EFFECT OF LEVELS OF BORON ON PREHARVEST DROP OF FRUIT AND INORGANIC LEAF COMPOSITION IN STARKING APPLE TREES

by

Salem Abu-Khalil

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Approved:

Ramzi Khalidy
In Charge of Major Work

Frank O. Smith

A. S. Jalloul

[illegible]

R. H. Porter

Salim Makdisi
Chairman, Graduate Committee

American University of Beirut
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BORON AND PREHARVEST DROP IN APPLE TREES

Abu-Khalil

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ABSTRACT

A one-year study was conducted in the 1958 growing season to determine the effect of boron supply on preharvest drop of fruit and inorganic leaf composition in Starking Delicious apple trees located at Mashgara. Four levels of borax were applied, namely 25, 50, 100, and150 grams, each level being replicated five times, while five trees served as a check. Leaf samples were collected at four different periods, June 29, July 29, August 29 and October 1, 1958. Also data on yield and preharvest drop was obtained.

Analysis of the data by the use of the "t" test revealed that the 100 grams borax treatment caused a significant decrease in drop. The reduction of drop obtained by the use of 25 and 50 grams of borax was not significantly different from the control. Failure to control drop resulted with the 150 grams borax treatment. Considering the absolute values for boron, there were indications of increased boron uptake with the advance of the season in the case of the treated trees, but there were little or no such indications for the checks.

The ratios of Ca/B, N/B, K/B, P/B, $\frac{Ca + K}{Mg}$, $\frac{Ca + Mg}{K}$, $\frac{Mg}{B}$ and $\frac{Ca + K + Mg}{B}$ were computed for this experiment. Considering the average over the last three months in which leaf sampling was done, the trees receiving the 100 grams treatment showed a more balanced $\frac{Ca + K + Mg}{B}$ ratio than those receiving the lower levels or those receiving the 150 grams treatment.

The ranges and averages of each of the elements analyzed for were presented for each of the sampling dates. Based on the average of the four months, the trees receiving the 25 grams of borax had significantly higher amounts of calcium than those receiving the 100 and 150 grams treatment while those receiving the 150 grams of borax had significantly lower manganese and phosphorus and higher magnesium content than the control. The sodium, iron and total nitrogen content of the leaves did not seem to be influenced by the amount of borax applied. The analysis of variance also revealed significant differences in the percentage content of elements from leaves sampled during different months.

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INTRODUCTION

Boron is probably the most important micro element required by all plants for healthy growth (3). In 1857, Wittstein and Apoiger were the first to discover that boron occurs in the seeds of *Maesa picta* (77). It was until 1895 that Jay suggested after exhaustive analyses of many plants that boron might be universally distributed throughout the plant kingdom(72).

Losses incurred through boron deficiency may be enormous. In an apple growing region in British Columbia, it was found that out of an estimated crop of 120,000 boxes, only 60,000 to 80,000 boxes remained on the tree and even these were not worth picking. The remainder of the crop dropped mainly due to boron deficiency (65).

Although various workers have reported that boron deficiency as well as excess increase preharvest drop in apples, very little work was reported on the control of preharvest drop by the use of borax. The little work that was reported was mostly performed on the variety McIntosh, which under U.S. conditions is more subject to drop than other varieties. This drop is greatly increased under conditions of boron deficiency. Little or no work has been reported on the effect of boron on the apple variety Starking.

In the area in which the experimental orchard is located, no McIntosh apples are grown, and the three main varieties are Starking Delicious, Starking, Golden Delicious, and a few other varieties such as Winesap, Jonathan and Reinette de Canada. It was observed that preharvest drop is much more severe on Starking and Starking Delicious than on the remaining varieties. To reduce the loss caused by preharvest drop, the growers in said region pick their fruit early. This early picking has resulted in immature, low quality fruit. Furthermore, it was found that the bark of some trees and the fruits in the experimental orchard showed symptoms of boron deficiency, as seen in figure 1.

This experiment was initiated in the growing season of 1958 on Starking apple trees mainly for the purpose of trying to reduce preharvest drop and to study the influence of the level of boron supply on inorganic leaf composition.

Figure 1. Fruits from control trees showing external cork, a boron deficiency symptom - (Photo taken by Dr. R. Khalidy).

REVIEW OF THE LITERATURE

Much information has been published on the effect of boron on preharvest drop of fruit in apples and to a much lesser extent about its effects on the inorganic leaf composition. To achieve a better understanding of the effect of boron on inorganic leaf composition, it was felt advantageous to include in this review part of the work performed on citrus and on deciduous trees other than apples.

I. Boron content in soils

Boynton (17) referring to the work of Whetstone, Robinson and Byers stated that boron is found in all soils in varying amounts depending on the boron content of the parent material and the weathering action that has taken place since the parent material was deposited. The available soil boron is made up of organic and inorganic forms which are in equilibrium with the fixed forms of boron (14). The readily available boric acid or borate salts are present in very small quantities and the available supply is obtained through the mineralization of organic matter (11).

Gardner Bradford and Hooker (44) stated that there is little correlation between the boron content of soils and deficiencies, because generally less than 5 percent of the total amount is in a form available to the plant. In some soils, boron deficiency is due to a low content, of said element, while in other soils the deficiency is due to a fixing power for boron caused by poor aeration and poor root absorption (28). Well-drained sandy soils having a coarse texture were found low in boron (85).

II. Soil moisture and boron deficiency.

Boron deficiency is more prevalent in dry summers than in rainy ones (41). This latter case of deficiency was explained by Tisdale and Nelson (86) as being due to the slow rate of decomposition of organic matter. Also the rate of boron - containing minerals going into solution is decreased when the soil moisture content is low (11). Boron deficiency may also result from excessive leaching (86).

III. Effect of liming and pH on boron availability.

Boron availability is greatest in acid soils but decreases rapidly in the range of pH six to ten (69). Various workers have reported that liming seems to cause boron deficiency symptoms, and have offered different explanations for this phenomenon (5, 68, 33, 86, 17).

IV. Boron absorption and translocation.

Boron is generally considered to be absorbed in one of its ionic forms such as $B_4O_7^{=}$, $H_2BO_3^{-}$, $HBO_3^{=}$ or $BO_3^{=}$ (86). Boron is needed in a continuous supply as it is immobile in the plant. Thus deficiency may develop at any time during the season when the supply of said element drops (36). By examining the distribution of boron in lemon leaves, Eaton (42) reported that boron moves from the interveinal tissues towards the leaf margins, and there is comparatively little back movement through the mesophyll. He further stated that on the other hand, boron is quite freely translocated from one region to another in stone fruits.

Different species and even different varieties of the same species differ markedly in their ability to absorb boron from the same substrate. Thus, when the boron content of the soil is high, the proper choice of the stocks is important so as to overcome toxicity effects (44). This fact has well been demonstrated in citrus (34, 30).

After growing several plants in sand culture, Chapman and Vanselow (30) concluded that boron absorption is determined in part by the character of the absorbing root cells, nature of boron compounds accumulating in leaf cells and the equilibrium between mobile and non-mobile forms within the plant. Boron accumulation is increased in the vegetative parts of apple trees grown in soils high in available magnesium content (8). Applications of nitrogen fertilizers which increase the growth of apple trees also increase the boron requirements (35).

Reeve and Shive (74) reported an increased boron content of tomatoes with an increase in the pottasium concentration of the substrate. Collings (33) referred to the work of Parks, Lyon and Hood who found out that an increased absorption of boron by plants may bring about a great increase in the absorption of all mineral nutrients.

V. <u>Relationship between boron and calcium</u>.

For its normal growth, each plant needs to have a certian balance between calcium and boron (57). The optimum calcium to boron ratio varies with the different kinds of plants (40). It was found out that in many cases, symptoms of calcium and boron deficiencies are similar (55). According to Collings (33), boron in the soil enables the plant to absorb more calcium.

VI. <u>Functions of boron</u>.

The role of boron in plant metabolism still remains obscure (53). In a recent review of the physiological action of boron in higher plants, fifteen distinct postulated roles of boron have been noted. Many of these roles are based on the concept that boron increases the translocation of sugars (41). Gauch and Dugger, (46) postulated two mechanisms for the manner in which boron helps in the translocation of sugars which are, the formation of a sugar-borate complex, and the interaction of the sugar molecule with the borate ion which might be located in the cellular membranes. However, boron - sugar complexes have not been isolated from plants (45). Dugger Humphreys and Calhoum (41) later postulated a third mechanism by which boron might enhance sugar translocation. They statedthat boron decreases the enzymatic conversion of glucos-1-phosphate to starch (Glucose-1-$PO_4 \rightleftharpoons$ Starch + PO_4) thus resulting in an increase in the concentration of glucose-1- phosphate which in turn increases the synthesis of soluble carbohydrates that could be translocated from the site of synthesis to the other plant parts. Skok (79) quoted Scripture and McHarque who considered boron as functional in the translocation of carbohydrates, but not through the formation of a complex. Experiments performed by Skok (79) seemed to indicate a close relationship between boron and cellular activity at the meristems, and it was suggested that sugar translocation is related to such cellular activity.

Another possible function of boron in the plant is to stabilize the oxidative system (28). It appears that boron is a component of the cell wall and is necessary for cell division (56).

Boron plays a role in the formation of pectic compounds. It also forms compounds with some sugars or organic acids through adjacent OH^- groups (55). Possibly, the formation of polyhydroxyl - boric acid compounds regulates the rate of cyclic oxidation in phenol oxidase systems (52). There also is an indication that boron functions in protein metabolism (44). Referring to the work of Eaton, Batjer and Co-workers (7) mentioned that one of the functions of boron in plant nutrition is related to the formation of plant hormones.

Hewitt (52) referred to experiments performed by Rosenberg which seemed to indicate the failure in phosphorylation or resynthesis of A.T.P. in case of boron deficiency. Alexander (2) working on squash reported that boron deficient organs showed more catalase activity than control organs. Quoting Beckenbaugh, Gardner Bradford and Hooker (44) stated that phosphorus or boron may act as essential juice buffers in precipitating out excess cations through the formation of insoluble salts.

Gauch and Dugger (46) referred to the work of Minarik and Shive who found an inverse relationship between boron level and percentage moisture in plant tissues.

Experiments on tomatoes have indicated that the presence of both calcium and boron in the nutrient medium is essential to the growth and functional integrity of roots (50).

Burström (26) reported that there are indications of interaction of calcium,boron and auxin in the growth regulating system, although there is no direct evidence of the participation of boron in the growth mechanism. Thomas, Mack and Fagan (85) referred to the work of McLean and Hughes who stated that boron is withdrawn from the leaves by the developing auxiliary flowers and may be necessary before fruit can set. Boric acid sprays applied during bloom significantly increased the set of Anjou pears (7).

Finally, it may be mentioned that soil boron treatments seemed to increase nitrogen fixation by *Azotobacter chroococcum* (58).

VII. Visual symptoms of boron deficiency.

Boron deficiency symptoms in apples vary with the variety, climatic conditions, stage of development at which they appear and vigour of the tree (95, 78, 42, 37).

Also different apple varieties have different boron requirements. Symptoms may be manifested one year by one group of symptoms and another year by a different group (36). The first pathogenic effects of boron deficiency are not externally visible as they are physiological and tend to speed up cell division and growth (88).

The most common symptoms of boron deficiency are shown in the form of internal or external cork on the fruit (17). External cork or "drought spot" always develops early in the season and may appear within two weeks after petal fall (36). In general, it appears before the fruit is half-grown (21). Fruit drop may be heavy as harvest approaches and the keeping quality of the fruit is reduced (31).

Internal cork, sometimes referred to as deep drought spot or corky core (63) may develop in the fruit at any time from two weeks after petal fall until harvest. The brown lesions developed in mature fruits may have a bitter taste, and there is also an increased preharvest drop (36). Referring to the work of Burrell, Davidson and Judkins (36) stated that irrespective of variety, cork developing more than eight weeks after petal fall is usually of the internal type.

Besides the fruit symptoms caused by boron deficiency, vegetative organs may be severely affected under conditions of very severe deficiency (17). Symptoms include dieback, incipient dieback, production of rosettes and internal bark necrosis, sometimes referred to as "apple measles" (21, 36, 39, 54).

Boron deficiency affects the leaves in that they will have large veins in comparison to their size, become leathery and may acquire a glossy appearance. Some interveinal yellowing may occur particularly at the leaf tips (31). Leaves may also be dwarfed and narrow at the terminals (10).

Boron deficiency also causes poor root development and the death of the growing regions of the roots (16, 92). Boron deficient pear trees may also show more winter injury than those having a satisfactory level of boron (4).

VIII. Tissue analysis.

According to Lundergårdh (61) the fundamental idea behind leaf analysis is that the amount of nutrients absorbed by the plant reflects the available amount of these salts in the soil. He also lists several advantages of leaf analysis as compared with soil analysis. Walrath and Smith (89) also consider leaf analysis to be superior to soil analysis.

While some workers have reported the leaf to be a good index of boron deficiency, others have reported the fruit as being a better index (15, 52, 47, 17).

Shear, Crane and Myers (76) reported that in evaluating the "nutritional status" of the plant, consideration must be given to all the essential elements present in the leaf which must be present in the proper proportion to each other. They also pointed out that low levels of the bases (Ca, K, Mg) in proportion to boron lead to "boron toxicity" while high levels of the bases lead to "boron deficiency" (75).

Experimenting with several crops, Muhn (67) reported that the tissues of plants inadequately supplied with boron, contained in most cases higher percentages of calcium, nitrogen, magnesium and iron than the tissues of plants grown in the presence of sufficient boron. It was also reported that in Valencia orange trees, high potassium usually depresses calcium and high calcium depresses potassium, (82). Young Valencia orange trees grown for 3 years outdoor in sand culture and receiving different levels of boron showed no appreciable difference in the mineral composition of their mature leaves except for boron. In the presence of a low boron supply, potassium accumulation in the young leaves was retarded and magnesium accumulation accentuated. There was a decrease in the rate of calcium accumulation at the highest boron level, (81).

In an experiment on peaches, an antagonism between boron and manganese was reported, (32). Burrell, Boynton and Crowe (25) reported that the boron content was inversely related to the nitrogen content in McIntosh apple leaves.

Beattie (8) reported that boron may vary widely in the apple foliage without greatly affecting growth, and without the development of symptoms of boron deficiency or toxicity. However, Haller and Batjer (47) referred to the work of Wilcox and Woodbridge who pointed out that the optimum range of boron may be rather narrow. Walrath and Smith (89) reported that the critical level for boron in apple leaves is about 25 p.p.m. Thomas, Mack and Fagan (85) stated that the critical value based on the percentage of boron in the dried mature foliage of apple trees, found by many workers varies between 9 and 12 p.p.m. They also pointed out to the work of De Long who reported a critical value of 27 p.p.m. for spur leaves of apple trees at picking time. Beattie (8) working at Ohio suggested that borax should be applied whenever the boron content of apple mid-shoot leaves is 20 p.p.m. or less (dry weight basis) in late July. Burrell, Boynton and Crowe reported 8 to 18 p.p.m. boron on a dry-weight basis for mid-terminal leaves collected in summer from boron deficient apple trees, and 29 to 37 p.p.m. from comparable trees that had received 6 annual applications of borax or boric acid. Leaves from trees that developed chlorosis due to boron toxicity contained up to 200 p.p.m. of boron. Batjer and Haller (6) reported 45 p.p.m. of boron from borax treated apple trees, as compared to 30 p.p.m. for the checks. Heinicke <u>et al</u>. (52) working at Cornell, reported a boron content of 4.5 to 10.3 p.p.m. in dry matter for McIntosh leaves sampled in early July from trees that showed severe preharvest drop.

Beattie and Ellenwood (9) conducted leaf analysis on 47 commercial apple orchards located in the major fruit producing regions of Ohio State. The results of said experiment are reported here under on dry weight basis.

	Apple Variety +	
Plant nutrient	Stayman Winesap	Delicious
Percent nitrogen	1.51-2.34	1.74-2.53
Percent calcium	0.55-1.82	0.94-1.48
Percent magnesium	0.108-0.499	0.201-0.474
Percent potassium	0.65-2.07	0.85-2.51
p.p.m. boron	16.2-35.0	17.2-42.5
p.p.m. manganese	20.0-120	20.0-156
p.p.m. iron	65.0-507.0	95.0-505.0

+ Leaves sampled from July 12 to August 5.

A survey of commercial orchards with healthy vigorous Stayman apple trees was carried out in Southern Pennsylvania, and the values reported on dry-weight basis were as follows:

	Date of sampling			
Plant nutrient	June 26	July 27	Sept. 27	Mean
Percent nitrogen	2.58	2.63	2.34	2.50
Percent calcium	1.17	1.28	1.41	1.30
Percent magnesium	0.30	0.29	0.23	0.27
Percent potassium	1.34	1.21	0.99	1.18
Boron (γ/g)	38	47	40	41
Manganese (γ/g)	62	64	68	65

The concentrations of nitrogen, phosphorus and potassium decreased markedly, while calcium and manganese tended to increase. Boron was irregular (80).

Walrath and Smith (89) carried a survey on 40 mature apple orchards in Massachussets samples being taken about August 1 for each of three years. The range and average values for several elements for the years, 1948, 1949, 1950 are reported as follows on the basis of percent dry weight.

	Year		
Element	1948	1949	1950
Potassium - range	0.94-2.50	0.61-2.16	0,90-2.19
Potassium - average	1.74	1.43	1.57
Magnesium - range	0.18-0.50	0.17-0.46	0.10-0.45
Magnesium - average	0.26	0.24	0.21
Phosphorus - range	0.12-0.28	0.12-0.39	0.11-0.30

Element	Year		
	1948	1949	1950
Phosphorus - average	0.18	0.16	0.17
Calcium - range	0.82-1.89	0.74-2.42	0.74-1.91
Calcium - average	1.27	1.35	1.27
Parts per million			
Boron - range	26-46	20-40	14-36
Boron - average	35	29	27
Manganese - range	24-172	26-195	23-280
Manganese - average	68	62	75
Iron - range	66-420	73-390	70-315
Iron - average	200	166	170

Walrath and Smith (89) also reported that for nitrogen, the optimum critical leaf level is considered 1.5 percent, and the optimum leaf level 2.0 percent. The potassium critical level is considered one percent, that for phosphorus 0.1 percent, and that for calcium one percent.

Kenworthy (59) carried leaf analysis on 100 blocks of fruits located in various parts of Michigan State. The leaves were sampled between July 15 and August 15. The nutrient element composition of leaves (percent dry weight) were as follows:

Element	Apple variety	
	McIntosh	Jouathan
Nitrogen - range	1.69-2.84	2.09-2.79
Nitrogen - average	2.37	2.45

Element	Apple variety	
	McIntosh	Jonathan
Phosphorus - range	0.140-0.749	0.090-0.538
Phosphorus - average	0.299	0.232
Potassium - range	0.97-2.61	0.60-2.82
Potassium - average	1.52	1.65
Calcium - range	0.69-2.63	0.80-2.67
Calcium - average	1.39	1.58
Magnesium - range	0.283-0.745	0.292-0.619
Magnesium - average	0.427	0.443
Manganese - range	0.0038-0.0200	0.0041-0.0190
Manganese - average	0.0107	0.0112
Iron - range	0.0040-0.0630	0.0040-0.0490
Iron - average	0.0284	0.0214
Boron - range	0.0012-0.0150	0.0010-0.0120
Boron - average	0.0059	0.0051

Cain (27) working on McIntosh apple leaves reported that there was a marked decrease in leaf potassium and phosphorus and increases in calcium, magnesium as the nitrogen application was increased, as the growing season advanced and with a heavy set of fruit. Several other workers reported an increase in boron content and a decrease in nitrogen, potassium and phosphoric acid as the apple leaf advanced in maturity (85, 80, 52). However Burrell et al. (25), reported rather stable values for boron from apple leaves sampled at various periods during the summer. Besides leaves, twigs and fruits were also used for analysis. Woodbridge (93) reported a range of 11.8-14.1 p.p.m. for healthy apple twigs and 6.4-9.3 p.p.m. for diseased ones. He also stated that less than 6 to 7 p.p.m. of boron in the fruit may constitute a serious deficiency.

Burrell, Boynton and Crowe (25) found that among fruit tissues, the endocarp had the highest boron concentration, the skin, the fleshy ovary and the seeds somewhat less, and the floral tube, the least.

IX. <u>Preharvest drop as affected by boron and other factors</u>.

The view has been expressed that the mechanism of leaf and fruit abscission is not clearly understood (1, 78).

MacDaniels (62) stated that the "abscission zone" at the base of the petiole in the apple fruit is not clearly delimited. He also described the normal pedicel structure of an apple as consisting of a central pith made up largely of stone cells. A ring of well developed xylem mostly of secondary origin surrounds the pith area. Outside the xylem, there is a well defined ring of phloem, surrounded first by another ring of well developed elongate fibers and secondly by irregularly formed groups of stone cells. The outer layers are made up of cortical parenchyma, some collenchyma and normal epidermis. At harvest time, there is a change in the chemical nature of the cell walls which causes the collenchyma to split easily thus facilitating abscission.

McCown (64) also reported that the process involved in the abscission of some apple fruits is a change in the pectin compounds, especially those in the middle lamella of the cell walls of the pedicel and abscission zone. He also mentioned that the course of abscission proceeds from the epidermis and cortex, through the fibers and stone cells of the pericycle, reaching the xylem. Separation across pericycle, xylem and pith is of a mechanical nature. MacDaniels (62) reported that varieties differ in the ease of abscission partly due to differences in rapidity with which these chemical and physiological changes take place and due to differences in the structure of the abscission zone.

Varieties with a short stiff pedicel such as McIntosh are also more likely to drop than those having a long flexible pedicel. Environmental factors may also influence the ease with which apples are separated from the tree (62). Relatively high temperatures just before harvest seem to increase the severity of drop in McIntosh apples (52). Fruits from trees making slow growth and having an excess of carbohydrates in relation to nitrogen, have a strong abscission zone due to the increased formation of woody tissue (62). Shoemaker and Teskey (78) pointed out that preharvest drop is usually greater from the more shaded parts of the tree due to the high carbohydrate to nitrogen ratio in the woody tissue. Addicott and Lynch (1) explained that carbohydrates can affect abscission in at least two ways, first by increasing the thickness of the cell walls, thus making abscission more difficult, and second, by supporting the development of embryos which in turn produce auxin that delays abscission. Dickson (38) referred to the work of Southwick who found that the presence of many seeds tends to delay the preharvest drop of apples from individual trees.

Factors that cause a reduction in efficient leaf surface such as diseases or insects, excessive shading and dull weather toward harvest time also tend to increase preharvest drop (78). Dickson (38) reported that in McIntosh apples, the percentage of drops increased with increasing yields, especially when this increase was induced by better cultural or growth conditions than by "on" year cropping.

Benson (12) pointed out that in the case of boron deficiency, the Delicious variety of apple produces misshapen fruits that ripen early, and preharvest drop is severe. Childers (31) also reported that in the case of boron deficiency in the apple, fruit drop may be heavy near harvest and keeping quality poor. Batjer and Haller (6) on the other hand, reported an increase in preharvest drop from borax fertilized apple trees, the year following the treatment, due to excess borax application.

X. <u>Control of boron deficiency</u>.

In reviewing the literature, one finds that three approaches have been used in the control of boron deficiency. The first approach is the use of injection, either as a solution or as dry crystals. The second approach is the use of foliar sprays, while the third one is by soil application of boron - containing compounds, (17). Bonyton (17) referred to Askew who was the first to make a positive diagnosis of boron deficiency by the use of the injection technique in 1935. Young and Bailey (95) explained that in the wet injection method the element in solution is injected directly into the branch, using a non-toxic concentration. In the dry injection method, the dry material is placed in holes bored in the tree trunk. As boring of holes is undesirable, Young and Bailey (95) recommended the use of one pound of borax per tree as a ground application to trees with a trunk diameter of approximately 7 inches. They also noted that soil applications of borax at the rate of four pounds per twenty year old apple tree have failed to produce injury seven weeks after the time of application.

In 1936, Degman <u>et al</u>. (37) working in the Shenandoah Potomac fruit district in the U.S.A. were able to control internal corking of apples by applying boric acid as an injection to the tree or by soil application, and they recommended the use of approximately one pound of borax ($Na_2B_4O_7 \cdot 10\ H_2O$) or two-thirdspound of boric acid per mature tree applied beneath the drip of the branches in late fall or early spring.

Burrell (23) noted that borax soil applications to apple trees made in the spring of one year were still effective throughout the third year, and that part of the boric acid injections made in the late summer of one year had become ineffective by the third year. He also reported that a soil application of borax on June 30, prevented late - season development of cork which was abundant on checks. Various workers have reported some injury to the bark around the injection holes by the use of the injection technique (22, 63,66). Latimer and Percival (60) considered top-dressing as being more practical than injection. In order to avoid the possibility of boron deficiency in apples, Weeks (91) stated that applications of borax should be made every three to five years at the rate of ten ounces per tree up to ten years of age, eight ounces for trees ten to 20 years, and eight to sixteen ounces for trees over twenty years, and not more than fifty pounds of borax should be applied per acre. Hansen (48) recommended from fifty to hundred pounds of borax per acre for olives, pears and apples and indicated that a single treatment will remain effective for three or four years. Chandler (28) recommended only about thirty to fifty pounds of borax to the acre, or two-thirds of this amount of boric acid spread under the branches of mature trees. Burrell, Boynton and Crowe (25) noted that less boron was absorbed when broadcast than when restricted to a ring beneath the branches. However, Shoemaker and Teskey (78) stated that broadcasting could be used efficiently since borax is very highly soluble and is fixed to a very small extent by the soil.

In an investigation as to the minimum dose that will cause injury to trees, Latimer and Percival (60) reported that five pounds of borax per tree marked the borderline between safe and toxic amounts to use on Delicious and Golden Delicious apple trees that were not showing symptoms of boron deficiency. The injury from excess borax application was observed the year following the treatment. In another test, the same workers found that the more acid soils were not able to fix boron, and they pointed out that in making safe recommendations to use in an apple orchard, the following factors should be considered. Previous treatment, rainfall, drainage, leaching, content of organic matter and buffering power of the soil.

Wear and Wilson (90) reported that the use of a very soluble boron carrier such as borax may prove toxic to some plants in small amounts due to its high initial solubility, and in addition, it may be easily lost from sandy soils through leaching. Thus, they suggested the use of more insoluble types of boron carrier such as colemanite ($Ca_2B_6O_{11} \cdot 5H_2O$) having 10.1 per cent boron, and Howlite ($4\ CaO \cdot 5\ B_2O_3\ 2\ SiO_2$) having 11.0 per cent boron. Page and Paden (69) reported that colemanite may be safely applied at high rates, and with various crops, it gave similar results as borax.

Benson (10) pointed out that leaves can absorb chemicals applied in the form of a spray. However the correct concentration of spray solution should be used so as not to injure the cells. He also stated that the most convenient method of applying boron is by spray application. However, Proebsting (73) indicated that sprays are only used to speed up the response, especially in the first year of treatment.

Materials which can be applied as foliage sprays to trees include borax, boric acid and the new material "Polybor" (Sodium pentaborate). All of these are water-soluble (11). "Polybor" is easily dissolved, is nearly neutral in its reaction and compatible with several spray materials, as compared to borax that is difficult to wet, is relatively slow-dissolving and probably not compatible with many spray materials due to its alkaline reaction. "Polybor" is usually applied at the rate of five pounds per acre, using one pound per hundred gallons of water (11).

Chandler (28) reported that adding a boron compound such as borax to one or two of the early summer sprays at the rate of two pounds per hundred gallons prevented boron deficiency in some districts in Canada.

Burrell (24) reported that sodium pentaborate which is available under such names as "Solubor" (20.5 percent boron) and "Boro-Spray" (18.3 percent boron) is superior to soil application of borax. One sodium pentaborate spray per year applied one to three weeks after petal-fall has maintained the boron concentration of apple fruits within a moderate range. Benson and Sprague (13) reported the compatibility of "Solubor" with several pesticides and urea, but not with oil. They also reported that polybor-chlorate should not be used as a spray since it is harmful to trees even in dilute solution. Burrell (24) reported that the date at which symptom development begins might determine whether or not late boron sprays would prevent internal cork.

XI. Boron toxicity.

Different species of trees differ in their tolerance to excess boron (28). Burrell (22) reported that in the case of injury from excess boron in the apple, shoots become thin and tapering, and leaves become smaller from the base to the tip of the shoot. There is also marginal scorching and leaf-rolling giving the upper surface a concave shape. Leaves become blanched and in severe cases they drop.

XII. Boron and pressure tests.

Batjer and Haller (6) reported that pressure test measurements on the fruits of various varieties of apples at harvest indicated no appreciable difference in firmness due to boron. The rate of soil borax application was one-third pound to eight year old trees and one pound to twenty year old trees.

XIII. Benefits obtained through the control of boron deficiency.

McLarty (65) reported that in British Columbia, the average crop of saleable fruit from trees treated with borax was increased in one year from 3.61 to 10.6 boxes per tree, whereas on the check trees, it fell on the average from 3.8 to 2.5. Woodward (94) also reported that the use of boron resulted in an increase of over 1,000,000 boxes per year in British Columbia. Brown (20) reported a great improvement in quality of apples sprayed with borax three weeks after the Calyx spray and then three weeks later.

MATERIALS AND METHODS

This study was conducted in an orchard located in the apple growing district of Mashgara (Western Beka'a) with an altitude of approximately 950 meters. Winds are prevalent in the area in summer, but the area is well protected with wind-breaks. Oak treese and wild shrubs were growing on the land before it was put into apples. The land is terraced and slopes gently from West to East. The soil has good drainage, a pH of 7.8 and a calcium carbonate content of 19.04 percent.

The trees are of the Starking Delicious variety (hereafter referred to as Starking) thought to be propagated on Malus communis rootstocks. They were set in the spring of 1943 at a distance of five meters following the triangular system of planting. The other main variety in the orchard is Golden Delicious.

Every other year or sometimes every third year, each tree receives about twenty kilograms of goat manure. Small amounts of complete fertilizer were applied at irregular intervals. In the spring of 1957, a winter cover crop of vetch was turned under. In 1958, no fertilizer was applied.

The orchard was irrigated five times during the 1958 growing season, at intervals of about 21 days, and by the use of the flooding system.

Twenty five uniform Starking trees of the same age were included in this study. Each tree was given a number from one to twenty five.

Treatments applied were randomized and consisted of the following materials.

1. Check - Twelve liters of irrigation water per tree.
2. Twenty-five grams of borax containing 2.82 grams of boron dissolved in twelve liters of water.
3. Fifty grams of borax containing 5.63 grams of boron dissolved in twelve liters of water.
4. 100 grams of borax containing 11.26 grams of boron dissolved in twelve liters of water.
5. 150 grams of borax containing 16.90 grams of boron dissolved in twelve liters of water.

Each of the said treatments was replicated on five trees. On May 30, 1958, the borax was applied evenly in the rim 60 to 90 cms. inside the drip of the branches, after the method recommended by Heinicke, Walter and Cain (52).

Beginning with July 30th, all fruits dropping under each of the numbered trees were collected daily and their number and weight were recorded. This procedure was continued until September 15th, when harvest was completed. Also the number and weight of fruit harvested from each of the experimental trees was recorded.

The drops from each tree were totaled by number and by weight covering the period from July 29th through September 15th. The apples harvested from each tree were totaled in a similar manner. The percentage drop was calculated from each tree in the following manner:

$$\frac{\text{No. of fruits dropping}}{\text{No. of fruits harvested + No. of fruits dropping}} \times 100$$

and $\frac{\text{Weight of fruits dropping}}{\text{Weight of fruits harvested + weight of fruits dropping}} \times 100$.

It seemed better to consider the percentage drop rather than the absolute values for drops so as to minimize differences due to variabilities in bearing. Dickson (38) reported that the percentage of drops in McIntosh apples increased with increasing yields, especially, when this increased yield was induced by better cultural or growth conditions.

To determine if the boron level had any influence on maturity, pressure tests on a random sample of fruits from the different treatments was taken with the help of a fruit pressure tester.

Leaf samples were collected during the period, beginning with June 29 to October 1, 1958, at about 30 days' intervals. (June 29, July 29, August, 29 and October, 1). Each sample consisted of 70 to 80 mid-shoot leaves selected at random around the periphery of the tree. The leaves were apparently free from insect damage. At all sampling dates, leaves were placed in cheesecloth bags at the time of collection which was 4.0 p.m. and were stored under refrigeration for the remainder of the day according to Emmert recommendation (43). The following morning, the leaves from each sample were washed with a detergent by wiping both sides with a damp cheesecloth; they were rinsed with tap water and then scrubbed with 0.1 normal hydrochloric acid, washed with tap water and finally rinsed twice with distilled water. Each Cheesecloth bag was washed in the same manner as the leaves. The bags with the leaves were shaken off to remove excess water and were immediately dried at 70 $\pm$ 1° C for 48 hours in a forced draft oven (9, 43, 84). The oven-dried material was ground in a wiley mill to pass through a 60 mesh sieve for a more homogenous sample (71) and were then stored in screw-top sampling bottles appropriately labelled.

Prior to the analysis of any of the elements, the bottles with the caps off were put in a vacuum-oven at a temperature of $70 \pm 1^{\circ}$ C, for about 15 hours, after which they were closed tightly, removed and put in a dessicator to cool before any weighing was done. All determinations were run in duplicate and calculations were made on the dry-weight basis. The percentage error for each determination was computed, and all duplicate samples with more than 6 percent difference were repeated.

Boron was analysed according to a modified method of Hatcher and Wilcox (49). Nitrogen analysis was done by the standard Kjeldahl method, while the rest of the elements namely, potassium, calcium, sodium, manganese, iron, magnesium, and phosphorus, were analyzed after, the method of Tooth et al., (87).

Inorganic leaf analysis data was statistically analyzed using the method of analysis of variance. The data on preharvest drop was statistically analyzed according to the "t" test.

RESULTS AND DISCUSSION

I. Effect of levels of boron on preharvest drop of fruit.

One objective of the present study was to evaluate the effect of different levels of boron applied as borax on preharvest drop of fruit in Starking apple trees. The data on yield and preharvest drop by weight and by number are presented in table one.

The results on the effect of rate of borax application on fruit drop along with the analysis of variance appear in table two, computed as percent drop by weight, and simultaneously in table three computed as percent drop by fruit number. It is apparent from studying tables two and three, that there was a decrease in fruit drop as the borax application was increased. This decrease in drop was highest for the trees receiving the 100 gram borax treatment, and was significantly different from the control. However, the higher rate of application, namely 150 grams per tree caused a higher drop than the trees receiving the 100 grams per tree. The average percent drop for the trees receiving the 100 grams treatment was 5.57 by number as compared with 9.67 for the checks, and 4.63 by weight as compared with 8.54 for the checks. Both values, the reduction of drop by weight and by number were significantly different from the check at the 0.05 level. Although there seemed to be a close correlation between percent drop by weight and percent drop by number, the percent drop by weight may be considered a more reliable index than percent drop by number due to size differences among the individual fruits. The reduction in drop

Table 1. Data on yield and preharvest drop, by weight and by number, of Starking apple trees in the 1958 summer season.

Tree No.	Treatment Gr.Borax/ tree	Weight harvested (lbs)	No. of Fruits harvested	Weight of drops (lbs)	No. of drops	Percent drop by number	Percent drop by weight
1	0	289.56	1064	17.73	78	6.83	5.77
2	0	160.62	418	26.40	77	15.55	14.12
5	0	158.44	466	12.58	47	9.20	7.35
16	0	128.19	326	8.87	22	6.32	6.42
18	0	81.38	197	8.09	23	10.45	9.04
Total		818.19	2471	73.67	247		
4	25	162.62	463	16.16	51	9.92	9.04
10	25	215.50	462	13.04	33	6.66	5.70
13	25	165.06	474	5.19	19	3.85	3.05
19	25	202.19	574	11.32	42	6.81	5.30
25	25	65.25	185	8.39	27	12.73	11.39
Total		810.62	2158	54.10	172		
7	50	176.00	386	8.07	24	5.85	4.38
11	50	332.06	579	9.74	28	4.61	4.03
20	50	182.38	475	15.04	46	7.40	7.62
21	50	311.56	820	49.90	145	15.02	13.80
22	50	236.06	716	13.35	47	6.15	5.35
Total		1238.06	2976	96.10	290		

Table 1. Cont'd.

Tree No.	Treatment Gr.Borax/ tree	Weight harvested (lbs)	No. of Fruits harvested	Weight of drops (lbs)	No. of drops	Percent drop by number	Percent drop by weight
3	100	153.31	505	6.14	25	4.71	3.85
6	100	298.62	863	18.48	67	7.20	5.99
12	100	199.19	633	7.07	26	3.94	3.43
14	100	190.50	445	12.76	38	7.86	6.28
17	100	381.38	1089	14.19	47	4.13	3.59
Total		1223.00	3535	58.64	203		
8	150	87.15	244	13.60	42	14.68	13.50
9	150	124.89	282	20.97	54	16.07	14.38
15	150	122.81	338	6.93	17	4.78	5.34
24	150	336.31	769	17.73	52	6.33	5.00
23	150	124.62	348	4.69	20	5.43	3.63
Total		795.78	1981	63.92	185		

Table 2. Average percent drop (by weight) of Starking apple trees during the 1958 summer season

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	5.77	9.04	4.38	3.85	13.50
2	14.12	5.70	4.03	5.99	14.38
3	7.35	3.05	7.62	3.43	5.34
4	6.42	5.30	13.80	6.28	5.00
5	9.04	11.39	5.35	3.59	3.63
Mean	8.54	6.90	7.04	4.63	8.37

Treatments

Calculated t_8 between check (0) and 25 = 0.78 (n.s.)

Calculated t_8 between check (0) and 50 = 0.64 (n.s.)

Calculated t_8 between check (0) and 100 = 2.41 (Highly Significant at the 0.05 level)

Calculated t_8 between check (0) and 150 = 0.03 (n.s.)

Table 3. Average percent drop (by number) of Starking apple trees during the 1958 summer season

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	6.83	9.92	5.85	4.71	14.68
2	15.55	6.66	4.61	7.20	16.07
3	9.20	3.85	7.40	3.94	4.78
4	10.45	6.81	15.02	4.13	6.33
5	6.32	12.73	6.15	7.86	5.43
Mean	9.67	7.99	7.81	5.57	9.46

<u>Treatments</u>:

Calculated t_8 between check (0) and 25 = 0.75 (n.s.)

Calculated t_8 between check (0) and 50 = 0.90 (n.s.)

Calculated t_8 between check (0) and 100 = 2.22 (Significant at the 0.05 level)

Calculated t_8 between check (0) and 150 = 0.071 (n.s.)

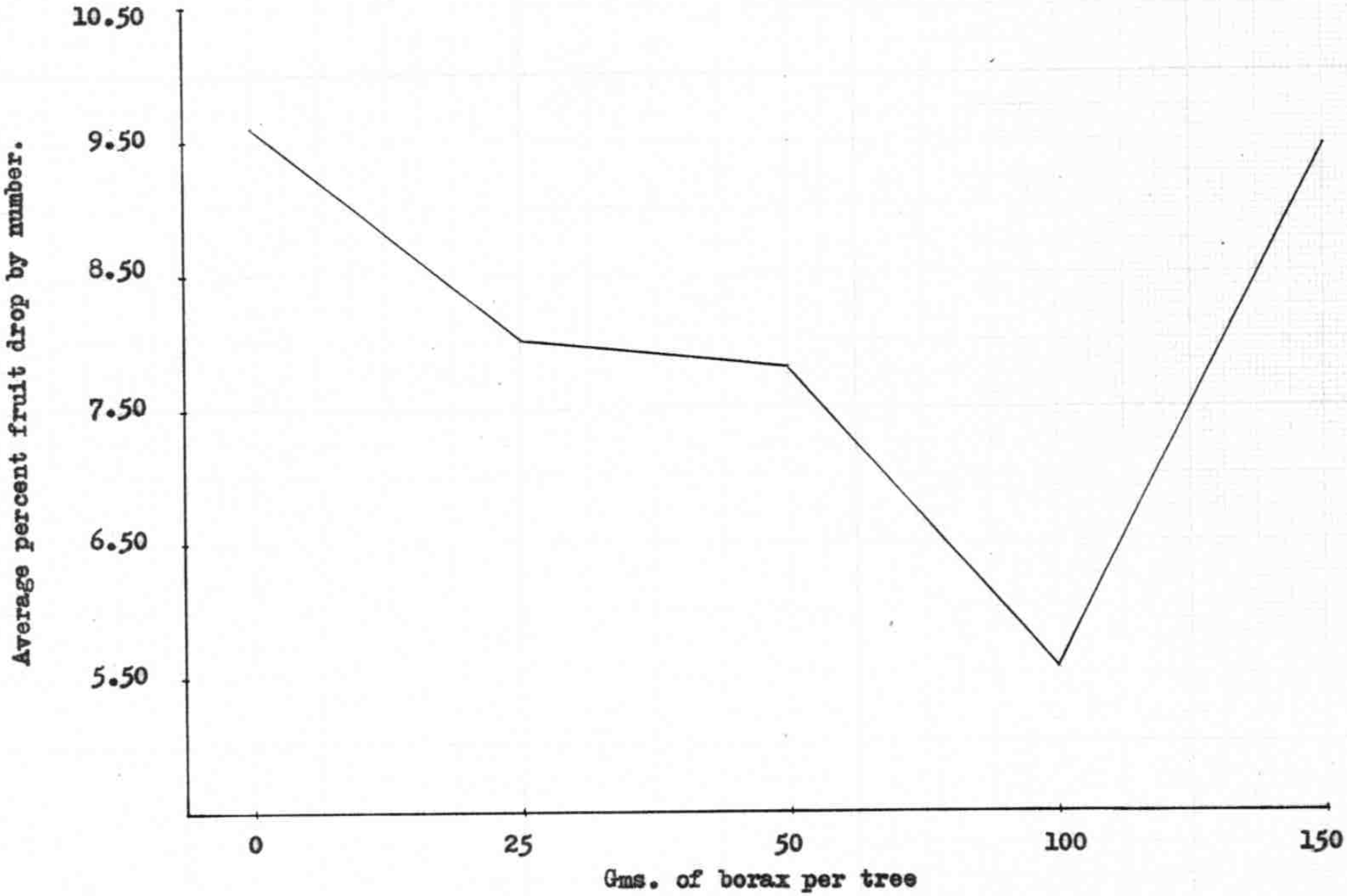

Figure 2. Effect of boron supply on preharvest drop of fruit by number

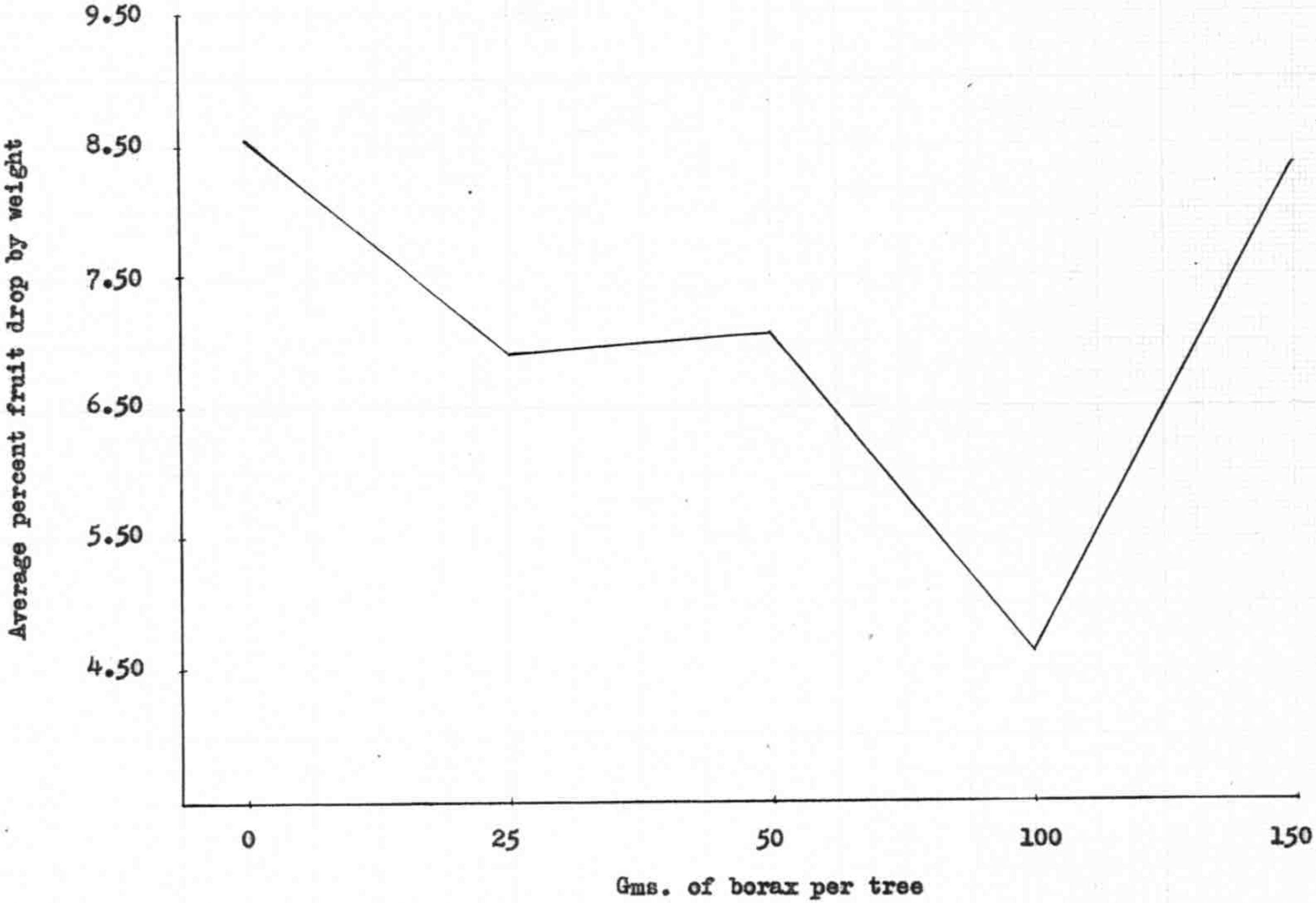

Figure 3. Effect of boron supply on preharvest drop of fruit by weight

obtained by the application of 25 and 50 grams of borax was not significantly different from the control. Failure to control drop resulted when the rate of borax application was as much as 150 grams per tree. Figures two and three give a clear picture of the effect of rate of borax per tree on fruit drop.

In trying to relate preharvest drop to the boron content of the leaf tissue, it was observed that the boron content of the checks is relatively high in comparison to values reported in the literature for apple leaves from boron-deficient trees, Table 4. Some of the critical values reported by other workers varied between 9 and 27 p.p.m. on a dry-weight basis (80, 85). Results obtained in this study showed that the boron content was in the neighborhood of 50 p.p.m., Tables four and five. However, it should be recognized that results obtained in one part of the world may not necessarily apply to other parts. In this case it is to be noted that no work has yet been published on the boron content of apple leaves in Lebanon, with which comparisons could be made. Moreover, while some workers have reported that the leaf is a good index of boron deficiency, others have reported better association between deficiency symptoms and fruit analysis than with leaf analysis due to the high accumulation of boron in the fruit, (47, 17). Another possible explanation for these relatively high values is that the boron content of the tissues rose to above deficiency level before they were sampled for analysis, and this usually happens under conditions of acute temporary deficiency, (17). Moreover, as apple trees receiving the same borax treatment show different

Table 4. Boron content (p.p.m. dry weight basis) of apple leaves sampled June 29, July 29, August 29, and October 1, 1958

Tree No. (Replica-tion)	Treatment Gr. Borax/ tree	Date of Sampling			
		June 29	July 29	August 29	Oct. 1
1	0	48.50	40.70	40.02	42.54
2	0	62.20	57.97	73.05	61.53
5	0	56.10	44.92	51.02	62.07
16	0	56.94	44.90	64.71	43.24
18	0	52.49	64.42	57.69	43.66
Mean		55.25	50.58	57.30	50.61
4	25	48.60	38.13	36.49	43.24
10	25	43.83	37.68	47.50	44.99
13	25	40.21	39.93	49.44	48.43
19	25	47.59	40.16	60.79	62.02
25	25	55.97	53.75	61.97	59.54
Mean		47.24	41.93	51.24	51.64
7	50	48.46	39.24	62.22	42.22
11	50	48.06	41.28	65.75	58.82
20	50	48.81	45.04	51.80	57.40
21	50	54.18	40.73	52.29	47.19
22	50	45.02	51.09	49.98	53.60
Mean		48.90	43.48	56.41	51.85

Cont'd. on next page.

Table 4. Cont'd.

Tree No. (Replication)	Treatment Gr. Borax/ tree	Date of Sampling			
		June 29	July 29	August 29	Oct. 1
3	100	48.72	43.32	46.33	62.07
6	100	47.53	38.77	46.26	48.95
12	100	42.44	37.50	49.02	42.59
14	100	41.22	57.84	65.49	51.05
17	100	43.60	59.60	61.87	59.98
Mean		44.70	47.21	53.79	57.93
8	150	52.59	50.99	54.88	64.48
9	150	52.40	56.14	51.83	53.86
15	150	48.27	56.22	64.57	51.01
24	150	43.63	46.85	59.98	65.19
23	150	52.30	48.04	60.97	72.29
Mean		49.84	51.65	60.25	61.37

Table 5. Average boron content (p.p.m. dry weight basis) of apple leaves sampled during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	55.25	47.24	48.90	44.70	49.84	49.19
July 29	50.58	41.93	43.48	47.21	51.65	46.97
Aug. 29	57.30	51.24	56.41	53.79	60.25	55.80
Oct. 1	50.61	51.64	51.85	52.93	61.37	53.68
Mean	53.44	48.01	50.16	49.66	55.78	

Treatments

Calculated F 4/12 = 4.71 (significant at the 0.05 level)

Critical difference for the treatment means at 0.05 level 3.99

Groups at 0.05 level: (25, 100, 50) (100, 50, 0) (0, 50) (0, 150).

Dates

Calculated F 3/12 = 9.79 (significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 4.45

b) 0.01 level 6.24

Groups at 0.05 level: (June 29, July 29) (August 29, Oct. 1)

Groups at 0.01 level: (June 29, July 29) (June 29, Oct. 1)

(Oct. 1, Aug. 29)

responses in the boron content of their tissues, no definite limits of boron sufficiency or deficiency have been set for apples, (17, 85).

Neglecting leaves sampled in October, it is also to be noted that the trees receiving the 100 grams of borax and in which good control of drop was obtained indicated a lower average percent boron than the control. However in some individual trees, the percent of boron was higher than in some of the trees in the control group. This is also noticed for the groups receiving the 25 and 50 grams of borax, but the trees receiving the 50 grams had a higher boron content than those receiving the 25 grams in each of the four months. Boron uptake might not have been in direct relation to its concentration in the external soil solution, (84).

This lack of apparent response to boron in the treated trees might have also been due to the higher original boron content of the control. It was reported that even homologous apple leaves collected from adjacent trees in the same orchard differed greatly in their composition, (84). Thus the 25 to 100 grams of borax that were applied per tree might not have been enough to raise the boron content of <u>all</u> the trees receiving the same treatment to a considerable extent. However the boron content of some of the individual trees might have been raised considerably, thus reaching higher values than some of the trees in the control group. This point is well illustrated in an experiment performed by Heinicke, Reuther and Cain (52), on the control of pre-harvest drop in McIntosh apples. These workers reported that the boron content of leaves from trees showing symptoms of boron deficiency varied from 4.7 to 10.3 p.p.m. on dry weight basis. Following the application of half a pound of borax per tree, the values ranged from 7.0 p.p.m. to 20.3 p.p.m.; while in one tree, the increase was from 7.9 to 9.4 p.p.m., in another, the increase was from 8.6 to 20.3 p.p.m. They related the increase in boron content of the leaves for each tree (irrespective of the absolute values) to the decrease in preharvest drop, and they pointed out that the borax treatment reduced the drop, even though in many trees there was no accompanying increase in the boron content of the leaf tissue.

In trying to explain this "discrepancy" between the treated and the untreated trees as to boron content in the leaves, also the individuality of the tree and the size of the crop should not be neglected, as these were reported to influence the nutrient content of the leaves (85, 43). In this connection, it is to be noted that the trees receiving the 100 grams of borax and in which best control of drop was obtained were among the high yielding group, being only exceded by the group receiving the 50 grams, while the trees receiving the 150 grams of borax had the lowest yield, Table one. It may be that boron was withdrawn from the leaves by the developing auxiliary flowers, as this element is necessary for fruit set, thus contributing to a relatively low boron content in the leaves, (85). Moreover, three-quarters of the boron removed by a tree was estimated to be in the fruit, (17).

These results further indicate that it is very difficult to recommend a certain fixed dose of boron for deficient trees and the size of the tree as well as that of the crop should be considered.

In studying the seasonal trend in boron nutrition in this experiment, it was observed that in most cases, there was a steady increase in the average boron content with the advance of season in the case of the trees receiving the 100 and 150 grams of borax, Table 5. On the other hand, there appeared to be a decrease in the average boron content in the case of the checks. These results are in agreement with the work of Askew Chittenden and Thompson, (17) who reported a downward trend in the boron content of fruit from boron-deficient trees. Regardless of the absolute values, this may indicate that the trees receiving the 100 or 150 grams of borax were in a better nutritional status in respect to boron than the checks. Or, it may at least indicate that there was some increased boron absorption in the case of the treated trees, as no such increase was reported for the checks. This increase did not only indicate an uptake of boron, but also showed that the 100 grams of borax per tree supplied enough boron that resulted in a successful control of drop.

As to the trees receiving the 150 grams of borax, there was a definite increase in the average boron content of the leaves. This increase was most marked for leaves sampled in October, when the average boron content was 61.37 p.p.m. as compared with 50.61 p.p.m. for the control, Table 4. However, leaves from the control trees collected in June seemed to have a higher average boron content than those receiving the 150 grams. This might be due to the relatively short period of time lapse (four weeks) after the treatment, thus not allowing enough time for boron assimilation. In most studies of this type, leaf analysis data and data on preharvest drop were taken the year following that in which the treatments were applied. Even, some workers reported that toxicity symptoms resulting from applications of high levels of boron were evident the year following the application and not in the same year in which the application was made (22). This further indicates that such studies must be conducted over a prolonged period.

Although the average boron content over the four months for the trees receiving the 150 grams was higher than those for the control, the differences were not statistically significant, Table 5. However, the boron content of the trees receiving the 150 grams was significantly higher than those receiving the 100 grams. The failure to control drop with an application of 150 grams per tree might have been due to "toxicity", because the margin between boron deficiency and toxicity is very small, (18). Moreover, a small change in quantity (which might not be statistically significant) may represent a large percentage change in concentration of boron, (17).

Several workers have indicated the importance of the proper balance between elements in the leaf, and the examination of their ratios rather than their absolute values as a diagnostic procedure (75, 29, 84). Thomas, Mack and Fagan (85) have applied the concept of calacium to boron ratio in apple leaves as an index of deficiency or sufficiency taking a ratio of 600:1 above which a deficiency is expected, and they found this index of doubtful value as a diagnostic procedure. When the calcium to boron ratios were computed for this experiment, the values were much lower than 600:1, and no trend was indicated with increasing levels of borax application. (Appendix, Tables I to V). It is possible that this concept may not be applicable to the apple variety used in this experiment, as it has also been reported not to apply to the Rome apple variety, (85).

Thomas, Mack and Fagan (85) indicated that as boron has been reported to play a part in protein synthesis, it should be related to factors affecting plant growth. Then they tried to relate boron to the elements, N,P,K, by computing the ratios of N/B, P/B and K/B. The said authors concluded that the value of these ratios as indices is as questionable as the Ca/B ratio. When the ratios of N/B were computed for leaves sampled in June (Appendix, Table VI), it was observed that the trees receiving the 100 grams of borax had the highest ratio, and the trees receiving the150 grams of borax had also a high ratio as compared to the checks indicating a relatively high nitrogen level in relation to boron.

For leaves sampled in July, (Appendix, Table VII) it was observed that there was a decrease in the ratios of N/B; the trees receiving the 150 grams showing the lowest ratio, while there seemed to be an increase in the case of the checks. For leaves sampled in August, (Appendix, Table VIII), there was still a very marked decrease in the ratio of the trees receiving the 100 and 150 grams, with those receiving the 150 grams still showing the lowest ratio. In the case of the checks there was also a decrease. For leaves sampled in October, (Appendix, Table IX) the trees receiving the 150 grams showed the lowest ratio, while those receiving the 100 had the next lowest ratio. These results seemed to indicate an irregular trend over the four months in the case of the checks. On the other hand, the trees receiving the 100 and 150 grams showed on the whole a constant decrease. Thus with the advance of the season, the treated trees were showing higher boron content in relation to nitrogen as compared with the checks.

When the average nitrogen to boron ratio was computed for the four months, Table 6, it was observed that the trees receiving the 150 grams had apparently the lowest average ratio. The average ratios for the months of June and July were significantly lower than those for August and October.

When the ratio of K/B was computed (Appendix, Tables X to XIII) it was observed that in the month of June, this ratio was high for the trees receiving the 100 and 150 grams as compared with the checks. With the advance of season, there was a marked decrease in the ratio of trees receiving the higher levels of borax, thus reaching lower ratios than those for the control. In the month of October, there appeared to be a graduation from higher ratios to lower ones with an increase in the level of borax applied.

From Table 7, it was observed that the average K/B ratios for the months of June and July were significantly lower than those for August and October.

When the P/B ratio was computed (Appendix, Tables XIV to XVII), it was observed that this ratio steadily decreased with the advance of the season, always appearing to the lowest in the case of

*Table 6. The average nitrogen to boron ratio in apple leaves at different levels of borax application, and at different sampling dates during the 1958 growing season (Boron being taken as unity)

Date	Treatment (Gms. of borax per tree) 0	25	50	100	150	Mean
June 29	461.96	546.78	541.84	572.34	541.18	532.82
July 29	513.90	602.70	402.90	538.80	334.40	383.08
Aug. 29	347.30	438.90	402.90	391.90	334.40	383.08
Oct. 1	420.66	406.16	410.90	368.34	340.30	389.27
Mean	435.96	498.64	485.04	467.85	426.03	

* Means for data presented in Appendix, Tables VI to IX.

Treatments:

Calculated F 4/12 = 3.77 (significant at the 0.05 level)

Critical difference for the treatment means at 0.05 level 44.21

Groups at the 0.05 level: (0,100,150) (25,50,100).

Dates:

Calculated F 3/12 = 38.10 (highly significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 49.43.

b) 0.01 level 66.30

Groups at the 0.05 level: (August 29, Oct. 1) (June 29, July 29)

Groups at the 0.01 level: (August 29, Oct. 1) (June 29, July 29) the trees receiving the 150 grams. From Table 8, it was observed that although the average ratios were significantly different from each other, there was no consistent trend which could be correlated with the level of borax applied. The average ratios were also significantly higher for the months of June and July than those for August and October.

Shear, Crane and Myers (1946) have indicated the importance of a balanced ratio between boron and the three major bases, calcium, potassium and magnesium. They also pointed out that high levels of the bases in proportion to boron lead to "boron deficiency", while low levels lead to "toxicity". In this experiment, the ratios of $\frac{Ca + K + Mg}{Boron}$ were computed for all four months, for the purpose of examining them as indices of boron sufficiency or toxicity, and to try to see if there was an indication of a better boron balance in the case of the trees receiving the 100 grams of borax, this latter application having shown a significant reduction in preharvest drop. Due to the fact that there are no set standards with which comparisons could be made, all ratios were compared on a relative basis. In the month of June, it was observed that the checks had a significantly lower average ratio than those receiving the 100 and 150 grams, indicating a more balanced boron level in the leaves, Table 9. This may be due to the fact that leaves were sampled only four weeks after the treatment, thus not allowing enough time for boron assimilation. Boynton (18) indicated that a borax soil application had a greater influence on leaf and fruit content of boron in the year after treatment. Moreover, it was seen that the absolute values of boron were

*Table 7. The average potassium to boron ratio in apple leaves at different levels of borax application, and at different sampling dates during the 1958 growing season (Boron being taken as unity).

Date	Treatment (Gms. of borax per tree) 0	25	50	100	150	Mean
June 29	324.43	322.09	274.09	345.72	364.96	326.26
July 29	324.90	355.16	302.58	262.61	301.54	309.36
Aug. 29	267.76	243.08	206.63	223.84	244.81	237.22
Oct. 1	267.97	235.32	226.02	223.10	212.65	233.01
Mean	296.27	288.91	252.33	263.82	280.99	

*Means for data presented in Appendix, Tables X to XIII.

Treatments:

Calculated F 4/12 = 1.98 (n.s.)

Dates:

Calculated F 3/12 = 17.62 (significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 35.44

b) 0.01 level 49.68

Groups at the 0.05 level: (Aug. 29, Oct. 1) (June 29, July 29)

Groups at the 0.01 level: (Aug. 29, Oct. 1) (June 29, July 29).

*Table 8. The average phosphorus to boron ratio in apple leaves at the different levels of borax application, and at different sampling dates during the 1958 growing season (Boron being taken as unity)

Date	0	25	50	100	150	Mean
June 29	36.41	39.70	33.90	42.10	34.35	37.29
July 29	38.57	46.85	39.65	42.71	31.18	39.79
Aug. 29	28.31	31.29	25.61	30.00	23.51	27.74
Oct. 1	31.24	38.20	26.22	28.28	23.20	29.43
Mean	33.63	39.01	31.35	35.77	28.06	

*Means for data presented in Appendix, Tables XIV to XVII.

Treatments:

Calculated F 4/12 = 10.97 (Significant at 0.01 level)

Critical difference for the treatment means

a) at 0.05 level 1.10

b) at 0.01 level 1.54

Groups at 0.05 level: (0) (25) (50) (100) (150)

Groups at 0.01 level: (0) (25) (50) (100) (150)

Dates:

Calculated F 3/12 = 27.14 (significant at 0.01 level)

Critical difference for the date means at

a) 0.05 level 3.89

b) 0.01 level 5.45

Groups at the 0.05 level: (Aug. 29, Oct. 1) (June 29, July 29)

Groups at the 0.01 level: (Aug. 29, Oct. 1) (June 29, July 29) higher in the checks than in those receiving the higher levels of borax for the month of June, Table 4. For the month of July, it may be noted that there was a sharp drop in the average ratio of the trees receiving the 100 grams of borax thus indicating a better nutrient level in relation to boron than in the previous month, Table 10. Similarly, in the case of the trees receiving the 150 grams of borax, there was a remarkable drop. The average ratios for the trees receiving the 100 and 150 grams of borax appeared to be lower than those for the check, however, this difference was not statistically significant. It may be also noted that in this particular month, the orchard was irrigated twice, and leaf samples were collected about four days after the second irrigation. This may have increased boron availability and absorption. Leaves sampled in the month of August, showed that those receiving the 100 and 150 grams of borax had approximately the same ratio which dropped lower than in the previous month, Table 11. As to leaves sampled in October, the lowest ratio was seen in the case of the trees receiving the 150 grams, being followed by the ratio of those receiving the 100 grams, Table 12. When comparing the average ratio of $\frac{Ca + K + Mg}{Boron}$ over the four months, it was observed that the trees receiving the 150 grams had apparently the lowest average ratio, while the checks had a slightly higher average ratio than those receiving the 100 grams, Table13. However, if the values for the month of June are neglected, due to the fact that not enough time was allowed for boron assimilation, and if the average is computed over the last

Table 9. The ratio of (Ca + K + Mg) to boron in apple leaves sampled June 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	601.65	651.17	633.14	457.70	621.85
2	572.44	694.55	632.52	612.16	603.09
3	571.41	791.49	522.99	827.36	721.07
4	596.66	714.62	537.23	863.10	840.50
5	707.89	529.07	635.83	838.74	547.44
Mean	610.01	676.18	592.34	719.81	666.79

Treatments:

Calculated F 4/16 = 10.80 (Significant at the 0.01 level)

Critical difference for the treatment means at

a) 0.05 level 47.22

b) 0.01 level 65.06

Groups at the 0.05 level: (0, 50) (150, 25) (25, 100)

Groups at the 0.01 level: (0, 50) (0, 150) (150, 100, 25).

Table 10. The ratio of (Ca + K + Mg) to boron in apple leaves sampled July 29, 1958, (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	729.19	620.09	813.33	621.72	663.74
2	635.31	897.48	832.05	359.63	562.79
3	683.08	973.70	721.34	793.52	621.93
4	685.57	916.78	927.25	661.95	721.45
5	599.94	606.07	676.38	536.36	697.38
Mean	666.62	782.82	794.07	594.64	653.46

Treatments:

Calculated $F_{4/16}$ = 3.00 (n.s.)

three months, it appears that the trees receiving the 150 grams had the lowest ratio being followed by those receiving the 100 grams, Table 14.

It can be concluded therefore that the trees receiving the 100 and 150 grams of borax, showed very marked decrease in the $\frac{Ca + K + Mg}{Boron}$ ratio after the month of June. This decrease in ratio was also correlated with an increase in the absolute values of boron as seen from Table 5. In the case of the checks, there seemed to be an increase in the $\frac{Ca + K + Mg}{Boron}$ ratio with the advance of the season. This was correlated with a decreasing trend in the average boron content of the leaves, Table 5. Thus, it appears that the control of drop obtained in the case of the trees receiving the 100 grams of borax was due to an increase in the boron content of the leaves, and thus to a more balanced $\frac{Ca + K + Mg}{Boron}$ ratio. The failure to control drop in the case of the trees receiving the 150 grams seemed to be due to an unbalanced boron nutrition as evidenced by the apprently lowest $\frac{Ca + K + Mg}{Boron}$ ratio averaged over the last three months. Whether this unbalance is called "toxicity", or is described by some other term is immaterial. Shear, Crane and Myers (75) have indicated that a high ratio of $\frac{Ca + K}{Mg}$ consistently resulted in boron toxicity, while a high $\frac{Ca + Mg}{K}$ ratio has also increased boron toxicity. They also indicated a relationship between $\frac{Mg}{B}$ ratio and boron toxicity in the tung tree (76). When all

Table 11. The ratio(of Ca + K + Mg) to boron in apple leaves sampled August 29, 1958 . (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	778.59	831.21	545.69	617.03	644.72
2	501.66	713.64	533.78	626.24	695.54
3	605.96	788.88	625.71	714.65	570.65
4	531.26	593.57	635.36	607.10	588.66
5	662.30	447.25	525.45	577.95	460.90
Mean	615.95	674.91	573.20	509.70	592.09

<u>Treatments:</u>

Calculated F 4/16 = 0.93 (n.s.)

Table 12. The ratio of (Ca + K + Mg) to boron in apple leaves sampled October 1, 1958. (Boron being taken as unity).

Replica-tion	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	663.61	815.89	753.41	476.19	562.16
2	539.09	781.15	540.26	626.50	571.05
3	472.24	728.04	529.98	772.06	600.04
4	722.92	676.83	668.70	694.71	583.97
5	783.55	468.27	701.21	538.66	400.14
Mean	636.28	694.40	638.71	621.62	543.47

Treatments:

Calculated $F\ 4/16 = 0.99$ (n.s.)

* Table 13. The average ratio of (Ca + K + Mg) to boron in apple leaves sampled during the 1958 growing season

Date	Treatment (Gms of borax per tree)					
	0	25	50	100	150	Mean
June 29	610.01	676.18	592.34	719.81	666.79	653.03
July 19	666.62	782.82	794.07	594.64	653.46	698.32
Augu.19	615.95	674.91	573.20	628.59	591.89	616.91
Oct. 1	636.28	694.04	638.71	621.62	543.44	626.82
Mean	632.22	706.99	649.58	641.17	613.89	

* Means for data presented in tables 9 to 12.

Treatments:

Calculated F 4/12 = 1.53 (n.s.)

Dates

Calculated F 3/12 = 2.05 (n.s.)

Table 14. The average ratio of (Ca + K + Mg) to boron in apple leaves sampled July, August and October 1958. (Boron being taken as unity)

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
July 29	666.62	782.82	794.07	594.64	653.46	698.34
Aug. 29	615.95	674.91	573.20	628.59	591.89	616.91
Oct. 1	636.28	694.04	638.71	621.62	543.44	626.82
Mean	639.62	717.26	668.66	614.95	596.26	

Treatments:

Calculated F 4/8 = 2.63 (n.s.)

Dates

Calculated F 2/8 = 3.82 (n.s.)

three ratios were computed for this experiment, no trend was indicated with the increasing level of boron supply, and as such the said calculations were not presented.

II. Effects of levels of boron on inorganic leaf composition.

The data on the inorganic leaf composition is presented in Appendix, Tables XVIII to XXI. Using the analysis of variance, each element was studied separately at each of the sampling dates to determine if the concentration of that particular element in the leaf was influenced by the amount of borax applied to the soil. The said data namely the effect of rate of borax application on inorganic leaf composition is presented in Tables 15 to 46. An analysis of variance was also run on the average of each of the five replications at each of the sampling dates. This analysis of variance was for the purpose of studying the seasonal trend for each of the elements and to see if there was any definite influence of borax application on the average percentage content of a particular element over the four months. The data is presented in Table 44 to 54. Each element will be discussed separately, values being always reported as percent dry weight.

Potassium: The range of potassium was between 1.157 percent and 1.957 percent with an average of 1.589 for leaves sampled on June 29 between 0.498 and 1.857, with an average of 1.43 for leaves sampled on July 29; between 0.917 and 1.767 with an average of 1.304 for leaves sampled on August 29; between 0.619 and 1.586, with an average of 1.232. Appendix, Tables XVIII to XXI and Table 55. The critical level for potassium is considered one percent, and thus the averages were above the critical level (89). The ranges however seemed to be narrower than those reported by Walrath and Smith (89) which were 0.94 to 2.50, with an average of 1.74 for one year, 0.61 to 2.16 with an average of 1.43 for the second year, 0.90 to 2.19 with an average of 1.57 for the third year. Although the ranges for potassium were narrow, the averages were in fair agreement with those of Walrath and Smith (89). The ranges reported by Kenworthy (59) for McIntosh and Jonathan apple leaves, and those reported by Beattie and Ellenwood (9) for Stayman Winesap and Delicious apples seemed also to be wider than the potassium ranges found from this experiment. However, the average potassium values reported in this experiment seemed higher than those reported by Smith and Taylor (80), and which included an average of 1.34 percent for Stayman apple leaves sampled June 26, 1.21 for leaves sampled on July 27; 0.99 for those sampled on September 27.

From Table 15 it was observed that in the month of June, there was a decrease in potassium accumulation in the leaves at the lower levels of boron supply. However, when the supply was raised to 150 grams, there tended to be a rise in potassium accumulation. The same trend was observed in the months of July, August and October, but was less striking than for the month of June, Tables 16, 17 and 18. Based on the average of the four months, the trend still held true, and the potassium content for the trees receiving the 150 grams borax was significantly higher than those receiving the 25, 50 and 100 grams but was not significantly different from the control, Tables 47 and 56. This is in agreement with the findings of Smith and Reuther (82) who reported that in the presence of a low boron supply, potassium accumulation in young citrus leaves was retarded.

It was also observed that the values for potassium were significantly higher in the months of June and July than in the months of August and October, Tables 47 and 55. This is in agreement with the findings of Smith and Taylor (80) and those of Cain (27) who reported a decrease in potassium content with the advance of the season.

Calcium: The range for calcium was between 0.723 and 1.723 with an average of 1.285 for the month of June; between 0.697 and 2.096, with an average of 1.546 for the month of July; 1.173 to 2.496 with an average of 1.797 for the month of August; 1.372 to 2.500 with an average of 1.765 for the month of October, Appendix, Tables XVIII to XXI and Table 55. These results were somwhat higher than those reported by Smith and Taylor (80) for leaves of Stayman apple trees, the values being 1.17 for leaves sampled on June 26, 1.28 for those sampled on July 27, 1.41 for those sampled on September 27. The average values for calcium found in this experiment were also higher than those reported by Walrath and Smith (89) and those of Kenworthy (59). This high amount of calcium in the leaves was correlated with a high amount of calcium carbonate in the soil.

As to the effect of boron supply on calcium absorption, it was observed from Tables 23 to 26 and Table 56, that there was a tendency for calcium to be present in greater amounts when the boron supply was low. When the values were averaged over the four months, it was observed that the trees receiving the 25 grams of borax had significantly higher amounts of calcium than those receiving the 100 and 150 grams of borax, Table 48. This is in agreement with the results

Table 15. Potassium content of apple leaves (per cent dry weight) sampled June 29, 1958

Replica-tion	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.596	1.317	1.397	1.157	1.794
2	1.938	1.496	1.594	1.257	1.792
3	1.584	1.516	1.159	1.616	1.918
4	1.857	1.735	1.315	1.957	1.917
5	1.958	1.436	1.217	1.618	1.595
Mean	1.778	1.500	1.336	1.521	1.803

Treatments:

Calculated F 4/16 = 5.55 (significant at the 0.01 level)

Critical difference for the treatment means at

a) 0.05 level 0.255

b) 0.01 level 0.352

Groups at 0.05 level: (25, 50, 100) (0, 150)

Groups at 0.01 level: (25, 50, 100) (0, 25, 100, 150).

Table 16. Potassium content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.519	0.987	1.354	0.988	1.637
2	1.753	1.453	1.589	0.498	1.587
3	1.337	1.717	1.318	1.358	1.659
4	1.657	1.698	1.297	1.857	1.455
5	1.818	1.497	0.878	1.597	1.433
Mean	1.616	1.470	1.287	1.259	1.544

Treatments:

Calculated F 4/16 = 1.25 (n.s.)

Table 17. Potassium content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.417	0.878	1.097	0.999	1.495
2	1.737	1.257	1.376	0.698	1.417
3	1.179	1.337	1.238	1.197	1.437
4	1.456	1.498	1.177	1.767	1.358
5	1.678	1.198	0.917	1.397	1.398
Mean	1.493	1.233	1.161	1.211	1.421

Treatments:

Calculated $F\ 4/16 = 2.15$ (n.s.)

Table 18. Potassium content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.099	0.619	1.084	0.937	1.457
2	1.438	1.398	1.417	0.919	1.238
3	1.097	1.438	1.295	1.137	0.998
4	1.418	1.497	1.058	1.515	1.586
5	1.498	1.098	0.979	1.278	1.218
Mean	1.330	1.210	1.166	1.157	1.299

Treatments:

Calculated F 4/16 = 0.44 (n.s.)

Table 19. Calcium content of apple leaves (per cent dry weight) sampled June 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.047	1.497	1.272	0.723	1.171
2	1.324	1.272	1.170	1.272	1.095
3	1.220	1.434	1.099	1.596	1.224
4	1.322	1.434	1.270	1.328	1.435
5	1.548	1.221	1.434	1.723	0.997
Mean	1.292	1.371	1.249	1.328	1.184

Treatments:

Calculated F 4/16 = 0.55 (n.s.)

Table 20. Calcium content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.174	1.820	1.431	1.248	1.323
2	1.656	1.630	1.574	0.697	1.273
3	1.323	1.909	1.597	1.373	1.549
4	1.175	1.323	2.096	1.772	1.545
5	1.847	1.372	2.096	1.372	1.655
Mean	1.434	1.610	1.758	1.292	1.469

Treatments:

Calculated F 4/16 = 1.79 (n.s.)

Table 21. Calcium content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree) 0	25	50	100	150
1	1.435	2.496	1.883	1.373	1.657
2	1.597	1.821	1.820	1.820	1.821
3	1.548	2.320	1.660	2.170	1.947
4	1.720	1.822	1.821	1.772	1.772
5	1.998	1.173	2.045	1.945	1.498
Mean	1.659	1.926	1.846	1.816	1.739

Treatments:

Calculated F 4/16 = 0.50 (n.s.)

Table 22. Calcium content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gs. of borax per tree)				
	0	25	50	100	150
1	1.499	2.500	1.660	1.595	1.771
2	1.598	1.823	1.497	1.774	1.548
3	1.434	1.885	1.498	1.946	1.772
4	1.548	2.498	1.773	1.944	1.883
5	1.773	1.372	2.397	1.772	1.373
Mean	1.570	2.015	1.765	1.806	1.669

Treatments:

Calculated F 4/16 = 1.45 (n.s.)

Table 23. Sodium content of apple leaves (per cent dry weight) sampled June 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.00972	0.01797	0.01122	0.01072	0.00797
2	0.00799	0.00972	0.00622	0.00898	0.00896
3	0.01071	0.00973	0.01198	0.01621	0.01573
4	0.00798	0.00897	0.00797	0.01398	0.00798
5	0.00899	0.00798	0.00898	0.01523	0.00673
Mean	0.00907	0.01087	0.00927	0.01302	0.00947

Treatments:

Calculated F 4/16 = 1.86 (n.s.)

Table 24. Sodium content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.01474	0.01920	0.02689	0.01298	0.01847
2	0.02077	0.01792	0.01849	0.00971	0.01797
3	0.02070	0.01747	0.01522	0.01848	0.01748
4	0.01846	0.01473	0.01847	0.02421	0.01919
5	0.01223	0.01197	0.01622	0.01796	0.01194
Mean	0.01738	0.01625	0.01905	0.01666	0.01701

Treatments:

Calculated $F\ 4/16 = 0.38$ (n.s.)

Table 25. Sodium content of apple leaves (per cent dry weight)sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.01198	0.00973	0.01631	0.01523	0.02542
2	0.01971	0.01522	0.01396	0.01022	0.01632
3	0.01633	0.01472	0.01523	0.01572	0.02246
4	0.01748	0.01298	0.02021	0.01920	0.01248
5	0.01621	0.01473	0.01521	0.01073	0.01847
Mean	0.01634	0.01347	0.01618	0.01422	0.01903

Treatments:

$F_{4/16}$

Calculated F = 1.60 (n.s.)

Table 26. Sodium content of apple leaves (per cent dry weight)sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.01474	0.01298	0.02371	0.01570	0.01397
2	0.01633	0.01623	0.01572	0.01849	0.01623
3	0.02420	0.02198	0.01470	0.01347	0.01922
4	0.01748	0.02171	0.01922	0.01620	0.01845
5	0.02072	0.01522	0.01573	0.01747	0.01748
Mean	0.01869	0.01742	0.0178	0.01625	0.01707

<u>Treatments:</u>

Calculated F 4/16 = 0.44 (n.s.)

Table 27. Manganese content of apple leaves (percent dry weight) sampled June 29, 1958

Replica-tion	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.02453	0.01867	0.01537	0.01267	0.01535
2	0.01998	0.02574	0.01215	0.01517	0.01513
3	0.01952	0.00668	0.02185	0.01396	0.01099
4	0.00329	0.01346	0.01265	0.02697	0.01947
5	0.01098	0.01586	0.01726	0.02797	0.01566
Mean	0.01582	0.01602	0.01580	0.01934	0.01532

Treatments:

Calculated F 4/16 = 0.28 (n.s.)

Table 28. Manganese content of apple leaves (percent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.02998	0.02114	0.01573	0.01098	0.01398
2	0.02171	0.02539	0.01349	0.01395	0.01577
3	0.02175	0.01218	0.01577	0.00899	0.00699
4	0.00798	0.01268	0.00998	0.02296	0.01575
5	0.00799	0.01976	0.01697	0.02545	0.01095
Mean	0.01788	0.01823	0.01438	0.01647	0.01268

Treatments:

Calculated F 4/16 = 0.65

Table 29. Manganese content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.02546	0.00599	0.01796	0.01498	0.01993
2	0.02625	0.02894	0.01596	0.01795	0.02196
3	0.01728	0.01497	0.02217	0.01577	0.00998
4	0.01097	0.01578	0.01347	0.02466	0.01998
5	0.01498	0.01937	0.01945	0.03093	0.01577
Mean	0.01898	0.01701	0.01780	0.02085	0.01752

Treatments:

Calculated F 4/16 = 0.30 (n.s.)

Table 30. Manganese content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.03349	0.02397	0.01617	0.01575	0.01936
2	0.02197	0.02398	0.01796	0.01699	0.00898
3	0.01726	0.01268	0.01694	0.01696	0.01218
4	0.01099	0.01617	0.01498	0.02746	0.01865
5	0.01568	0.01727	0.01498	0.02543	0.01498
Mean	0.01987	0.01881	0.01620	0.02052	0.01483

Treatments:

Calculated F 4/16 = 0.99 (n.s.)

Table 31. Iron content of apple leaves (Per cent dry weight) sampled June 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.00448	0.00549	0.00610	0.00499	0.00348
2	0.00499	0.00328	0.00498	0.00486	0.00398
3	0.00597	0.00374	0.00461	0.00485	0.00374
4	0.00424	0.00498	0.00394	0.00824	0.00449
5	0.00424	0.00448	0.00293	0.00586	0.00448
Mean	0.00478	0.00439	0.00471	0.00576	0.00403

<u>Treatments:</u>

Calculated F 4/16 = 2.13 (n.s.)

Table 32. Iron content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.00524	0.00648	0.00660	0.00798	0.00524
2	0.00697	0.00394	0.00524	0.00526	0.00624
3	0.00735	0.00512	0.00526	0.00599	0.00699
4	0.00524	0.00656	0.00524	0.00724	0.00660
5	0.00624	0.00548	0.00499	0.00798	0.00547
Mean	0.00621	0.00552	0.00547	0.00689	0.00611

<u>Treatments:</u>

Calculated F 4/16 = 1.87 (n.s.)

Table 33. Iron content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.00549	0.00674	0.00698	0.00699	0.00548
2	0.00598	0.00610	0.00535	0.00548	0.00549
3	0.00615	0.00549	0.00573	0.00499	0.00574
4	0.00498	0.00711	0.00623	0.00735	0.00649
5	0.00536	0.00624	0.00660	0.00531	0.00549
Mean	0.00559	0.00633	0.00617	0.00531	0.00573

Treatments:

Calculated F 4/16 = 1.58 (n.s.)

Table 34. Iron content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.00549	0.00836	0.00835	0.00867	0.00623
2	0.00700	0.00624	0.00623	0.00712	0.00624
3	0.00848	0.00549	0.00656	0.00499	0.00712
4	0.00561	0.00861	0.00649	0.00656	0.00811
5	0.00949	0.01048	0.00562	0.00811	0.00924
Mean	0.00721	0.00783	0.00665	0.00709	0.00738

Treatments:

Calculated $F_{4/16} = 0.50$ (n.s.)

Table 35. Magnesium content of apple leaves (per cent dry weight) sampled June 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.2750	0.3507	0.3992	0.3499	0.3053
2	0.2986	0.2762	0.2759	0.3806	0.2732
3	0.4016	0.2326	0.2947	0.2993	0.3386
4	0.2184	0.2319	0.3257	0.2727	0.3151
5	0.2087	0.3042	0.3755	0.3159	0.2711
Mean	0.2806	0.2791	0.3342	0.3237	0.3007

Treatments:

Calculated F 4/16 = 1.11 (n.s.)

Table 36. Magnesium content of leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree) 0	25	50	100	150
1	0.2748	0.4457	0.4065	0.3951	0.4244
2	0.2739	0.2987	0.2717	0.1993	0.2995
3	0.4084	0.2620	0.3339	0.2447	0.2885
4	0.2495	0.2592	0.3837	0.1997	0.3800
5	0.1998	0.3886	0.4816	0.2277	0.2622
Mean	0.2813	0.3308	0.3754	0.2533	0.3309

Treatments:

Calculated F 4/16 = 2.22 (n.s.)

Table 37. Magnesium content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.2639	0.4493	0.4153	0.4870	0.3862
2	0.3306	0.3118	0.3136	0.3790	0.3618
3	0.3646	0.2432	0.3432	0.2694	0.3007
4	0.2618	0.2883	0.3243	0.2171	0.4008
5	0.1448	0.4006	0.4895	0.2338	=0.3289
Mean	0.2731	0.3386	0.3772	0.3173	0.3556

Treatments:

Calculated F 4/16 = 1.20 (n.s.)

Table 38. Magnesium content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.2250	0.4089	0.4369	0.4327	0.3698
2	0.2810	0.2934	0.2638	0.3746	0.2897
3	0.4002	0.2029	0.2491	0.2052	0.2908
4	0.1599	0.2027	0.3246	0.0875	0.3367
5	0.1500	0.3181	0.3825	0.1809	0.3016
Mean	0.2432	0.2952	0.3314	0.2544	0.3231

Treatments:

Calculated F 4/16 = 0.87 (n.s.)

Table 39. Phosphorus content of apple leaves (per cent dry weight) sampled June 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.1661	0.2258	0.1681	0.1776	0.1455
2	0.1779	0.1648	0.1693	0.1986	0.1568
3	0.2341	0.1900	0.1583	0.1456	0.1798
4	0.1941	0.1805	0.1554	0.2069	0.2021
5	0.2276	0.1635	0.1733	0.2083	0.1600
Mean	0.1999	0.1849	0.1648	0.1874	0.1688

Treatments:

Calculated F 4/16 = 1.63 (n.s.)

Table 40. Phosphorus content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.1681	0.2358	0.1693	0.1807	0.1431
2	0.1718	0.1613	0.1749	0.1787	0.1538
3	0.2177	0.2151	0.1582	0.1668	0.1763
4	0.1926	0.1723	0.1692	0.2511	0.2053
5	0.1967	0.1764	0.1821	0.2196	0.1214
Mean	0.1893	0.1921	0.1707	0.1993	0.1560

Treatments:

Calculated F 4/16 = 1.73 (n.s.)

Table 41. Phosphorus content of apple leaves (per cent dry weight) sampled August 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.1283	0.1912	0.1486	0.1628	0.1587
2	0.1398	0.1277	0.1399	0.1426	0.1246
3	0.1723	0.1507	0.1360	0.1362	0.1222
4	0.1603	0.1428	0.1387	0.1777	0.1358
5	0.1835	0.1439	0.1506	0.1801	0.1303
Mean	0.1568	0.1512	0.1427	0.1599	0.1363

Treatments:

Calculated $F\ 4/16 = 1.46$ (n.s.)

Table 42. Phosphorus content of apple leaves (per cent dry weight) sampled Oct. 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	0.1339	0.1698	0.1278	0.1425	0.1192
2	0.1385	0.1390	0.1517	0.1499	0.1228
3	0.1696	0.1723	0.1370	0.1137	0.1397
4	0.1588	0.1791	0.1258	0.1707	0.1733
5	0.1655	0.3356	0.1313	0.1602	0.1359
Mean	0.1532	0.1991	0.1347	0.1474	0.1401

Treatments:

Calculated F 4/16 = 2.40 (n.s.)

Table 43. Total nitrogen content of apple leaves (per cent dry weight) sampled 29, 1958
June

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	2.68	2.71	2.57	2.67	2.76
2	2.65	2.58	2.53	2.57	2.69
3	2.60	2.42	2.74	2.36	2.54
4	2.34	2.53	2.70	2.56	2.66
5	2.40	2.54	2.67	2.59	2.78
Mean	2.53	2.56	2.64	2.55	2.69

Treatments:

Calculated F 4/12 = 1.6 (n.s.)

Table 44. Total nitrogen content of apple leaves (per cent dry weight) sampled July 29, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	2.74	2.64	2.42	2.47	2.53
2	2.66	2.48	2.37	2.45	2.53
3	2.50	2.49	2.64	2.44	2.35
4	2.36	2.35	2.61	2.45	2.54
5	2.28	2.44	2.58	2.48	2.56
Mean	2.51	2.48	2.52	2.46	2.50

Treatments:

Calculated $F\ 4/16 = 0.33$ (n.s.)

Table 45. Total nitrogen content of apple leaves (per cent dry weight) sampled August 29, 1958

Replica-tion	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	1.91	1.97	2.28	1.95	2.23
2	2.18	2.21	2.22	2.09	2.27
3	2.45	1.99	2.31	2.12	1.92
4	1.00	2.31	2.02	2.07	1.00
5	1.89	2.25	2.38	2.09	2.22
Mean	1.89	2.15	2.24	2.06	1.93

<u>Treatments:</u>

Calculated $F_{4/16}$ = 1.20 (n.s.)

Table 46. Total nitrogen content of apple leaves (per cent dry weight) sampled October 1, 1958

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	2.35	2.16	2.11	1.98	2.09
2	2.17	2.11	1.95	2.06	2.08
3	2.12	1.93	2.19	1.91	1.86
4	1.84	1.93	2.06	1.78	2.10
5	1.88	2.01	2.17	1.83	2.20
Mean	2.07	2.03	2.10	1.91	2.07

<u>Treatments:</u>

Calculated F 4/16 = 1.62 (n.s.)

Table 47*. Seasonal average potassium content of apple leaves (percent dry weight) during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	1.778	1.550	1.336	1.521	1.803	1.588
July 29	1.616	1.470	1.287	1.259	1.554	1.437
Aug. 29	1.493	1.233	1.161	1.211	1.421	1.304
Oct. 1	1.330	1.210	1.166	1.157	1.299	1.232
Mean	1.554	1.353	1.238	1.287	1.519	

*Means for data presented in Tables 15 to 18

<u>Treatments:</u>

Calculated F 4/12 = 18.31 (significant at the 0.01 level)

Critical difference for the treatment means at:

a) 0.05 level 0.090

b) 0.01 level 0.127

Groups at 0.05 level: (50, 100) (25) (150, 0)

Groups at 0.01 level: (50, 100, 25) (25, 100) (150, 0)

<u>Dates:</u>

Calculated F 3/12 = 28.46

Critical difference for the date means at

a) 0.05 level 0.101

b) 0.01 level 0.142

Groups at 0.05 level: (June 29) (July 29) (August 29, Oct. 1)

Groups at 0.01 level: (June 29((July 29) (August 29) (Aug. 29, Oct. 1)

Table 48*. Seasonal average calcium content of apple leaves (percent dry weight) during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	1.292	1.371	1.249	1.328	1.184	1.285
July 29	1.434	1.610	1.758	1.292	1.469	1.513
Aug. 29	1.659	1.926	1.845	1.816	1.739	1.800
Oct. 1	1.570	2.015	1.765	1.806	1.669	1.765
Mean	1.489	1.731	1.654	1.561	1.515	

*Means for data presented in Tables 19 to 22

Treatments:

Calculated F 4/12 = 3.53 (significant at 0.05 level)

Critical difference for the treatment means at 0.05 level 0.148

Groups at 0.05 level: (0, 100, 150) (150, 100, 50) (100, 50) (50, 25).

Dates:

Calculated F 3/12 = 25.02

Critical difference for the date means at

a) 0.05 level 0.165

b) 0.01 level 0.232

Groups at 0.05 level: (June 29) (July 29) (Aug. 29, Oct. 1)

Groups at 0.01 level: (June 29, July 29) (Aug. 29, Oct. 1)

Table 49*. Seasonal average sodium content of apple leaves (Percent dry weight) during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	0.00807	0.01087	0.00927	0.01302	0.00947	0.01034
July 29	0.01738	0.01625	0.01905	0.01666	0.01701	0.01727
Aug. 29	0.01634	0.01347	0.01618	0.01422	0.01903	0.01585
Oct. 1	0.01869	0.01742	0.01782	0.01625	0.01707	0.01424
Mean	0.01537	0.01450	0.01558	0.01504	0.01565	

*Means for data presented in Tables 23 to 26.

Treatments:

Calculated F 4/12 = 0.35 (n.s.)

Dates:

Calculated F 3/12 = 19.79 (significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 0.00259

b) 0.01 level 0.00364

Groups at 0.05 level: (June 29) (Oct. 1, Aug. 29) (Aug. 29, July 29)

Groups at 0.01 level: (June 29) (July 29, Aug. 29, Oct. 1)

Table 50*. Seasonal average manganese content of apple leaves (percent dry weight) during the 1958 growing season

Date	Treatment (Gms. borax per tree)					
	0	25	50	100	150	Mean
June 29	0.01582	0.01602	0.01580	0.01934	0.01532	0.01646
July 29	0.01788	0.01823	0.01438	0.01647	0.01268	0.01593
Aug. 29	0.01898	0.01701	0.01780	0.02085	0.01752	0.01843
Oct. 1	0.01987	0.01881	0.01620	0.02052	0.01483	0.01805
Mean	0.01814	0.01752	0.01605	0.01930	0.01509	

*Means for data presented in Tables 27 to 30

Treatments:

Calculated F 4/12 = 8.00 (significant at the 0.01 level)

Critical difference for the treatment means at

a) 0.05 level 0.00169

b) 0.01 level 0.00237

Groups at 0.05 level: (150, 50) (50, 25) (25, 0) (0, 100)

Groups at 0.01 level: (150, 50) (50, 25, 0) (25, 0, 100)

Dates:

Calculated F 3/12 = 5.55 (Significant at the 0.05 level)

Critical difference for the date means at 0.05 level 0.00134

Groups at 0.05 level: (June 29, July 29) (Aug. 29, Oct. 1)

Table 51*. Seasonal average iron content of apple leaves (percent dry weight) during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	0.00478	0.00439	0.00471	0.00576	0.00403	0.00478
July 29	0.00621	0.00552	0.00547	0.00689	0.00611	0.00604
Aug. 29	0.00559	0.00633	0.00617	0.00602	0.00573	0.00597
Oct. 1	0.00721	0.00783	0.00665	0.00709	0.00738	0.00723
Mean	0.0595	0.00602	0.00575	0.00644	0.00581	

*Means for data presented in Tables 31 to 34.

Treatments:

Calculated F 4/12 = 0.41 (n.s.)

Dates:

Calculated F 3/12 = 16.23

Critical difference for the date means at

a) 0.05 level 0.00076

b) 0.01 level 0.00107

Groups at 0.05 level: (June 29) (July 29, Aug. 29) (October 1)

Groups at 0.01 level: (June 29) (July 29, Aug. 29) (Oct. 1).

Table 52*. Seasonal average magnesium content of apple leaves (percent dry weight) during the 1958 growing season

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	0.2806	0.2791	0.3342	0.3237	0.3007	0.3037
July 29	0.2813	0.3308	0.3754	0.2533	0.3309	0.3143
Aug. 29	0.2731	0.3386	0.3772	0.3173	0.3556	0.3324
Oct. 1	0.2432	0.2852	0.3314	0.2544	0.3231	0.2875
Mean	0.2696	0.3084	0.3546	0.2872	0.3276	

*Means for data presented in Tables 35 to 38.

Treatments:

Calculated F 4/12 = 9.05 (significant at the 0.01 level)

Critical difference for the treament means at

a) 0.05 level 0.0308

b) 0.01 level 0.0432

Groups at 0.05 level: (0, 100) (100, 25) (25, 150) (150, 50)

Groups at 0.01 level: (0, 100) (100, 25, 150) (150, 50)

Dates:

Calculated F 3/12 = 3.73 (Significant at the 0.05 level)

Critical difference for the date means at 0.05 level 0.0345

Groups at 0.05 level: (June 29, July 29, Oct. 1) (June 29, July 29, August 29).

Table 53*. Seasonal average phosophorus content of apple leaves (percent dry weight) during the 1958 growing season.

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	0.1999	0.1849	0.1648	0.1874	0.1688	0.1812
July 29	0.1893	0.1912	0.1707	0.1993	0.1560	0.1815
Aug. 29	0.1568	0.1512	0.1427	0.1599	0.1363	0.1494
Oct. 1	0.1532	0.1991	0.1347	0.1474	0.1401	0.1549
Mean	0.1748	0.1818	0.1432	0.1735	0.1503	

*Means for data presented in Tables 39 to 42.

Treatments:

Calculated $F\ 4/12$ = 5.05 (Significant at the 0.05 level)

Critical difference for the treatment means at 0.05 level 0.0173

Groups at 0.05 level: (150, 50) (0, 25, 100)

Dates:

Calculated $F\ 3/12$ = 9.05 (significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 0.0194

b) 0.01 level 0.0272

Groups at 0.05 level: (June 29, July 29) (August 29, Oct. 1)

Groups at 0.01 level: (Aug. 29, Oct. 1) (Oct. 1, June 29)

(June 29, July 29).

Table 54*. Seasonal average total nitrogen content of apple leaves (percent dry weight) during the 1958 growing season.

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	2.53	2.56	2.64	2.55	2.69	2.59
July 29	2.51	2.48	2.52	2.46	2.50	2.50
Aug. 29	1.88	2.15	2.24	2.06	1.93	2.05
Oct. 1	2.07	2.05	2.10	1.91	2.07	2.04
Mean	2.23	2.31	2.38	2.25	2.30	

*Means for data presented in Tables 43 to 46.

Treatments:

Calculated $F_{4/12}$ = 2.57 (n.s.)

Dates:

Calculated $F_{3/12}$ = 73.72 (highly significant at the 0.01 level)

Critical difference for the date means at

a) 0.05 level 0.11

b) 0.01 level 0.16

Groups at 0.05 level: (Aug. 29, Oct. 1) (June 29, July 29)

Groups at 0.01 level: (Aug. 29, Oct. 1) (June 29, July 29)

Table 55. Seasonal trend in the average percent inorganic constitutents of apple leaves sampled in the 1958 growing season, irrespective of boron supply

Date	Av. Percent K	Av. Percent Ca	Av. Percent Na	Av. Percent Mn	Av. Percent Fe	Av. Percent Mg	Av. Percent P	Av. Percent N	Av. p.p.m. B
June 29	1.589	1.285	0.01034	0.01646	0.00473	0.3148	0.1812	2.59	49.19
July 29	1.437	1.546	0.01727	0.01592	0.00604	0.3143	0.1815	2.49	46.87
Aug. 29	1.304	1.797	0.01584	0.01843	0.00597	0.3323	0.1494	2.05	55.80
Oct. 1	1.232	1.765	0.01744	0.01804	0.00723	0.2875	0.1549	2.04	53.68

Table 56. Average percent mineral constitutents of apple leaves (dry weight basis) over 4 months of the 1958 growing season, and at the different levels of boron supply

Treat- ment Gr. borax	Av. Percent K	Av. Percent Ca	Av. Percent Mn	Av. Percent Mg	Av. Percent P	Av. Percent N	Av. Percent Na	Av. Percent Fe	Av. Percent B
0	1.554	1.489	0.01840	0.2693	0.1748	2.25	0.01537	0.00595	53.44
25	1.353	1.731	0.01752	0.3084	0.1818	2.31	0.01450	0.00602	48.03
50	1.238	1.654	0.01605	0.3545	0.1533	2.38	0.01157	0.00575	50.16
100	1.287	1.561	0.01787	0.2872	0.1735	2.25	0.01504	0.00644	49.66
150	1.519	1.515	0.01509	0.3274	0.1503	2.30	0.01565	0.00581	55.78

of Muhn (67) who reported, in most cases higher percentages of calcium in the tissues of plants inadequately supplied with boron than in those grown in the presence of sufficient boron. The values are also in agreement with the results of Smith and Reuther (81) who reported a decrease in the rate of calcium accumulation in citrus leaves at high boron levels.

The values for calcium were significantly higher in the months of June and July than in the months of August and October, Tables 48 and 55. This finding is in agreement with results reported by Smith and Taylor (80) and also by Cain (27).

<u>Sodium</u>: The values reported for sodium ranged between 0.00797 and 0.01797 percent, with an average of 0.01034 for June; between 0.00971 and 0.02684 with an average of 0.01727 for July; between 0.00973 and 0.02546 with an average of 0.01584 for August; between 0.01347 and 0.02420 with an average of 0.01744 for October, Appendix, Tables XVIII to XXI and Table 55.

The sodium content of the apple leaves did not seem to be influenced by the amount of borax applied, as evidenced from Tables 23 to 27 and Table 49.

The sodium content of the leaves was significantly higher in the month of June than in the remaining three months, and the sodium content in July was significantly higher than that in October. Thus, there seemed to be an increase in sodium content from June to the end of July, followed by a decrease from August to October.

<u>Manganese</u>: The values for manganese ranged between 0.00329 to 0.02797 percent with an average of 0.01646 for June; between 0.00699 and 0.02998,

with an average of 0.01592 for July; between 0.00599 and 0.03093 with an average of 0.01843 for August; between 0.00898 and 0.03349 with an average of 0.01804 for October. These values were higher than those given by Beattie and Ellenwood (9) who reported a range of 0.0020 to 0.0120 for Stayman apple leaves, and a range of 0.0020 to 0.0156 for Delicious apple leaves. They were also higher than values reported by Walrath and Smith (89) and also higher than those of Kenworthy (59) who reported averagesof 0.0107 for McIntosh and 0.0112 for Jonathan apple leaves.

As to the effect of borax on manganese absorption, it was observed that the trees receiving the 150 grams of borax appeared to have a lower manganese content than the checks, Tables 27 to 31. When the average was computed over the four months, it was found that the trees receiving the 150 grams of borax had a significantly lower manganese content than the control, Table 50. This is in agreement with the results of Cibes, Hernandez and Childers (27) who reported that manganese content was high in peach trees receiving no boron and boron content was high in trees receiving no manganese, Tables 50 and 56.

The manganese content was siginificantly higher in the months of August and October than in June and July, Tables 50 and 55. This is in agreement with the findings of Smith and Taylor (80) who reported an increase in manganese content of Stayman apple leaves with the advance of the season.

Iron: The values for iron ranged between 0.00348 and 0.00824 percent with an average of 0.00473 for June; between 0.00394 and 0.00798 with an average of 0.00604 for July; between 0.00498 and 0.00735 and an average of 0.00597 for August; between 0.00549 and 0.00949 with an average of 0.00723 for October, Appendix, Tables XVIII to XXI and Table 55. These values were much lower than those of Beattie and Ellenwood (9) who reported a range of 0.0065 to 0.0507 for leaves of Stayman apple trees, and a range of 0.0095 to 0.0505 from leaves of Delicious apple trees. The experimental data was also much lower than average values of 0.020, 0.0166 and 0.0170 reported by Walrath and Smith (89), as well as much lower than average values of 0.0284 and 0.0214 for McIntosh and Jonathan apple leaves respectively, reported by Kenworthy (59). This low iron content of the leaves may be due to the high amounts of calcium carbonate in the soil and thus to the soil fixation of the said element, and probably due to the high manganese content.

There appeared to be no effect of boron supply on the iron content of the leaves, Tables 31 to 35 and Tables 51 and 56. This is not in agreement with the results of Muhn (67) who reported in most cases, a higher percentage of iron in the tissues of plants inadequately supplied with boron than from those grown in the presence of sufficient amounts of boron.

There was an increase in the iron content of the leaves with the advance of the season. In October, the average iron content of the leaves was significantly higher than in June, July and August, Tables 51 and 55.

Magnesium: The percent magnesium in the leaves ranged between 0.2186 and 0.4016, with an average of 0.3148 for June; between 0.1993 and 0.4457, with an average of 0.3143 for July; between 0.1448 and 0.4870 with an average of 0.3323 for August; between 0.0875 and 0.4327, with an average of 0.2875 for October, Appendix Tables XVIII to XXI and Table 55. These results were more or less in agreement with those of Beattie and Ellenwood (9) who reported a magnesium range of 0.0108 to 0.499 for Stayman apple leaves and 0.0201 to 0.474 for Delicious apple leaves. The average values for magnesium seemed also to be in agreement with those of Smith and Taylor (80) who reported values of 0.30 percent magnesium for Stayman apple leaves sampled June 26, 0.29 percent for those sampled July 27 and 0.23 for those sampled September 27. However, the magnesium values reported in this experiment were higher than values reported by Walrath and Smith (89) and which included 0.26 percent, 0.24 percent, 0.21 percent, as averages for each of three years.

By examining Tables 35 to 39 and Table 56, it appeared that the borax applications increased the level of magnesium in the leaves, in comparison to the control. When the average over the four months was considered, it was found that the trees receiving the 150 grams of borax had significantly higher amounts of magnesium than the control, Tables 52 and 56. These values were not in agreement with those of Muhn (67) who reported that in most cases, the tissues of plants inadequately supplied with boron contained higher amounts of magnesium than the tissues of plants grown in the presence of sufficient boron. It was not also in agreement with the findings of Smith and Reuther (82) who reported similar findings in the young leaves of citrus.

The average values for magnesium were significantly higher in August than in October, Tables 52 and 55. Thus, there seemed to be a gradual increase in the average magnesium content from June to August, followed by a decrease in October. This was in agreement with the findings of Cain (27) who reported a decrease in magnesium content with the advance of the season. Moreover, magnesium values reported by Smith and Taylor (80) for the months of June, July and September seemed to indicate an increase with the advance of the season.

Phosphorus: The values reported from this experiment ranged between 0.1455 and 0.2276 percent with an average of 0.1812 for June; between 0.1431 and 0.2358 with an average of 0.1815 for July; between 0.1222 and 0.1777 with an average of 0.1494 for August; between 0.1192 and 0.1733 with an average of 0.1549 for October, Appendix Tables XVIII to XXI and Table 55. These results seemed to be in very close agreement with values reported by Smith and Taylor (80) which were as follows, for June 26, 0.18 percent; July 27, 0.17; September 27, 0.14. They also seemed in fair agreement with values reported by Walrath and Smith (88). However, the said results were slightly lower than values reported by Kenworthy (59) for McIntosh and Jonathan apple leaves. They were also above 0.1 percent which was the critical value reported by Walrath and Smith (89).

By a study of Tables 39 to 43, it appeared that phosphorus tended to be present in smaller amounts at the highest level of boron supply. When the average was considered over the four months, it was found that the trees receiving the 150 grams of borax had significantly lower amounts of phosphorus than the control, Appendix Tables 53 and 56. This finding was not in agreement with the findings of Smith and Reuther

(81) who reported that phosphorus tended to be present in slightly greater concentration in the leaves of young Valencia orange trees in the presence of boron.

The phosphorus content of the leaves was significantly greater in the months of June and July than in the months of August and October, Tables 53 and 55. This was in agreement with the findings of Cain (27) who reported a marked decrease in the phosphorus content of McIntosh apple leaves with the advance of the season.

Total nitrogen

The values found for total nitrogen in this experiment ranged between 2.34 and 2.78 percent with an average of 2.59 for June; between 2.28 and 2.74 with an average of 2.49 for July; between 1.00 and 2.38 with an average of 2.05 for August; between 1.84 and 2.35 with an average of 2.04 to October. These values were close to those reported by Beattie and Ellenwood (9) who gave a range of 1.51 to 2.34 for Stayman Winesap apple leaves, and a range of 1.74 to 2.53 for Delicious apple leaves. They were also close to values reported by Smith and Taylor (80) who included values of 2.58 for June 26, 2.63 for July 27 and 2.34 for September 27. They were not very far from values reported by Kenworthy (59) which included a nitrogen range of 1.69 to 2.84 with an average of 2.37 for McIntosh apple leaves; a range of 2.09 to 2.79 with an average of 2.45 for Jonathan apple leaves. Daouk (35) working on Starking Delicious apple trees propagated on different rootstocks reported average of 3.15, 2.19 and 3.22 for leaves sampled June 25; averages of 3.07, 2.94 and 3.15 for those sampled July 16; 2.68, 2.43 and 2.63 for August 27; 2.67, 2.43 and 2.66 for October 8. These values were higher than those found from this experiment.

From a study of Tables 43 to 47, and Table 54, it appeared that nitrogen content in the leaves was not influenced by the level of borax applied. This was not in agreement with the work of Muhn (67) who reported in most cases a higher percentage of nitrogen in the leaves of plants inadequately supplied with boron than in the tissues of plants grown in the presence of sufficient boron.

The total nitrogen content of the leaves was significantly higher in the months of June and July than in August and October, Tables 54 and 55. This was in agreement with the findings of Smith and Taylor (80) as well as those of Daouk (35) who reported a decrease in nitrogen concentration with the advance of the season.

III. <u>Boron supply and pressure tests</u>.

Readings were conducted randomly on some fruits from trees receiving the different levels of boron, by the use of a fruit pressure tester. There were indications of decreased firmness at the high levels of boron supply, but the sample used was not large enough to warrant definite conclusions.

SUMMARY AND CONCLUSIONS

This study was undertaken in an effort to evaluate the effect of boron level on preharvest drop of fruit and inorganic leaf composition of apples.

Conclusions drawn from the above experiment follow:

There was an apparent reduction in preharvest drop through the application of 25 and 50 grams of borax per tree, but the differences were not statistically significant from the control. The 100 gram borax treatment produced a significant decrease in drop. Failure to control drop resulted when the rate of borax application was as much as 150 grams per tree.

In trying to relate preharvest drop to the boron content of the leaf tissue, it was observed that the boron content of the checks seemed high in comparison to values reported in the literature for boron - deficient trees. Possible explanations were given for these high values.

It was also noted that the trees receiving the 100 grams of borax and in which good control of drop was obtained indicated a lower average percent boron than the control in the months of June, July and August. Possible explanations for the lack of apparent response to boron were offered.

In studying the seasonal trend in boron nutrition, there was an indication of increased boron uptake in the case of the trees receiving the 100 and 150 grams with the advance of the season, and that the 100 grams of borax per tree supplied enough boron to result in a successful control of drop. There were no indications of increased boron uptake in the case of the checks. The failure to control drop at the high level of 150 grams borax per tree seemed to be due to "toxicity" as the margin between deficiency and "toxicity" levels is very small.

An examination of ratios showed that the Ca/B ratio was not a useful index of sufficiency or deficiency for boron in this experiment. By computing the N/B, P/B and K/B ratios it was revealed that there was a decreasing trend with the advance of the season for the trees receiving the 100 and 150 grams of borax, which was more marked than in the case of the checks.

A computation of the $\frac{Ca + K + Mg}{B}$ ratio clearly indicated an increased boron absorption in the case of the trees receiving the 100 and 150 grams. The control of drop obtained in the case of the 100 grams treatment seemed to be due to a more balanced $\frac{Ca + K + Mg}{B}$ ratio as compared to the checks and those receiving the lower levels of boron supply. The failure to control drop in the case of the 150 gram treatment seemed to be due to an unbalanced $\frac{Ca + K + Mg}{B}$ ratio. This unbalanced ratio might be "toxicity" by definition.

It should be stressed that in this experiment control of drop was obtained even in the same year in which the borax applications were made, and even though treatments were applied rather late. However, the preharvest drop was not severe that particular year. A greater response might be expected the year following the treatment. An application of 100 grams early in the season may have caused toxicity because of the longer time allowed for boron assimilation.

The ranges and averages of each of the elements analyzed for, were presented for each of the sampling dates, and comparisons were made with values reported in the literature. The effect of the level of boron supply on inorganic leaf composition was as follows:

The potassium content of the leaves from the trees receiving the 150 grams treatment was significantly higher than those receiving the 25, 50 and 100 grams, but was not significantly larger than the control. There was a tendency for calcium to be present in greater amounts when the boron supply was low. Based on the average of the four months, the trees receiving the 25 grams of borax had significantly higher amounts of calcium than those receiving the 100 and 150 grams.

The sodium content of the leaves did not seem to be influenced by the amount of borax applied. This was also true for iron and the total nitrogen content of the leaves.

Based on the four months' average, the trees receiving the 150 grams of borax had a significantly lower manganese content than the control. A similar trend was observed for phosphorus.

Considering the average of the four months, it was observed that the trees receiving the 150 grams of borax had significantly higher amount of magnesium than the control.

As to the seasonal trend exhibited by the elements, it was observed that there was a significant decrease in the leaf content of nitrogen, phosphorus, potassium and calcium, while there was a significant increase in the manganese and iron content with the advance of the season. Sodium and magnesium tended to increase early in the season and then decreased markedly at the end of the season.

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A P P E N D I X

Table I. The calcium to boron ratio in apple leaves sampled June 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	215.88	208.02	262.48	148.40	222.67
2	212.86	290.21	243.45	267.62	208.97
3	217.47	356.63	225.16	376.06	253.57
4	232.17	301.32	234.40	322.17	328.90
5	294.91	218.15	318.53	395.18	190.63
Mean	234.66	294.87	256.80	301.89	240.95

Table II. The ratio of calcium to boron in apple leaves sampled July 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	288.45	477.31	364.68	294.90	259.46
2	285.66	432.59	381.30	179.78	226.75
3	294.52	478.09	354.57	366.13	275.52
4	261.25	329.43	514.61	306.36	329.78
5	286.71	255.26	410.26	230.20	344.50
Mean	283.32	394.54	405.08	275.47	287.20

Table III. The ratio of calcium to boron in apple leaves sampled August 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	358.57	648.02	296.35	302.64	256.98
2	218.62	383.37	393.43	276.81	338.10
3	303.41	469.26	442.68	320.46	381.69
4	265.80	299.72	270.58	348.25	271.82
5	346.33	218.23	314.37	409.16	207.22
Mean	298.55	403.72	343.48	331.46	291.16

Table IV. The ratio of calcium to boron in apple leaves sampled October 1, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	352.37	578.17	393.18	256.97	274.66
2	259.71	405.20	254.51	362.41	287.41
3	231.03	389.22	260.98	456.91	347.38
4	358.00	402.77	375.72	380.80	288.85
5	406.09	230.43	447.20	295.43	189.93
Mean	321.44	401.16	346.32	350.50	277.65

Table V*. The average calcium to boron ratio in apple leaves sampled in the 1958 growing season (Boron being taken as unity).

Date	Treatment (Gms. of borax per tree)					
	0	25	50	100	150	Mean
June 29	234.66	294.87	256.80	301.89	240.95	265.83
July 29	283.32	394.54	405.08	275.47	287.20	329.12
Aug. 29	298.55	403.72	343.48	331.46	291.16	333.67
Oct. 1	321.44	401.16	346.32	350.50	277.65	339.41
Mean	284.49	373.57	337.92	314.83	274.24	

*Averages for data presented in Tables I to IV inclusive

Table VI. The ratio of nitrogen to boron in apple leaves sampled June 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	522.4	558.2	531.0	548.2	524.4
2	426.4	588.9	526.2	539.9	513.7
3	462.9	601.8	561.4	556.8	526.2
4	411.8	531.2	498.0	621.8	609.9
5	456.3	453.8	592.6	595.0	531.7
Mean	462.0	546.8	541.8	572.3	541.2

Table VII. The ratio of nitrogen to boron in apple leaves sampled July 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	674.2	692.4	617.4	569.9	496.0
2	459.1	658.1	574.7	633.0	451.5
3	556.2	623.8	585.6	650.2	418.4
4	525.9	584.6	639.8	424.2	541.6
5	353.9	454.8	504.9	416.7	533.7
Mean	513.9	602.7	584.5	538.8	488.2

Table VIII. The ratio of nitrogen to boron in apple leaves sampled August 29, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	476.8	541.1	366.0	420.9	406.8
2	297.9	464.7	338.0	452.4	437.3
3	479.7	402.6	446.8	432.1	296.9
4	155.1	379.9	387.0	315.8	167.5
5	327.1	406.3	476.6	338.3	363.3
Mean	347.3	438.9	402.9	391.9	334.4

Table IX. The ratio of nitrogen to boron in apple leaves sampled October 1, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	552.7	499.4	500.5	318.3	324.3
2	352.2	469.7	332.1	420.9	386.9
3	341.9	397.5	381.2	448.7	364.5
4	425.7	311.0	436.1	349.0	321.4
5	430.8	353.2	404.6	304.8	304.4
Mean	420.7	406.2	410.9	368.3	340.3

Table X. The ratio of potassium to boron in apple leaves sampled June 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	329.1	271.0	288.3	237.5	341.1
2	311.6	341.3	331.7	264.5	342.0
3	282.4	377.0	237.5	380.8	397.4
4	326.1	364.6	242.7	474.8	439.4
5	373.0	256.6	270.3	371.1	305.0
Mean	324.4	322.1	274.1	345.7	365.0

Table XI. The ratio of potassium to boron in apple leaves sampled July 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	373.2	258.9	345.1	233.5	321.0
2	302.4	385.6	384.9	128.5	282.7
3	297.6	430.0	292.6	362.1	295.1
4	369.0	422.8	318.4	321.1	310.6
5	282.2	278.5	171.9	268.0	296.3
Mean	324.9	355.2	302.6	262.6	301.54

Table XII. The ratio of potassium to boron in apple leaves sampled August 29, 1958. (Boron being taken as unity)

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	354.1	240.6	176.3	215.6	272.4
2	237.8	264.6	209.3	163.8	273.4
3	231.1	270.4	239.0	244.2	222.6
4	225.0	246.4	225.1	269.8	226.4
5	290.9	193.3	183.5	225.8	229.3
Mean	267.8	243.1	206.6	223.8	244.8

Table XIII. The ratio of potassium to boron in apple leaves sampled October 1, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	258.4	143.2	256.8	151.0	226.0
2	233.7	310.7	240.9	187.7	230.0
3	176.7	296.9	225.6	267.0	195.7
4	327.9	241.4	224.2	297.0	243.3
5	343.1	184.4	182.7	213.0	168.5
Mean	268.0	235.3	226.0	223.1	212.65

Table XIV. The ratio of phosphorus to boron in apple leaves sampled June 29, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	34.25	46.46	34.69	36.45	27.67
2	28.60	37.60	35.23	41.78	29.92
3	41.73	47.25	32.43	34.31	37.25
4	34.09	37.93	28.68	50.19	46.32
5	43.36	29.21	38.49	47.78	30.59
Mean	36.41	39.69	33.90	32.10	34.35

Table XV. The ratio of phosphorus to boron in apple leaves sampled July 29, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	41.30	61.84	43.14	42.70	28.06
2	29.64	42.81	42.37	46.09	27.40
3	48.46	53.87	35.12	44.48	31.36
4	42.90	42.90	41.54	43.41	43.82
5	30.53	32.82	35.64	36.85	25.27
Mean	38.57	46.85	39.56	42.71	31.18

Table XVI. The ratio of phosphorus to boron in apple leaves sampled August 29, 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	32.06	52.40	23.88	35.14	28.92
2	19.14	26.88	21.26	30.83	24.04
3	33.77	30.48	26.25	27.78	18.93
4	24.77	23.49	26.53	27.13	24.31
5	31.81	23.22	30.13	29.11	21.37
Mean	28.31	31.29	25.61	30.00	23.51

Table XVII. The ratio of phosphorus to boron in apple leaves sampled October 1 , 1958. (Boron being taken as unity).

Replication	Treatment (Gms. of borax per tree)				
	0	25	50	100	150
1	31.48	39.27	30.27	22.96	18.49
2	22.51	30.90	25.79	30.62	22.80
3	27.56	35.58	23.87	26.70	29.35
4	36.73	28.88	26.66	33.44	26.58
5	37.91	56.37	24.50	26.71	18.80
Mean	31.24	38.20	26.22	28.28	23.20

Table XVIII. Inorganic composition of apple leaves (Dry weight basis) sampled June 29, 1958

Tree No. (Replication)	Treatment Gr. Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
1	0	1.596	1.047	0.00972	0.02534	0.00448	0.2750	0.1661	2.68	48.50
2	0	1.938	1.324	0.00799	0.01998	0.00499	0.2986	0.1779	2.65	62.20
5	0	1.584	1.220	0.01071	0.0.1952	0.00597	0.4016	0.2341	2.60	56.10
16	0	1.857	1.322	0.00798	0.00329	0.00424	0.2184	0.1941	2.34	56.94
18	0	1.958	1.548	0.00899	0.01098	0.00424	0.2097	0.2276	2.40	52.49
Mean		1.778	1.292	0.00907	0.01582	0.00478	0.2806	0.1999	2.53	55.25
4	25	1.317	1.497	0.01797	0.01867	0.00549	0.3507	0.2258	2.71	48.60
10	25	1.496	1.272	0.00972	0.02574	0.00328	0.2762	0.1648	2.58	43.83
13	25	1.516	1.434	0.00973	0.00668	0.00374	0.2326	0.1900	2.42	40.21
19	25	1.735	1.434	0.00897	0.01346	0.00498	0.2319	0.1805	2.53	47.59
25	25	1.436	1.221	0.00798	0.01586	0.00448	0.3042	0.1635	2.54	55.97
Mean		1.500	1.371	0.01087	0.01602	0.00439	0.2791	0.1849	2.56	47.24
7	50	1.397	1.272	0.01122	0.01537	0.00610	0.3992	0.1681	2.57	48.46
11	50	1.594	1.170	0.00622	0.01215	0.00498	0.2759	0.1693	2.53	48.06
20	50	1.159	1.099	0.01198	0.02158	0.00461	0.2947	0.1583	2.74	48.81

Table XVIII. Cont'd.

Tree No. Replica- tion)	Treat- ment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
21	50	1.315	1.270	0.00797	0.01265	0.00394	0.3257	0.1554	2.70	54.18
22	50	1.217	1.434	0.00898	0.01726	0.00393	0.3755	0.1733	2.67	45.02
Mean		1.336	1.249	0.00927	0.01580	0.00471	0.3342	0.1648	2.64	48.90
3	100	1.157	0.723	0.00172	0.01267	0.00499	0.3499	0.1776	2.67	48.72
6	100	1.257	1.272	0.00898	0.01517	0.00486	0.3806	0.1986	2.57	47.53
12	100	1.616	1.596	0.01621	0.01396	0.00485	0.2993	0.1456	2.36	42.44
14	100	1.957	1.328	0.01398	0.02697	0.00824	0.2727	0.2069	2.56=	41.22
17	100	1.618	1.723	0.01523	0.02797	0.00586	0.3159	0.2083	2.59	43.60
Mean		1.521	1.328	0.01302	0.01934	0.00576	0.3237	0.1874	2.55	44.70
8	150	1.794	1.171	0.00797	0.01535	0.00348	0.3053	0.1455	2.76	52.59
9	150	1.792	1.095	0.00896	0.01513	0.00398	0.2732	0.1568	2.69	52.40
15	150	1.918	1.224	0.01573	0.01099	0.00374	0.3386	0.1798	2.54	48.27
24	150	1.917	1.435	0.00798	0.01947	0.00449	0.3151	0.2021	2.66	43.63
23	150	1.595	0.997	0.00673	0.01566	0.00448	0.2711	0.1600	2.78	52.30
Mean		1.803	1.184	0.00947	0.01532	0.00403	0.3007	0.1688	2.69	49.84

Table XIX. Inorganic composition of apple leaves (Dry weight basis) sampled July 29, 1958

Tree No. (Replica-tion)	Treat-ment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
1	0	1.519	1.174	0.01474	0.02998	0.00524	0.2748	0.1681	2.74	40.70
2	0	1.753	1.656	0.02077	0.02171	0.00697	0.2739	0.1718	2.66	57.97
5	0	1.337	1.323	0.02070	0.02175	0.00735	0.4084	0.2177	2.50	44.92
16	0	1.657	1.173	0.01846	0.00798	0.00524	0.2495	0.1926	2.36	44.90
18	0	1.818	1.847	0.01223	0.00799	0.00624	0.1998	0.1967	2.28	64.42
Mean		1.616	1.434	0.01738	0.01788	0.00621	0.2813	0.1893	2.51	50.58
4	25	0.987	1.820	0.01920	0.02114	0.00648	0.4457	0.2358	2.64	38.13
10	25	1.453	1.630	0.01792	0.02539	0.00394	0.2987	0.1613	2.48	37.68
13	25	1.717	1.909	0.01747	0.01218	0.00512	0.2620	0.2151	2.49	39.93
19	25	1.698	1.323	0.01473	0.01268	0.00656	0.2592	0.1723	2.35	40.16
25	25	1.497	1.372	0.01197	0.01976	0.00548	0.3886	0.1764	2.44	53.75
Mean	50	1.470	1.610	0.01625	0.01823	0.00552	0.3308	0.1921	2.48	41.93
7	50	1.354	1.431	0.02689	0.01573	0.00660	0.4065	0.1693	2.42	39.24
11	50	1.589	1.574	0.01849	0.01349	0.00524	0.2717	0.1749	2.37	41.28
20	50	1.318	1.597	0.01522	0.01577	0.00526	0.3339	0.1582	2.64	45.04
21	50	1.297	2.096	0.01847	0.00998	0.00524	0.3837	0.1692	2.61	40.72
22	50	0.878	2.096	0.01622	0.01697	0.00499	0.4816	0.1821	2.58	51.09
Mean		1.287	1.758	0.01905	0.01438	0.00547	0.3754	0.1707	2.52	43.48

Table XIX. Cont'd.

Tree No. (Replication)	Treatment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
3	100	0.988	1.248	0.01298	0.01098	0.00798	0.3951	0.1807	2.47	42.32
6	100	0.498	0.697	0.00971	0.01395	0.00526	0.1993	0.1787	2.45	38.77
12	100	1.358	1.373	0.01848	0.00899	0.00599	0.2447	0.1668	2.44	37.50
14	100	1.857	1.772	0.02421	0.02296	0.00724	0.1997	0.2511	2.45	57.84
17	100	1.597	1.372	0.01796	0.02545	0.00798	0.2277	0.2196	2.48	59.60
Mean		1.259	1.292	0.01666	0.01647	0.00689	0.2533	0.1993	2.46	47.21
8	150	1.637	1.323	0.01847	0.01577	0.00624	0.2995	0.1538	2.53	56.14
9	150	1.587	1.273	0.01797	0.01577	0.00624	0.2995	0.1538	2.53	56.14
15	150	1.659	1.549	0.01748	0.00699	0.00699	0.2885	0.1763	2.35	56.22
24	150	1.455	1.545	0.01919	0.01575	0.00660	0.3800	0.2053	2.54	46.85
23	150	1.433	1.655	0.01194	0.01095	0.00547	0.2622	0.1214	2.56	48.04
Mean		1.544	1.469	0.01701	0.01268	0.00611	0.3309	0.1560	2.50	21.65

Table XX. Inorganic composition of apple leaves (dry weight basis) sampled August 29, 1958

Tree No. (Replica-tion)	Treat-ment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
1	0	1.417	1.435	0.01198	0.02546	0.00549	0.2639	0.1283	1.91	40.02
2	0	1.737	1.597	0.01971	0.02625	0.00598	0.3306	0.1398	2.18	73.05
5	0	1.179	1.548	0.01633	0.01728	0.00615	0.3646	0.1723	2.45	51.02
16	0	1.456	1.720	0.01748	0.01097	0.00498	0.2618	0.1603	1.00	64.71
18	0	1.678	1.998	0.01621	0.01498	0.00536	0.1448	0.1835	1.89	57.69
Mean		1.493	1.659	0.01634	0.01898	0.00559	0.2731	0.1568	1.89	57.30
4	25	0.878	2.496	0.00973	0.00599	0.00674	0.4493	0.1912	1.97	36.49
10	25	1.257	1.821	0.01522	0.02894	0.00610	0.3118	0.1277	2.21	47.50
13	25	1.337	2.320	0.01472	0.01497	0.00549	0.2432	0.1507	1.89	49.44
19	25	1.498	1.822	0.01298	0.01578	0.00711	0.2883	0.1428	2.31	60.79
25	25	1.198	1.173	0.01473	0.01937	0.00624	0.4006	0.1439	2.25	61.97
Mean		1.233	1.926	0.01347	0.01701	0.00633	0.3386	0.1512	2.15	51.24

Table XX. Cont'd.

Tree No. Replica-tion)	Treat-ment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
7	50	1.097	1.883	0.01631	0.01796	0.00698	0.4153	0.1486	2.28	62.22
11	50	1.376	1.820	0.01396	0.01596	0.00535	0.3136	0.1399	2.22	65.75
20	50	1.238	1.660	0.01523	0.02217	0.00573	0.3432	0.1360	2.31	51.80
21	50	1.177	1.821	0.02021	0.01347	0.00623	0.3243	0.1387	2.02	52.29
22	50	0.917	2.045	0.01521	0.01945	0.00660	0.4895	0.1506	2.38	49.98
Mean		1.161	1.846	0.01618	0.01780	0.00617	0.3772	0.1427	2.24	56.41
3	100	0.999	1.373	0.01523	0.01498	0.00699	0.4870	0.1628	1.95	46.33
6	100	0.698	1.820	0.01022	0.01795	0.00548	0.3790	0.1426	2.09	46.26
12	100	1.197	2.170	0.01572	0.01577	0.00499	0.2694	0.1362	2.12	49.02
14	100	1.767	1.772	0.01920	0.02466	0.00735	0.2171	0.1777	2.07	65.49
17	100	1.397	1.945	0.01073	0.03093	0.00531	0.2338	0.1801	2.09	61.87
Mean		1.211	1.816	0.01422	0.02085	0.00602	0.3173	0.1599	2.06	53.79
8	150	1.496	1.657	0.02542	0.01993	0.00548	0.3862	0.1587	2.23	54.88
9	150	1.417	1.821	0.01632	0.02196	0.00549	0.3618	0.1246	2.27	51.83
15	150	1.437	1.947	0.02246	0.00998	0.00574	0.3007	0.1222	1.92	64.57
24	150	1.358	1.772	0.01248	0.01998	0.00649	0.4008	0.1458	1.00	59.98
23	150	1.398	1.498	0.01847	0.01577	0.00549	0.3289	0.1303	2.22	69.97
Mean		1.421	1.739	0.01903	0.01752	0.00573	0.3556	0.1363	1.93	60.25

Table XXI. Inorganic composition of apple leaves (dry weight basis) sampled October 1, 1958

Tree No. (Replication)	Treatment Gr.Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
1	0	1.099	1.499	0.01474	0.03349	0.00549	0.2250	0.1339	2.35	42.54
2	0	1.438	1.598	0.01633	0.02197	0.00700	0.2810	0.1385	2.17	61.53
5	0	1.97	1.434	0.02420	0.01726	0.00848	0.4002	0.1696	2.12	62.07
16	0	1.418	1.548	0.01748	0.01099	0.00561	0.1599	0.1588	1.84	43.24
18	0	1.498	1.773	0.02072	0.01568	0.00949	0.1500	0.1655	1.88	43.66
Mean		1.330	1.570	0.01869	0.01987	0.00721	0.2432	0.1532	2.07	50.61
4	25	0.619	2.500	0.01298	0.02397	0.00836	0.4089	0.1698	2.16	43.24
10	25	1.398	1.823	0.01623	0.02398	0.00624	0.2934	0.1390	2.11	44.99
13	25	1.438	1.885	0.02198	0.01268	0.00549	0.2029	0.1723	1.93	48.43
19	25	1.497	2.498	0.02071	0.01617	0.00861	0.2027	0.1791	1.93	62.02
25	25	1.098	1.372	0.01522	0.01727	0.01048	0.3181	0.3356	2.01	59.54
Mean		1.210	2.015	0.01742	0.01881	0.00783	0.2852	0.1991	2.03	51.64
7	50	1.084	1.660	0.02371	0.01617	0.00835	0.4369	0.1278	2.11	42.22
11	50	1.417	1.497	0.01572	0.01796	0.00623	0.2638	0.1517	1.95	58.82
20	50	1.295	1.498	0.01470	0.01694	0.00656	0.2491	0.1370	2.19	57.40

Table XXI. Cont'd.

Tree No. (Replication	Treatment Gr. Borax	Percent K	Percent Ca	Percent Na	Percent Mn	Percent Fe	Percent Mg	Percent P	Percent N	p.p.m. B
21	50	1.058	1.773	0.01922	0.01498	0.00649	0.3246	0.1258	2.06	47.19
22	50	0.979	2.397	0.01573	0.01498	0.00562	0.3925	0.1313	2.17	53.60
Mean		1.166	1.765	0.0178	0.01620	0.00665	0.3314	0.1347	2.10	51.85
3	100	0.937	1.595	0.01570	0.01575	0.00867	0.4237	0.1425	1.98	62.07
6	100	0.919	1.774	0.01849	0.01699	0.00712	0.3746	0.1499	2.06	48.95
12	100	1.137	1.946	0.01347	0.01696	0.00499	0.2052	0.1137	1.91	42.59
14	100	1.515	1.944	0.01620	0.02746	0.00656	0.0875	0.1707	1.78	51.05
17	100	1.278	1.772	0.01747	0.02543	0.00811	0.1809	0.1602	1.83	59.98
Mean		1.157	1.806	0.01625	0.02052	0.00709	0.2544	0.1474	1.91	52.93
8	150	1.457	1.771	0.01397	0.01936	0.00623	0.3968	0.1192	2.09	64.48
9	150	1.238	1.548	0.01623	0.00898	0.00624	0.2897	0.1228	2.08	53.86
15	150	0.998	1.772	0.01922	0.01218	0.00712	0.2908	0.1497	1.86	51.01
24	150	1.586	1.883	0.01845	0.01865	0.00811	0.3367	0.1733	2.10	65.19
23	150	1.218	1.373	0.01748	0.01498	0.00924	0.3016	0.1359	2.20	72.29
Mean		1.299	1.669	0.01707	0.01483	0.00738	0.3231	0.1401	2.07	61.37