BORON ASSIMILATION AND ITS

EFFECT ON THE QUALITY

OF SPANISH PEANUTS

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CHAPTER I

INTRODUCTION

Spanish peanuts are an important cash crop in Oklahoma, ranking third in total cash income, following wheat and alfalfa. They have the highest gross income per acre of any crop grown in Oklahoma. Improved varieties and the use of fungicides, herbicides, insecticides, fertilizers and irrigation have contributed greatly to peanut production.

Recently internal damage of peanuts has been considered commercially in peanut quality. Boron deficiencies cause hollowed, misshapen and dark colored nuts. This internal damage restricts the use of peanuts, lowering their value. As a result, some peanut producers have had large financial losses. Internal damage due to boron deficiencies can be eliminated and peanut quality can be greatly improved with boron fertilizer applications. Peanuts, however, have a very narrow range between boron deficiency and toxicity. A test is needed to determine the boron status of a peanut crop, which would aid in making boron fertilizer recommendations.

This study was designed to determine if a foliar analysis can be used to determine the boron status of a peanut crop.

CHAPTER II

LITERATURE REVIEW

Soils vary greatly in boron content. Some contain excessive amounts of boron and cause boron toxicity in many plants. Other soils contain insufficient boron to support normal plant growth. The soils where excess boron is most likely to occur are: 1) those derived from marine sediments, 2) arid soils, 3) soils derived from parent material rich in boron, and 4) soils derived from geologically young deposits. Those in which boron deficiencies are most common are: 1) soils naturally low in boron, such as derived from acid igneous rocks or fresh water sedimentary deposits, 2) naturally acid soils from which much of the original boron content has been removed by leaching, 3) light-textured sandy soils, 4) acid peat and muck soils, 5) alkaline soils, especially those containing free lime, 6) irrigated soils where the content of boron in the water is low and where salt or carbonate deposits occur, and 7) soils low in organic matter (Bradford, 1966).

Boron in the soil can be either fixed or water soluble. The fixed boron may be present as tourmaline (a borosilicate), organically combined boron, or adsorbed boron.

Tourmaline is probably the main source of boron in many soils of the humid regions (Berger and Pratt, 1963). It is very slow to weather, releasing only traces of soluble boron (Graham, 1957). This release of boron is undoubtedly too slow to supply the boron needs of most crops

(Berger and Pratt, 1963).

Organically fixed boron is present in organic matter of soils. Boron is released by microbial decomposition of organic matter as a water soluble form. Water soluble boron is found to be positively correlated with the organic matter of the soil (Gupta, 1968; Berger and Truog, 1945). Berger and Pratt (1963) and Page and Paden (1954) considered organic boron to be the main source of water soluble boron in humid regions.

Boron may also be fixed by adsorption on fine soil particles. A high correlation was found by Hatcher and Bower (1958) between the total surface area of three soils and their adsorptive capacity of boron. Adsorption or fixation was greatly influenced by the soil environment. Wetting and drying of the soil increased boron fixation (Parks and White, 1952; Biggar and Fireman, 1960). High pH decreased boron movement and increased the adsorption of boron (Hingston, 1964; Kubota et al., 1948; Okazaki and Chao, 1968; Olson and Berger, 1946).

Hingston (1964) found that boron was adsorbed by the clay fraction of the soil. Sims and Bingham (1967) attributed the boron retention on clay materials to the hydroxy iron and aluminum compounds that occurred as impurities in the clays. Boron retention by hydroxy iron and aluminum compounds was pH dependent with the maximum occurring in the alkaline range (Sims and Bingham, 1968a). Hydroxy aluminum retained more boron than hydroxy iron materials. The highest correlations with boron retention were found with free iron oxides and 1.0 N KCl extractable aluminum oxides (Sims and Bingham, 1968b).

Water soluble boron is mobile. Added water soluble boron moves very rapidly through coarse textured soils (Wilson et al., 1951, Kubota et al., 1948; Winsor, 1952). The boron movement lagged behind water movement, indicating some interaction with the soil (Kubota et al., 1948). Boron moved less rapidly in fine textured than in coarse textured soils (Kubota et al., 1948; Wilson et al., 1951).

The boron available for plant uptake was found to be the water soluble fraction. Red kidney bean seedlings responded directly to water soluble boron in soils and not to adsorbed boron (Hatcher et al., 1959). The amount of boron absorbed by sunflowers from aqueous solutions depended on the concentration of water soluble boron, regardless of the boron source (Colwell and Cummings, 1944).

Elseewi et al. (1968) concluded that H_3BO_3 was more available to plants than were borate ions. They found that the absorption of boron in barley was pH dependent. Sharp reductions in boron uptake occurred in substrates with pH values above 7 to 8.

The absorption of boron was found to be a passive process. Uptake in the acid range is rapid, resulting in concentrations within the plant tissue equal to that of the substrate. Absorption was not affected by metabolic inhibitors in the nutrient media or by temperature (Elseewi et al., 1968).

Factors that increased transpiration in barley seedlings also increased boron accumulation in the leaf tips. Factors that decreased water uptake resulted in less boron movement toward the leaf tips. However, no equivalence between boron and water uptake was observed. Water consumption was in excess of boron uptake (Oertli, 1963).

Boron moved away from veins in the leaf to the tips and marginal areas. In net veined leaves, boron became more concentrated in the marginal and interveinal areas (Oertli, 1960), while in parallel veined leaves the highest concentrations were found at the tips (Kohl and

Oertli, 1961). Boron can accumulate to toxic levels in these areas (Oertli and Kohl, 1961).

Boron toxicity results directly from high concentrations of boron in the plant cell. Oertli and Kohl (1961) found boron concentrations for toxicity to be about 1000 ppm. This concentration is of the same order of magnitude for all species investigated. The differences in time required for toxic symptoms to appear is directly related to the rate of boron accumulation by plants rather than differences in concentrations.

Boron deposited within a leaf appears to remain. Only in stone fruit did Eaton (1944) find any great degree of boron movement from leaves to other parts of the plant. Boron was found to be in a soluble and mobile form (Eaton, 1944; Kohl and Oertli, 1961).

Boron is not readily translocated to the root tips. In a split root system, Albert and Wilson (1961) found that roots supplied with boron did not support elongation of root tips deficient in boron. Neals (1960) found only 27 percent of the boron in the bean cotyledon to be available for radicle growth.

Boron deficiency symptoms occur in the young growth because boron is relatively immobile once deposited in plant tissue (Sprague, 1964).

Boron deficiency symptoms in peanuts can be observed in the young foliage. Boron deficient plants have stubby shoots. The leaves are frequently mottled, sometimes wilted, and may drop off. Dark areas may appear in the internodes of the branches, sometimes becoming cracked (Reid and York, 1958; Harris and Brolmann, 1966b).

The quality of peanuts and peanut production are greatly reduced by boron deficiencies. Nuts deficient in boron are hollowed, misshapen and dark colored. The tips of the plumules are tan in some cases (Harris and Brolmann, 1966c). Yields are decreased by poor fruit development (Harris and Gilman, 1957; Reid and York, 1958). Additions of calcium or boron will reduce cotyledon and plumule damage in peanuts. Boron, however, is more effective in eliminating cotyledon damage (Cox and Reid, 1964). Internal damage and boron deficiency symptoms were intensified by the addition of a complete fertilizer (Harris and Brolmann, 1963; Harris and Brolmann, 1966a).

Soil tests and plant analyses have been used to assay the ability of the soil to supply boron for plant growth. Using three soils, Berger and Truog (1940) found good correlations between hot water extractable boron and the boron content of beet leaves. Stinson (1953) found a positive relationship between maturity and productivity of alfalfa and the amount of water soluble boron in soils. Sunflower yields were significantly correlated with water soluble boron (Baird and Dawson, 1955). Smith (1948), on the other hand, found no good indications that water soluble boron could be correlated with yield response from soils of Southeastern Kansas.

Ouellette and Lachance (1954) considered plant analysis as being more reliable in determining the supply of boron for alfalfa in Quebec than water extractable boron in the soil. If soil texture is taken into consideration, then the soil analysis becomes a rather dependable indication of the boron status of a soil.

Baker and Cook (1959) found that water soluble boron was poorly correlated with the boron in alfalfa plant material from their greenhouse studies. The boron supplying power of soils seems to be a function of the rate of equilibrium establishment as well as the equilibrium concentration.

Wear and Patterson (1962) found that the uptake of boron by alfalfa is greater from acid and coarse textured soils than from fine textured soils and soils with higher pH values. This indicates that texture and pH must be considered when using water soluble boron as an indication of boron availability to plants.

Smith (1948) and Gupta and Munro (1969) considered plant analyses to be a better index of boron availability than soil testing. The soil test, however, has the advantage of indicating the possibility that a boron deficiency could occur before a crop is planted.

Boron contents from plant analyses varied with the plant part sampled. Dible and Berger (1952) found that the bottom part of an alfalfa plant could contain adequate boron while the tips were deficient. Stewart and Axley (1956) found a great seasonal variation in boron content of alfalfa. The top 15 inches of the plant were more responsive to changes of boron in the soil than were the total shoots. Baker and Cook (1959) found that the apical leaves of boron deficient alfalfa were lower in boron content than the lower leaves.

Martens et al. (1969) found that the boron content of the leaves and stems of Spanish peanuts decreased with maturity. The leaves decreased from about 40 ppm boron in June to 20 ppm in October. The plots used in his study were on a Woodstown loamy fine sand and contained 0.21 ppm hot water soluble boron.

Cox and Reid (1964) found an inverse correlation between internal damage and boron contents in NC 4x peanuts. Plants which contained

11 ppm boron at harvest had 10 percent damaged nuts while plants with 18 ppm boron had only 4 percent of the peanuts damaged.

CHAPTER III

MATERIALS AND METHODS

This study includes both greenhouse and field plot studies. Greenhouse experiments were divided into three areas; 1) boron uptake and distribution as influenced by boron availability in the soil, 2) critical levels of boron in peanut leaves, and 3) the critical time of supplying boron to the plant. The greenhouse work was then extended to field conditions.

Greenhouse Studies

Argentine variety Spanish peanuts were planted in pots containing 4000 grams of soil. One plant was grown in each pot. All pots received similar applications of 100 ppm K as K_2SO_4, 100 ppm P as $CaHPO_4$, and 20 ppm N as $Ca(NO_3)_2$ at planting. They received an additional 100 ppm K, 100 ppm P, and 30 ppm N as K_2HPO_4 and $(NH_4)H_2PO_4$, and 140 ppm Ca as $CaSO_4$ at 60 days. The greenhouse experiments were arranged in a completely random design.

Uptake and Distribution of Boron in Peanut Plants

In the preliminary study on boron uptake and distribution, peanuts were grown in a Eufaula loamy fine sand soil. The experiment extended over a 70 day period. The soil initially contained 0.12 ppm hot water soluble boron. Four levels of boron were applied to the soil, 0, 0.25, 0.5, and 1.0 ppm as boric acid. The treatments were applied after peanut emergence. Four replications were intended, but after boron determinations were made, it became apparent that one of the 0.25 ppm boron treatment pots had received no boron. During the period of 20 to 70 days after planting leaflet samples were collected at 10 day intervals. Sixty days after planting leaf petioles were also collected. At 70 days, petioles, gynophores, and leaf samples were collected for boron analysis.

Critical Levels of Boron in Peanuts

Peanuts were grown in a Yahola loamy very fine sand for this experiment. The soil initially contained 0.10 ppm hot water soluble boron. Young leaves were sampled for boron analysis every seven days. Boron was added and water was controlled in an attempt to maintain specific boron levels in the young leaves. Since the desired results were not obtained in the first try, this experiment was repeated. The second attempt differed only in that the soil was steam treated in an autoclave before planting. Both experiments were replicated four times. After 120 days, peanuts were harvested and graded for internal damage.

Critical Time of Boron Supply

Both steam treated and non-treated Yahola very fine sand was used for this study. In one group applications of 1000 μg boron were made to the soil (4000 g) at varied times. Another group of soils received 500 μg boron at emergence. At varied times pots were leached with 500 ml. of water daily for a two week period. The first group was unevenly replicated from 2 to 4 replications. The latter group was replicated twice. Leaf samples for boron analysis were collected every 15 days. After 120 days, the peanuts were harvested and graded for internal damage.

Field Experiments

Field studies were conducted at three locations; McAlester, Durant, and Ft. Towson, Oklahoma. Each experiment was arranged in a randomized complete block design, with three replications.

The plots at McAlester were on a Yahola loamy very fine sand. The soil contained 0.10 ppm hot water soluble boron. Starr Variety Spanish peanuts were planted on June 3, 1969. The fertilizer applications were made on June 23, applied as a band 3 to 4 inches from the row. The fertilizer treatments included 0-0-0, 20-80-40, 20-80-40 plus 0.5 pound of boron per acre and 20-80-40 plus 1 pound of boron per acre. The plots were established in 1967, and had received the same treatments each year thereafter. The plot size was 15 feet (six-30 inch rows) by 60 feet.

The plots were located on a Norfolk loamy fine sand at Ft. Towson. The soil contained 0.04 ppm hot water soluble boron. Starr peanuts were planted on June 6 in plots 17 feet (six-34 inch rows) by 60 feet. The nitrogen, phosphorus, and potassium fertilizers were applied as a band at planting. The boron applications were made on July 31. The boron was applied as a spray directed toward the base of the plants. The treatments included 0-0-0, 20-80-40, and 20-80-40 plus 1 pound of boron.

The plots at Durant were located on a Durant loam, which contained 0.48 ppm hot water soluble boron. Starr peanuts were planted on June 5.

The treatments were the same as for Ft. Towson.

Leaf and petiole samples were collected every 2 weeks at McAlester and every 4 weeks at Ft. Towson and Durant. The collections were made from July 16 through October 4. Three stages of growth were sampled on each sampling date. Each sample consisted of six leaves including petioles collected at random from the 2 center rows of the plot. Each leaf was dipped in distilled water at the time of sampling to remove any dust. The leaflets and petioles were separated, then stored in folded waxed paper. Soil moisture samples were also taken on each sampling date, and the soil moisture data are shown in Table VI, appendix.

The mature peanuts were dug with a peanut digger and threshed with a peanut combine. A one pound subsample was collected from each plot. From this subsample, 100 kernels were split and graded for internal damage.

Boron Analysis

All plant samples were oven dried at 85 degrees C. The boron determinations were made by the simplified curcumin procedure as described by Dible et al. (1954), with one change. The evaporated sample was taken up in technical grade acetone instead of 95% ethyl alcohol.

Hot water soluble boron in the soil samples was determined by the modified curcumin procedure as described by Baker (1964).

Statistical Analysis

An analysis of variance was made on each field location. An analysis of variance was performed for each leaf separately for the greenhouse data. Correlation coefficients were calculated where warranted.

CHAPTER IV

RESULTS AND DISCUSSION

Uptake and Distribution of Boron in Peanuts

The boron content of the peanut plant reflected the boron availability in the soil. In the greenhouse studies, plants grown in the soil with the highest boron treatment contained the most boron. Plants grown in the soil with the lowest boron treatment contained the least boron. The results are illustrated in Figures 1 and 2. As boron was removed from the soil by the plants, less remained available. This was indicated by the decreased boron content of the leaves at later sampling dates compared to the earlier sampling dates.

Boron Content of Leaves

Two assumptions were made in an attempt to establish boron concentration trends in individual leaves: 1) the boron content of each leaflet is the same as every other leaflet on the same leaf, 2) the remaining leaflets of each leaf will continue to function in a "normal" manner after the removal of a leaflet. A subsequent analysis was made to determine the validity of the first assumption. At the conclusion of the experiment on the critical boron levels, older leaves were collected for boron analysis. Each leaflet was analyzed and treated as a subsample. An analysis of variance, shown in Table I, indicated the

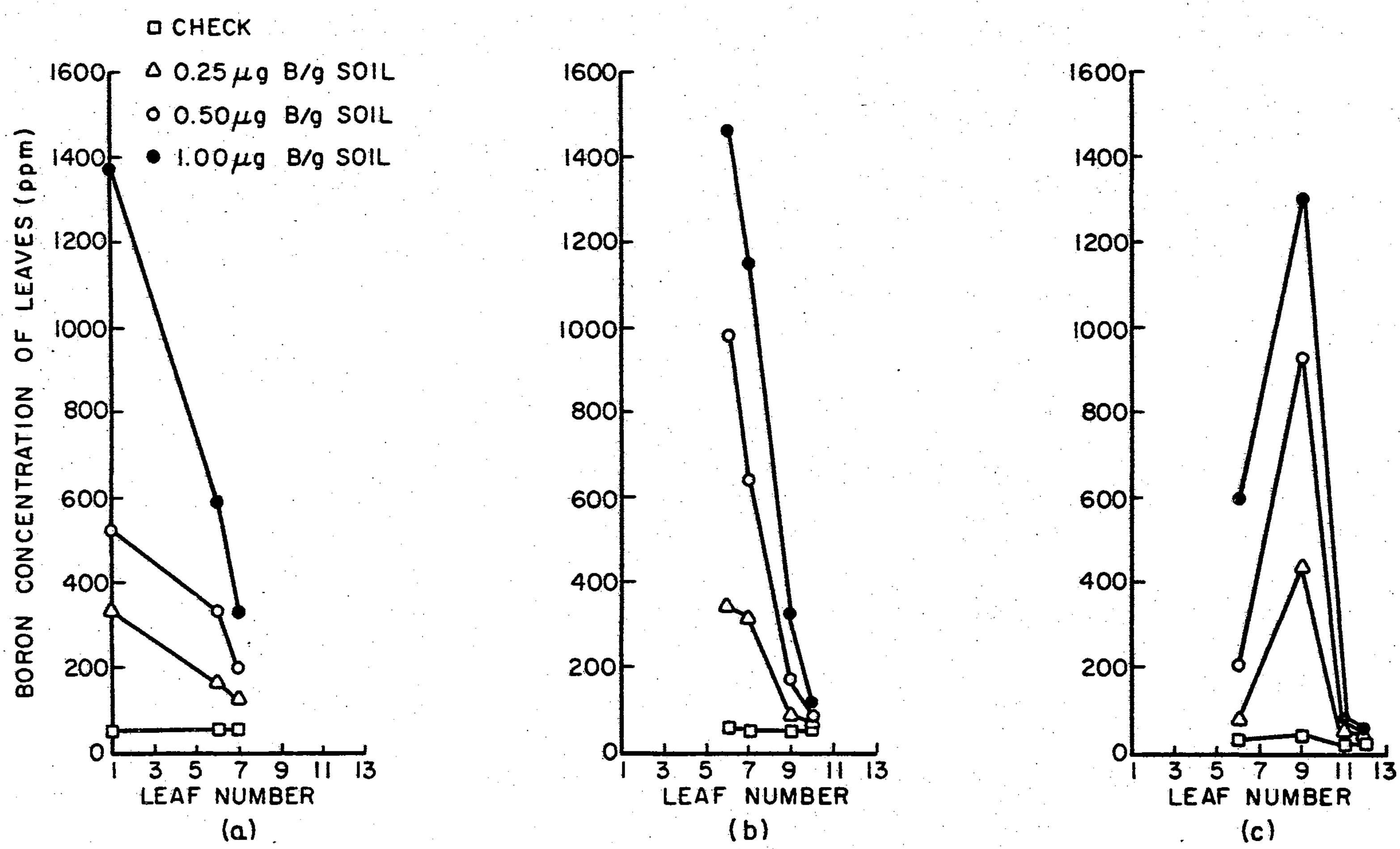

Figure 1. The Boron Concentrations of Leaves from Peanut Plants (a) 20, (b) 30, and (c) 40 Days After Planting as Influenced by Leaf Position on the Plant

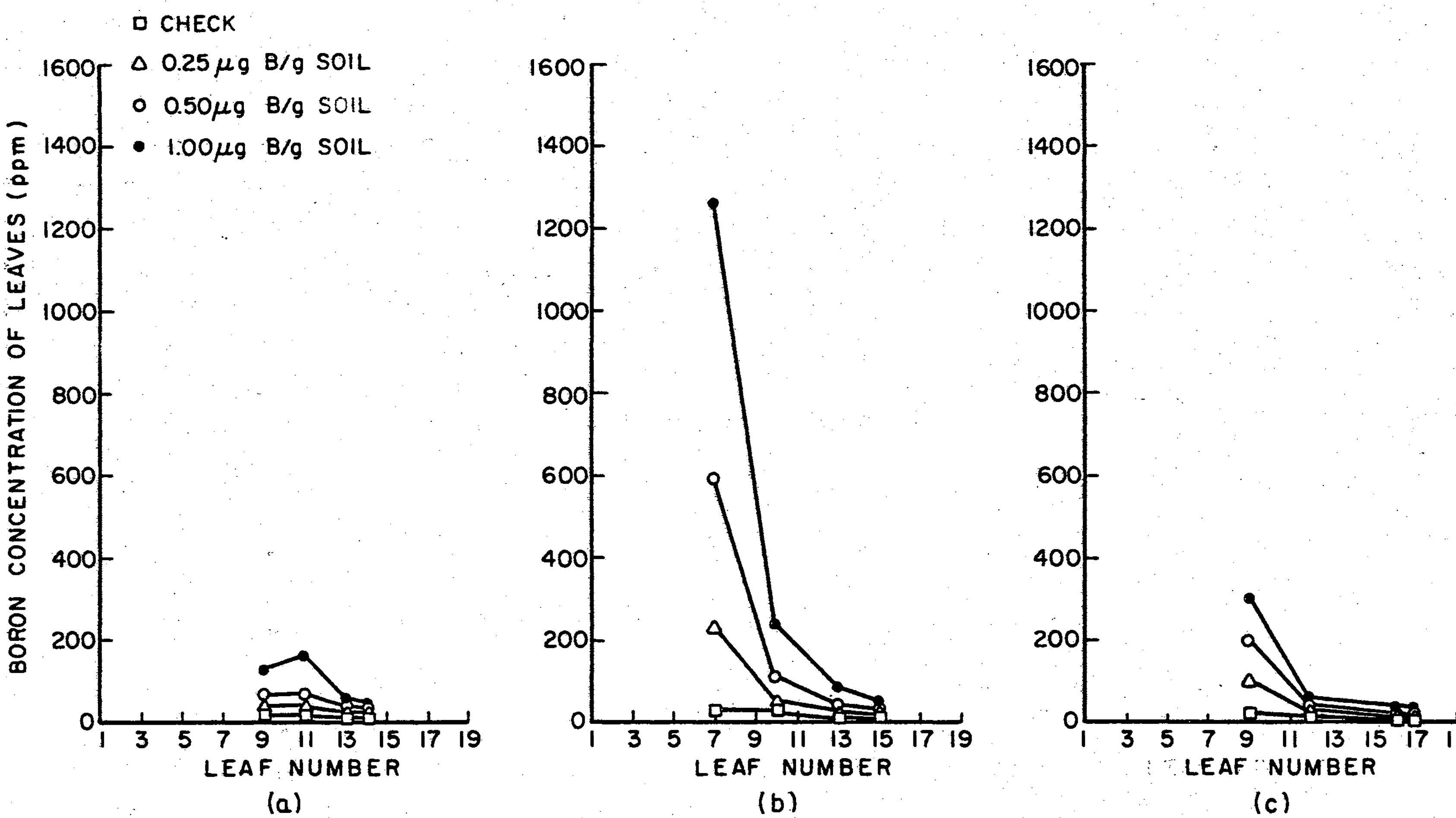

Figure 2. The Boron Concentration of Leaves from Peanut Plants (a) 50, (b) 60, and (c) 70 Days After Planting as Influenced by the Leaf Position on the Plant

experimental error was about four times higher than subsampling error.

TABLE I

AN ANALYSIS OF VARIANCE OF BORON CONTENT OF PEANUTS AS INFLUENCED BY BORON APPLICATIONS TO THE SOIL

Source	df	ss	ms	F
Total	63	2,282.11		
Treatment	3	1,738.14	579.38	12.78
Experimental error	12	543.97	45.33	4.20
Subsampling error	48	518.11	10.79	

Every leaf on the main stem and one lateral branch were numbered. Leaf 1 was the first leaf to develop on the peanut seedling. The leaves were numbered consecutively as they developed. The leaves on the lateral branch were also numbered consecutively, starting at the base of the plant. Several leaves, including the most recently developed from the main stem, were collected at each sampling date.

The oldest leaves collected from 20 and 30 day old plants contained the most boron (Figure 1a and 1b). Leaves 6 and 7 accumulated boron in this ten day period. Boron accumulation in the older leaves suggests that passive uptake and distribution may take place in the peanut plant. However, exceptions were found. There was no boron accumulation in the leaves from treatment 1 (no boron added to the soil). All leaves, old and young, collected from treatment 1 contained about 50 ppm of boron in the 20 and 30 day old plants. Fifty ppm of boron in peanut leaves was not considered to be a deficient level of boron. Absence of boron accumulation or unequal distribution suggests the peanut plant may exhibit an active transport of boron, directing it to the actively growing areas. Passive accumulation may occur only after "luxury consumption" conditions exist.

Boron will accumulate in the peanut leaves to the point of toxicity. The sixth leaf at the 30 day stage was rated for evidence of boron toxicity. The leaves were separated into groups showing: 1) necrosis, 2) chlorosis, or 3) no toxicity signs. The results are shown in Table II. The normal leaves contained 54 to 65 ppm boron. The chlorotic leaves ranged from 316 to 651 ppm boron. The necrotic leaves were the highest in boron content with 953 to 1754 ppm boron.

TABLE II

BORON CONCENTRATIONS OF PEANUT LEAVES SHOWING VARYING SYMPTOMS OF BORON TOXICITY

Boron concentrations (ppm)		
Necrosis	Chlorosis	Normal
1366	651	54
1754	316	63
1331	318	57
953	387	65
1283		63
1008		
1481		

The first indication that boron is translocated out of peanut leaves was observed in the 40 day plants (Figure 1c). The boron content of the sixth leaf decreased during the 30 and 40 day period (Figure 3a). During this same period leaf 9 accumulated boron in three of the four treatments (Figure 3c). Ten days later the boron content of leaf 9 was also greatly reduced. An inconsistency was found in leaf 7 as shown in Figure 3b. It accumulated boron from the 20 to 30 day period as did leaf number 6. However, the boron content remained at the same level through the 60 day sampling date.

Evidence was found that the boron accumulation is influenced by environmental factors. The boron content of leaf 9 (Figure 3c) was observed to increase, then decrease from the 30 to 50 day period, and increase again on the last sampling date (70 days). The greenhouse had a water cooler installed on the 64th day. The boron increase at the 70 day stage was attributed to the direct or indirect effect of cooler temperatures.

The boron contents of the two youngest leaves were found not to differ greatly in the 50 to 70 day stages (Figure 2). The exact stage of leaf development would, therefore, appear not to be too critical during the earlier growth period of the respective leaves.

The boron contents of older leaves on the lateral branches were noted to vary some from those on the main stem. A comparison of two leaves at the same growth stage is shown in Figure 4. At a young stage (40 days) the two leaves had the same boron content. Ten days later (50 days) leaf 8L from the lateral branch accumulated as much as 315 ppm boron compared to only 158 ppm in leaf 11 on the main branch.

The boron contents of the young leaves are compared in Figure 5.

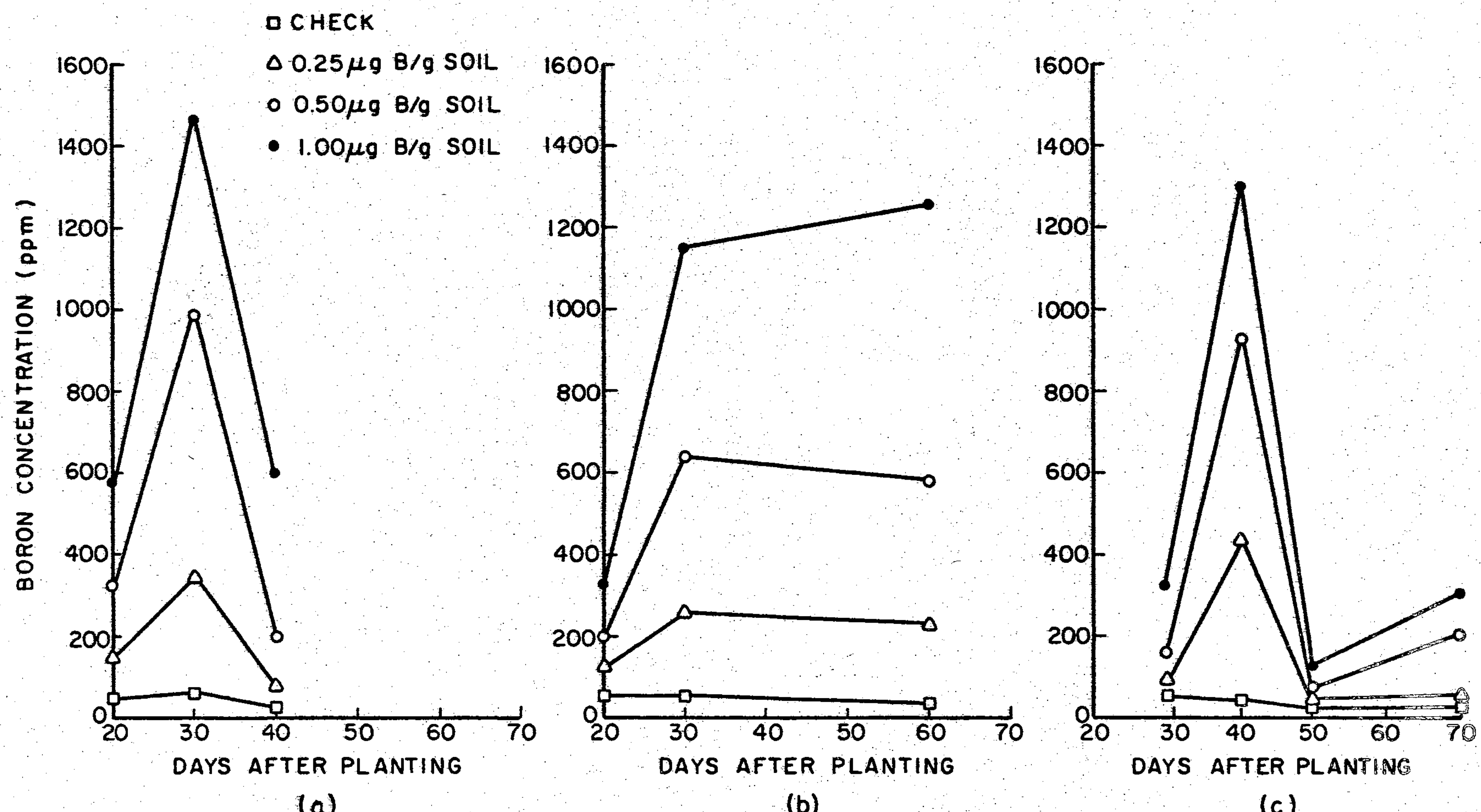

Figure 3. The Boron Concentrations of Leaf Numbers (a) 6, (b) 7, and (c) 9 as Influenced by the Sampling Date

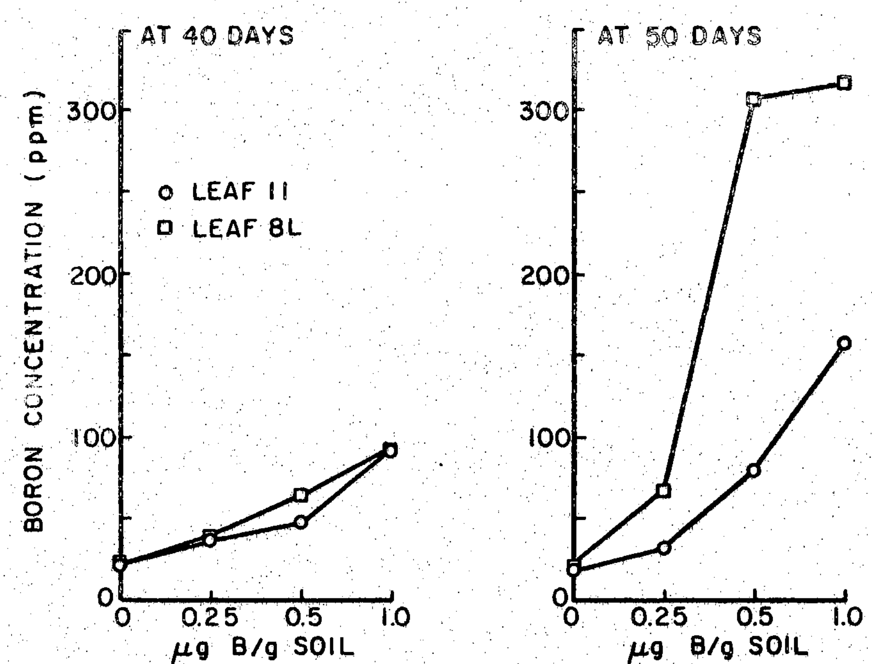

Figure 4. A Comparison of the Boron Concentrations of Leaves from a Lateral Branch (L) and the Main Stem at 40 and 50 Days

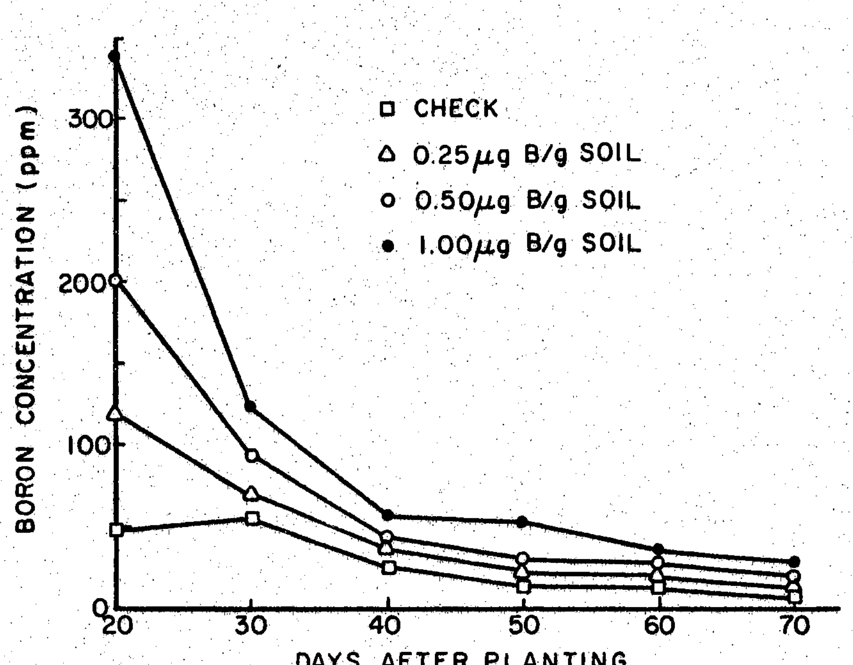

Figure 5. The Boron Concentrations of Young Leaves as Influenced by the Sampling Date.

The leaves are those that had completely unfolded but had not completely expanded. The plants that received the largest boron applications to the soil had the highest boron content in their leaves. There was a decrease of boron in the leaves in successive sampling dates, which could indicate a decreased availability of boron in the soil.

The leaf weights were found to vary with the treatment (Figure 6). The differences in weight were significant on the last two sampling dates. The plants receiving the higher boron treatments had smaller leaves (mature leaves compared).

Boron Content of Petioles

Boron contents of peanut petioles were also found to vary with the boron availability of the soil. The boron contents of petioles for the 60 day samples are shown in Figure 7. The older petioles contained higher concentrations of boron than the younger petioles. The borons content of the leaves and petioles are compared in Figure 8. The leaves from 60 day old plants contained considerably more boron than did the corresponding petioles. The differences in boron contents of a leaf and its petiole were greater in the high boron treatment than the low boron treatment. This difference was greater for the older leaves and petioles than for the younger ones. The comparisonsof boron content between the petioles and leaves collected from 70 day old plants are shown in Figure 9. The two younger leaves and petioles showed no difference in boron contents.

Boron Content of the Gynophore

The gynophores varied in boron content according to the treatment imposed on them. The boron contents of gynophores which had not

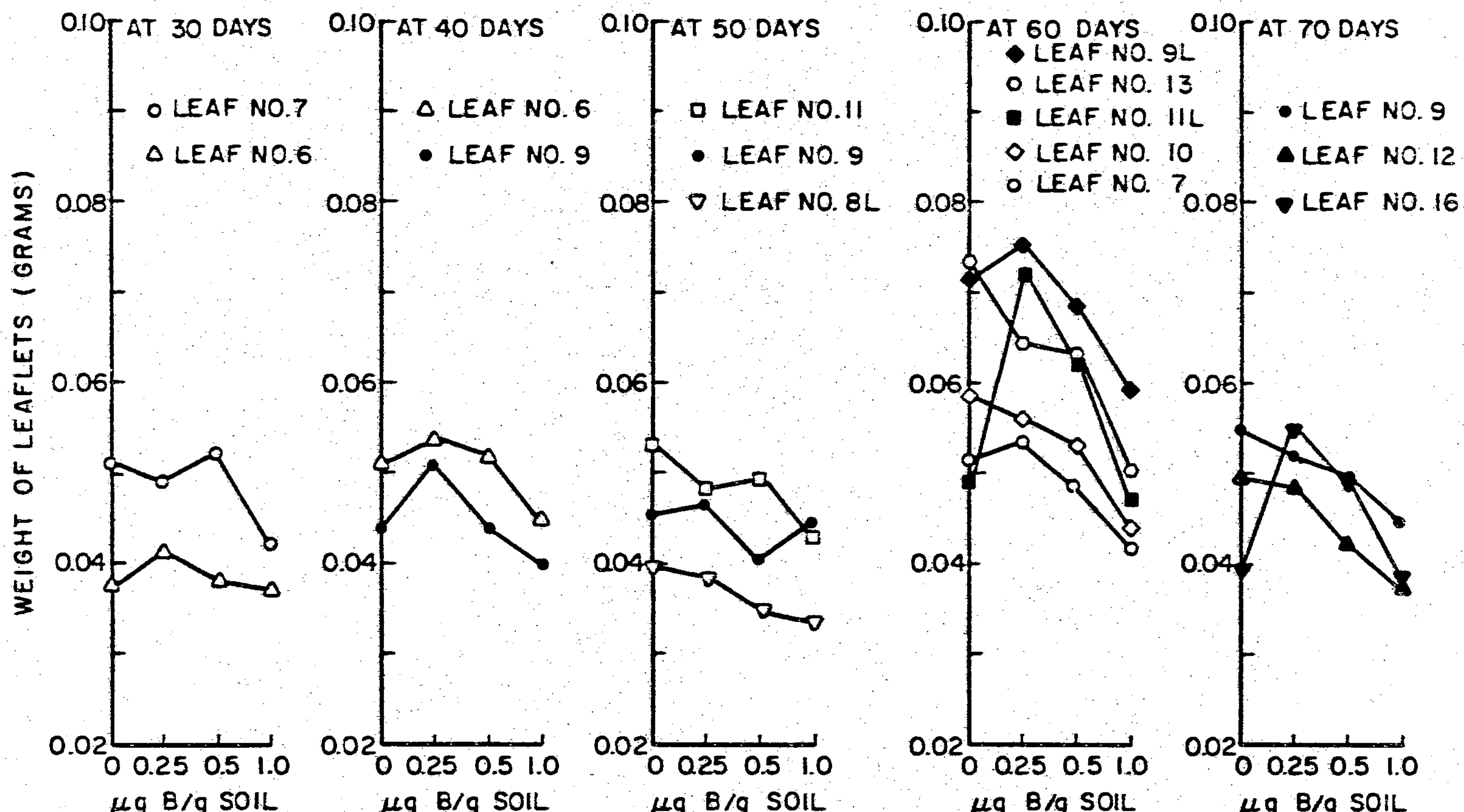

Figure 6. The Weight of Leaflets as Influenced by Boron Applications

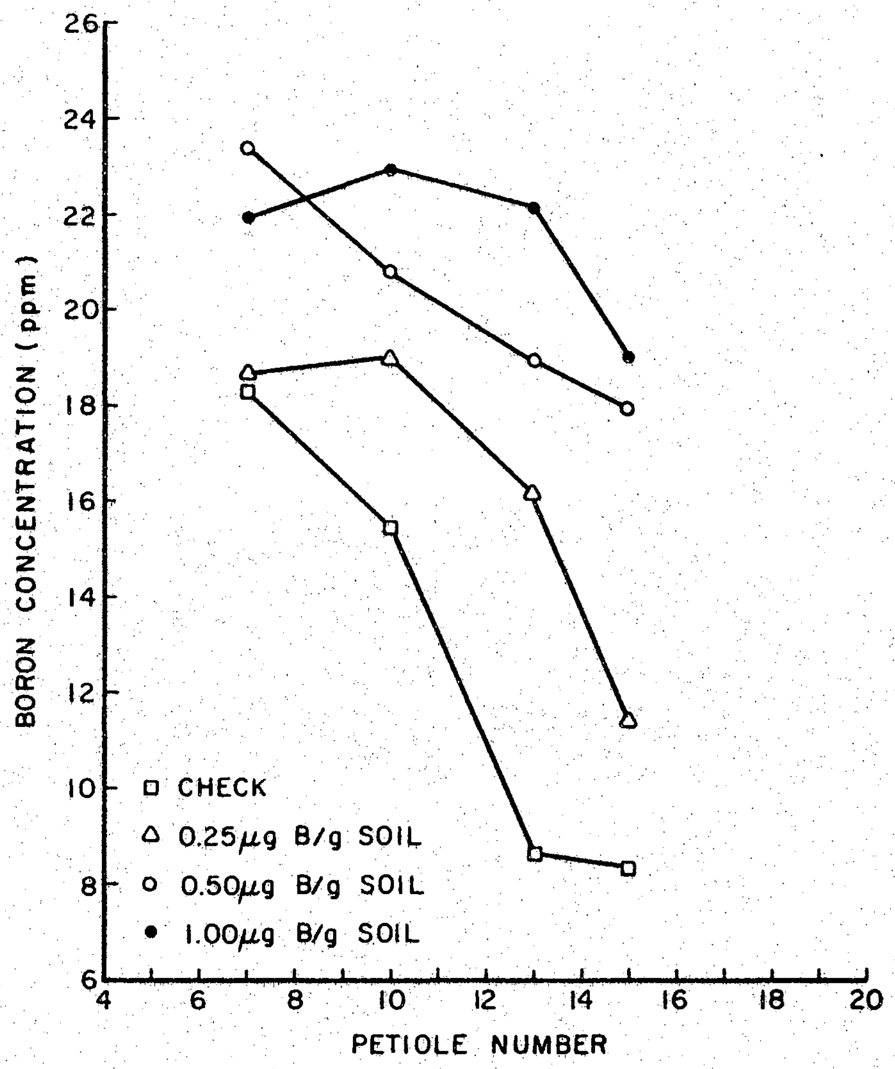

Figure 7. The Boron Concentrations of Petioles at 60 Days as Influenced by the Petiole Position on the Plant

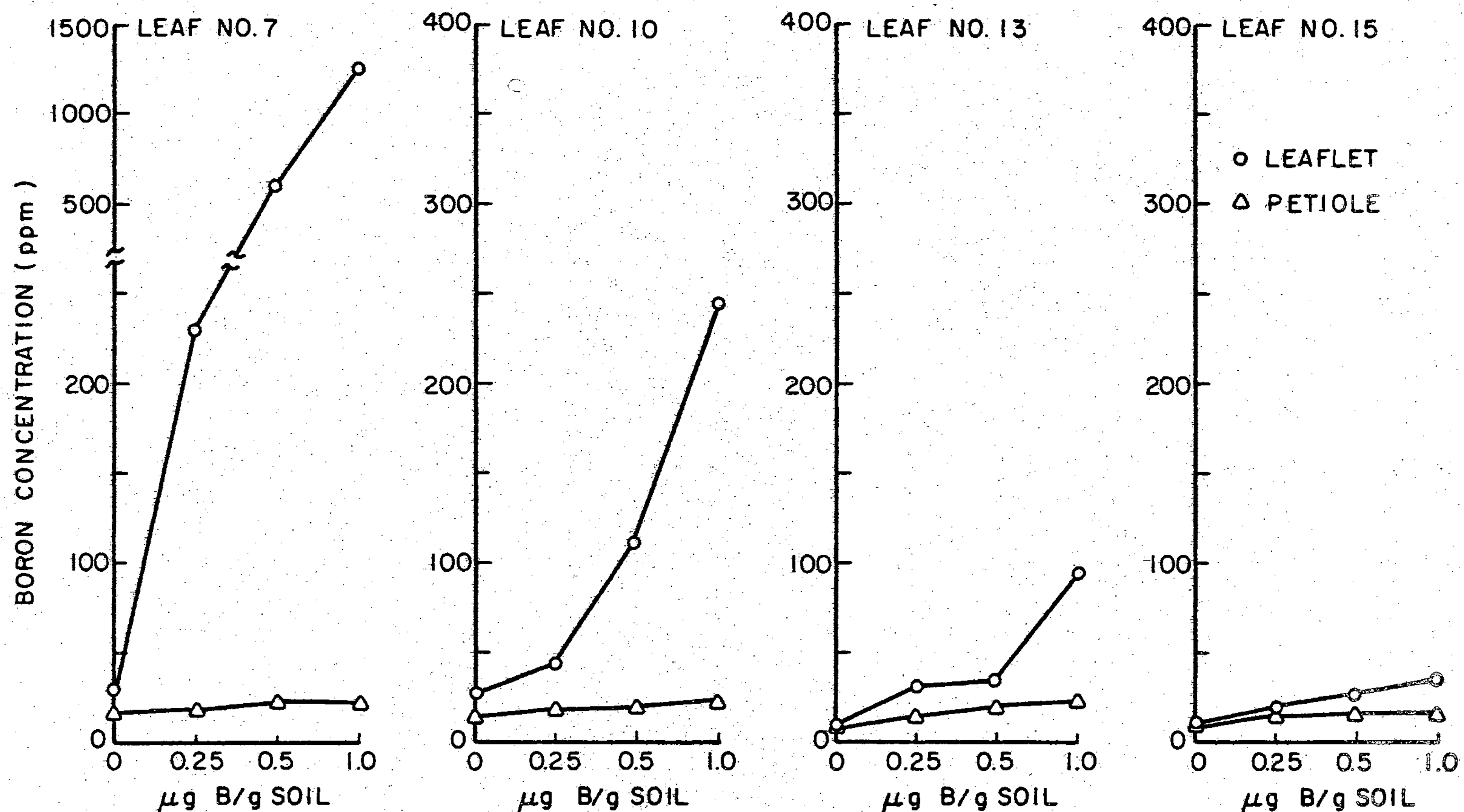

Figure 8. A Comparison of the Boron Concentrations Between the Leaf and Petiole of 60 Day Old Peanut Plants

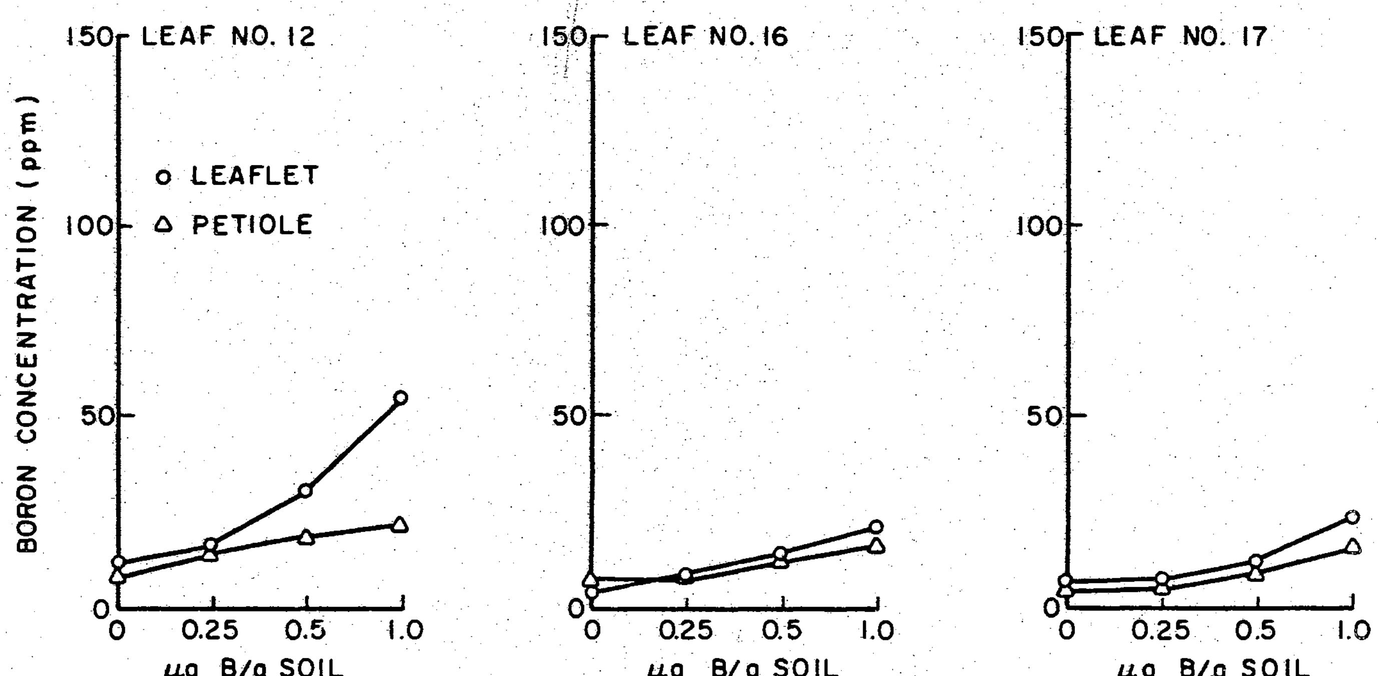

Figure 9. A Comparison of the Boron Concentrations Between the Leaf and Petiole of 70 Day Old Peanut Plants

penetrated into the soil; those which had entered the soil, but had not developed nuts larger than 1 millimeter in length; and whole developing nuts that were larger than 1.5 millimeters are shown in Figure 10. The gynophores which had not entered the soil had the greatest differences in boron contents. The gynophores which entered the soil contained less boron than the gynophores above the soil in the high boron treatments. In the soils with no added boron, the gynophores which entered the soil contained more boron than those above the soil. This difference suggests boron uptake by the gynophores. Even with the bias of time and greater boron availability during early growth, the developing nuts had nearly the same boron content as did the gynophores that had entered the soil.

Correlation values (r) comparing boron contents of leaves and petioles and the gynophores and nuts from plants 70 days after planting are shown in Table III. A significant correlation was found to exist between the boron content of petioles and young leaves, and gynophores and developing nuts. The correlation values for the older leaves (leaves 9 and 12) and nuts were not significant.

The boron content of gynophores above the soil was more highly correlated with boron content of the leaves and petioles than was the boron content of the gynophores that had entered the soil. This difference in correlation would be expected if the gynophores were able to obtain boron directly from the soil.

Critical Boron Levels

Two attempts were made to determine the critical levels of boron, a value above which no internal damage occurs in the fruit of Spanish

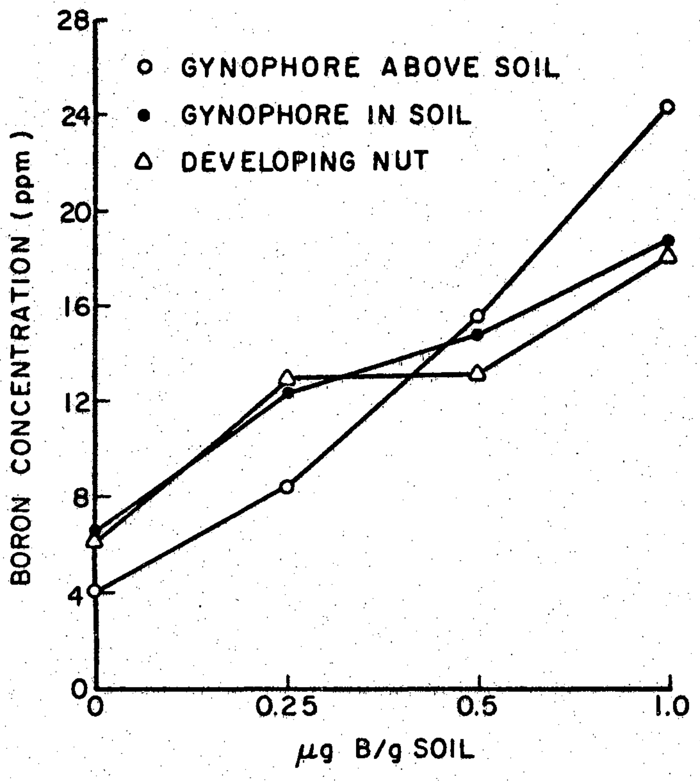

Figure 10. The Boron Concentrations of Gynophores and Developing Nut as Influenced by Boron Applications

TABLE III

CORRELATION COEFFICIENT VALUES (r) COMPARING THE BORON CONTENT OF LEAVES AND PETIOLES WITH THE BORON CONTENT OF GYNOPHORES AND DEVELOPING NUTS

	Gynophores above soil	Gynophores in soil	Developing nuts
Leaf 17	.943	.657	.749
Leaf 17L*	.862	.688	.678
Leaf 16	.932	.510	.741
Leaf 12	.775	.749	.599
Leaf 9	.793	.846	.473
Petiole 17L	.820	.790	.629
Petiole 16	.961	.707	.727
Petiole 12	.770	.685	.715

Significant (.05) r value = .602

*L indicates lateral branch

peanuts. The immature leaves that were almost fully expanded were sampled. The values obtained in the first attempt are shown in Figure 11. Boron levels were significantly different due to treatments for all sampling dates after day 45. The peanuts grown under low boron levels contained 12 ppm or less boron throughout the growing period, resulting in 83.5 percent of the nuts being damaged. The peanuts grown under higher boron levels contained 25 ppm or more boron after day 59. Only two damaged peanuts, both in the same shell, were found in these pots. They accounted for the 1.4 percent damage for the medium low boron level (treatment 2).

Since the range of the estimated critical level was rather broad, a second attempt was made to determine the critical boron level. The values for this second attempt are shown in Figure 12. Differences in boron uptake and accumulation were observed. In the first attempt (Figure 11) the boron content at 38 days ranged from 5 to 15 ppm. In the second attempt the boron content at this same growth stage ranged from 32 to 42 ppm. The only difference between the two studies, other than time, was that the soil was autoclaved before the second series of tests. The heat treatment appeared to have made the boron contained in the soil more available for uptake by the peanut plants.

The boron levels in the peanut leaves were fairly well maintained between 10 to 25 ppm, except for the leaves sampled on the 87th day. The boron levels, however, were not significantly different due to treatments on most sampling dates. The amount of internal damage observed was significantly different and was 82.1 percent for the low boron level, 45.8 percent for the medium, and 6.7 percent for the high boron level. One plant had peanuts entirely free of internal damage.

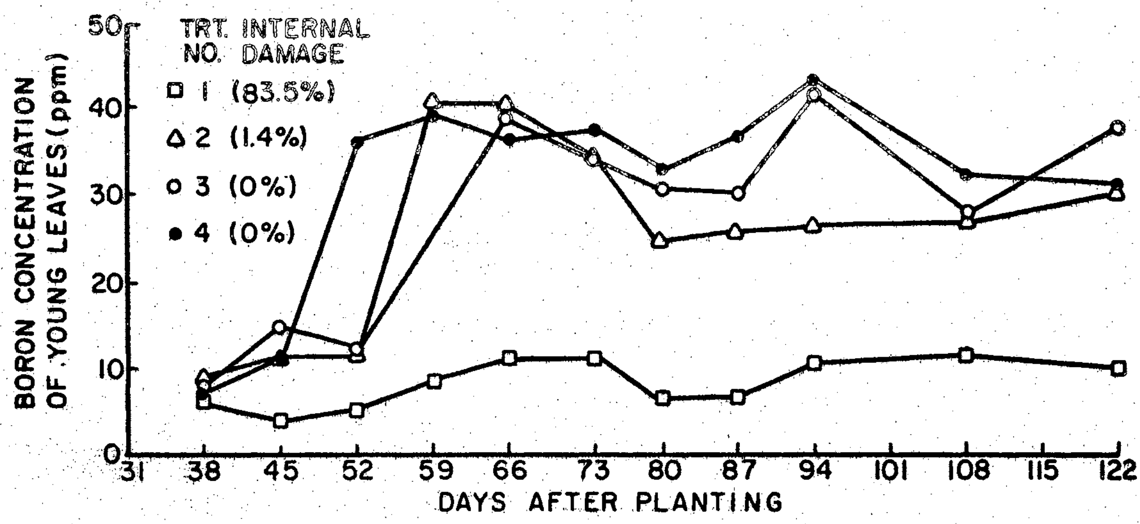

Figure 11. Boron Levels of Young Peanut Leaves as Related to Internal Damage of the Nuts (Series I)

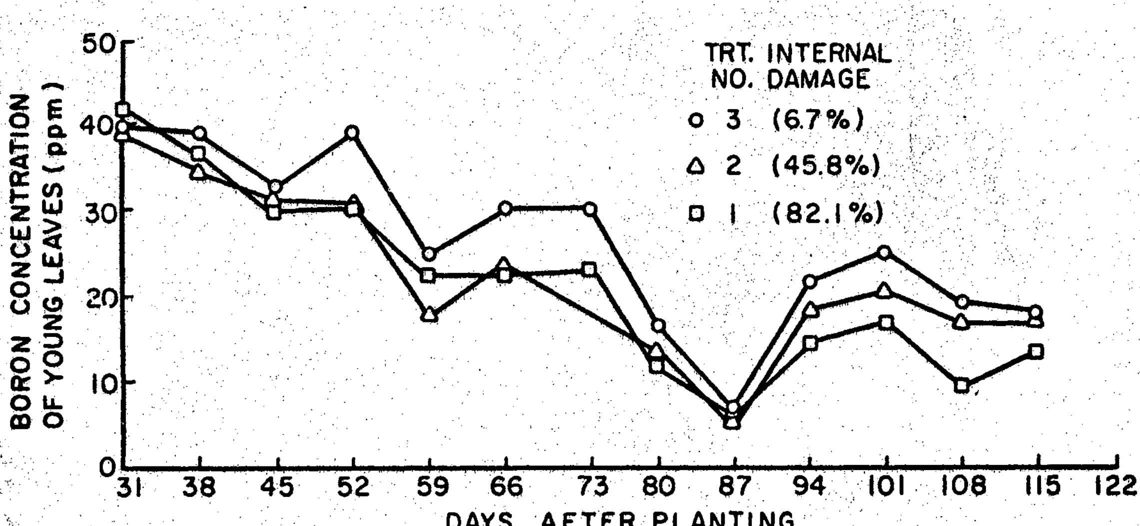

Figure 12. Boron Levels of Young Peanut Leaves as Related to Internal Damage of Peanuts Grown in Autoclaved Soil (Series II)

The boron contents of the leaves from this plant (pot 2) and from the plant from treatment 2 of the first series with 2 damaged nuts (pot 11) are compared in Figure 13. The boron content of the young leaves from the plant with no internal damage (pot 2) was 18 ppm or higher for all sampling days except day 87. The young leaves from the plant with 2 damaged nuts (pot 11) contained 16 ppm boron between day 80 and 94.

The data from the two series of studies suggests the critical level of boron to be 18 to 20 ppm. Peanut plants do not appear to suffer if the boron level is somewhat below the 18 to 20 ppm "critical" level for short periods of time. The length of time and the amount of differences that can be tolerated is apparently dependent upon the previous boron history and stage of growth.

Peanuts were shown to translocate boron, but the details of this translocation are not known. Therefore, the effects of boron translocation upon prevention of internal damage of the peanut and the critical levels of boron in peanut leaves are at present speculatory. It is apparent that internal damage will not occur if conditions of boron deficiency are corrected before the nuts have started to develop, if they occur after the nuts have matured.

The boron content of the nuts from the second test series was determined and found to be significantly different depending upon treatment. The boron content was 5.0 ppm for the low boron level, 9.2 ppm for the medium level, and 10.2 ppm for the high boron level.

Critical Time of Boron Supply

Both steam treated and non-treated soil were used in this experiment, resulting in different boron levels in the plant at the early

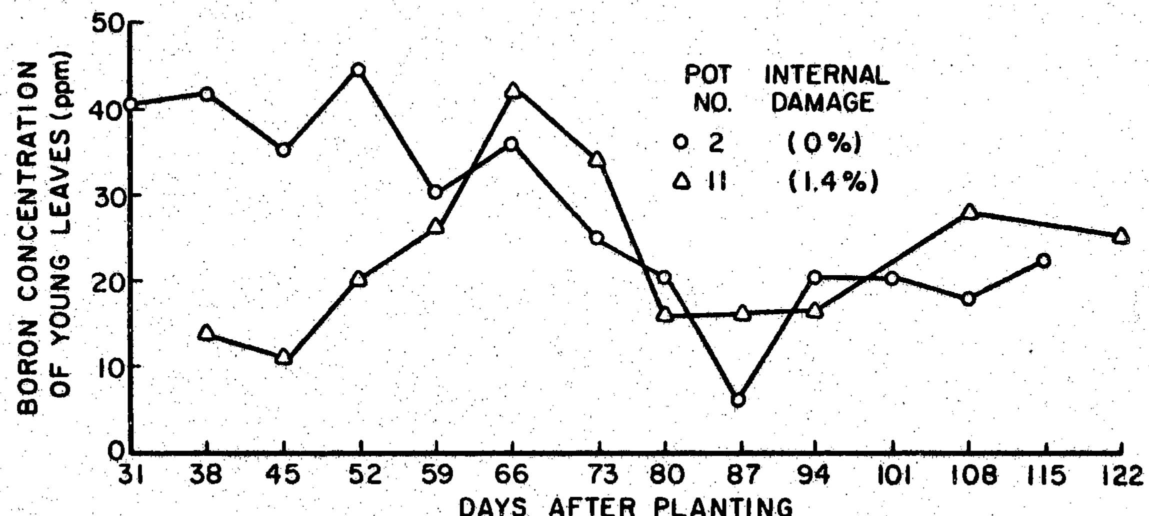

Figure 13. Boron Level Fluctuation With Time of Two Peanut Plants Producing Sound vs. Damaged Fruit

stages of growth. Since early boron levels in the plants had an effect on the response to boron applications, treatment means were not calculated. Instead, the boron concentration levels of the young leaves from each plant are presented graphically.

The boron concentrations of the immature leaves and percent internally damaged peanuts from plants which received no boron are shown in Figure 14. In three of the plants, 94 to 100 percent of the nuts were damaged. The boron levels in the leaves decreased to 20 ppm or less on or before the 55th day. Peanut plant number 29 differed in having 13.5 percent damage. Its boron content remained above 20 ppm to about 75 to 80 days after planting.

The nut production was also greatly affected by boron levels. The plants with low boron levels during the early stages of growth produced 7 to 16 nuts per plant. Plant 29, which had a high boron level in the leaves prior to day 82, yielded 37 nuts.

Supplying boron to the peanut plants 108 days after emergence had no effect on nut quality. Even though the boron content of the peanut leaves increased to well above 50 ppm at this time, 80 to 100 percent of the nuts were damaged (Figure 15). Again the nut production was low (12 and 5 nuts per plant).

Two plants that received boron applications 90 days after planting had 100 percent damaged nuts. These plants had low levels of boron during the early growth period (Figure 16). They produced few nuts, 2 and 11 per plant. Plant number 21 was also supplied with boron at 90 days but contained more than 20 ppm of boron through the first 71 days. This plant produced 28 nuts, and 46 percent of them were damaged.

Peanut quality was greatly improved when boron was applied to the

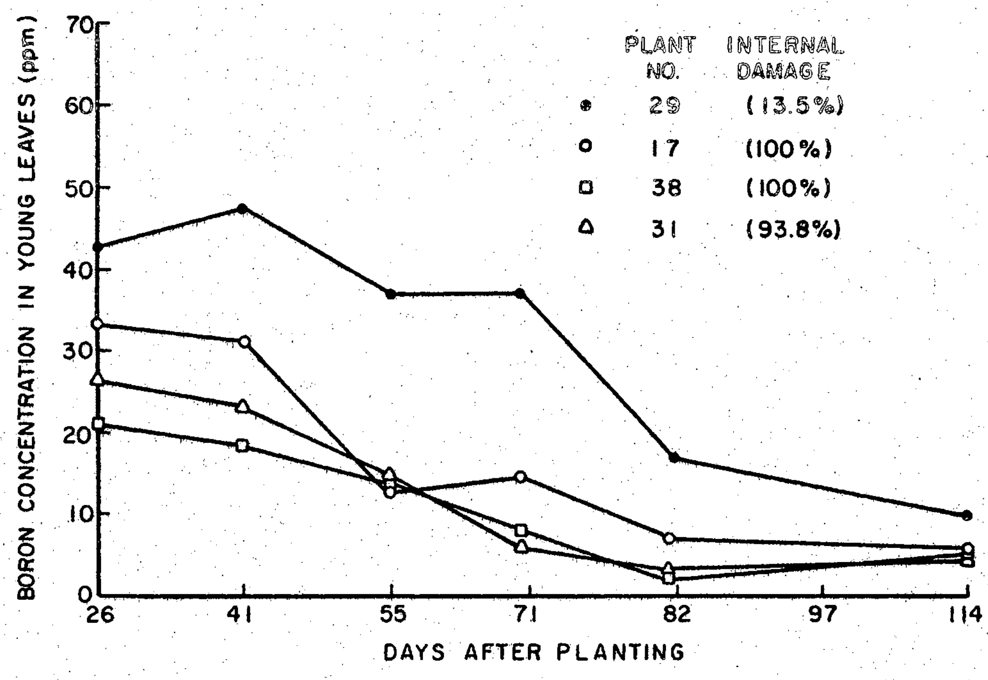

Figure 14. The Boron Concentrations of Young Peanut Leaves From Plants That Received No Boron Applications

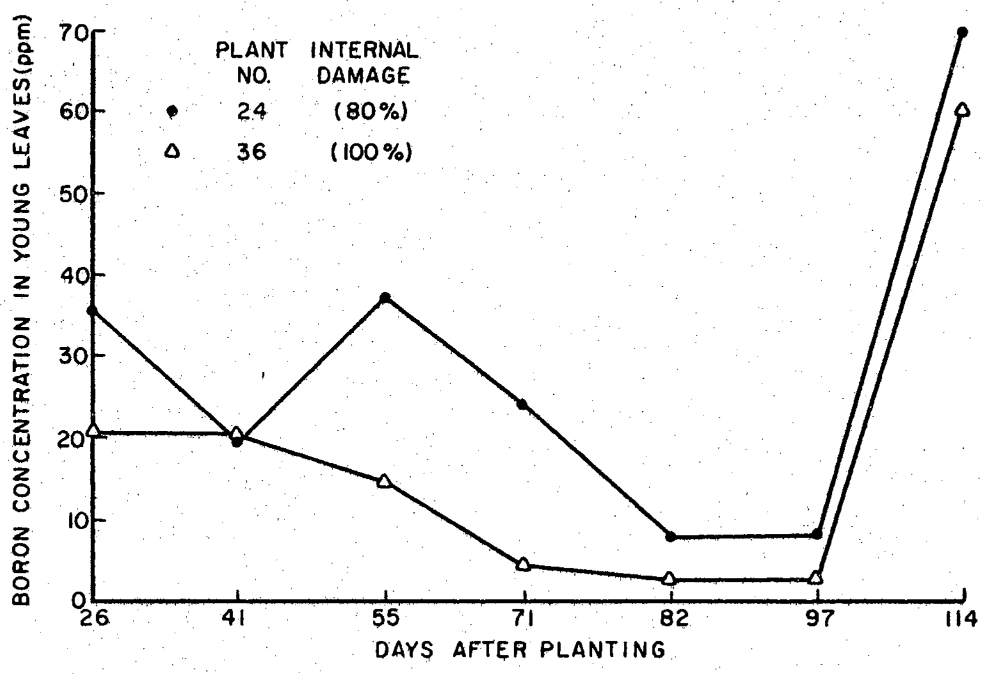

Figure 15. The Boron Concentrations of the Young Peanut Leaves From Plants That Received Boron Applications 108 Days After Planting

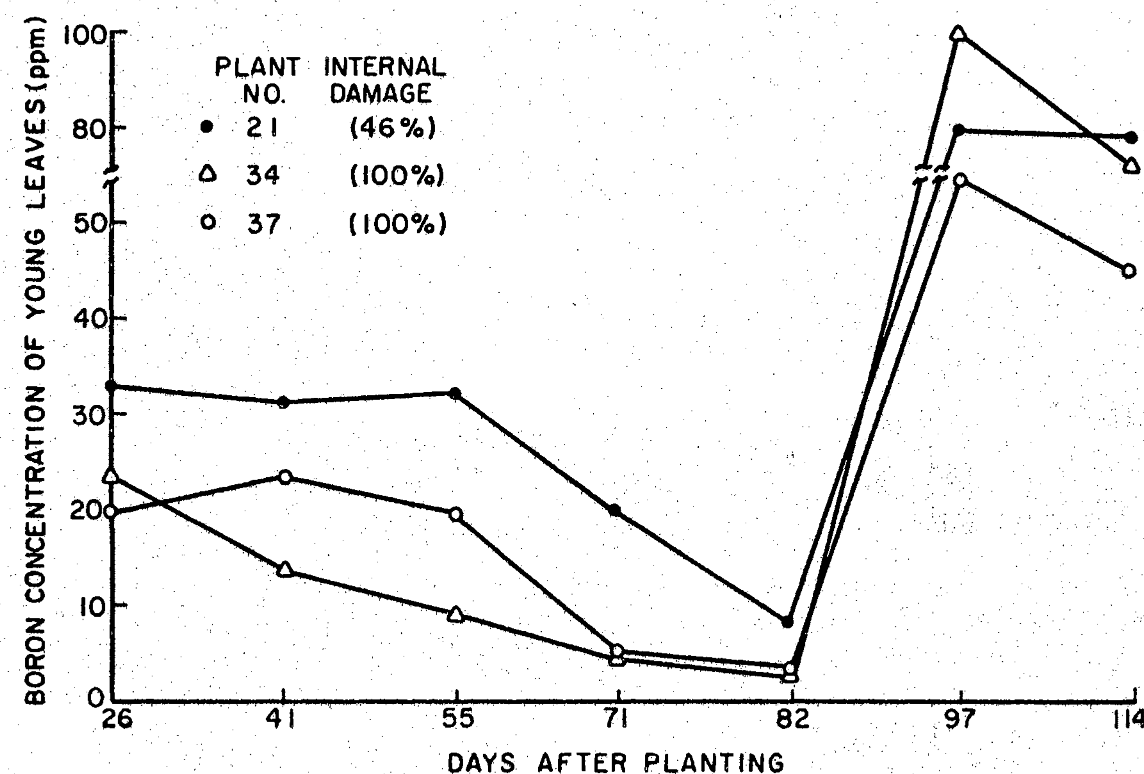

Figure 16. The Boron Concentrations of the Young Peanut Leaves From Plants that Received Boron Applications 90 Days After Planting

peanut plants 76 days after planting (Figure 17.) One peanut plant (number 32), which contained less than 20 ppm of boron prior to day 76, had 11 percent of its peanuts damaged. The plant that had 20 ppm or more boron prior to day 71 (number 27) produced nuts with no internal damage. Plant number 13 had less than 20 ppm boron on one sampling date, day 71, and had 1 damaged nut (3.3% damage).

The nut production of plant number 32 (28 peanuts) apparently was not decreased, even though it contained less than 20 ppm boron through the first 75 days. Plants 27 and 13 produced 27 and 30 nuts respectively.

Boron applications were also made 65 and 49 days after planting. The results are shown in figures 18 and 19 respectively. All of the nuts were free of internal damage, except for plant number 35 (Figure 19), which had one nut that showed evidence of slight damage due to a boron deficiency.

The boron contents of the nuts from this experiment are shown in Table IV. The plants that received no boron applications had the lowest boron levels in the nuts, 2.6 ppm. The highest boron level, 25.1 ppm, was found in the nuts from plants that received boron applications at 90 days. This treatment had over 80 percent internal damage. The amount of internal damage found in the peanuts is not necessarily related to the boron content of the harvested nuts. Boron can apparently be accumulated after the time internal damage can be prevented.

The effects of a decreased boron supply at advanced growth stages were also studied. The peanuts were supplied with adequate levels of boron at the beginning, then leached at various dates to make less boron available. A decrease of boron in the young leaves was observed (Figure 20). The boron levels became deficient and resulted in internal

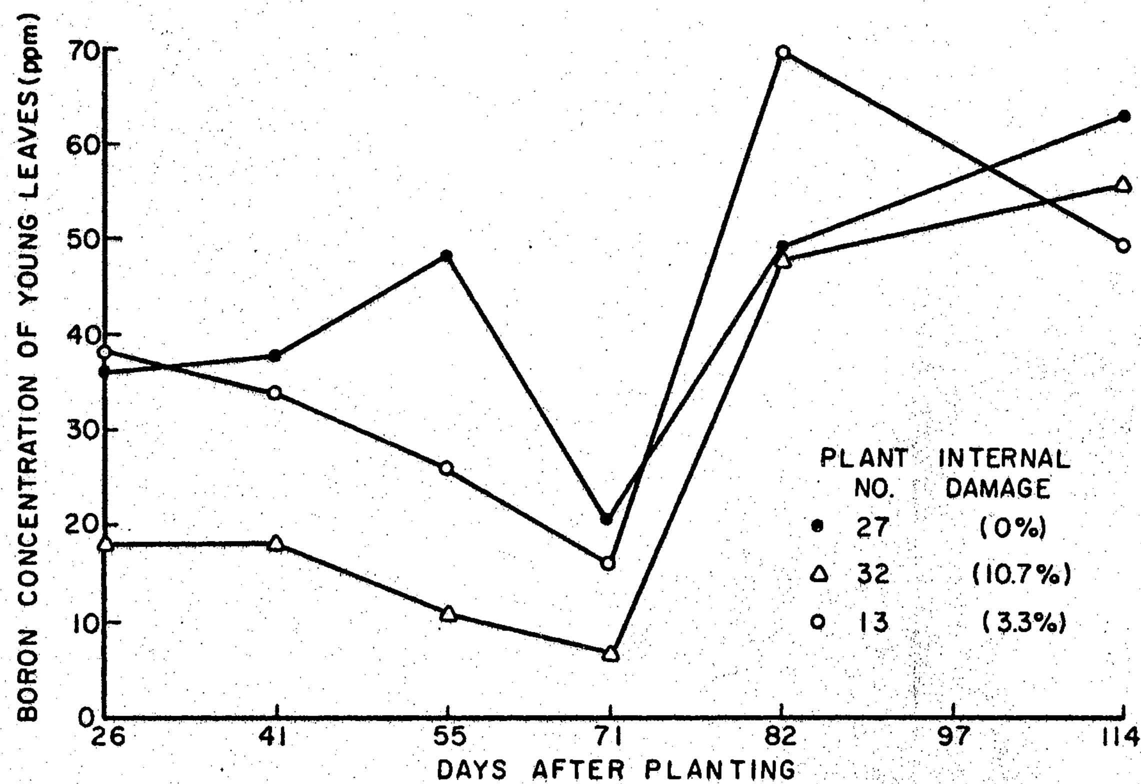

Figure 17. The Boron Concentrations of the Young Peanut Leaves From Plants that Received Boron Applications 76 Days After Planting

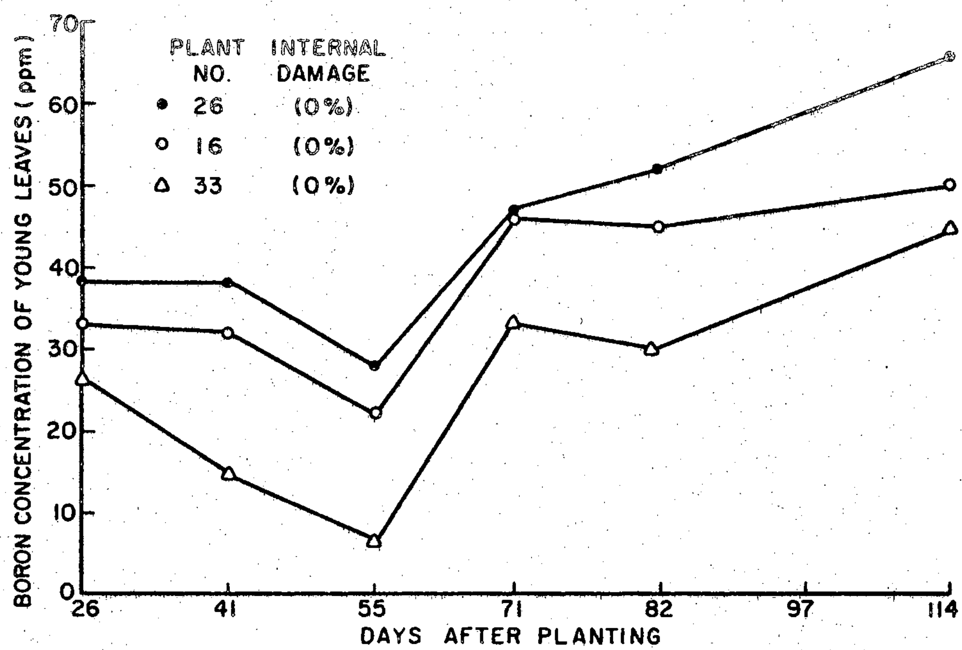

Figure 18. The Boron Concentrations of the Young Peanut Leaves From Plants That Received Boron Applications 65 Days After Planting

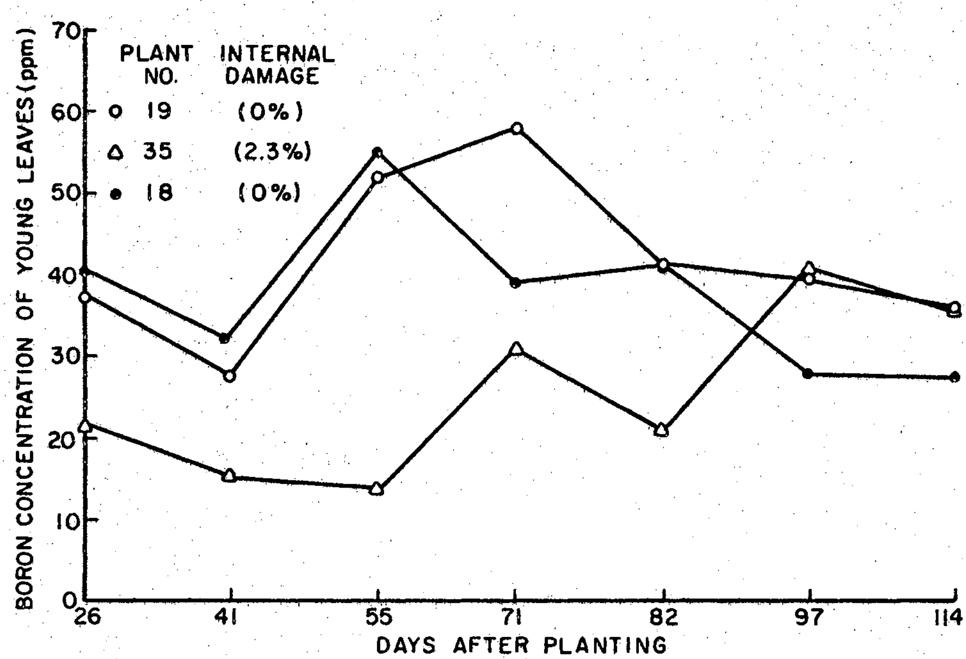

Figure 19. The Boron Concentrations of the Young Peanut Leaves From Plants That Received Boron Applications 49 Days After Planting

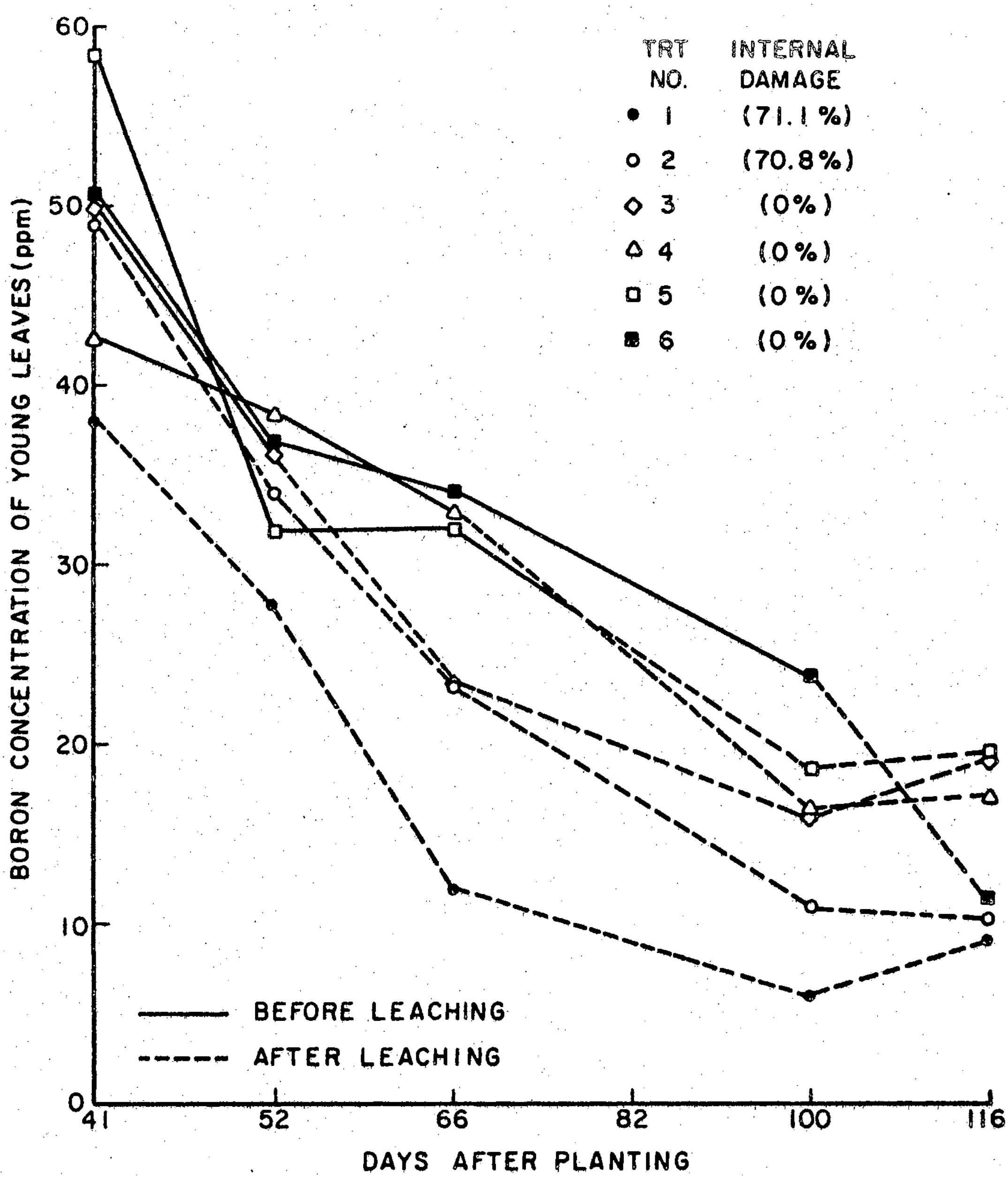

Figure 20. The Boron Concentrations of the Young Peanut Leaves as Influenced by Boron Removal From the Soil by Leaching

damage in two treatments; treatment 1 (leached at emergence) and treatment 2 (leached at 41 days). The boron levels were below 20 ppm on day 66 in treatment 1 and between day 66 and 100 in treatment 2. Reading from the graph (Figure 20), boron levels decreased below 20 ppm on day 75 in treatment 2. This approximation was necessary because the data for day 82 was lost and made the results incomplete. Boron levels below 20 ppm at day 100 and after were not detrimental to peanut quality in this experiment.

TABLE IV

THE RELATIONSHIP BETWEEN BORON CONTENT OF PEANUTS AND INTERNAL DAMAGE

Treatment Applied Boron (day)	Internal damage (percent)	Boron content (ppm)
65	0.0	19.5
76	4.7	21.7
90	82.0	25.1
108	90.0	13.9
none	98.0	2.6

Field Experiments

The Yahola loamy very fine sand at McAlester, and Norfolk loamy fine sand at Ft. Towson are low in boron. Peanuts grown on these soils frequently show internal damage due to their low boron supplying capacity. Responses to boron treatments are expected on these soils. The Durant loam at Durant had a high boron supplying capacity. No response to boron applications is expected for peanuts on this soil.

The 1969 growing season was exceedingly dry at Ft. Towson and Durant. The soil was dry through August 12 at McAlester, then received sufficient moisture for the remainder of the season.

Comparisons of boron content in peanuts were made among these three conditions: 1) a low boron soil under adequate moisture conditions, 2) a high boron soil under a moisture stress, and 3) a low boron soil under a moisture stress.

Three growth stages of leaves and petioles were sampled on each sampling date. The stages were identified at I, II, and III. Leaf I was an immature leaf with the leaflets partially to fully folded. Leaf II was an immature leaf that was completely unfolded, but not fully expanded. Leaf III was the youngest fully mature leaf.

Uptake and Distribution of Boron

The moisture conditions influenced boron uptake by the peanuts. The boron content of peanuts not receiving any boron fertilizer applications either decreased or remained constant as the season progressed. At McAlester, the boron content of peanuts receiving boron applications decreased from July 16 to August 12, then increased through October 4.

Boron Content of Leaves

The boron contents of the leaves were increased by the application of boron fertilizers at all locations except Durant (Figures 21, 22, and 23). Adding a 20-80-40 fertilizer at the McAlester and Ft. Towson locations resulted in a decrease in the boron contents of the peanut leaves.

The treatments receiving no boron applications at McAlester and Ft. Towson produced internally damaged nuts. The most internal damage

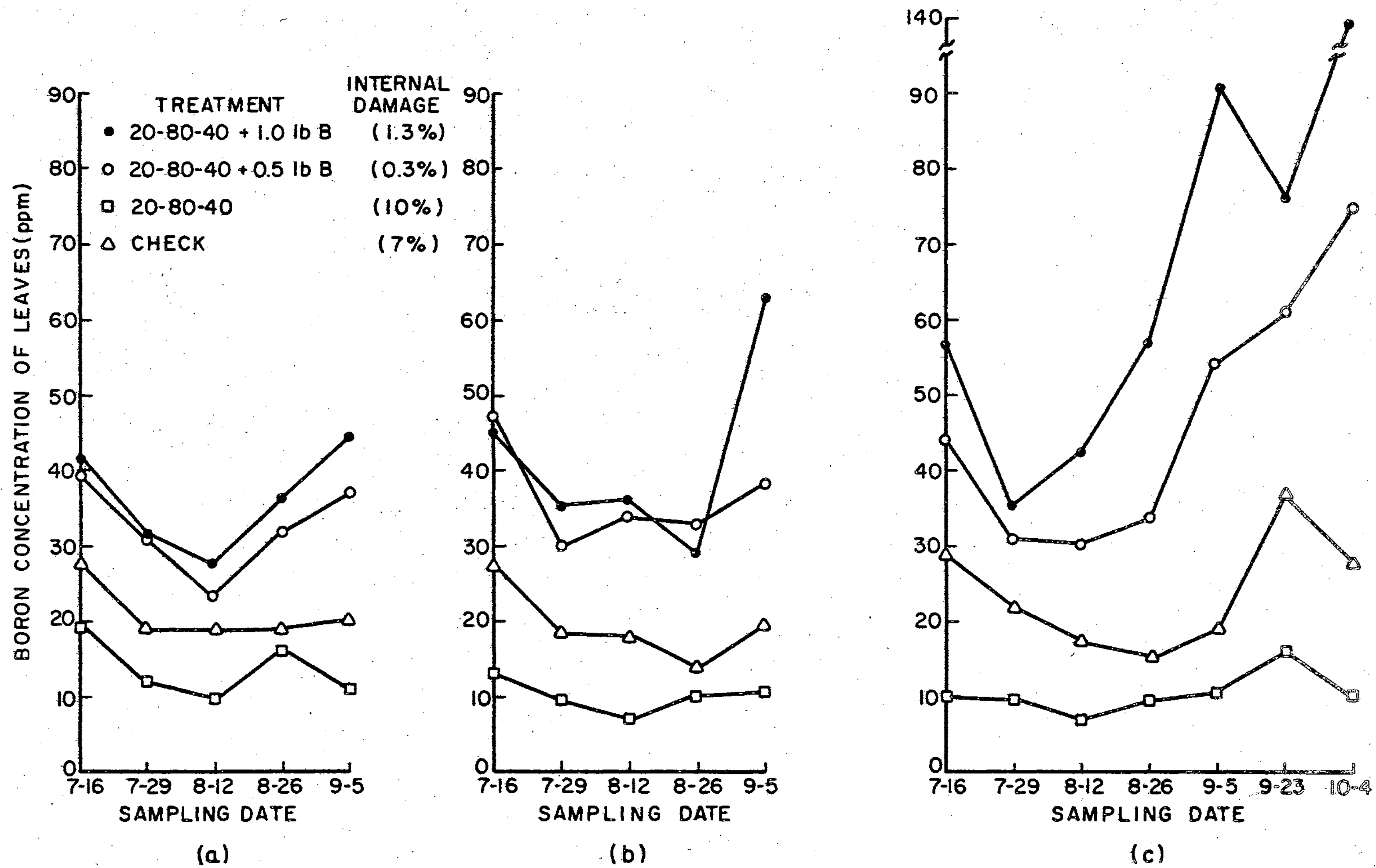

Figure 21. The Boron Concentrations of Leaves in Three Stages of Development; (a) I, (b) II, and (c) III as Influenced by Time at McAlester, Oklahoma.

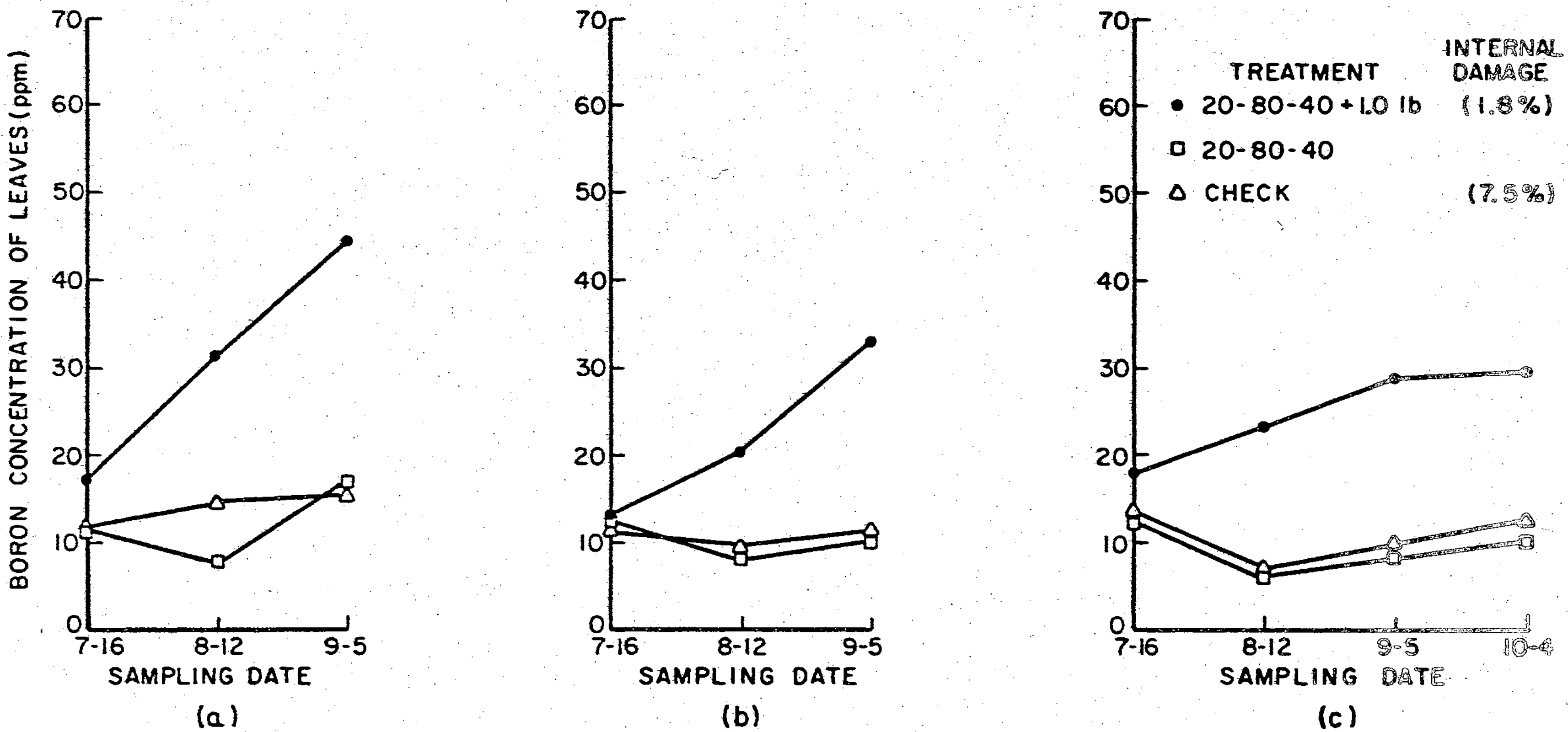

Figure 22. The Effect of Three Fertilizer Treatments on the Boron Concentrations of Peanut Leaves With Time for Three Stages of Development; (a) I, (b) II, and (c) III at Ft. Towson, Oklahoma.

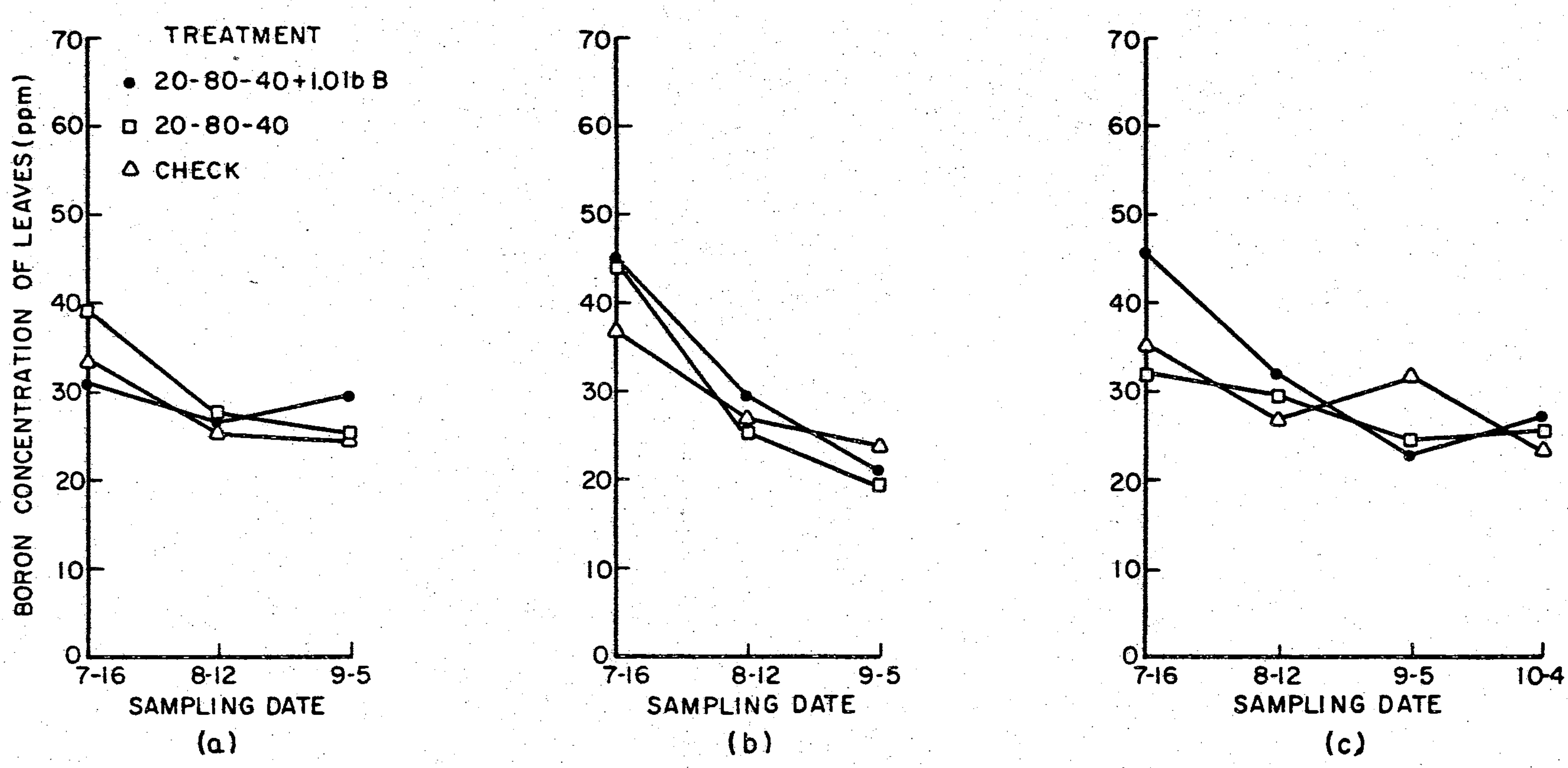

Figure 23. The Effect of Three Fertilizer Treatments on the Boron Concentrations of Peanut Leaves With Time for 3 Stages of Development; (a) I, (b) II, and (c) III at Durant, Oklahoma.

(10%) and the lowest boron content of the young leaves occurred in the 20-80-40 treatment at McAlester. The 0-0-0 treatment had 7 percent internal damage. The internal damage found in the 0-0-0 treatment at Ft. Towson was 7.5 percent. The young leaves from the plots with no added boron contained less than 20 ppm boron at McAlester and at Ft. Towson (Figures 21 and 22). The leaves from the plots that had boron treatments contained more than 20 ppm boron at these two locations, and the resulting nuts had low amounts of internal damage (less than 2%). The peanut leaves from Durant did not contain less than 20 ppm boron (Figure 23).

The boron contents of the three stages of leaves collected at McAlester, Ft. Towson, and Durant are shown in figures 24, 25, and 26 respectively. The youngest leaf (stage I) contained the highest boron concentration and the oldest leaf (stage III) contained the lowest concentration of boron in treatment 20-80-40 at McAlester and Ft. Towson (Figures 24b and 25b). The plants from the 20-80-40 treatment contained the lowest boron levels, indicating the lowest boron supply. This suggests that under low boron conditions the peanut plant actively transports boron to the new growth. The opposite was true under a high boron supply. The oldest leaf (stage III) contained the highest boron concentration while the youngest leaf (stage I) contained the lowest concentration of boron for the 20-80-40 plus 1 pound of boron per acre treatment at McAlester. A passive accumulation of boron is thereby indicated under conditions of high boron. These results are consistant with observations made in the greenhouse.

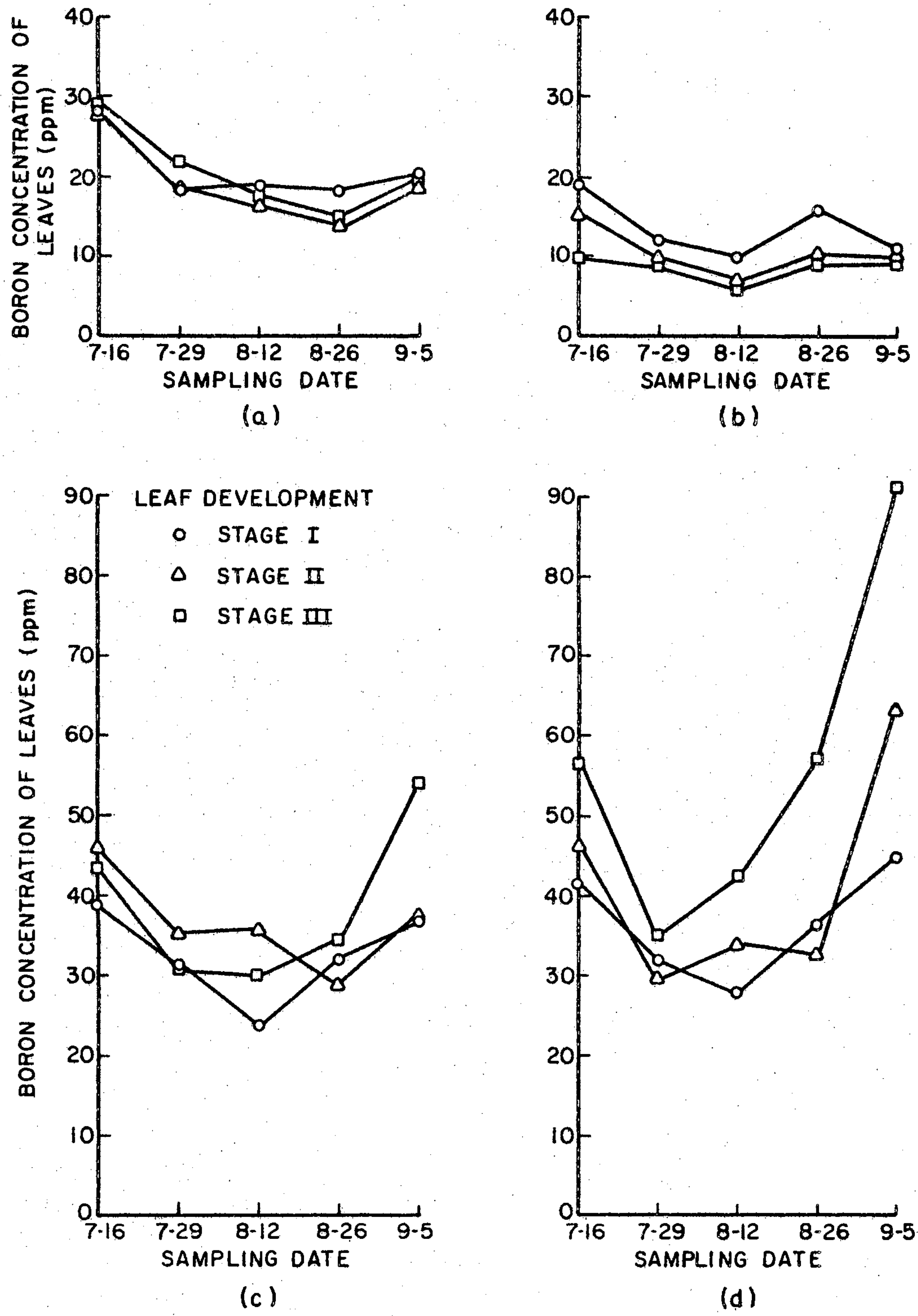

Figure 24. The Boron Concentrations of the Three Stages of Leaves as Influenced by Time for Treatments (a) 0-0-0, (b) 20-80-40, (c) 20-80-40 plus 0.5 lb. Boron, and (d) 20-80-40 plus 1 lb. Boron at McAlester, Oklahoma.

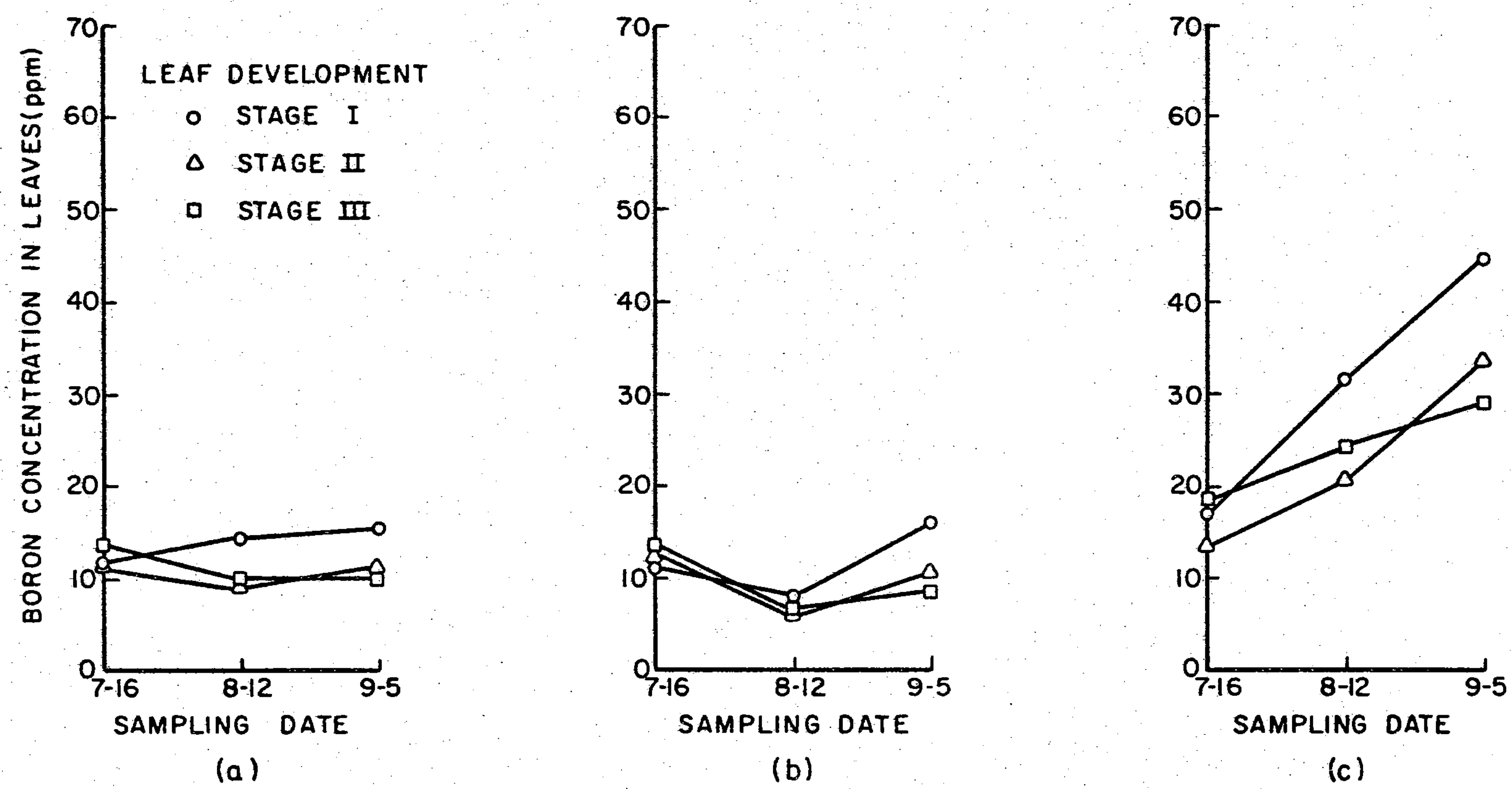

Figure 25. The Boron Concentrations of the Three Growth Stages of Leaves Sampled With Time for Treatments (a) 0-0-0, (b) 20-80-40, and (c) 20-80-40 plus 1 lb. Boron at Ft. Towson, Oklahoma.

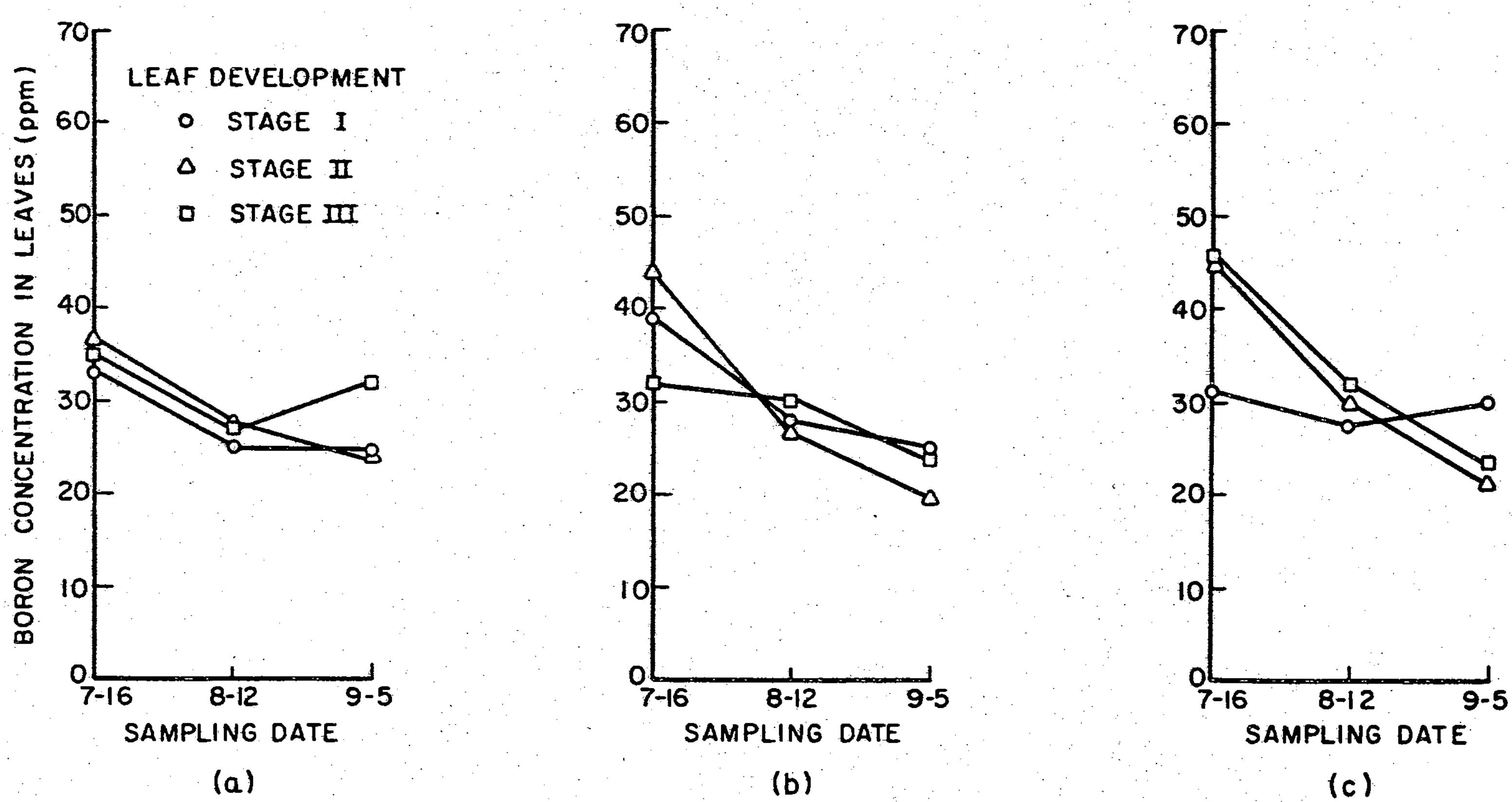

Figure 26. The Boron Concentrations of the Three Growth Stages of Leaves Sampled With Time for Treatments (a) 0-0-0, (b) 20-80-40, and (c) 20-80-40 plus 1 lb. Boron at Durant, Oklahoma.

Boron Content of Petioles

The boron concentrations of petioles from McAlester, Ft. Towson, and Durant are shown in Figures 27, 28, and 29 respectively. The boron concentrations of the petioles remained relatively constant throughout the season in the treatments with no boron. The youngest petiole (stage I) at McAlester was an exception; its boron content increased from August 12 to September 5. The boron contents of petioles were increased by boron applications at McAlester and Ft. Towson (Figures 27 and 28). No response to boron was observed at Durant.

Differences were found in the boron content at the three stages of development of petioles at McAlester and Ft. Towson (Figures 30 and 31). The youngest petioles collected (stage I) contained the highest boron concentrations and the oldest petioles collected (stage III) contained the lowest concentrations. The differences between stages II and III were small. No trend was observed at Durant (Figure 32).

In a routine analysis, stages II and III would be the preferred sample. The petioles are larger than stage I, making them easier to collect and handle. Differences in boron content between stages II and III were small. The exact stage, therefore, would not be too critical.

Boron Content of Peanuts

The boron concentrations of the peanuts at McAlester and Ft. Towson are shown in Figure 33. The concentrations of the shells and nuts increased with an increase in the boron supply to the soil. The nut nearer to the peg (nut 1) contained a lower boron level than the nut farther from the peg (nut 2). The shells contained less boron

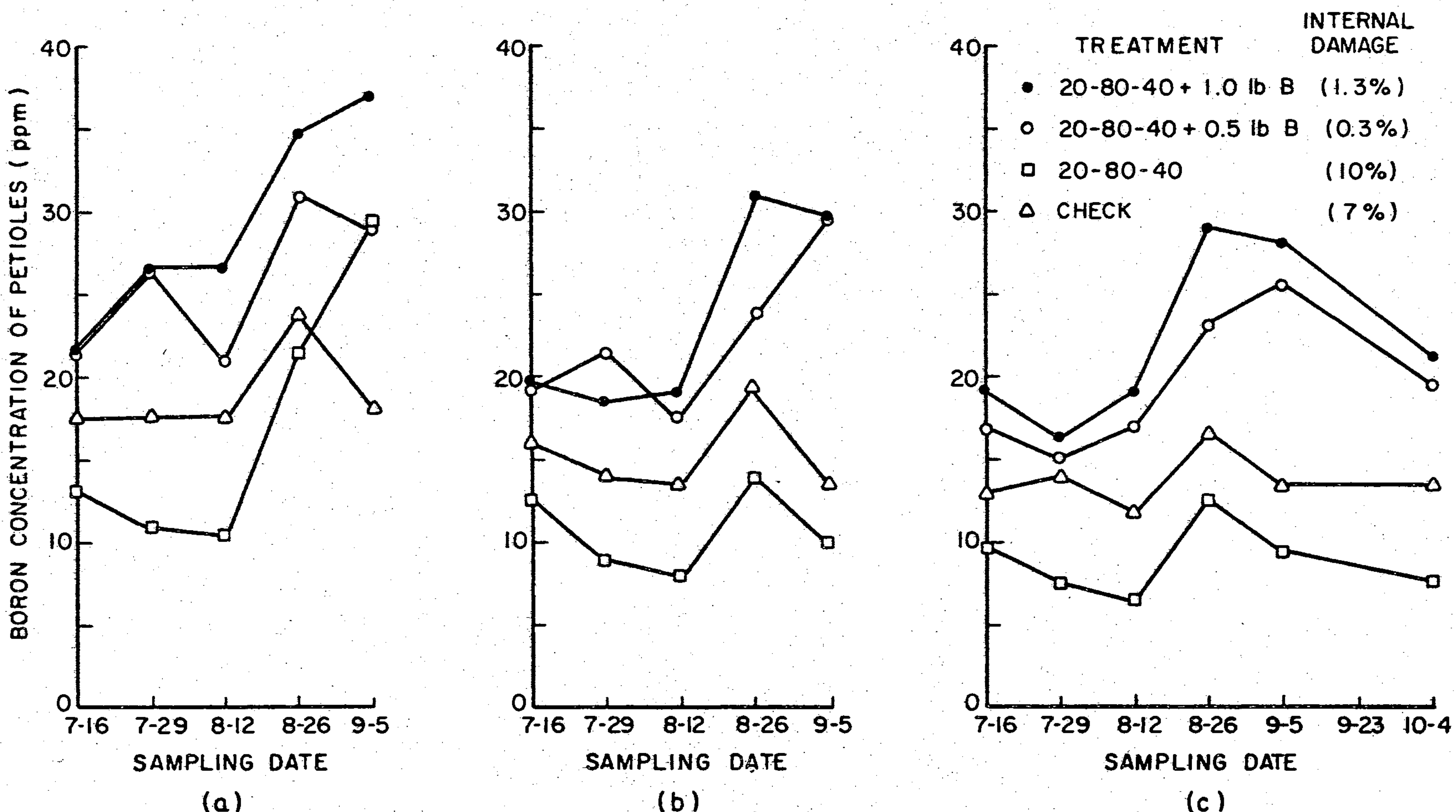

Figure 27. The Boron Concentrations of the Petioles From Four Treatments as Influenced by Time for 3 Stages of Development; (a) I, (b) II, and (c) III at McAlester, Oklahoma.

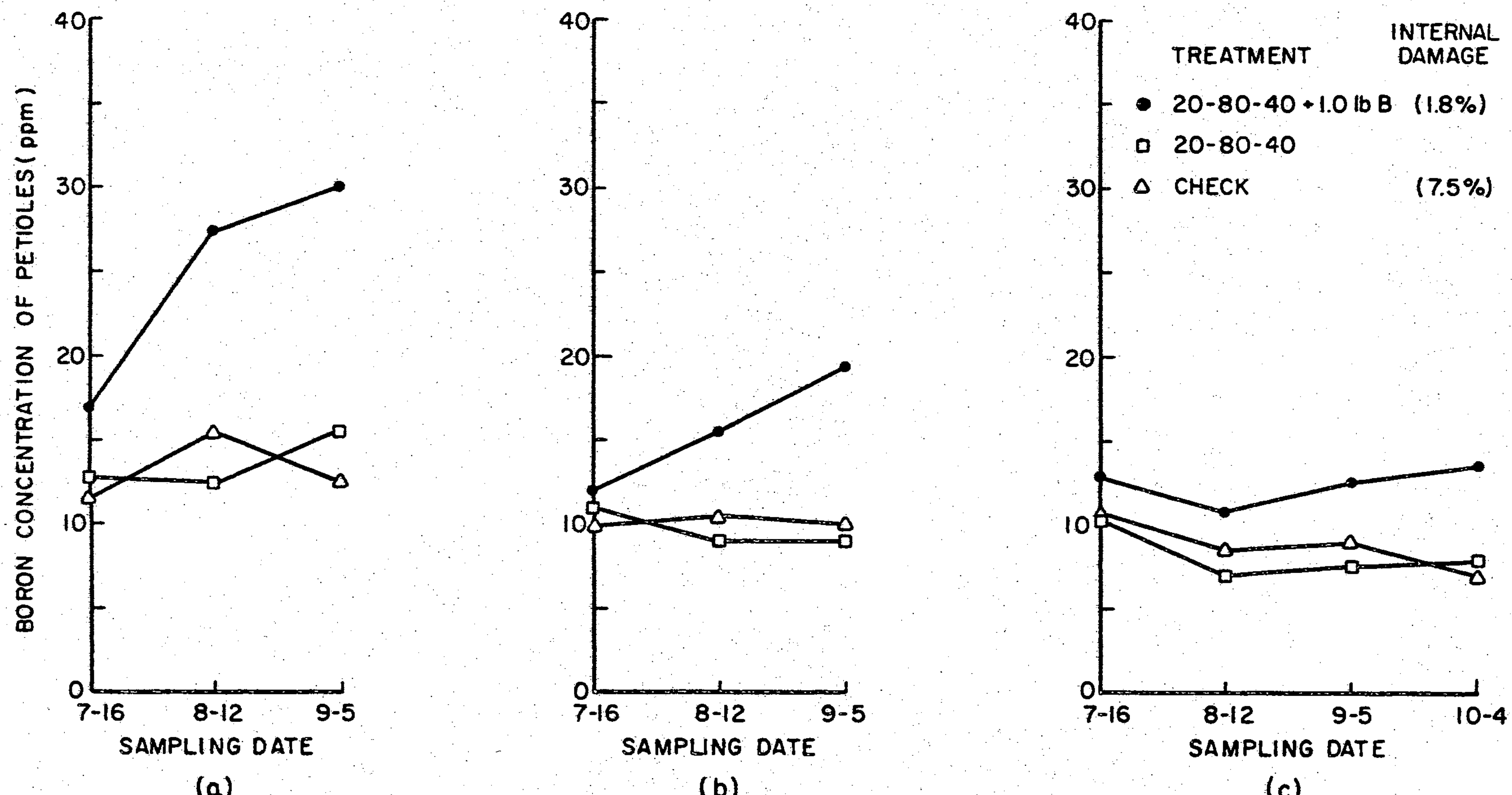

Figure 28. The Effect of Three Fertilizer Treatments on the Boron Concentrations of Peanut Petioles With Time for 3 Stages of Development; (a) I, (b) II, and (c) III at Ft. Towson, Oklahoma.

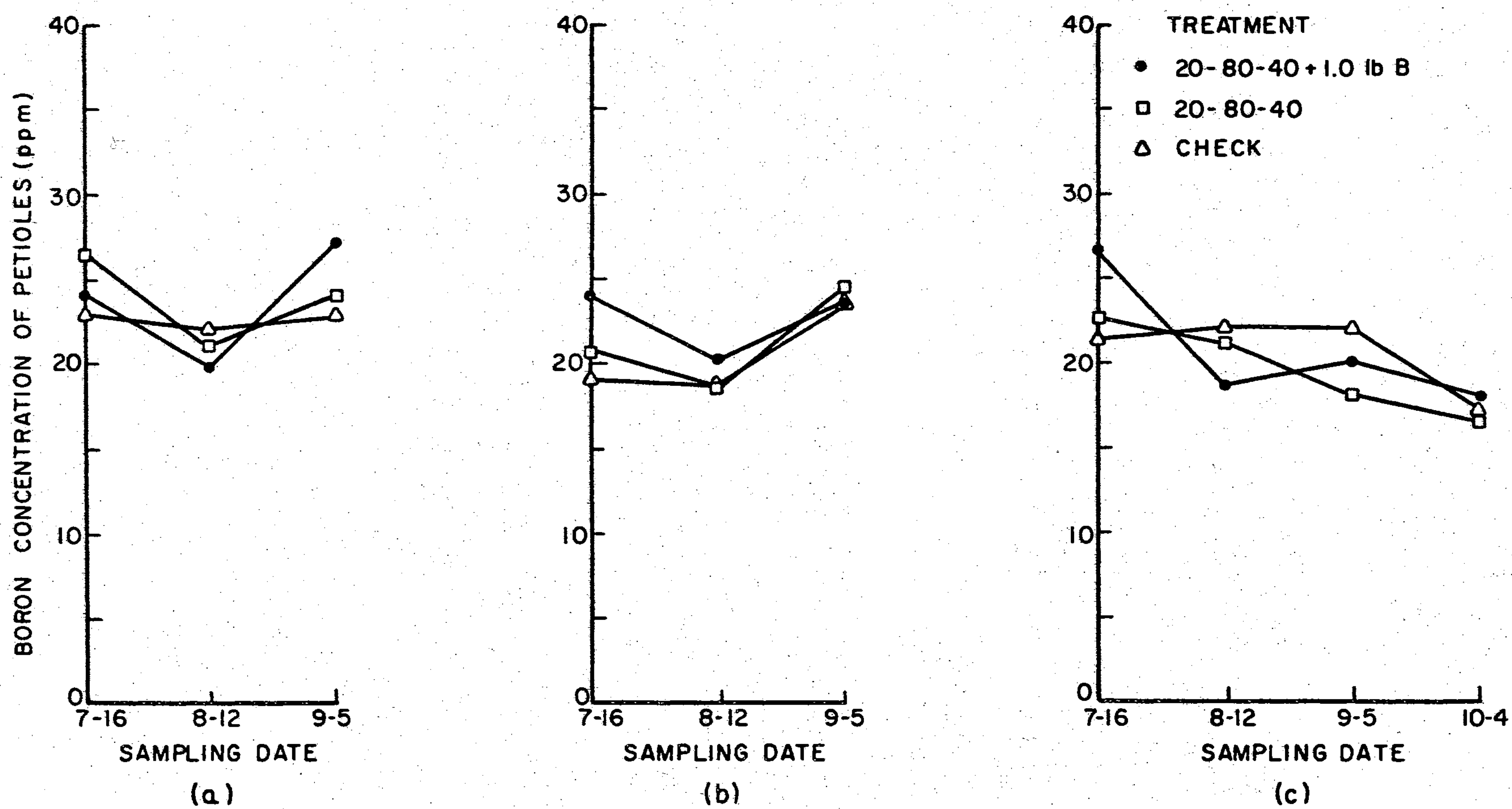

Figure 29. The Effect of Three Fertilizer Treatments on the Boron Concentrations of Peanut Petioles With Time for 3 Stages of Development; (a) I, (b) II, and (c) III at Durant, Oklahoma.

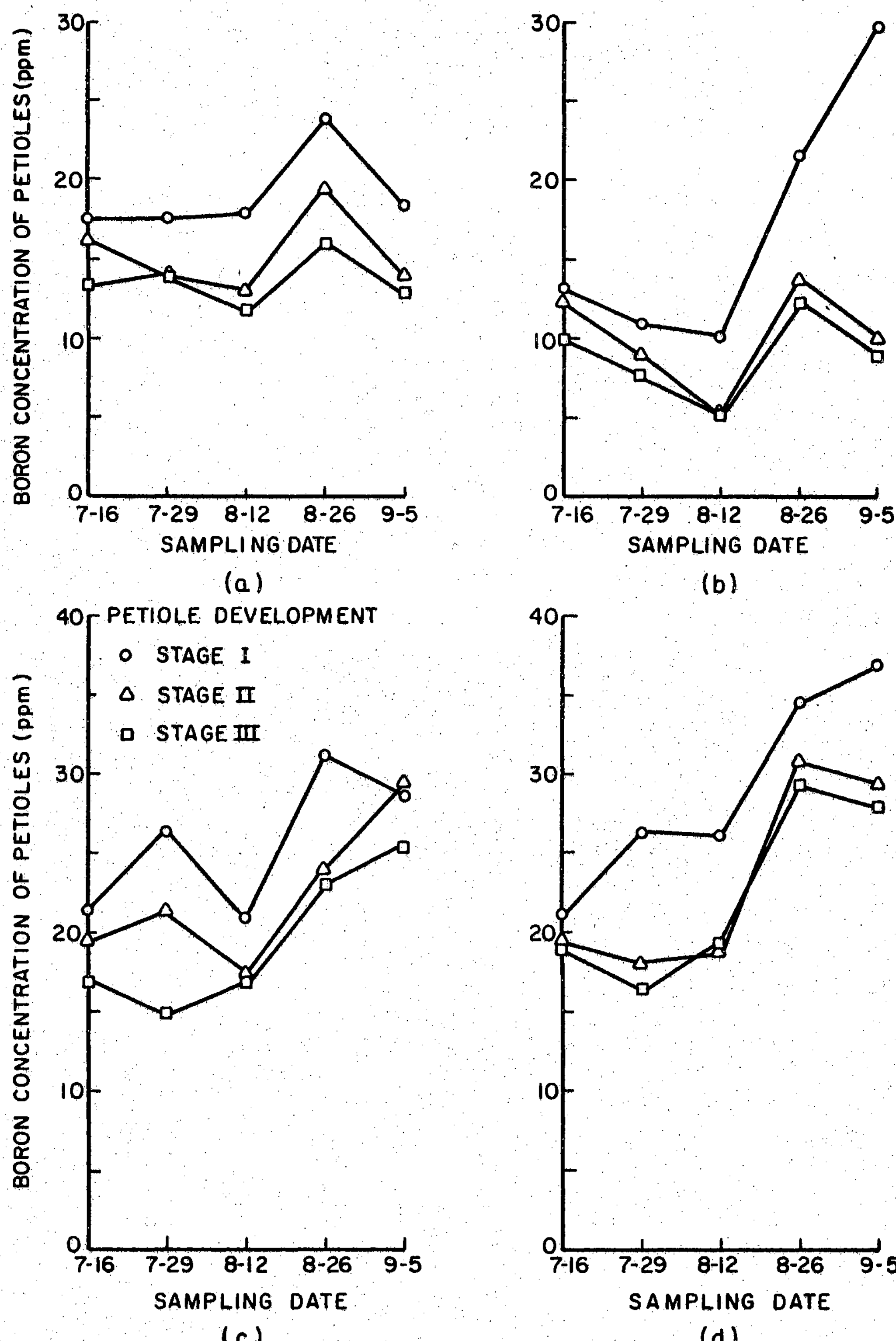

Figure 30. The Boron Concentrations of Three Stages of Petioles With Time for Treatments (a) 0-0-0, (b) 20-80-40, (c) 20-80-40 plus 0.5 lb. Boron, and (d) 20-80-40 plus 1 lb. Boron at McAlester, Oklahoma.

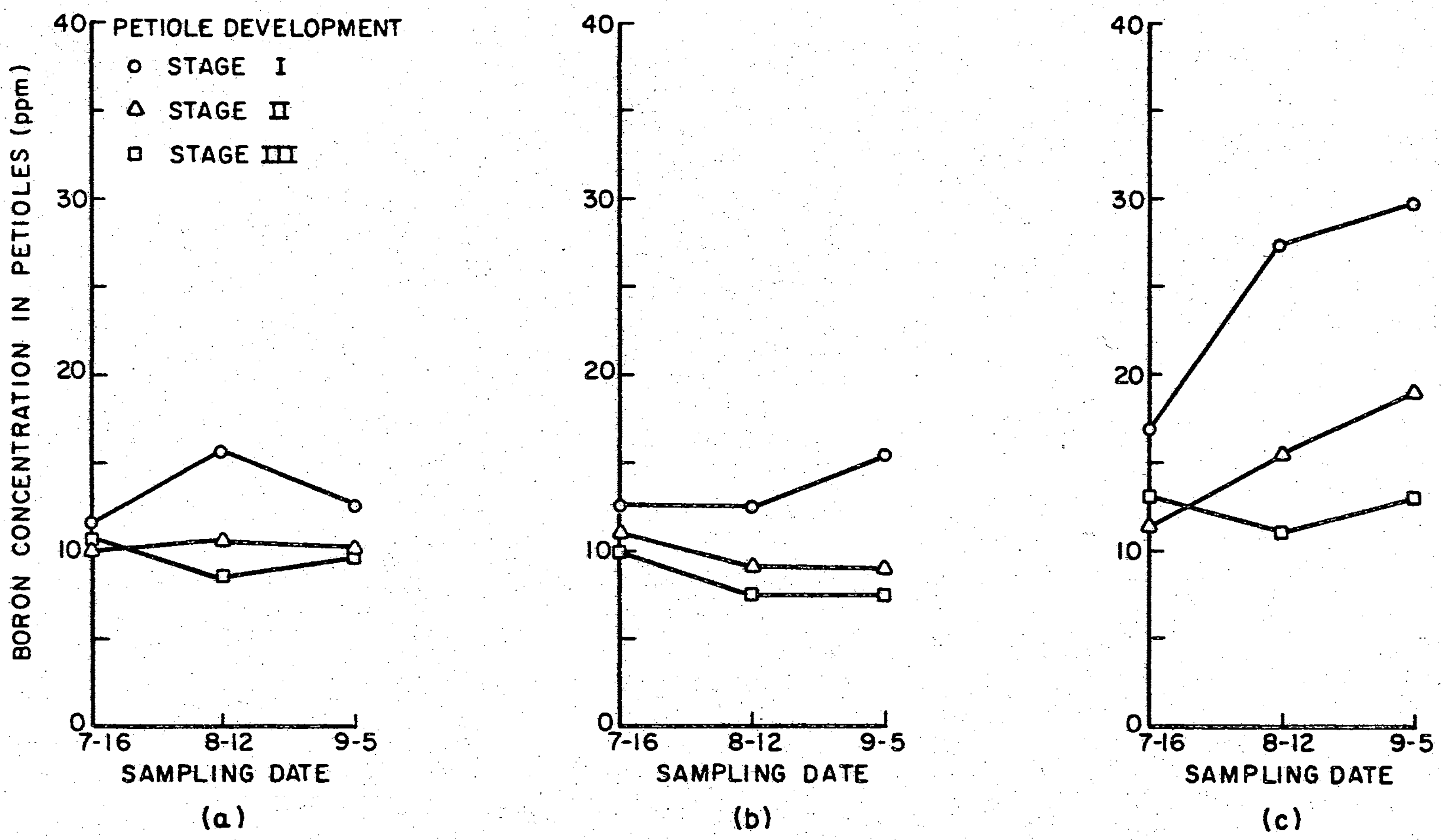

Figure 31. The Boron Concentrations of the Three Stages of Petioles Sampled With Time for Treatments (a) 0-0-0, (b) 20-80-40, and (c) 20-80-40 plus 1 lb. Boron at Ft. Towson, Oklahoma.

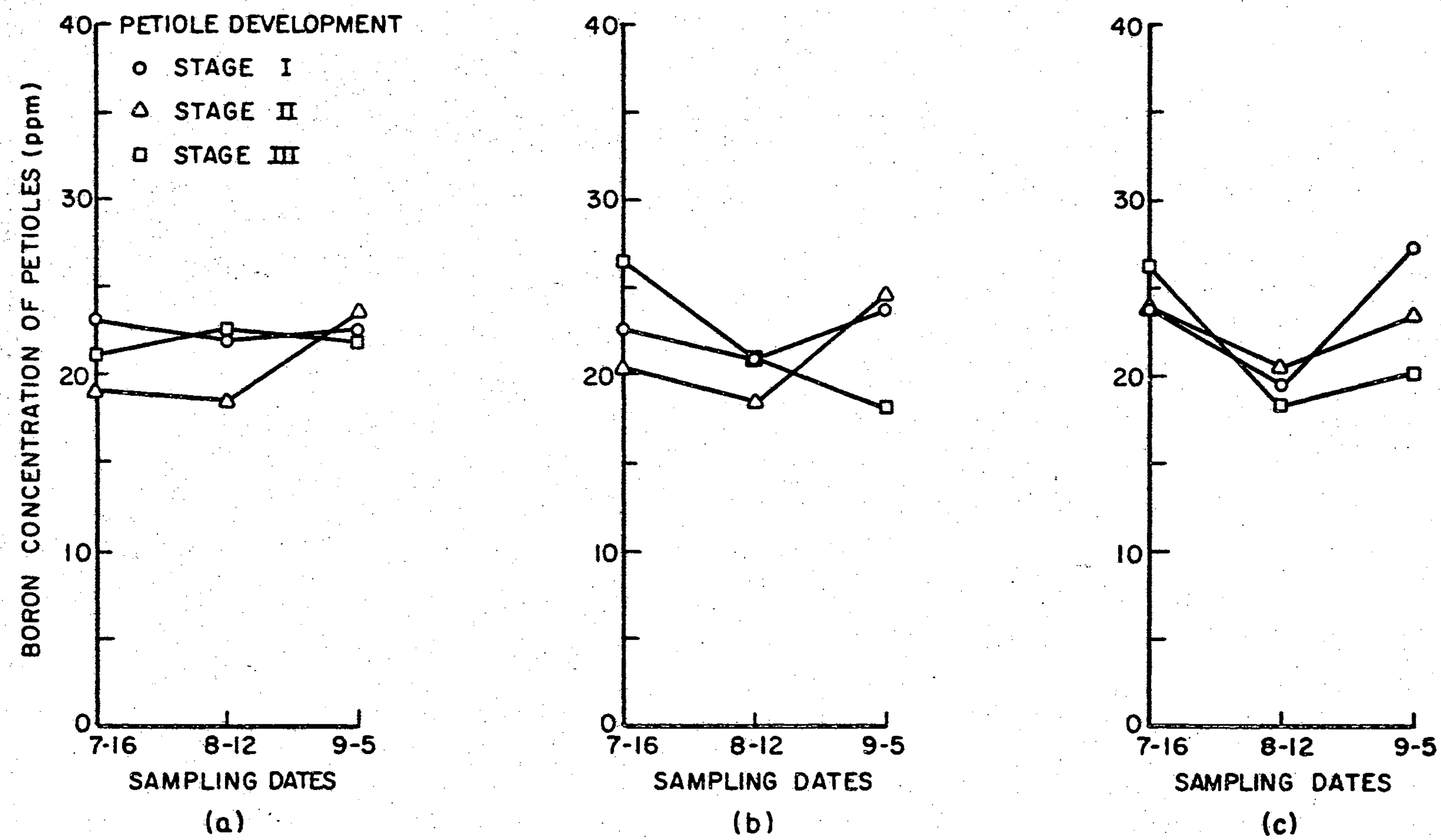

Figure 32. The Boron Concentrations of the Three Stages of Petioles Sampled With Time for Treatments (a) 0-0-0, (b) 20-80-40, and (c) 20-80-40 plus 1 lb. Boron at Durant, Oklahoma.

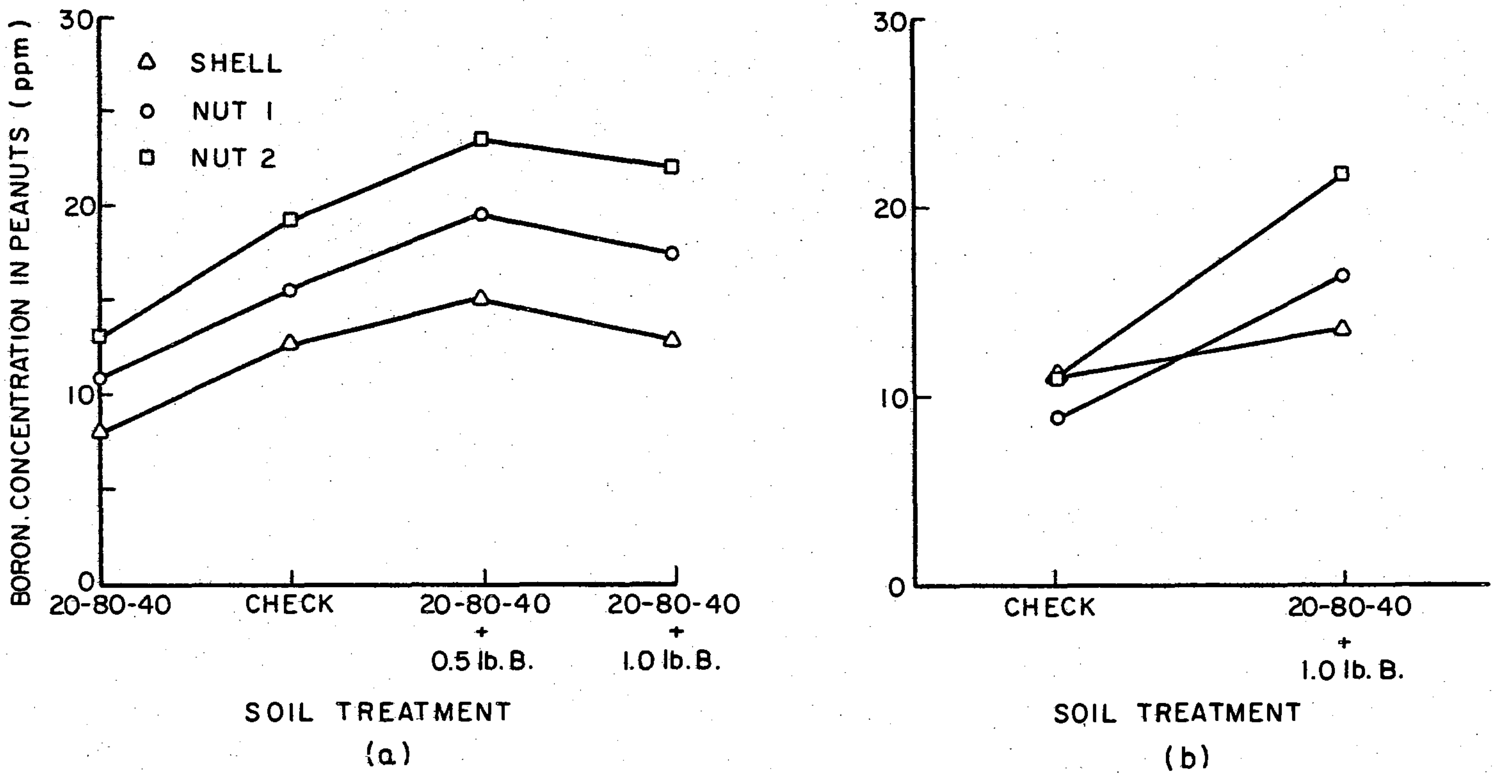

Figure 33. The Boron Concentrations of the Peanuts and Shells as Influenced by Boron Applications at (a) McAlester, and (b) Ft. Towson, Oklahoma.

than the nuts at McAlester. Peanut shells grown under low boron conditions at Ft. Towson contained more boron than nut 1 and as much as nut 2 (Figure 33b). The shells from plots fertilized with boron contained less boron than the nuts.

Foliar Analysis for Boron

The boron levels of peanut leaves from the three sites studied are compared in Figure 34. The boron levels of the leaves, in most cases, decreased from July 16th to the August 12th sampling date. All treatments that had boron concentrations below 20 ppm on August 12 had less than 30 ppm boron at the July 16 sampling date. On the other hand, no plot with more than 30 ppm boron in the young leaves at the July 16 sampling date had boron levels decrease below 20 ppm during the growing season.

Boron levels in petioles are compared in Figure 35. Boron concentrations in the petioles appear to be relatively consistent throughout the growing season. Significant amounts of internal damage were found in the plots with boron levels below specific values. These values differed with the petiole stages. They were 20 ppm boron for stage I, 17.5 ppm for stage II, and 15 ppm for stage III.

The boron contents of the leaves and petioles were significantly correlated with the internal damage of peanuts. The correlation coefficient values for the field data are shown in Table V. Correlation values for the leaves were higher on the earlier sampling dates than the later dates. Correlation values were higher for the petioles than for leaves.

TABLE V

CORRELATION COEFFICIENT VALUES (r) COMPARING THE BORON CONTENT OF LEAVES AND PETIOLES WITH THE INTERNAL DAMAGE OF THE NUTS AT THREE EXPERIMENTAL LOCATIONS IN OKLAHOMA

Sample Date	Leaf 1	Leaf 2	Leaf 3	Petiole 1	Petiole 2	Petiole 3
7-16	-.609	-.654	-.643	-.697	-.586	-.667
8-12	-.703	-.690	-.591	-.716	-.763	-.738
9-5	-.611	-.524	-.472	-.723	-.745	-.692
10-4			-.410			-.829

Significant (.05) r value .497

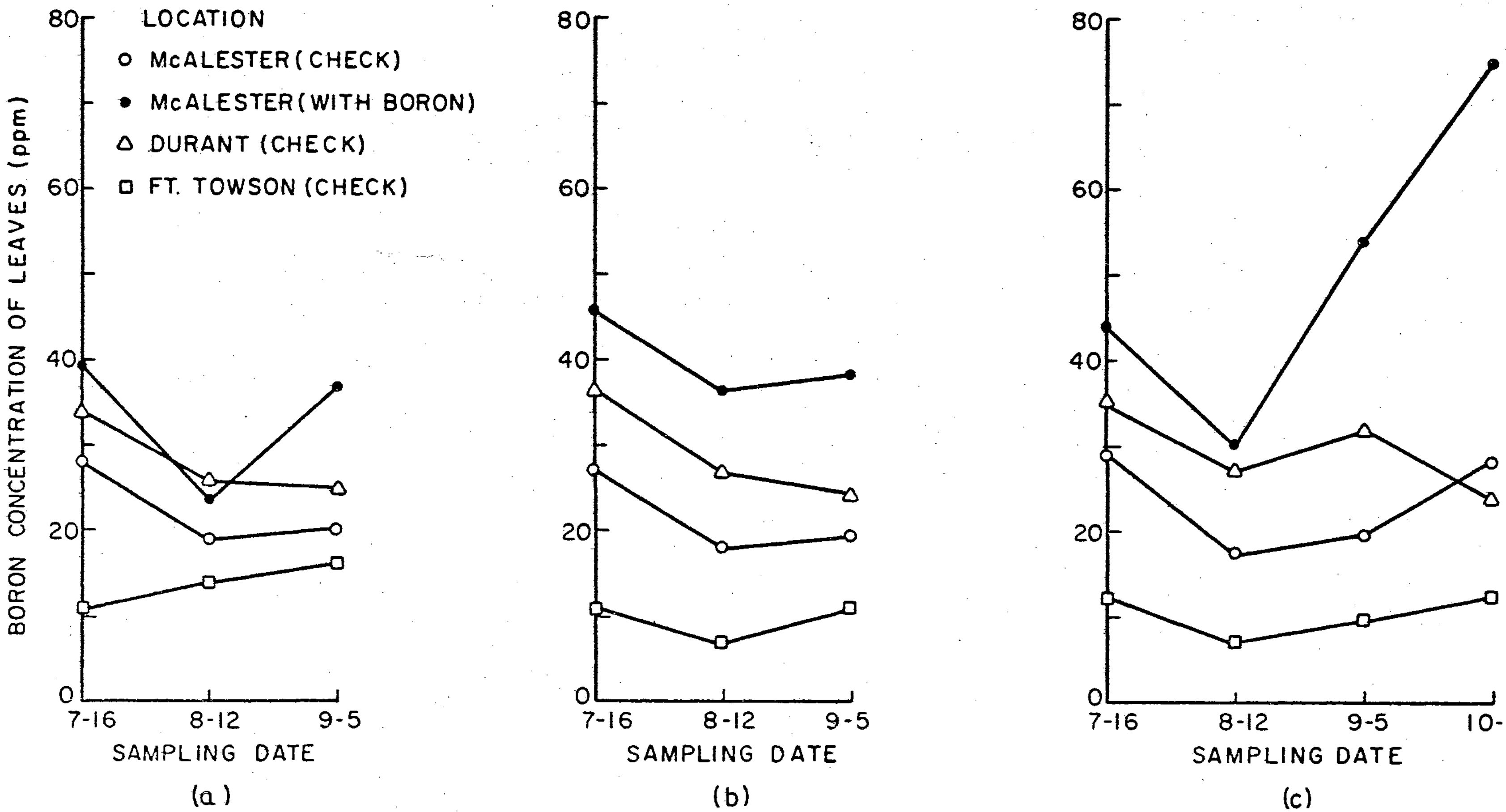

Figure 34. A Comparison of the Boron Concentrations of the Leaves in 3 Stages of Development; (a) I, (b) II, and (c) III from Three Experimental Locations in Oklahoma in 1969.

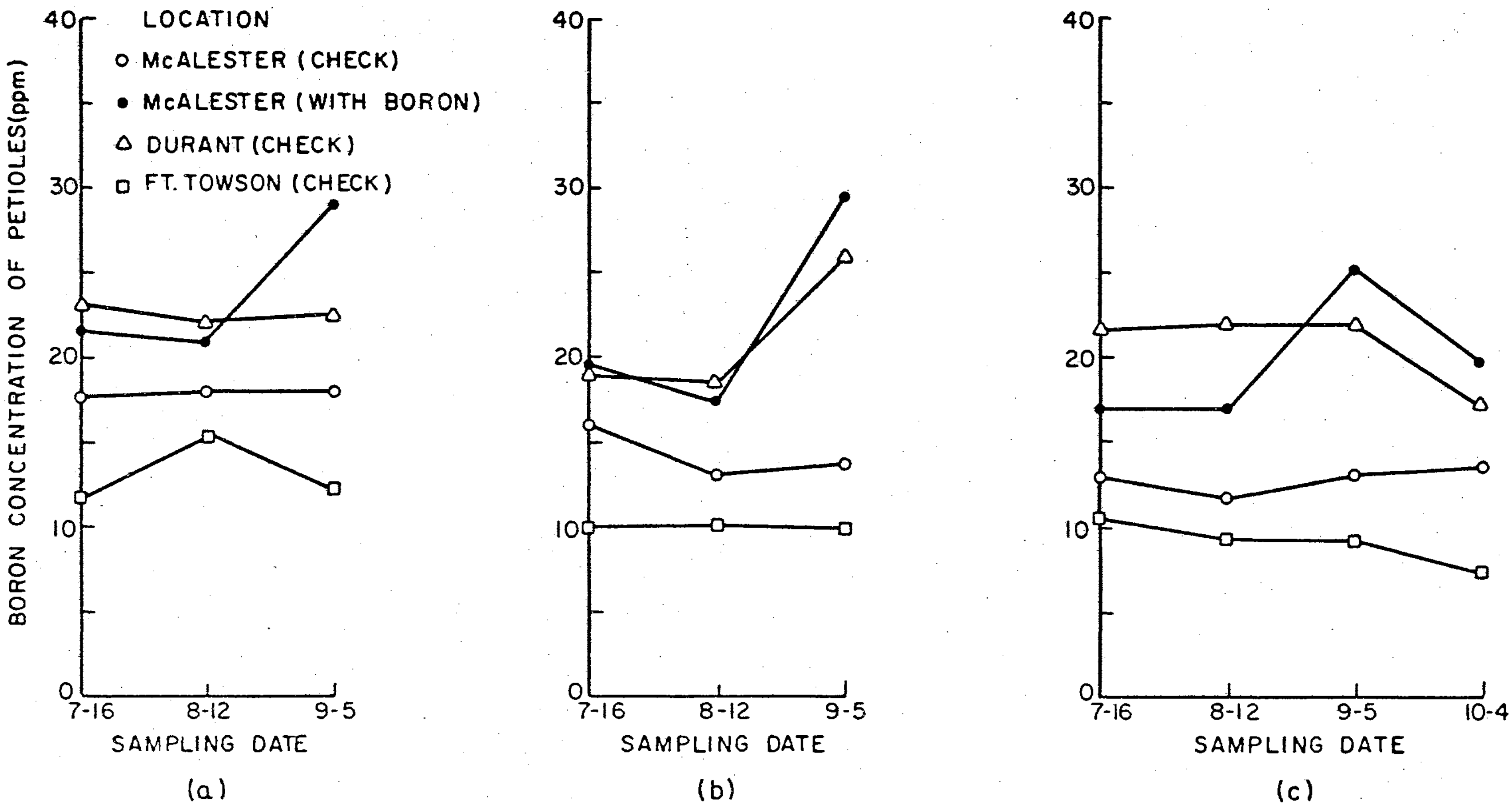

Figure 35. A Comparison of the Boron Concentrations of the Petioles in 3 Stages of Development; (a) I, (b) II, and (c) III from Three Experimental Locations in Oklahoma in 1969.

CHAPTER V

SUMMARY AND CONCLUSIONS

Spanish peanuts were grown in the greenhouse and in field plots to determine the feasibility of the use of foliar analysis for evaluation of the boron status of peanuts. Leaf and petiole samples were collected and analyzed for boron, and related to the internal damage of peanuts.

Boron uptake and distribution patterns were observed in the greenhouse. After this preliminary work, attempts were made to establish critical boron levels, and the critical time of boron supply for Spanish peanuts. The boron concentration-internal damage relationships were then studied under field conditions in three Oklahoma soils.

The boron contents of peanut plants were found to be related to the boron availability in the soil. A significant correlation was found between the boron content of 70 day old peanut plants grown in the greenhouse and their gynophores and developing nuts. The boron content of the nuts at harvest time was not necessarily related to the amount of internal damage present, but more closely related to the availability of boron in the soil at harvest time.

Peanuts exhibited both passive and active transport of boron. Peanut leaves accumulated boron under conditions of high boron availability. Peanut plants translocated boron from older leaves to other parts of the plant under conditions of decreasing boron availability.

The boron content of the gynophores grown in soils with low levels of available boron increased after entering the soil.

Corrections of boron deficiencies by 65 days after planting eliminated internal damage in the nuts under greenhouse conditions. Corrections of boron deficiencies 82 days after planting increased the boron content of the plant and nuts, but had no beneficial effect on the quality of the nuts. The nuts from plants in which boron levels decreased below the critical level on day 100 showed no evidence of internal damage on the 120 day harvest date.

Foliar analyses can be a useful guide in determining the boron status of a peanut crop, but interpretations from both foliar analysis and soil testing are subject to error caused by the unpredictable changes in soil moisture conditions during the growing season. The critical level of boron in the young leaves of Spanish peanuts was set at 18 to 20 ppm. Under field conditions, 30 ppm was considered critical for the first 45 days after planting to allow for a seasonal decrease in boron content. The critical level of boron in petioles of Spanish peanuts under field conditions was set at 20 ppm for stage I, 17.5 ppm for stage II, and 15 ppm for stage III for the first 45 days after planting.

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APPENDIX

TABLE VI

THE WATER CONTENT OF THE SOIL AT THREE PEANUT EXPERIMENTAL SITES, 1969

	Soil Depth (Inches)	Date of Sample						
		7-16	7-29	8-12	8-26	9-5	9-23	10-4
		Percent Moisture						
McAlester	0-6	3.5	2.0	0.8	6.5	3.4	4.3	1.1
	6-12	5.8	4.0	1.3	5.8	4.0	2.9	1.4
Ft. Towson	0-6	1.0		0.9		0.8		2.5
	6-12	3.3		1.2		1.0		3.0
Durant	0-6	14.4		14.2		14.6		17.2
	6-12	24.5				25.1		20.7

TABLE VII

BORON CONCENTRATIONS AND CALCULATED F VALUES OF LEAFLETS, PETIOLES, AND GYNOPHORES FROM SPANISH PEANUTS GROWN IN THE GREENHOUSE UNDER FOUR BORON LEVELS IN THE SOIL

Plant Sample		Treatment: Check	0.25 μg B per g soil	0.5 μg B per g soil	1.0 μg B per g soil	Calculated F
		ppm				
		at 20 days				
Leaf	1	50.4	332.4	518.3	1373.6	36.09
	6	51.6	158.4	330.7	587.7	24.74
	7	48.4	118.4	203.0	332.9	26.16
		at 30 days				
Leaf	6	60.8	340.8	986.4	1464.0	56.70
	7	49.9	264.5	638.3	1152.0	62.96
	9	50.1	85.3	167.0	329.5	68.84
	10	57.4	71.4	83.8	124.3	9.76
		at 40 days				
Leaf	6	29.1	74.2	203.0	602.2	6.58
	9	43.1	430.5	931.6	1305.0	7.26
	11	23.8	40.6	45.4	58.5	14.00
	8L*	23.0	40.9	59.5	82.0	13.80
	12	22.8	41.2	48.1	82.4	38.40
		at 50 days				
Leaf	9	19.4	34.7	70.8	129.4	18.27
	11	17.2	35.6	71.1	158.1	16.57
	8L	23.7	74.8	307.5	315.2	4.47
	13	10.4	27.7	35.9	60.1	16.07
	14	12.5	24.2	30.4	53.6	26.43
		at 60 days				
Leaf	7	31.6	231.8	583.1	1258.2	52.26
	10	27.4	44.8	112.3	244.8	16.85
	13	12.2	31.1	38.5	93.5	13.14
	15	12.0	19.9	28.5	36.2	3.01

TABLE VII (Continued)

Plant Sample		Treatment: Check	0.25μg B per g soil	0.5μg B per g soil	1.0μg B per g soil	Calculated F
		ppm				
Petiole	7	18.3	18.7	23.4	22.0	2.14
	10	15.5	19.0	20.8	23.0	23.10
	13	8.8	16.2	19.1	22.2	84.57
	15	8.3	11.4	18.0	19.1	48.68
at 70 days						
Leaf	9	25.5	50.1	195.7	299.8	6.46
	12	11.1	15.4	29.2	58.1	9.76
	16	4.7	6.5	13.0	24.6	67.14
	17	6.5	7.0	10.2	22.8	39.12
Petiole	12	9.7	16.8	19.1	22.1	11.38
	16	5.6	5.8	9.8	16.7	31.19
	17	6.2	8.2	12.9	16.8	47.78
Gynophore above soil		4.5	8.5	15.1	22.3	17.66
Gynophore in soil		6.6	12.4	14.9	18.7	3.78
Nuts in soil		6.3	12.8	13.2	18.2	5.07
				Tabulated F(.05) Value		3.49

*L indicates lateral branch

TABLE VIII

LEAF WEIGHTS AND CALCULATED F VALUES OF LEAFLETS FROM SPANISH PEANUTS GROWN IN THE GREENHOUSE UNDER FOUR BORON LEVELS IN THE SOIL

Leaf Number		Treatment: Check	Treatment: 0.25 μg B per g soil	Treatment: 0.5 μg B per g soil	Treatment: 1.0 μg B per g soil	Calculated F
		Grams				
				at 30 days		
Leaf	6	.037	.041	.038	.038	1.05
	7	.051	.049	.052	.042	2.72
				at 40 days		
Leaf	6	.051	.054	.052	.045	1.59
	9	.044	.051	.044	.040	2.11
				at 50 days		
Leaf	9	.046	.047	.041	.045	1.24
	11	.053	.047	.050	.043	3.41
	8L*	.040	.039	.035	.033	2.24
				at 60 days		
Leaf	9L	.072	.075	.069	.059	1.62
	13	.073	.064	.062	.050	3.79
	11L	.049	.072	.062	.047	2.94
	10	.059	.056	.053	.044	4.62
	7	.052	.054	.048	.041	4.51
				at 70 days		
Leaf	9	.055	.052	.050	.045	4.87
	12	.049	.048	.042	.037	3.88
	16	.040	.055	.049	.038	5.95
					Tabulated F(.05) Value	3.49

*L indicates lateral branch

TABLE IX

BORON CONCENTRATIONS OF YOUNG LEAVES, INTERNAL DAMAGE OF PEANUTS, AND CALCULATED F VALUES OF SPANISH PEANUTS GROWN IN THE GREENHOUSE FOR CRITICAL BORON LEVEL DETERMINATIONS (PART I)

Days after planting	Treatment: Boron level in young leaves				Calculated F
	Low	Medium low	Medium high	High	
	ppm				
38	8.1	8.8	8.3	7.9	0.05
45	5.2	11.2	14.4	10.9	2.28
52	5.3	11.8	12.2	36.1	53.65
59	8.5	40.1	38.7	40.0	17.93
66	11.3	39.6	38.6	36.6	19.94
73	11.6	34.0	33.9	37.5	35.15
80	6.2	24.5	30.7	33.1	20.13
87	6.5	25.8	30.2	36.4	24.84
101	11.8	27.3	42.2	43.5	11.45
115	11.2	27.9	27.6	32.3	18.92
122	10.7	31.6	37.5	31.6	8.32
Internal damage	83.5%	1.4%	0.0%	0.0%	

Tabulated $F_{(.05)}$ value 3.49

TABLE X

BOROON CONCENTRATIONS OF YOUNG LEAVES AND NUTS, INTERNAL DAMAGE OF PEANUTS, AND CALCULATED F VALUES OF SPANISH PEANUTS GROWN IN THE GREENHOUSE FOR CRITICAL BORON LEVEL DETERMINATIONS (PART II)

Days after planting	Treatment: Boron level in young leaves			Calculated F
	Low	Medium	High	
		ppm		
30	41.7	38.9	39.9	1.66
38	36.7	34.5	39.1	2.17
45	30.2	31.4	32.9	0.25
52	30.2	30.3	39.0	3.56
59	22.0	17.5	25.3	5.75
66	22.7	23.2	30.4	6.24
73	22.4	22.6	29.7	2.45
80	12.0	13.1	16.6	0.94
87	6.0	5.1	6.8	0.30
94	13.9	18.0	21.5	0.74
101	17.1	20.7	24.7	1.55
108	9.4	17.0	19.0	11.44
115	13.4	17.2	17.8	1.05
Nuts	5.0	9.3	10.2	18.81
		percent		
Internal damage	84.1	45.8	6.8	
			Tabulated $F_{(.05)}$ Value	4.26

TABLE XI

BORON CONCENTRATIONS OF LEAVES, PETIOLES AND NUTS OF SPANISH PEANUTS, STARR VARIETY, McALESTER, OKLAHOMA, 1969

Plant Sample		Treatments: 0-0-0	20-80-40	20-80-40 plus 0.5 lb. B	20-80-40 plus 1.0 lb B
		ppm			
July 16					
Leaf	1	27.3	18.9	39.1	41.4
	2	27.6	15.4	45.5	46.6
	3	28.9	10.0	43.6	56.6
Petiole	1	17.8	13.2	21.7	21.3
	2	16.2	12.4	19.7	19.7
	3	13.2	9.9	17.1	19.2
July 29					
Leaf	1	18.5	12.0	31.6	31.8
	2	18.5	9.4	35.2	29.8
	3	22.2	8.8	31.3	35.2
Petiole	1	17.8	11.0	26.5	26.5
	2	14.0	9.2	21.6	18.2
	3	14.0	7.6	14.9	16.3
August 13					
Leaf	1	18.9	10.1	23.6	27.9
	2	16.9	7.0	36.2	34.0
	3	17.4	6.6	29.8	42.5
Petiole	1	18.1	10.4	21.1	26.7
	2	12.8	6.2	17.4	19.0
	3	11.6	6.4	16.9	19.2
August 26					
Leaf	1	18.6	16.2	32.1	36.4
	2	14.2	10.1	29.1	33.1
	3	15.2	9.5	34.4	57.0
Petiole	1	24.1	21.5	31.3	34.6
	2	19.4	13.8	23.9	31.1
	3	16.5	12.4	23.3	29.1

TABLE XI (Continued)

Plant Sample		Treatments: 0-0-0	20-80-40	20-80-40 plus 0.5 lb. B	20-40-80 plus 1.0 lb. B
		ppm			
			September 5		
Leaf	1	20.2	11.3	37.2	44.8
	2	19.5	10.7	38.1	63.0
	3	19.4	10.4	54.2	91.0
Petiole	1	18.2	12.2	28.8	37.1
	2	13.8	9.9	29.6	29.6
	3	13.2	8.8	25.5	27.9
			September 23		
Leaf	3	37.3	16.8	61.2	75.7
Petiole	3	----	----	----	----
			October 4		
Leaf	3	28.2	9.8	75.6	141.6
Petiole	3	13.4	7.4	19.6	20.6
			October 25		
Shell		12.7	8.1	15.0	13.1
Nut	1	15.5	10.9	19.7	17.6
	2	19.3	13.0	23.6	22.0
			Percent		
Internal damage		7.0	10.0	0.3	1.3

TABLE XII

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF LEAVES FROM THE FIELD EXPERIMENT AT McALESTER, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	6.76	3.07
Treatments	100.97	2.68
Leaf stage	4.46	3.07
Sample date	11.42	2.45
Treatment X leaf stage	4.49	2.17
Leaf stage X sample date	1.31	2.08
Sample date X treatment	3.44	1.83
Treatment X sample date X leaf stage	0.57	1.61

TABLE XIII

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF PETIOLES FROM THE FIELD EXPERIMENT AT McALESTER, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	5.32	3.07
Treatments	87.16	2.68
Petiole stage	24.76	3.07
Sample date	19.71	2.45
Treatment X petiole stage	0.39	2.17
Petiole stage X sample date	0.62	2.08
Sample date X treatment	3.11	1.83
Treatment X sample date X petiole stage	0.36	1.61

TABLE XIV

BORON CONCENTRATIONS OF LEAVES, PETIOLES, AND NUTS OF SPANISH PEANUTS, STARR VARIETY, FT. TOWSON, OKLAHOMA, 1969

Plant Sample		Treatment		
		0-0-0	20-80-40	20-80-40 plus 1.0 lb. B
		ppm		
			July 16	
Leaf	1	11.7	11.2	16.8
	2	11.3	12.4	13.5
	3	13.7	12.5	18.1
Petiole	1	11.6	12.6	16.9
	2	10.1	11.0	11.8
	3.	10.7	10.4	13.0
			August 13	
Leaf	1	16.1	16.0	22.0
	2	9.1	8.8	15.9
	3	9.6	8.4	19.7
Petiole	1	18.9	15.7	20.7
	2	9.7	11.2	14.0
	3	8.5	9.0	9.3
			September 5	
Leaf	1	15.7	16.3	44.6
	2	11.2	10.8	33.7
	3	10.0	8.5	29.1
Petiole	1	12.5	15.5	30.0
	2	9.9	9.2	19.3
	3	9.5	7.6	12.7
			October 4	
Leaf	3	12.8	10.1	29.8
Petiole	3	7.1	7.7	13.5

TABLE XIV (Continued)

Plant Sample		Treatment 0-0-0	20-80-40	20-80-40 plus 1.0 lb. B
		ppm		
		December 11		
Shell		11.1		13.5
Nut	1	9.0		16.5
	2	11.4		22.0
		Percent		
Internal damage		7.5		1.8

TABLE XV

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF LEAVES FROM THE FIELD EXPERIMENT AT FT. TOWSON, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	6.78	3.19
Treatments	79.60	3.19
Leaf stage	7.84	3.19
Sample date	13.97	3.19
Treatment X leaf stage	1.03	2.57
Leaf stage X sample date	3.05	2.57
Sample date X treatment	12.13	2.57
Treatment X sample date X leaf stage	0.38	2.14

TABLE XVI

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF PETIOLES FROM THE FIELD EXPERIMENT AT FT. TOWSON, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	5.07	3.19
Treatments	93.24	3.19
Petiole stage	97.99	3.19
Sample date	6.65	3.19
Treatment X petiole stage	10.35	2.57
Petiole stage X sample date	11.63	2.57
Sample date X treatment	8.70	2.57
Treatment X sample date X petiole stage	1.64	2.14

TABLE XVII

BORON CONCENTRATIONS OF LEAVES AND PETIOLES OF SPANISH PEANUTS, STARR VARIETY, DURANT, OKLAHOMA, 1969

Plant Sample		Treatment 0-0-0	20-80-40	20-80-40 plus 1.0 lb. B
		ppm		
		July 16		
Leaf	1	33.6	39.1	31.0
	2	36.7	43.9	44.4
	3	35.1	32.1	45.7
Petiole	1	23.4	26.5	24.0
	2	19.2	20.4	24.1
	3	21.2	22.6	26.4
		August 13		
Leaf	1	25.6	27.7	27.4
	2	27.1	26.6	29.5
	3	26.9	29.6	32.1
Petiole	1	21.9	21.2	19.7
	2	18.4	18.5	20.1
	3	22.1	21.2	18.2
		September 5		
Leaf	1	24.7	24.9	29.8
	2	24.1	19.3	20.9
	3	31.9	23.9	23.6
Petiole	1	22.5	24.0	27.2
	2	23.6	24.3	23.5
	3	22.0	18.2	20.1
		October 4		
Leaf	3	23.6	25.0	26.9
Petiole	3	17.1	16.7	18.3

TABLE XVIII

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF LEAVES FROM THE FIELD EXPERIMENT AT DURANT, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	5.43	3.19
Treatments	0.83	3.19
Leaf stage	0.54	3.19
Sample date	30.75	3.19
Treatment X leaf stage	0.69	2.57
Leaf stage X sample date	2.09	2.57
Sample date X treatment	1.08	2.57
Treatment X sample date X leaf stage	1.35	2.14

TABLE XIX

CALCULATED AND TABULATED F VALUES OF THE BORON CONCENTRATIONS OF PETIOLES FROM THE FIELD EXPERIMENT AT DURANT, OKLAHOMA, 1969

Source	Calculated F	Tabulated F(.05)
Replications	2.00	3.19
Treatments	0.60	3.19
Petiole stage	3.09	3.19
Sample date	6.01	3.19
Treatment X petiole stage	0.47	2.57
Petiole stage X sample date	2.06	2.57
Sample date X treatment	1.28	2.57
Treatment X sample date X petiole stage	0.98	2.14

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