at the two pound B rate contained 0.82 percent Ca while the others contained 0.90 percent Ca.

The combined analysis of 1971 indicated a similar trend as in 1970 and a significant stage-boron interaction. As in 1970 it appeared, albeit nonsignificant, that increasing B rates tended to decrease the Ca content recovered in the soybean plant leaf. The ranges can be seen in Table XV. The boron-stage interaction indicated that the B treatments probably did not act the same on the Ca content over the stage studied in 1971.

The combined analysis for years indicated the same trend as in the individual years and a significant stage-year and stage-boron interactions. Table XV shows the same trend reported in the individual years occurred in the combined analysis for years. As B levels increased, although nonsignificant, Ca content tended to decrease as much as five percent.

The stage-boron interaction indicates that added B reacted differently on the leaf Ca content over the two stages. At the first stage, B rates had less of an effect in reducing the Ca content, but as the plant matured the B rates assumed a greater responsibility for reducing tissue Ca content.

There were differences in the mean Ca content by growth stages in 1970 and 1971 (Table XV). The Ca content in 1970 increased as the plant matured, while in 1971 the percent Ca decreased as maturity progressed.

The combined analysis for years revealed that stages, years and the stage-year interaction were significant. In 1970 on an average there was more tissue Ca present in bean leaves than in 1971 while over the two years the second stage averaged more tissue Ca than the first stage.

CHAPTER V

DISCUSSION

I. CORN

Soil Tests

The average soil pH values for the three and one half and seven ton lime rates reached their peak in 1970, one full year after the lime application. The 1971 soil pH values were approximately equal to the values reported for 1969. On most soils the lime application has its greatest effect on the soil pH level in the second year after application and the Loring series responded conventionally to the lime application.

In 1970 the plots treated at the three and one half ton lime rate contained more available B than any of the other treatments. Liming did not influence the soil B levels of 1971. The results of 1970 are somewhat contrary to the well documented observation that soil B availability often increases as the pH level decreases (Jackson, 27). The 1971 pH level differences, due to lime applications, were not great enough to result in any differences in the soil B availability. Perhaps in 1970 organic matter, pH level, microbial activity, and clay fixation interacted to increase the B availability in the three and one half ton lime plots.

Over the two years studied added lime did not influence soil B availability. The significant lime-year interaction occurred principally

because the 1969 lime applications influenced the 1970 soil B availability while the 1969 applications had no effect on the available B in 1971.

Boron treatments increased the water soluble B in 1970, 1971 and the combined analysis. Each treatment effect within the same year was different from all other effects. The results of the annual fertilizer B applications are similar to those results reported by Cox and Reid (9). These workers found that fertilizer B applications increased the available B in soils.

The yearly B applications of 1970 and 1971 acted differently on the soil B, as indicated by the boron-year interaction. The 1971 B applications had a greater effect on the available B than did the 1970 B applications. Climatic differences in the two years, pH levels, and clay fixation certainly could have resulted in the different effects on the soil B over the two years.

Yields

Lime treatments did not significantly increase the yields of Pioneer 511A and Tennessee 606 in 1969 and 1970 respectively. But the plots limed at the three and one half and the seven ton rate did outyield the check plots in both years. In 1971 the check plots yielded significantly lower than the two limed plots. The results of 1971 indicate that the Moews cultivar has either a greater need for Ca than the other varieties or the positive effects of liming on soils are more obvious with the Moews cultivar. If another experimental design had been used, the effects of lime applications on yields would have been more obvious.

Berger, Heikkinen and Zube (3) found that B applications significantly increased corn yields. In 1969 and 1970, the one and two pound B rates increased yields of Pioneer 511A and Tennessee 606 by nearly nine bushels in each year. The yields of Moews SM821W in 1971 was not affected by B applications. This varietal response seems to indicate that the Moews cultivar may be more efficient than the other cultivars with regard to the B requirement for optimum yields.

Tissue Boron

The lime application of 1969 did not influence ear leaf B in either 1969 or 1970. Pioneer 511A and Tennessee 606 appeared capable of obtaining equal amounts of leaf tissue B in the respective year regardless of the soil pH and lime level involved. In 1971 the Moews cultivar contained more leaf B at the check lime rate than at the other two lime application rates. The Moews cultivar removed greater B at the check lime rate, irrespective of the fact that the lime rates did not influence the 1971 soil B availability. The Moews cultivar apparently responds differently to the soil pH and B uptake than do the other cultivars. Climatic differences may also have influenced the apparent differences among cultivars.

The effect of fertilizer B applications on the resultant ear leaf B content of the three varieties was less than expected. Berger, Heikkinen and Zube (3) reported B applications increased the B content of the corn plant. In 1969 the two pound B treatments contained significantly more B than the other treatments. In 1970 the check and one half pound B treatments contained less B than the other two treatments, while

in 1971 the check and the two pound B application differed from the other treatments.

The results for 1969 indicated that two pounds of B were needed to raise the ear leaf B content significantly higher than the other treatments. The Moews SM821W and Tennessee 606 varieties required one half and one pound of B respectively to significantly raise the ear leaf B content over the check content. Again the effects of variety or year differences are shown because different B application rates are needed to significantly raise the leaf B content of these cultivars.

Gorsline, Thomas and Baker (19) have determined that the concentration of the ear leaf B is under genetic control with some degree of environmental influence. The results of this study seem to agree with their theory. Pioneer 511A, seeded in 1969 with probably the lowest available soil B, contained on the average, more ear leaf B than Tennessee 606 and Moews SM821W. However, the Moews cultivar, seeded in 1971 with the highest available soil B recorded in this study, contained more ear leaf B than Tennessee 606 but less than Pioneer 511A. If the B content had not been under genetic control and environmental control, the Moews cultivar should have contained the greatest ear leaf B in this study.

Tissue Calcium

Workers (26) have found that the greater the lime applications, the greater the resultant leaf Ca concentration. The results of this study did not show this relationship. The lime applications of 1969 did

not affect the leaf Ca level in the Tennessee 606 variety in 1970. The Moews cultivar in 1971 contained more ear leaf Ca at the three and one half ton lime treatment than the two other treatments. Perhaps a different experimental design might have illustrated that increasing lime applications resulted in greater ear leaf Ca.

Marsh and Shive (35) reported that B levels in nutrient solutions did not influence the corn leaf Ca content. The results of 1970 and 1971 are similar to those reported by Marsh and Shive. Tennessee 606 and Moews SM821W ear leaf Ca content was not influenced by fertilizer B rates.

Less than ten ppm B in monocots has been related with B deficiency by Wolf (62) while Marsh and Shive (35) have determined 25 ppm B in corn is the lower limit for B toxicity. No cultivar exhibited visual deficiency symptoms, even though the ear leaf B levels were less than ten ppm in two of the three cultivars. No toxicity symptoms appeared in any of the three years, therefore the soil B levels must not have reached a toxic level for the particular cultivar planted.

II. COTTON

Soil Tests

The lime applications of 1969 caused the soil pH level to behave in a similar manner as those reported for corn. The pH level reached its peak in the second year after application. The pH values for 1971 were very close to those of 1969.

Lime applications did not affect the available soil B in 1970 or 1971. Lime applications, having the effect of increasing soil pH levels,

have long been associated with decreased B availability. However, the experimental design used in this study did not illustrate this fact.

Fertilizer B applications increased the soil B levels in both years. The effects of B applications were more pronounced in 1971, as indicated by the significant boron-year interaction. Yearly climatic and pH differences may have caused the 1971 fertilizer B applications to have a greater influence on the soil B levels of the two years.

Yields

Additions of lime did not influence the individual yearly yields of the Hancock cotton cultivar, but over the three year study the seven ton lime rate yielded significantly more seed cotton than the check. This indicated the beneficial effects of lime on cotton yields on a Loring silt loam contrary to that reported by Long (33).

Fertilizer B rates did not influence the Hancock cultivar yields reported in this study. Long (33) received, with the Stardel cultivar, a significant yield response to banded B applications at three lime levels on a Loring silt loam. Long attributed his yield increases to the B applications effect on the soil B availability, which had been reduced by overliming. The results of this and Long's study seem to indicate varietal differences may influence the yield response to B applications.

Tissue Boron

In the first stage of 1970 the check plots contained significantly more leaf B than the other two treatments. In the second stage of the

same year all treatment effects were the same and the combined analysis gave information similar to that at the first stage. In 1971 the seven ton lime plots at the first stage contained less leaf B than the two other treatments while at the second stage and in the combined analysis, lime did not affect the B content of the Hancock cultivar. The data indicates that as maturity progressed the lime treatments had less of an influence on leaf B content. Wear and Patterson (61) found decreasing soil pH values resulted in greater B uptake in alfalfa. This study showed that the cotton check plots, with a pH of 5.1 in 1970, contained greater B than the limed plots. In 1971 the three and one half ton lime rate had less of an effect on the B content because the pH of levels of the plots were nearer to that of the check.

Fertilizer B applications significantly increased the cotton leaf B content in both stages of 1970 and 1971. Berger and Truog (5), Cox and Reid (9), Marsh and Shive (35), and Wear and Patterson (61) found similar results with other crops. The actual increase in the B content at each stage depended upon the fertilizer B increment. Using the 1970 and 1971 average B contents, each fertilizer B increment resulted in approximately the same B increase in 1970 as in 1971. It seems that the fertilizer B rates acted on the Hancock variety the same over the two years even though the check plot tissue B content nearly doubled from 1970 to 1971. This occurred irrespective of the fact that the available soil B was less in 1971 than in 1970. The check leaf tissue B content differences in the two years probably was due to the different rainfall distribution from year to year.

The two stages within 1970 and 1971 differed in leaf B content. At the first stage, the leaf B was on an average, four and three ppm greater than at the second stage, in 1970 and 1971 respectively. The dilution effect seemed to be responsible for the decrease in the B content as maturity progressed.

The stage-boron interaction over the two years studied indicated that fertilizer B rates increased the B content more at the first than at the second stage. This interaction might be more of a reflection of the dilution effect which occurs as maturity progresses.

Eaton (13) reported that less than 16 ppm B represents deficiency levels, 16 to 30 ppm B is an intermediate range and greater than 200 ppm B represents toxicity in cotton. By Eaton's standards, in 1970, the Hancock cultivar plots treated at the check and one half pound B application rate should have been deficient in B, although no visual symptoms were evident. In 1971, no plots contained less than 16 ppm and greater than 52.0 ppm B. No deficiency or toxicity symptoms appeared in either year. It seems that the Hancock cultivar has different B deficiency limits than those reported by Eaton and it might be necessary to include the stage of growth into B deficiency or toxicity symptoms, since the B content varies with maturity.

Tissue Calcium

In 1970 and 1971 lime applications did not affect the first stage Ca content but at the second stage the check plot tissue contained less Ca than the two limed plots. Over the two stages of 1970, liming rates

did not affect the leaf Ca content. In 1971 over both stages, the check contained less Ca than other lime treated plots. The combined analysis for 1970 and 1971 indicated the same results as those reported for 1971. These results are similar to those reported by Hourigan et al. (26), and Cox and Reid (9). These workers found greater lime applications resulted in increased Ca content of several plants.

It seems likely that over the two stages of 1970, the lime additions would have significantly affected the leaf Ca content had there been four replications and thus a greater number of degrees of freedom in the analysis of variance.

Fertilizer B rates did not influence the leaf Ca content at the first, second or combined stages of 1970. At the first and combined stages of 1971, B applications did not affect the leaf Ca content. These results agree with those published by Reeve and Shive (49) and Cox and Reid (9), where they report Ca and B uptake are independent of each other.

At the second stage of 1971 the plants treated at the two pound B rate averaged 0.28 to 0.42 percent less Ca than the other three B treatment effects. The combined analysis for years showed the one and two pound B treated plants contained less leaf Ca than the one half pound B rate (Table X, page 36). The high B rate at the second stage of 1971 and over the two year period seems to have hindered the accumulation of Ca in the leaf, or perhaps the total Ca level in the plant.

In 1970 the two stages did not differ in the percent Ca in the leaf tissue. At the second stage of 1971 the Ca content was significantly less than at the first stage. In 1971 the dilution effect was

apparent while in 1970, climatic variation may have accounted for the failure of the Ca content to drop significantly. If the available soil moisture was limiting early in the growing season, less nutrient uptake and dry matter were produced. Late season rainfall could result in higher nutrient concentrations, capable of overcoming the dilution effect.

The average leaf Ca contents of the Hancock cotton cultivar were greater in 1970 and 1971 than those values of the low and intermediate ranges of cotton leaves as reported by Melich and Reed (36). Although this was a lime study, this also indicates the apparent varietal differences.

III. SOYBEANS

Soil Tests

As in the case of the other two crops, the lime applications of 1969 had their greatest effect in the 1970 soil pH values. The soil pH levels reached their peak in 1970 and in 1971 the soil reaction was very close to that of 1969.

In 1970 the plots treated at the seven ton lime rate contained significantly less available soil B than the two other treatments. As in the case of the corn experiment of 1970 the three and one half ton lime application had the highest available B. The effect of the seven ton lime treatment on the soil B was conventional. Normally the three and one half ton lime treatment and the resultant higher pH value, would be expected to contain less available soil B than the check plots. The three and one half ton lime treatment may have stimulated the microbial

activity which enabled the microbes to free B from the organic matter and thereby nullify the depressing effect of liming on soil B availability.

The lime treatments of 1969 did not affect the 1971 soil B levels. It seems that the soil pH values of 1971 were close enough to nullify the decreased availability due to liming. Another experimental design might have shown the pH differences to be large enough to influence the B availability.

The fertilizer B rates significantly increased the available soil B levels of 1970 and 1971. The B applications did not influence the soil B in the same manner in 1970 as in 1971. The 1971 B fertilizer application increased the soil B more than the 1970 B applications. This was probably due to the decrease in the soil pH values from 1971 to 1970.

Yields

Lime rates did not have a significant effect on the yield of the Lee variety in any individual year. In each of the three years, although nonsignificant, the three and one half ton lime treatment resulted in the highest yields and the check treatments yielded the lowest. The three year average indicated that the three and one half ton lime treatment yielded more than the check (Table XIII, page 43). The three year average increase of 2.2 bu/A, due to the three and one half ton lime rate, occurred after a Mo seed treatment. Although this was not a Mo-lime-soybean study, the results point to the beneficial effect of liming at a three and one half ton rate. Had there been no Mo seed treatments in each year, the response due to lime would probably have been much greater.

Fertilizer B applications did not influence soybean yield averages in any of the three years or the three year average. This study agrees with that work reported by Long et al. (34), in which they received no response to B applications on Lee soybeans grown on a limed and unlimed Loring silt loam.

Tissue Boron

The 1970 leaves from plants from the lime check plots contained more B at the first and second stage than did plants from the other lime treatments. In 1971 the lime treatments did not affect the leaf B content at either stage. It is interesting to note in 1970 that the check plot tissue B content was the highest of the three treatments although the available soil B in the check plots was not the highest. This seems to indicate that the soil pH value may have a more important role in B uptake than that ascribed to soil B availability. It seems that the 1971 soil pH differences were not large enough to significantly influence the leaf B content.

The tendency of soybeans to accumulate B efficiently was indicated by the great response in B content due to the one half and one pound B applications. In both years, regardless of stage, these fertilizer B applications resulted in greater leaf B content. This greater efficiency may be manifested by the greater need for B. Chapman (7) reported that dicots require greater B than monocots, and Stinson (56) found that legumes require greater B than other plant families. It seems that the efficiency in B uptake may be due to necessity.

There was no evidence of deficiency or toxicity in any of the three years, probably due to the plant efficiency and the failure to reach toxic soil B levels. Evans, Lathwell and Mederski (14) reported 20 ppm B as an intermediate range for Earlyana soybeans. The B check plots averaged 24.0 and 36.0 ppm B in 1970 and 1971 respectively. The Lee cultivar was within the intermediate range in 1970 but not in 1971. Environmental differences in years or the decline in the soil pH level probably can account for the check plot tissue B differences, since the 1970 and 1971 check soil B levels were nearly the same.

Leaf B tended to accumulate as the soybean plant matured, as evidenced by the significant differences in the stage B content within years. The second stage of both years contained an average of ten percent more leaf B than the first stage. This failure of the leaf B to decline may indicate either soybeans, due to their efficiency in soil B removal, tend to remove B at a near constant rate throughout the growing season, or the sampling procedure used in this study was incapable of illustrating a dilution effect.

Tissue Calcium

Lime applications had mixed effects on the leaf Ca content within years. At the second stage of 1970 and the first stage of 1971, lime rates resulted in increases in the leaf Ca content. At the first stage of 1970 and the second stage of 1971, the lime applications did not affect the leaf Ca. The probable cause for the variation was an early moisture limitation in 1970 which resulted in a low Ca uptake. The data for 1970 (Table XV, page 48) indicates that in dry weather the soil Ca

level will not increase the leaf B content at early bloom. However as the plant matures, lime rates will increase the leaf tissue Ca content. In 1971 perhaps a more normal year, as the plant matured, liming rates had less of an influence on the leaf Ca. These results agree with those reported by Cox and Reid (9) and Hourigan et al. (26).

Fertilizer B applications did not significantly influence the leaf Ca content at any time during this study. The 1970 and 1971 averages did reveal, although nonsignificant, that as B rates increased, the leaf Ca content tended to decrease. Cox and Reid (9) have reported that Ca and B do not affect the uptake of each other. The results of this study tend to refute this theory. The stage-boron interaction in the combined analysis of years, further supports the theory that B may affect the Ca level in the soybean plant. At the first stage B rates had less of an effect on the leaf Ca content than at the second stage. It seems that as the plant matured the B rates tended to depress the leaf Ca content. The Lee cultivar in both years, accumulated leaf B as maturity progressed. Perhaps an imbalance, such as that described by Shear, Crane and Myers (52), occurred and resulted in less Ca in the leaf.

The stage of growth sampled had a significant effect on the Ca content. In 1970 the leaf Ca increased as the plant matured, while in 1971 the Ca content decreased with maturity. Early season moisture deficits in 1970 probably caused the increase in the Ca content with maturity. In 1971 the dilution effect was prominent.

Evans, Lathwell and Mederski (14) studied the Ca content of mature leaves of Earlyana soybeans. They report that leaf Ca contents

of less than 0.57 percent indicate deficiency while 1.34 percent is an intermediate range. The Lee cultivar contained neither less than 0.88 percent or more than 1.21 percent Ca in the youngest mature leaf. Evans, Lathwell, and Mederski (14) however did not reveal if the leaf sampled was the youngest or oldest mature leaf. The relative immobility of Ca within the plant, the particular growth stage and varietal differences could all account for the differences in the leaf Ca content of Earlyana or Lee soybeans.

CHAPTER VI

SUMMARY

Experiments were conducted on a Loring silt loam in 1969 through 1971 to determine the effects of B and lime applications on the yield and the B and Ca content of corn, cotton, and soybeans. Two growth stages in 1970 and 1971 were studied on cotton and soybeans to determine the extent of Ca and B fluctuations in the leaf with physiological maturity.

The yields of two corn varieties, Pioneer 511A and Tennessee 606, were significantly increased by B applications. In 1969 corn yields were increased by 8.1 bu/A with a one pound B application, while in 1970 the yields were increased by 7.9 bu/A with the two pound B treatment. Fertilizer B applications significantly raised the 1970 and 1971 available soil B and the B rates increased the ear leaf B content although the effects varied with the cultivar or year. Fertilizer B rates did not influence the ear leaf Ca content of the Tennessee 606 and the Moews SM821W cultivars.

Liming the soil significantly increased the yield of the Moews SM821W corn variety in 1971. Lime applications had a mixed effect on the soil B availability in 1970 and 1971. Liming did not influence the leaf B content in 1969 and 1970. In 1971 the added lime increased the leaf Ca and decreased the B content. Liming did not affect the 1970 ear leaf Ca level.

Fertilizer B applications did not affect the yields of the Hancock cotton cultivar in any year. Available soil B levels were greatly

increased by the B applications of 1970 and 1971. Additions of B raised the cotton leaf B levels in 1970 and 1971. At the late bloom stage of 1971 and over the two years, the high fertilizer B rates reduced the leaf Ca content of the Hancock cultivar.

Lime applications did not significantly influence the yearly Hancock yields but over the three years the high lime treatment yielded significantly greater than the check. Lime did not influence the available soil B or the 1971 leaf B content. In 1970 the two lime treatments reduced the leaf B content. In 1970 the leaf Ca content was not influenced by liming while in 1971 the two lime treatments contained more Ca than the check leaves.

In both years the B content of Hancock cotton decreased with maturity while the effects of growth stage and Ca were mixed. In 1970 the Ca content remained constant as maturity progressed. The 1971 leaf Ca content decreased significantly as the plants matured.

Fertilizer B rates had no effect on the yield of Lee soybeans in any year. The added B did significantly increase the available soil B levels in both years. The leaf B levels of 1970 and 1971 were increased markedly by B applications. Although nonsignificant, B applications seemed to decrease the leaf Ca level of Lee soybeans.

Lime applications did not affect the soybean yields in an individual year, but over the three years the three and one half ton lime treatment yielded 2.2 bu/A more than the check. The effects of lime rates on soil B availability were mixed and the two lime treatments reduced the leaf B content in 1970. Lime treatments had a significant effect on the tissue Ca content in 1970 and 1971.

Soybean leaf B tended to increase as the plant matured while the Ca content varied with maturity and year. In 1970 the Ca content increased significantly and in 1971 the leaf Ca decreased with age.



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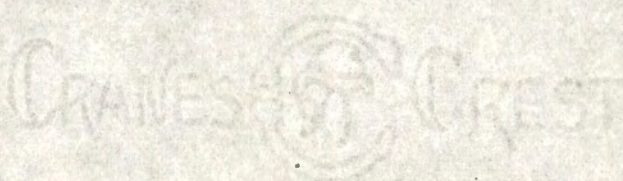
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APPENDIXES



APPENDIX A

PROCEDURE FOR THE DETERMINATION OF PLANT TISSUE B

1. Prepare the B stock solution by dissolving 0.572 gm of dry reagent grade H_3BO_3 in one liter of distilled water, giving 100 μgm of B per ml of standard. The stock solution is then employed for making up a series of standards for the calibration curves.
2. Dissolve 0.10 gm of finely ground curcumin and 12.5 gm of $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ in 250 ml of 95 percent ethanol. Store in a cool dark place.
3. Weigh a 0.500 gm of oven dry ground plant sample into a crucible.
4. Ignite gently in a muffle furnace at 500°C for four hours.
5. Allow the crucible to cool. Pipette 10.0 ml of 0.1N HCl into each crucible and triturate thoroughly. Filter the material with retentive filter paper into plastic beakers.
6. Aliquot one ml of the filtered liquid into plastic beakers and add four ml of the curcumin-oxalic acid solution. Evaporate to dryness at $55 \pm 3^\circ\text{C}$.
7. Add 25 ml ethanol to the dried residue to extract the color. Filter the solution into one cm cuvettes and read on a spectrophotometer at 540 m μ .
8. From the standard curve absorbances, read the μgm B, subtract the blank and multiply by 20 to calculate the ppm B in the sample.

APPENDIX B

METHOD FOR THE DETERMINATION OF THE HOT WATER

SOLUBLE B IN SOILS

1. Prepare the B stock solution and the curcumin-oxalic acid solution as in Appendix A.

2. Place a 20 gram sample of the air dried and sieved soil in a 125 ml boron free boiling flask, add 40 ml of distilled water, and attach a reflux condenser constructed with B free tubing. Reflux for five minutes and cool. Prepare a blank with 40 ml of distilled water in the same manner. Carry the blank through all subsequent steps.

3. Add three drops of 1N CaCl_2 and filter. Pipette 20 ml into a plastic centrifuge tube. Centrifuge for ten minutes. Pour the 20 ml into a porcelain evaporating dish. Add one ml of saturated $\text{Ca}(\text{OH})_2$ and evaporate to dryness.

4. Add five ml of 0.1N HCl to the dish, triturate thoroughly, and filter the solution with nine cm filter paper into plastic beakers.

5. Pipette a one ml aliquot into another plastic beaker and add four ml of the curcumin-oxalic acid solution. Mix the two solutions by rotating the beaker. Proceed with the determinations as in Appendix A, parts six and seven.

6. From the standard curve absorbances, read the $\mu\text{gm B}$, subtract the blank, and multiply by one half to calculate the hot water soluble B in the soil.

APPENDIX C

PROCEDURE FOR THE ALUMINUM HEATING BLOCK METHOD OF WET ASHING OF PLANT TISSUE FOR Ca, Mg, K, AND P ANALYSIS

1. Weigh 0.500 gm of each oven dry, ground sample into a 50 ml tube containing two small glass beads.
2. Add three ml of concentrated nitric acid to each sample, and place a small glass funnel in the mouth of each tube to act as a condenser. Allow the samples to predigest at room temperature overnight in the aluminum heating block.
3. Place the heating block on a hotplate, heat to 150°C , and digest at this temperature for one hour. Allow samples to cool to room temperature.
4. Add two ml of 60 to 70 percent perchloric acid to each tube through the funnel, and digest at 235°C for two hours or until the liquid in each sample is clear. Remove funnels and allow to cool to room temperature.
5. Add one ml of concentrated hydrochloric acid, and digest at 150°C for 15 to 20 minutes.
6. Transfer the cooled samples to 100 ml volumetric flasks and bring to volume with distilled water.
7. Shake flasks to mix contents, and allow to stand overnight before analysis on the AutoAnalyzer.

APPENDIX D

DETERMINATION OF Ca TISSUE CONCENTRATION BY AUTO ANALYSIS

1. Calcium determinations were made by using the Technicon III dual channel flame photometer. Lithium nitrate (0.525 g in one liter of water) was used as a standard and lanthanum chloride (five g in one liter of distilled water) was used to increase the Ca flame response. The proportioning pump-manifold supplies the correct volume of sample, LiNO_3 and LaCl_3 to the flame photometer.
2. From a series of Ca standards, calculate the ppm and multiply by .02 to determine the percent Ca of the dry weight.

VITA

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