BORON DEFICIENCY AS A POSSIBLE CAUSE OF PETECA DISEASE IN CITRUS

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BORON AND THE PETECA DISEASE

JAMALI

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AN ABSTRACT OF THE THESIS OF

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Title: Boron deficiency as a possible cause of peteca disease in citrus.

Peteca is a disease of lemons which causes sunken spots in the rind. The disease can develop on both unpicked and stored fruit. In 1962 Peteca was reported to be widespread on lemons in Lebanon. Work had been done to determine if B deficiency may be the cause of the disease. To that end Borax and Polybor sprays as well as soil applications were made in 1964 to Eureka lemon trees which are of the variety most affected in Lebanon. Those treatments did not reduce Peteca significantly but it was thought this lack of significance was due to the small number of fruits examined. On June 17, 1965 higher treatment rates were used. From each tree 100 fruits were picked in January 1966. The treatments had no effect on the incidence of Peteca on unpicked fruits nor on those in storage since none of the stored fruits developed the disease.

Leaves were collected in June, July, and October, 1965. They were analyzed for B, N, P, K, Ca, Mg, Mn, NO_3^-, Na, and Fe. It was found that both Borax and Polybor sprays increased leaf B. A Borax spray of 250g/100L water applied once in June and again in September significantly increased leaf Fe. Calcium was found to be much higher in the leaves in June and July than in October.

Histological studies of the Peteca-affected rind in 1964 showed that the diseased tissue had roundish cells with numerous calcium oxalate crystals and no intercellular spaces as compared with the Polygonal cells with intercellular spaces of the healthy tissue. In 1966 fruit injections of a saturated oxalic acid solution produced symptoms of stylar-end rot whereas saturated solutions of sodium oxalate produced Peteca-like symptoms on both Eureka and on the supposedly resistant late varieties of lemons.

In 1964 the irrigation interval for July and August the two hottest months was extended. It was then that Peteca appeared in the experimental orchard. The soil of

the experimental trees was shallow and calcareous. It was also observed that only the fruits which had their critical period of growth during the hot summer months of water stress, developed Peteca.

From the above it seems that Peteca is caused by a Ca disturbance which is brought about by a high atmospheric temperature coupled with a longer irrigation interval and shallow soil. It was proposed that Ca disturbance causes Peteca either by becoming unavailable to cell walls in the form of calcium oxalate and by having its uptake from the soil reduced due to the water stress. Or calcium could also be causing Peteca by limiting the availability of another element which might be necessary for growth or meristematic activity in the rind thus causing parts of the rind to stop growth while others are still growing thus resulting in Peteca. An analysis of lemon fruits showed that Ca was higher in the rind of diseased fruits than in that of healthy ones. This agrees with the explanation of Peteca presented above since the higher Ca was probably due to the accumulation of Ca in the unavailable calcium oxalate form.

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Peteca is a non-parasitic disease of citrus which causes sunken areas to appear in the rind of lemons either while in storage or while still on the tree (4, p. 45), (34, pp. 53-54), and (23, pp. 441-443).

This disease was reported to be widespread in Lebanon (55) and since its extent and exact cause had not been determined (35, pp. 53-54) an investigation was undertaken to discover its cause. Eureka lemons which are most affected by this disease in Lebanon were found to be lower in B content than the local resistant varieties (4, p.45). The work was directed towards ascertaining if Peteca might be due to a deficiency of B or some related nutritional imbalance.

II. REVIEW OF LITERATURE

Introduction

Fawcett and Lee (23, pp. 441-443) reported that Peteca has been present in the U.S. as long as the lemon industry. They credit R.E. Smith and E.H. Smith (1911) with first using the name. The above workers stated that Peteca usually appears after picking and the pits sometimes disappear when the affected fruit is soaked in water. Attempts to isolate black pit causing bacteria from beginning stages of Peteca have failed as have attempts to reproduce the symptoms by innoculations with black pit bacteria.

Bolkan (4, p. 45) found that Eureka lemons (the variety most affected by Peteca in Lebanon) are lower in B leaf content than are the local varieties resistant to Peteca. He also found a large number of CaOx crystals in the sunken peel tissues of some of the affected fruits.

Bolkan (4, p. 45) applied B foliar sprays using Borax and Polybor on Eureka lemon trees as well as Borax soil application. The above treatments had no significant effect on reducing the incidence of Peteca in storage. He attributed the lack of significance in the case of Borax soil application to the small number of fruits sampled.

Symptoms

The symptoms of Peteca can be summarized from the work of Fawcett and Lee (23, pp. 441-443), Klotz (35, pp. 53-54), and Bolkan (4, p. 45) they are:

1. A deep pitting due to the sinking of the surface of the rind.

2. Upon the appearance of the disease, surface cells in the depressions are free of any abrasions or sign of mechanical injury and may remain normal in mild cases.

3. Tissue under the sunken spot is shrunken, dried, and may be either white or slightly discolored.

4. The pits provide areas of weakness through which infection may later occur.

Bolkan (4, pp. 40-45) carried out a histological study of tissue showing the symptoms of Peteca and found that the epidermal layer of cells was normal though more heavily cutinized, and in severe cases rougher than the epidermal cells of healthy tissue. The shape of the cells in the epicarp was round as compared to the polygonal cells of the healthy tissue. The cells of the hypoderm were found completely dry, shrunken and dark. The above worker concluded that Peteca occurs beneath the outer wall of the epicarp and above the inner mesocarp layers of the peel.

Important Physiological Diseases Similar to Peteca

Bunemann (7) summarized the different explanations for bitter-pit in apples (which like Peteca is a non-parasitic disease) into three theories:

1. The B theory.

2. The water supply and evaporation theory.

3. The general nutrient theory, which may include N supply, cation balance and certain effects of minor elements besides B. He found (6), (7), (8), and (9) that Ca is higher in healthy fruit and that high Ca tended to reduce the occurence of the disease. High K had the opposite effect. He mentioned that physiological diseases seem to be influenced by nutritional factors (10).

Geraldson (26, pp. 2-4) reporting on blossom-end rot of tomatoes a non-parasitic disease, showed that the appearance of the symptoms of this disease followed a sequence similar to that of Peteca. The sequence was as follows:

1. Water soaked area.

2. Rapid tissue breakdown.

3. Blackened, dry, sunken, leathery spots.

4. Dead tissue later attacked by saprophytes.

He further discussed how Ca deficiency, Ca imbalance or unfavorable moisture conditions can cause the above mentioned symptoms.

Evans and Troxler (22) discussing the relation of Ca nutrition to the incidence of blossom end-rot in tomatoes proposed the theory that organic acids chelate the Ca thus causing blossom end-rot. They also suggested that a decrease in soil moisture can cause an increase in the dry matter and organic acid content of fruit (e.g. citric and oxalic acids) and that it is these acids which will interfere with the assimilation of Ca and cause blossom end-rot. They were able to produce symptoms similar to blossom end-rot by injecting the tomatoes with 2 ml of a saturated solution of citric acid.

Klotz (34) had produced symptoms similar to Peteca by injecting lemon fruits with orange and lemon oils, geraniol, methyl and ethyl alcohols. He concluded that some direct product of the rind or a product derived from anaerobic respiration may be thought of as the possible cause of Peteca.

Boron Nutrition

Khalidy (37, p. 81) found that leaves of Washington Navel scions on sour orange rootstocks had a lower boron content than did those on rough lemon rootstocks. Embleton (20) and (21) studied the effect of rootstocks on boron uptake. Of the rootstocks he studied it was found that the two varieties of sour orange rootstocks did not significantly decrease B-uptake of Eureka lemon trees.

Bramlage and Thompson (2) using Solubor (78% $Na_2B_8O_{13} \cdot 4H_2O$ and 20% $Na_2B_4O_7 \cdot 5H_2O$) at the rate of 1 lb/100 galons of water foliar spray found that sprays caused only a temporary increase in B content of leaves, whereas the increase in B content of fruits persisted. Eaton (19) found B in leaves to be immobile, however there was some movement of B from the leaves to the fruits. Burrel _et al_. (10) found that soil applications caused a persistent increase in the leaf B which was apparent in subsequent years.

Relation of Calcium to Boron

Boynton (5) found that the range between toxic and non-toxic rates of application of Borax to the soil was very narrow. This finding will make borax soil applications critical especially in acid soils. Drake _et al_. (15) found that boric acid is not fixed by $Ca(OH)_2$ in soils ranging in pH from 4.11 to 11.6. He concluded that B is not absorbed by the soil complex or made insoluble by Ca. He did find however, that a high Ca/B ratio was associated with B deficiency.

Working with alfalfa and oats Calder and Langille (11) found that the yield of unlimed oats decreased in proportion to the increase of B applied. They found chlorosis and toxicity to be greater in lower pH soils. The yield of oats began decreasing when Borax was applied at more than 50 lb's/acre in the highest limed soils whereas in the case of alfalfa, yield started decreasing at 100 lbs/acre of Borax.

Haynes and Robbins (28) found that both Ca and B were necessary for healthy root-systems. They reported that plants died without Ca in the root medium. Boron was found necessary for the effective uptake of minerals. They concluded that Ca and B are interdependent for plant nutrition.

Chapman (12, pp. 719-725) states that Ca in citrus is immobile and that high Ca may cause K deficiency. Cooper _et al_. (14) working with citrus found that high B in the irrigation water caused an increase in the uptake of K and a decrease in the uptake of Ca. They also found that the rootstocks had no significant effect on this uptake.

Calcium Availability

Geraldson (26, pp. 2-4) discussed the immobility of Ca and suggested that since it is the only macronutrient which does not translocate to younger parts, even a temporary deficiency will cause abnormalities such as tomato blossom end-rot. He divides the causes of Ca deficiency into two:

A- Excess soluble NH_4^+, Mg, K, Na or a deficiency of soluble Ca i.e. a low Ca ratio (Ca/total salts). All the above will cause a decrease in Ca uptake. Uptake will also be decreased by fertilizer applications of NH_4^+, Mg, K or Na.

B- Excess total salts may cause Ca deficiency even if the Ca ratio is not low.

Geraldson also states that low Ca ratios are associated with low pH and high NH_4^+ in the soil. Rapid growth with its consequent increased demand for Ca can upset the soil nutrient balance. The Ca ratio where blossom-end rot was most common was 15% of the base exchange complex or lower. It was also found that 75 to 90% Ca in the soil exchange complex is arbitrarily considered to be sufficient. Below 25% Ca deficiencies appear in different crops (Reuther, 46, p. 99).

Marsh and Shive (40) found that the metabolically effective Ca which is maintained in the soluble available form in active plant tissue was directly correlated with the supply of available B in the same tissue.

Gauch (25, pp. 31-64) in a survey of the literature on mineral nutrition of plants found only one report of Ca mobility and that in the white pine. Foliar sprays of Ca were found to cause an accumulation of Ca in the leaves. Little or no Ca movement was found to occur in plants. He also reported results that question the fact that in cell walls Ca is found in the pectate form. He further affirmed that Ca is a constituent of the middle lamella, and that Ca and Mg can replace each other in precipitating oxalate ions. His report showed that there may or may not be an inverse Ca:K relationship.

Reeve and Shive (45, pp. 10-14) confirmed reports that if the Ca uptake by the plants is low, the tolerance for B is low. While if the uptake of Ca is in large quantities the B requirement increases. This increase is due to the Ca-B relation in metabolism. They further found that more B is accumulated if there is more K in the soil especially at high B levels. In addition they found that at high K more B-deficiency symptoms appear and that Ca cannot be effectively utilized or absorbed in the absence of B.

The Role of Boron in the Plant

From the reviews of Abu-Khalil (1, pp. 6-9) and Bolkan (4, pp. 3-6) it was clear that B could play a diversity of possible roles. The theories on the role of this element are: 1- Boron has a close relationship to meristematic activity, 2- Boron possibly functions as a stabilizer for oxidative systems, 3- Boron is reported to be a component of cell walls and to affect the production of pectates, 4- Boron is thought to be necessary for cell division and as an essential juice buffer which precipitates excess cations through the formation of insoluble salts, 5- Boron is also said to be necessary for sugar translocation and affects the rate of sugar conversion to starch.

Walker (54) working with sugar beets (*Beta vulgaris* L.) found that the breakdown of tissue in the meristematic region due to B-deficiency was at the time of most active growth.

Boron Deficiency and Excess Symptoms

Haas and Klotz (27) describe B deficiency symptoms in citrus as corking and splitting of leaf veins, abscision of leaves, increased production and premature death of new growth, multiple buds, extreme cases of twig and trunk-bark splitting followed by exhudations of gum, root decay and excessive carbohydrate accumulation in the leaves. A degeneration of the cambium and phloem was also found. Additions of B resulted in fast recoveries from the above symptoms in lemons.

Kelley and Brown (33) found that normal lemon trees contain 19 to 45 ppm of B whereas injured leaves contained from 266 to 407 ppm. The toxicity symptoms they describe are yellowing of leaf margins and tips followed by a die-back which starts at the margins. They also found that B was readily accumulated in the leaves.

Summary

Peteca is a non-parasitic disease which causes sunken spots in the rind of lemons. The cause of the disease is not certain. It was found that Eureka lemons which are most susceptible to the disease were lower in leaf B content than the resistant Mughaizly variety. A study was undertaken which tentatively showed that Peteca was not caused by B-deficiency.

Calcium oxalate crystals were found in the diseased tissue of some fruits. The cells of the diseased tissue were round compared to the polygonal cells of healthy tissue. Bitter pit of apples and blossom-end rot of tomatoes were similar to Peteca. Both these physiological diseases were found to be affected by water relations, Ca imbalance, and have been thought to be caused by B-deficiency.

Injections of citric acid caused symptoms similar to blossom-end rot to appear in tomatoes. In lemons, injections of geraniol, lemon and orange oils, methyl and ethyl alcohols produced Peteca-like symptoms.

Work on Washington Navels showed that sour orange rootstocks gave a lower scion leaf B content than leaves of the same scion on rough lemon rootstocks. However, work with Eureka lemons showed no significant decrease in B uptake due to sour orange rootstocks.

Soil applications of B to apples were found to cause a persistent increase in the leaf B-content as compared with the temporary increase due to foliar sprays. It was also found that B is not tied up by the soil complex or Ca $(OH)_2$ in soils with pHs ranging from 4.1 to 11.6. However, B-deficiency was associated with high Ca and toxicity with low Ca. The toxicity of B was found to be greater on soils with a lower pH and the range between toxicity and deficiency was found to be narrow.

Calcium is immobile in the plant and is necessary for plant life. Boron influences the uptake of Ca and they are interdependent for healthy growth. Calcium is a constituent of the middle lamella, and it has been reported that B plays a role in the formation of pectates. It has also been reported that B is essential for meristematic activity and cell division.

III. MATERIALS AND METHODS

The experiment was conducted in the orchard of A.K. Tabbarah at Adloun on the coast of South Lebanon. The experimental Eureka lemon trees were 12 years old and planted 5 m apart. In places the soil depth of the blocks where the above trees grew was as little as 50 cm above bedrock. The soil is of a clay texture and has a pH of 8.5 (4, p. 8). According to an analysis of the orchard's soil made by the Institute of Agricultural Research, Soil Laboratory at Tel-Amara the total $CaCO_3$ was 7%, 11%, and 10% at 30, 60, and 90 cm depths, respectively. The milliequivalents of exchangeable bases at 60 cm depth were: K, 0.18; Na, 1.14; Ca, 15.0; and Mg, 6.0.

Cultural Practices

The source of irrigation water for the orchard is the Qasmiyeh river. Since 1964 the orchard has received one irrigation turn every 20 days whereas in previous years irrigation turns were every 15 days during July and August.

Chemical fertilizer was applied to each tree at the rate of 2 Kg K_2SO_4, 1.5 Kg triple super phosphate in October, and 2 Kg of NH_4NO_3 in February with another 2 Kg of NH_4NO_3 early in June. One bag per tree of barnyard manure weighing 60 to 70 Kg was applied in October.

The spraying program included Kalthane and Sevine in spring. Cultivation was in the spring with later hand mowing of weeds.

Experimental Design and Statistical Analysis

Since the Eureka trees at the Tabbarah orchard are interplanted with other citrus trees in two separate blocks it was decided to improve on Bolkan's (4, p. 8) completely randomized design by using the Randomized Complete Block (RCB) design. This design comprised 5 replicates of 6 treatments each making a total of 30 trees. Two replicates were in one orchard block and three in the other.

The statistical analysis for the RCB design was done according to the method suggested by Le Clerg _et al_. (39, pp. 137-144). If the F-test showed a significant difference between the treatments the LSD test was carried out. Throughout the experiment and chemical analysis, the randomization within the replicates, and the treatment of replicates as whole units was observed.

When the RCB design was not used, as with the analysis of Bolkan's treatments 1 and 2 for B, the "t" test (39, pp. 50-54) for the means of paired samples was used. This test of significance was also used in the case of the fruit analysis for Ca. Any tests for correlation made also followed Le Clerg _et al_. (39, pp. 76-83).

Peteca in Storage

To see if the treatments applied had any effect on the development of Peteca in storage 100 good quality tree ripened fruit were picked on January 29, 1966. The above date was the time for the regular and biggest Eureka picking. The fruits were put in used apple boxes which had been out in the open for a considerable time. The fruits were then stored at room temperature in the same apple boxes in which they were first put. The temperature and relative humidity (R.H.) were recorded by a Hair Thermohygrograph. The temperature remained fairly constant between 21^{o} and $23^{o}C$. The R.H. was $70 \pm 5\%$. The fruits were observed for the appearance of Peteca and were twice counted at which time the fruits which had rotted were discarded after the cause was noted down.

Soil and Spray Applications

The preliminary toxicity tests for Borax ($Na_2B_4O_7 \cdot 10H_2O$) foliar sprays were conducted on a Cleopatra mandarin and two sour orange trees located on the American University campus at Beirut. All sprays were applied with a garden power sprayer. The concentration of the first spray applied to all three trees was 250 g Borax/100L water, drip-sprayed on May 2, 1965. The second application was made on the 29th of May and consisted of 500 g Borax/100L water to one of the sour orange trees. To the mandarin and the other sour orange a 250 g Borax/100L spray was applied. The tank of the sprayer was always rinsed out several times between one treatment and another. No toxic effect or injury was found on any of the three trees.

Treatments

Two methods of B-application were used on the Eureka lemon trees. These were the foliar spray and the soil application. The Borax and Polybor ($Na_2O.5B_2O_3.10H_2O$) foliar spray procedure was exactly like that for the Borax toxicity tests already described. Borax was applied to the soil by spreading it in a trench which was dug 10 cm deep and 150 to 200 cm around the trunk of the tree. The Borax was then covered with soil.

The treatments applied to the Eureka trees on June 17, 1965 were:

1. Control
2. 150 g Borax/tree soil application.
3. 500 g Borax/100L of water foliar drip-spray.
4. 200 g Borax/tree soil application.
5. 250 g Borax/100L of water foliar drip-spray, repeated on September 9, 1965.
6. 375 g Polybor/100L of water drip-spray.

Leaf Collection and Tissue Analysis

Leaves were collected on April 9, 1965 from the trees comprising Bilkan's (4, p. 8) treatments 1, (Control) and 2, (100 g Borax/tree soil application). These leaves were analyzed for B to ascertain if there was a delayed increase in leaf B due to soil applications of Borax.

From the author's experiment leaf samples for analysis were harvested on June 22, July 23, and October 14, 1965. The leaves were analyzed for the following: N, NO_3^-, Mn, Fe, Mg, P, Na, K, Ca, and B.

Eighty leaves were collected at random from each tree and placed in an individual paper bag with the replicate and treatment number on it. Only normal mature leaves from bearing terminals were picked (46, pp. 81-88). As soon as the leaf samples were brought to the laboratory (2) and (4, p. 7) they were washed with a detergent by swabbing each leaf on both sides with a sponge. The leaves were then rinsed in tap-water, immersed in 0.1% HCl for less than 30 seconds and finally dipped twice into distilled H_2O. Excess water was shaken off and each sample was placed into a perforated paper bag and dried in a forced draft oven (30, p. 22) at $70 \pm 1^{o}C$. When the leaves were completely dried they were chopped up in a Waring blendor and then ground in a Wiley mill using a 40 mesh sieve. The ground material was then placed in a screw capped bottle. All the equipment used was cleaned thoroughly for each treatment and all bags, bottles and other containers were marked with the sample's collection date and the treatment and replicate number. Before each weighing the sample bottles were opened and kept in the oven at $70 \pm 1^{o}C$, for around 6 hours then cooled in desiccators.

Boron and NO_3^- -N were analyzed for according to the methods of Johnson and Ulrich (30, pp. 62-63) and (30, p. 44), respectively. Nitrogen was analyzed for by the modified Kjeldahl method where the digestion was by concentrated H_2SO_4 using $CuSO_4$ as catalysts. The distillation was then made with 45% NaOH using 4% boric acid as a trap for the NH_3. The remaining elements were analyzed for according to the method of Toth et al. (53).

Fruit Injection

Evans and Troxler (22) injected tomatoes with citric acid which produced blossom end-rot-like symptoms. Klotz (34) had injected lemons with a number os substances, which produced symptoms similar to Peteca. Further Bolkan (4, p. 43) had found NaOx crystals in abundance in Peteca-affected tissue. The writer therefore decided to inject the fruits while on the tree with saturated solutions of citric and oxalic acid.

The injections were made with a hypodermic needle using a graduated 5 ml syringe. Injections were either 0.5 ml into the albedo or 1 ml into the fruit axis. Each fruit each treatment and all bags, bottles and other containers were marked with the sample's collection date and the treatment and replicate number. Before each weighing the sample bottles were opened and kept in the oven at $70 \pm 1^{o}C$, for around 6 hours then cooled in desiccators.

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Fruit Injection

Evans and Troxler (22) injected tomatoes with citric acid which produced blossom-end rot-like symptoms. Klotz (34) had injected lemons with a number of substances, which produced symptoms similar to Peteca. Furthermore, Bolkan (4, p. 43) had found NaOx[1] crystals in abundance in Peteca-affected tissue. The writer therefore, decided to inject the fruits, while on the tree, with saturated solutions of citric and oxalic acids.

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1. NaOx in this text; sodium oxalate is abreviated as NaOx and calcium oxalate as CaOx.

The injections were made with a hypodermic needle using a graduated 5 ml syringe. Injections were either 0.5 ml into the albedo or 1 ml into the fruit axis. Each fruit was labeled after injection. The above injections comprised 4 treatments replicated 5 times making a total of 20 treated fruits. The first injection was done on December 11, 1965 and the fruits were inspected ten days later by which time symptoms had appeared. A second set of injections was made on the same day of inspection to confirm the symptoms previously obtained. All injected fruit were again inspected on January 13, 1966. On that date in addition to the saturated solutions a 0.005 and a 0.001 g/ml of oxalic acid were tried, as well as a saturated NaOx solution. On January 19, 1966 the injected fruits were checked for symptoms. Photographs of these and other fruit symptoms were made.

The author maintained a record of the condition of the orchard and trees as well as the fruit. This record was based on his observations during his many visits to the orchard over a period of two years.

IV. RESULTS AND DISCUSSION

Observations on Lemon Tree Growth Habits and Peteca

It was observed that though lemon trees can have blossoms and fruit on the tree throughout the year, in Adloun there are two main flower flushes. The first flower flush occurs around the middle of February and the second about the middle of June. Thus the Eureka lemon variety in the above area had two main harvests, the first in early September, and the second in late January. However, some fruits mature inbetween the above dates and there is a regular small harvest in November. It was this harvest that was observed to be most affected by Peteca. Peteca occurred to a small extent in the early September harvest. The late January picking was free of Peteca, the exceptions usually being the fruits missed in the November picking[1]. On September 13, 1965 observations were made on the fruits that were not picked in the early harvest which had occurred 10 days before. Some of the trees were found to have up to 100% of their mature fruit affected by Peteca.

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1. By November harvest is meant the fruit picked between the two main harvests. This in the case of Eureka lemons at Adloun can be any time from September 10 to January 1.

Bolkan's findings (4, p. 28) confirm this high percentage as he found Peteca to occur on 0% to 62% of the unpicked fruits which he observed between November 13 and November 30.

Peteca has up till now been considered a storage disease which only occasionally appears on fruits before they are picked (35, p. 53), (23, p. 441), and (4, p. 2). From the present findings as well as those of Bolkan it is obvious that Peteca occurs often and to a large extent on mature unpicked fruits. This is because in Lebanon, unlike the places where Peteca was considered mainly a storage disease, ripe fruits are left on the tree for long periods.

Relation of Peteca to Temperature and Irrigation

The growth habits of the varieties resistant to Peteca is similar to that of the susceptible Eureka except that Eureka lemons mature about 3 weeks earlier. The author has found a few fruits of supposedly resistant varieties which showed Peteca symptoms (see Figure 1), however, those few fruits had matured very early as the Eureka fruits do. Thus the time of fruit development and maturity seems to be critical in making a fruit susceptible to Peteca.

Before 1964 no Peteca appeared in the Tabbara orchard but since then the irrigation interval was changed to 20 days rather than every 15 days.

Following this change in irrigation schedule the owner reported that the fruit was smaller in size, of a poorer quality, and showed Peteca symptoms. It seems that it is this lengthening of the time between irrigations during July and August, which are the two hottest months of the year (55), that may be the original cause of Peteca. This water shortage is aggravated by the relatively shallow soil, and occurs when the fruits are in a critical period of their growth. This is born out by the fact that the later varieties which have not reached the critical stage of their growth during the two hottest months of summer do not have Peteca. The rare exceptions are those few fruits which mature early on the resistant late varieties. From the foregoing discussion it is clear that Peteca is not an inherent characteristic of the Eureka variety. This view is backed by the fact that NaOx fruit injections produced Peteca-like symptoms in resistant varieties as well as in Eureka. The symptoms can be clearly seen in Figure 2. The symptoms appeared in the fruit of the resistant variety even though it was still immature. This proves that the sunken-peel symptom is not restricted to the Eureka variety. Thus whenever the causal factors of the sunken peel come into existence the symptom appears. However, these causal factors occur naturally only on fruits which have their critical growing period at a time of adverse environmental conditions mainly high atmospheric

Figure 1. Peteca-resistant Asasly variety on the left and a Eureka lemon variety on the right both showing Peteca symptoms.

Figure 2. Lemon fruits injected with 1 ml saturated NaOx solution. The fruit on the right is of the Peteca-resistant Mughaizly variety while the other two are of the susceptible Eureka variety. All three fruits show the sunken peel symptom.

temperature, and water stress due to the shallow soil and extended irrigation interval which further may cause a nutritional imbalance.

Observation of Eureka lemon trees which had been topworked to the Peteca-resistant Mughaizly variety supports the foregoing explanation. On the topworked trees there were both Mughaizly, and Eureka fruit from regrown branches of the original scion. The Mughaizly fruits were green, immature, and Peteca-free, whereas the Eureka were yellow, ripe, and showed Peteca symptoms.

Effect of Nutrition on Peteca

There are several possible ways which could show how Peteca is influenced by nutritional imbalances. One way which was tested was to determine if Peteca was caused by B-deficiency. It would seem that since both Bolkan (4, p. 45) and the author managed to increase the B content of the leaves without decreasing Peteca, this theory should be rejected. Most of the leaf samples analyzed were much higher than 45 ppm B. The level of B in the leaves was never found to be deficient since Kelley and Brown (32) found that the normal B content of lemon tree leaves was between 19 and 45 ppm. The only treatment mean that was lower than 45 ppm B was the one for Borax 150g/tree soil application (Tables 2, 3, and 4). However, if we consider the findings of Eaton (19) that B is relatively immobile, and the concept of nutrient balance (48) where it is the relative amount of an element rather than its absolute quantity that determines a plant's requirement for it, it is less likely to discount B from the picture altogether. This would be especially so if the claim that B is essential for meristematic activity is true (4, p. 5), and (1, pp. 7-8). But even this B-deficiency explanation can be discounted providing all meristematic activity has stopped at the time of Peteca initiation. Thus the 19 to 45 ppm B which is sufficient in the leaf at 5% Ca may be limiting at 7% and above (31). Reuther (49, p. 90) reinforced this line of thought by stating that at above 7% leaf Ca content a nutritional imbalance is likely to occur. It can be seen from Table 8 that all the treatment means give a percent leaf Ca higher than 7. Table 9 shows all treatment means have a Ca percent around 8 with only two means slightly less than 7. It should be remembered that those leaves were collected at the end of June and July, respectively, when the temperature was high, the water supply was short, and the fruit crop which later showed Peteca, was developing. In contrast to this high leaf Ca% in the first two collections, the October collection (Table 10) did not show any mean much higher than 6% Ca.

From the above it is clear that there is still the possibility that B plays a role in Peteca development through a possible Ca-caused imbalance. It is also clear from the results obtained that there is no correlation (see Tables 8, 9, and 10), between applications of B and the Ca level in leaves. This is contrary to the results obtained by Bolkan (4, p. 24), who found an increase in Ca from all his B-applications.

Since in both bitter-pit of apples (7), (8), and (9) and blossom-end-rot of tomatoes (26, pp. 2-4) it was found that Ca seemed to play a role, it was decided to analyze for this element in peels and pulps of fruits that showed and those that did not show Peteca symptoms. Since this analysis was made on a small sample the results should be considered only as preliminary indications. It was found that Ca is higher (see Table 32) in the peels of diseased fruit. This result was obtained in all three varieties analyzed. As for the pulp or peeled fruit, there was no consistent result since, though the other two varieties had higher Ca in the diseased fruit Eureka lemons had exactly the same Ca percent in both diseased and un-diseased fruit (see Table 33).

The results of the peel analysis seem to be contrary to those reported for, in both blossom end-rot (26, pp.2-4) and bitter-pit of apples (7), (8), and (9). In the latter two diseases tissue breakdown and sunken spots were associated with low Ca. However, it can be suggested that this high Ca is due to the existence of chemical substances such as oxalates which are actually accumulating the Ca in the peel in the form of CaOx crystals. It is this idea that seems to best explain Peteca. Evans and Troxler (22) have already suggested that a decrease in soil moisture will cause an increase in the dry matter and organic acids of the fruit. It is these acids they further suggest, that interfere with the assimilation of Ca thus causing blossom-end rot in tomatoes. To prove this point the author like Troxler and Evans (22) injected the fruit with organic acids. Likewise sunken spots resembling the disease in question were obtained except that the spots were caused by the injected NaOx rather than by the natural factors that would result in Peteca. The way the oxalate ion causes the sunken spots is probably by chelating the Ca ions out of the middle lamella thus causing the round cells with no cell spaces in between, which Bolkan (4, p. 44) observed.

There is also the possibility of considering Peteca a result of Ca toxicity. This reasoning can not be accepted due to the fact that the orchard soil analysis made at Tel-Amara showed that the $CaCO_3$ in the soil was 11% which was not very high. This is further supported by Reuther (46, p. 99) who considers Ca sufficient if it constitutes 75 to 90% of the soil cation exchange complex (CEC). According to the Tel-Amara analysis the Ca is only

70% of the CEC. Thus though below the optimum range it is well above the deficient range (46, p. 99) which is lower than 25%.

From the above it is clearly seen that Peteca is a disorder caused by a disturbance of Ca. Calcium can be involved with Peteca directly, by becoming unavailable to the new cell walls either by being chelated in the rind (22) or having its uptake from the soil reduced by water shortage at a time when it is required in large quantities for growth (26, pp. 2-4). It is possible that both these mechanisms of causing Ca to be unavailable are operating jointly to cause Peteca. The results of the rind analysis would seem to indicate that there is no lack of Ca in the affected tissue (Table 32) however, it may be that Ca was being tied up in the form of CaOx crystals such as the ones abundantly found in the diseased tissue by Bolkan (4, p.43). The source of the Ca in the crystals can be the cell walls in which case the established cells as well as the younger cells are affected. It is proposed that the higher Ca found in the diseased peel is due to the CaOx and that these crystals indicate the presence of factors such as organic acids which make Ca unavailable.

Boron Application

Borax spray toxicity tests carried out during May 1965 showed that rates considerably higher than those which were later used on Eureka lemons were safe. The rates tested were a first 250g/100L water, Borax drip-spray followed by a second 500g/100L drip-spray applied 25 days later.

Boron applications had a significant effect on the leaf content of only two of the inorganic leaf constituents analyzed for. These two were B and Fe. B was increased significantly by all the spray treatments but never by the soil applications. However there seemed to be a difference in the time it takes B to accumulate in the leaves. It can be seen from the means in Table 2 that the Polybor and the 500g/100L water, Borax sprays were significant at only the 0.05 level and that the 250g/100L water, Borax spray had increased the B level but not significantly. One month later (see Table 3) the increase of the latter spray had become significant at the 0.05 level whereas that of the former two had become highly significant. In the October leaf collection (see Table 4) the B increase from the Polybor spray was reduced to the 0.05 level of significance, the 500g/100L water, Borax maintained leaf B's high significance, and since by that time the second 250g/100L Borax spray had been applied, that treatment also showed a highly significant increase. Thus for an increase in leaf B which comes rapidly and persists longer it seems that the 500g/100L water, Borax treatment was best. The above results are in agreement with those of several workers who found an increase in leaf B content due to foliar sprays (2), (16), and (4, p. 45).

The only element besides B which was found to be affected significantly in the leaves after B application, was Fe. As with B it was the foliar sprays which tended to increase the Fe level especially the 500g/100L Borax spray (see Tables 5 and 6). However, the only mean which was significantly higher in leaf Fe content was that of the 2 x 250g/100L Borax in the October collection (see Table 7). From the above results it seems that B sprays can and do sometimes cause an increase in the leaf Fe of Eureka lemons. These results agree with the findings of Bolkan (4, p. 45) who found that both Polybor and Borax sprays increased Ca, Na, and Mg. Although of the 10 elements analyzed for only B and Fe were significantly increased by B application (see Tables 2-31) there was a trend in Mg to be increased by the 500g/100L Borax spray in June and July (see Tables 14 and 15). There was also a tendency for the Mn to be increased by the Borax foliar sprays in the July leaf collection (see Table 11). The present findings also showed that no increase in any of the constituents resulted from Borax soil applications (see Tables 2-31).

Peteca and Leaf Boron Content as Affected by Borax Soil Applications

The first leaf-B analysis was that of Bolkan's (4, p. 8) treatments 1 and 2 which were respectively the check and the 100g/tree Borax soil application. The latter treatment was of interest for two reasons, the first being that Bolkan (4,p. 27) had mentioned that the soil treatment had reduced the occurrence of Peteca in stored fruit. He also reported that if he had more fruits under examination the decrease might have been significant. Bolkan also suggested that the reason the reduction in Peteca was not significant was the short time elapsed between the soil application and the harvest of the 10 fruit sample . Presumably he was referring to B soil applications not becoming immediately available but rather causing a prolonged persistent increase in the leaf and fruit B content. This is what Bramlage and Thompson (2) as well as Burrel et al. (10) found to be true in apples. It is these results which were the second reason for the interest in the soil treatment because if the Borax was going to become available later it would certainly show an increase in leaf-B one year after application. It was found however, that at the rate used the soil application of Borax did not cause an increase in the B-content of leaves (Table 1) even 11 months after application. Thus the B from the soil applications was probably not being tied

Table 1. Boron content of Eureka lemon leaves (ppm dried weight basis) collected on April 10, 1965 from Bolkan's (4) trees which had been treated on July 14, 1964.

Treatments	Replication					Mean
	I	II	III	IV	V	
Control	75	76	93	52	50	69.2
Borax 100g/tree soil application	71	79	68	64	60	68.4

up and slowly made available but rather was kept from being taken up by the high Ca in the soil. Such results agree with those of Drake <u>et al</u>. (15) which state that boric acid is not fixed by the soil complex, or $Ca(OH)_2$, irrespective of the soil pH. They did find however, that B-deficiency was associated with a high Ca/B ratio.

To find out if an increase in the rate of soil application of Borax would give an increase in leaf B content, two treatments were included one of which was 150g/tree and the other, 200g/tree of Borax. These rates were well below the 5 lb/tree which Latimer and Percival (38) report as the safety limit in apples. The experimental soil is calcareous and high in pH, characteristics which Calder and Langille (11) as well as Boynton (5) found make it safe for higher applications of Borax.

Table 2. Boron content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	49	41	124	53	91	114
II	87	45	137	89	141	156
III	81	84	83	40	105	130
IV	106	50	176	73	115	136
V	105	98	125	90	82	161
Mean	85.6	63.6	129.0[x]	69.0	106.8	139.4[x]

[x] Significant at the 0.05 level.

Table 3. Boron content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	40	26	124	36	82	126
II	72	26	138	41	125	138
III	56	40	96	17	125	101
IV	80	26	17	105	141	138
V	16	40	156	48	78	111
Mean	52.8	31.6	106.2^{xx}	49.4	110.2^{x}	122.8^{xx}

^{x} Significant at the 0.05 level.

^{xx} Significant (highly) at the 0.01 level.

Table 4. Boron content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	57	85	89	84	126	103
II	64	58	155	65	116	117
III	61	42	86	37	153	107
IV	71	43	131	102	133	86
V	43	88	150	75	148	116
Mean	59.2	63.2	122.2[xx]	72.6	135.2[xx]	105.8[x]

[x] Significant at the 0.05 level.

[xx] Significant (highly) at the 0.01 level.

Table 5. Iron content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	114	124	151	132	107	134
II	113	121	119	117	144	134
III	146	143	170	140	131	138
IV	150	116	150	162	146	122
V	115	167	192	125	130	151
Mean	127.6	134.2	156.4	135.2	131.6	135.8

Table 6. Iron content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	127	82	117	97	122	71
II	109	53	67	60	75	77
III	77	48	94	52	87	75
IV	88	54	155	86	123	114
V	90	99	96	128	121	159
Mean	98.2	67.2	105.8	84.6	105.6	99.0

Table 7. Iron content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	94	93	78	81	99	99
II	94	62	55	79	103	115
III	131	106	155	82	223	98
IV	126	82	87	96	122	95
V	126	104	149	129	187	122
Mean	114.2	89.4	104.8	93.4	146.8 [x]	105.8

[x] Significant at the 0.05 level.

Table 8. Calcium content of Eureka lemon leaves (percent dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	8.19	7.90	7.60	8.00	7.42	7.09
II	6.69	7.45	7.48	7.46	8.86	7.60
III	7.33	7.13	7.29	7.07	7.28	6.74
IV	8.75	6.68	6.58	7.50	8.28	7.70
V	6.71	8.73	6.66	7.08	5.45	7.90
Mean	7.53	7.58	7.12	7.42	7.46	7.41

Table 9. Calcium content of Eureka lemon leaves (percent dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil application	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil application	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	11.04	7.04	6.46	7.88	7.25	7.09
II	5.43	12.18	10.89	10.97	11.27	10.39
III	4.22	4.50	5.35	4.34	6.11	8.54
IV	8.14	8.59	6.19	10.64	6.60	7.27
V	4.15	6.95	5.92	7.18	8.31	6.67
Mean	6.60	7.85	6.96	8.20	7.91	7.99

Table 10. Calcium content of Eureka lemon leaves (percent dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	6.21	6.09	5.38	6.55	5.23	5.90
II	5.15	4.02	5.31	6.53	6.27	5.58
III	6.37	5.80	6.24	6.47	5.99	5.71
IV	6.55	4.78	5.36	5.59	5.51	6.24
V	5.66	5.58	5.29	5.82	4.81	7.17
Mean	5.99	5.25	5.52	6.19	5.56	6.12

Table 11. Manganese content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	8	8	5	4	11	3
II	10	8	13	10	9	10
III	8	35	6	8	10	14
IV	10	17	16	4	10	4
V	4	4	6	2	6	5
Mean	8.0	7.2	9.2	5.6	9.2	7.2

Table 12. Manganese content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	24	11	8	9	23	11
II	17	11	8	7	12	6
III	10	3	14	12	7	4
IV	26	7	7	36	11	10
V	6	5	10	7	7	11
Mean	16.6	7.4	9.4	14.2	12.0	8.4

Table 13. Manganese content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	21	14	8	8	30	10
II	17	18	18	15	17	16
III	8	8	10	13	12	9
IV	9	12	9	16	8	14
V	16	14	9	10	14	13
Mean	14.2	13.2	10.8	12.4	16.2	12.4

Table 14. Magnesium content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1942	1285	1747	2379	1659	258
II	1463	1126	2210	174	756	1836
III	1242	1664	2365	2356	744	522
IV	514	322	959	303	1379	186
V	1095	574	958	630	1678	2217
Mean	1251.2	994.2	1647.8	1168.4	1243.2	1003.8

Table 15. Magnesium content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	2354	1446	1172	1228	1691	1323
II	1111	2506	2240	1969	2432	2175
III	613	911	842	1188	1146	1653
IV	1867	1710	1281	1887	1321	1376
V	985	1750	1577	1846	4830	1303
Mean	1386.0	1422.4	1623.6	1664.6	2284.0	1566.0

Table 16. Magnesium content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil application	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil application	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1432	1208	1354	1275	1360	1351
II	1295	774	1072	1268	1621	1419
III	1138	1228	1391	1302	1491	1271
IV	1226	1177	1196	1435	1414	1357
V	1554	1280	1399	1494	1250	1300
Mean	1329.0	1133.4	1282.4	1354.8	1427.2	1339.8

Table 17. Nitrate-N content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	133	173	187	164	189	188
II	168	110	180	196	164	198
III	174	158	220	170	206	131
IV	182	106	149	185	139	93
V	137	91	105	120	141	138
Mean	158.8	127.6	168.2	167.0	167.8	149.6

Table 18. Nitrate-N content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	152	122	106	112	144	105
II	211	154	186	151	105	225
III	136	108	106	144	115	197
IV	162	211	141	136	134	141
V	114	150	167	229	265	259
Mean	115.0	149.0	141.2	154.4	152.6	185.4

Table 19. Nitrate-N content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	147	142	120	120	102	170
II	143	167	127	132	128	117
III	141	139	145	128	157	102
IV	119	163	122	131	110	109
V	137	104	116	92	159	105
Mean	137.4	143.0	126.0	120.6	131.2	120.6

Table 20. Nitrogen content of Eureka lemon leaves (percent dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1.84	2.98	2.23	2.13	2.10	1.98
II	1.95	2.00	1.90	1.94	1.93	1.96
III	1.99	2.03	2.18	1.96	2.19	2.17
IV	2.16	3.13	1.88	2.13	2.12	1.82
V	1.96	2.00	2.01	1.85	1.97	2.02
Mean	1.98	2.43	2.04	2.00	2.06	1.99

Table 21. Nitrogen content of Eureka lemon leaves (percent dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1.96	1.70	2.04	1.85	1.92	2.14
II	1.87	1.96	1.96	1.84	1.83	2.08
III	1.99	2.01	2.10	1.99	2.09	2.08
IV	2.02	1.94	2.01	1.98	2.02	1.80
V	1.86	1.71	1.72	1.87	2.01	1.86
Mean	1.94	1.86	1.97	1.91	1.97	1.99

Table 22. Nitrogen content of Eureka lemon leaves (percent dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1.96	2.05	2.12	2.09	2.16	2.00
II	2.16	2.15	2.06	2.27	1.90	2.15
III	1.98	1.89	2.14	1.99	2.09	1.69
IV	1.84	2.22	1.99	2.17	2.12	1.86
V	1.94	1.94	1.88	1.78	1.94	1.89
Mean	1.98	2.05	1.02	2.06	2.04	1.92

Table 23. Phosphorus content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1000	426	1270	1523	855	352
II	624	1121	390	849	427	484
III	1535	1964	1399	1508	613	680
IV	536	597	393	463	380	315
V	309	310	829	910	712	148
Mean	800.8	883.6	856.2	1050.6	597.4	395.8

Table 24. Phosphorus content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil application	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil application	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1610	1353	1303	1166	1118	869
II	948	1915	1712	1815	1406	1863
III	763	858	832	927	856	1422
IV	1141	1285	966	1658	1038	831
V	809	942	1127	1128	1671	1068
Mean	1054.2	1270.6	1188.0	1338.8	1217.8	1210.6

Table 25. Phosphorus content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	1033	1271	1216	2806	1441	2026
II	1218	867	962	1157	1037	1147
III	856	977	951	989	939	1142
IV	975	1463	950	1243	1225	928
V	868	1104	881	1035	1026	889
Mean	990.0	1136.4	992.0	1446.0	1133.6	1226.4

Table 26. Potassium content of Eureka lemon leaves (percent dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	0.44	0.73	0.69	0.62	0.59	0.68
II	0.55	0.61	0.53	0.63	0.53	0.40
III	0.48	0.28	0.28	0.51	0.32	0.37
IV	0.25	0.36	0.37	0.42	0.31	0.30
V	0.30	0.32	0.33	0.31	0.36	0.25
Mean	0.40	0.23	0.44	0.50	0.42	0.40

Table 27. Potassium content of Eureka lemon leaves (percent dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	0.62	0.81	0.73	0.53	0.53	0.82
II	0.53	0.82	0.73	1.01	0.52	0.83
III	0.19	0.35	0.25	0.76	0.26	0.80
IV	0.36	0.82	0.45	0.96	0.42	0.44
V	0.37	0.48	0.55	0.55	1.14	0.32
Mean	0.41	0.66	0.54	0.76	0.57	0.64

Table 28. Potassium content of Eureka leaves (percent dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli-cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli-cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	0.57	1.08	0.94	0.60	0.82	0.83
II	0.93	0.63	0.60	0.74	0.58	0.51
III	0.57	0.69	0.64	0.64	0.49	0.77
IV	0.59	0.78	0.72	0.84	0.82	0.61
V	0.62	0.67	0.73	0.61	0.92	0.41
Mean	0.66	0.77	0.73	0.69	0.73	0.63

Table 29. Sodium content of Eureka lemon leaves (ppm dried weight basis) collected on June 22, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil application	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil application	250g/100L water Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	183	146	161	270	136	34
II	113	80	171	35	89	215
III	97	132	147	199	75	41
IV	44	35	92	33	112	29
V	67	44	64	50	112	181
Mean	100.8	87.4	127.0	117.4	104.8	100.0

Table 30. Sodium content of Eureka lemon leaves (ppm dried weight basis) collected on July 23, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	111	71	132	87	75	90
II	69	100	103	95	124	102
III	36	54	44	41	51	75
IV	62	67	58	80	61	83
V	43	54	68	51	68	57
Mean	64.2	69.2	81.0	70.8	75.8	81.4

Table 31. Sodium content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965.

Replication	Treatments					
	Control	150g/tree Borax soil appli- cation	500g/100L water, Borax foliar drip-spray	200g/tree Borax soil appli- cation	2x250g/100L water, Borax foliar drip-spray	375g/100L water, Polybor foliar drip-spray
I	30	27	29	38	29	27
II	28	21	37	33	66	31
III	24	24	36	26	29	33
IV	37	22	31	40	28	25
V	29	33	28	29	32	44
Mean	29.6	25.4	32.2	33.2	36.8	32.0

Table 32. Calcium content of peels of lemon fruits (percent dried weight basis) showing Peteca symptoms and peels of the same varieties not showing Peteca.

	Varieties			Mean
	Eureka	Assasly	Mughaizly	
Fruit showing Peteca symptoms	1.46	1.48	1.41	1.45[xx]
Fruits not showing Peteca symptoms	0.99	0.98	1.17	1.04

[xx] Significant (highly) at the 0.01 level.

Table 33. Calcium content of peeled lemon fruits (percent dried weight basis) showing Peteca symptoms and peeled fruits of the same varieties not showing Peteca.

	Varieties			Mean
	Eureka	Assasly	Mughaizly	
Fruits showing Peteca symptoms	0.39	0.48	0.44	0.44[x]
Fruits not showing Peteca symptoms	0.39	0.44	0.37	0.40

[x] Significant at the 0.05 level.

However, the latter stated that the range between toxic and non-toxic rates of Borax is very narrow. For this reason and because the experimental orchard is privately owned, higher rates of application were not used. Consequently no toxicity symptoms appeared due to the soil applications. The rate of 200g/tree Borax was safe and higher rates could have been used. The leaf analysis of the soil treatments at all three leaf collection dates showed (see Table 2, 3, and 4) that the B content of leaves was not increased and at times even tended to decrease though never significantly.

Eureka Lemons in Storage

One hundred fruits from each experimental tree were harvested on January 29, 1966 and stored under room conditions to observe the development of Peteca, however no such symptoms developed. No Peteca was found irrespective of the treatment applied. The same trees from which the present fruits were harvested produced fruit which Bolkan (4, pp. 36-39) found to show up to 40% Peteca in less than 8 weeks of storage. The storage place was also the same as Bolkan's. The main difference between the fruits which showed 40% and those which showed no Peteca was the date of harvest. Bolkan's fruits were picked on November 13, 1964, whereas the fruits from the harvest that did not have any Peteca were picked on January

27, 1965. The latter fruits were observed until June, a period of 5 months, by which time they were completely shrunken and dry without any Peteca having developed.

From the above it was concluded that it was not the B-applications which stopped Peteca from appearing since the controls were also free of the disease. It is also concluded that Peteca must be potentially present in the fruit before picking in order for it to appear in storage. Finally these results support the explanation of Peteca as a result of nutritional imbalances brought about by the high temperature and water stress.

Fruit Injection

To find out if Peteca symptoms could be produced by injections of organic acids, saturated solutions of citric and oxalic acids were injected into Eureka lemon fruit. The result was negative in the case of citric acid, however the oxalic acid produced stylar-end rot symptoms (see Figure 3) as described by Chapot and Delucchi (13, p. 143) and Fawcett and Lee (23, pp. 399-400). All the fruit injected showed the symptoms but the 1 ml injections into the fruit axis had a sunken spot on the stem end as well as the stylar end.

Injections of saturated NaOx solutions produced symptoms which looked like the final stages of Peteca or like Alternaria spot (see Figures 4 and 5). This symptom appeared on the Mughaizly variety as well, even though the fruit was still green (see Figure 2 to the right).

A symptom of Peteca which was approximated by the NaOx injections was the appearance of a water-soaked area (see Figure 6) as the first symptom. This is a symptom which also occurs in blossom end-rot of tomatoes and which had not been mentioned by any of the workers reviewed. Peteca was also found to follow certain patterns (see Figure 7) such as producing pits in circular or semicircular bands as well as circular areas full of pits. It is also clear from Figure 8 that the Peteca is restricted to the rind.

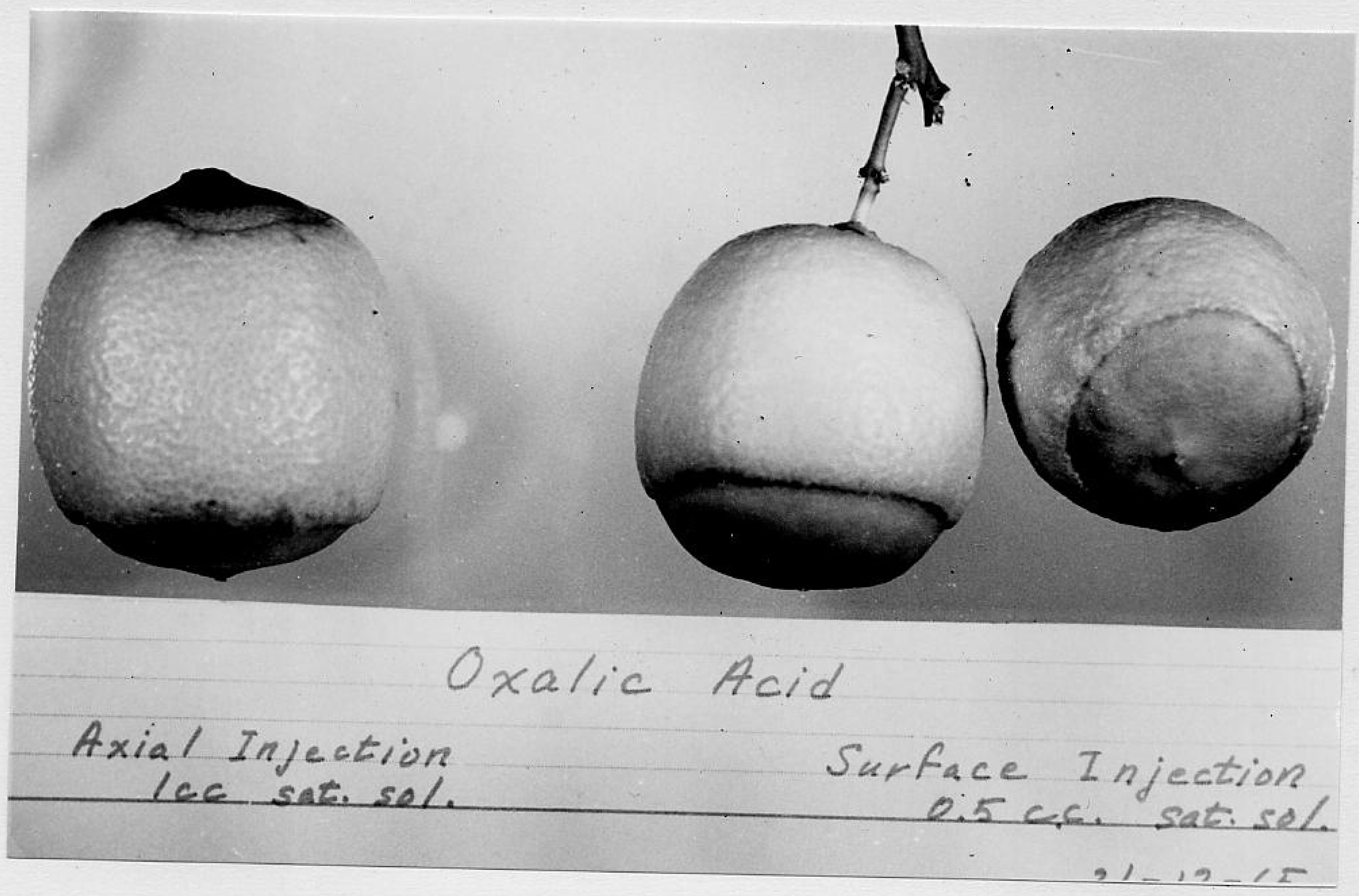

Figure 3. Eureka lemons injected with different amounts of oxalic acid showing the symptoms of stylar end-rot.

Figure 4. Lemon fruits showing three disorders: Peteca, spot caused by Alternaria species, with a central scar, and spot caused by a 1 ml saturated NaOx solution injection.

Figure 5. Eureka lemon fruit with a Peteca-affected area containing a spot probably caused by _Alternaria_ species.

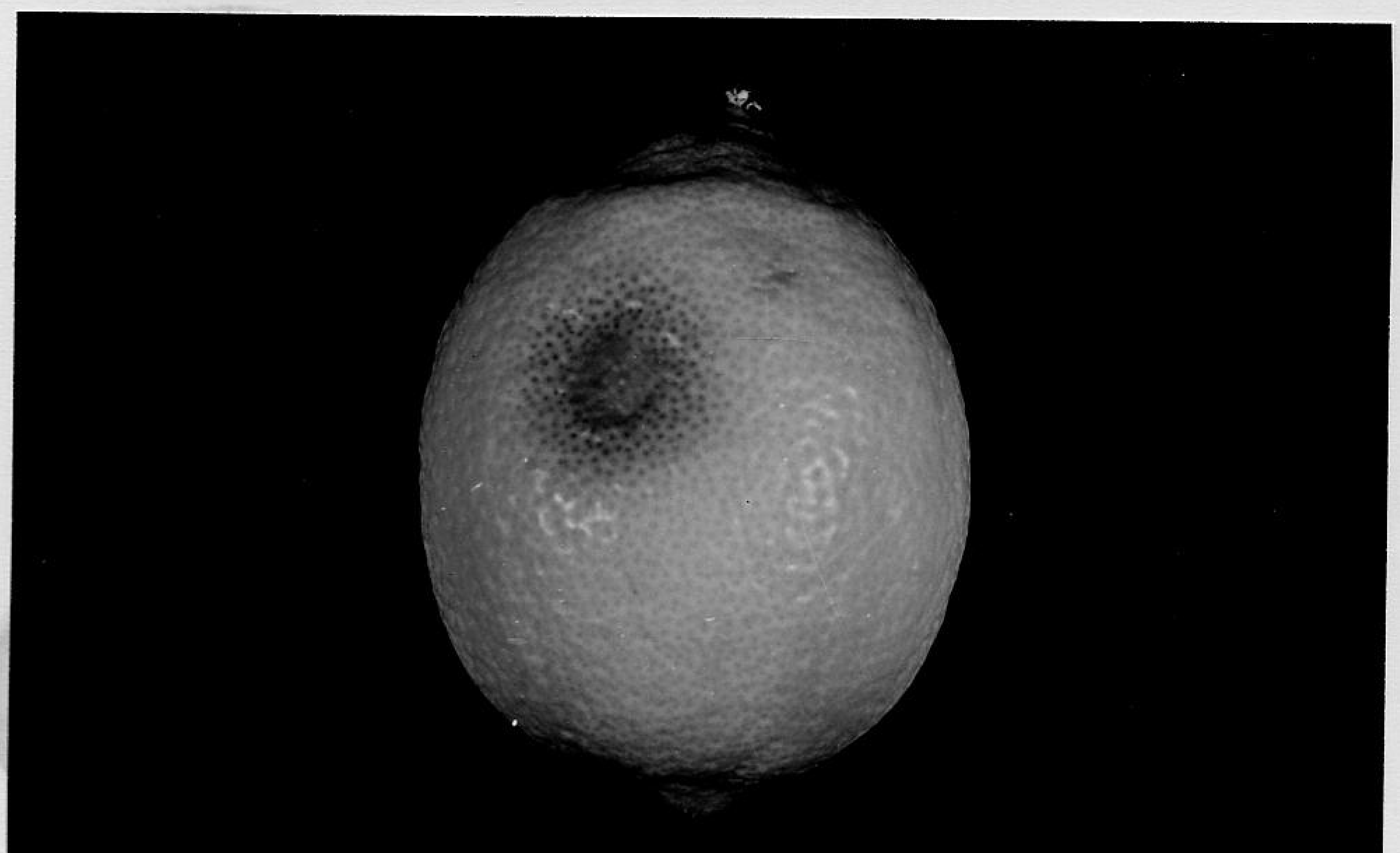

Figure 6. Eureka fruit injected with a 1 ml saturated NaOx solution showing the water-soaked area which usually precedes the collapse of the peel (sunken spot).

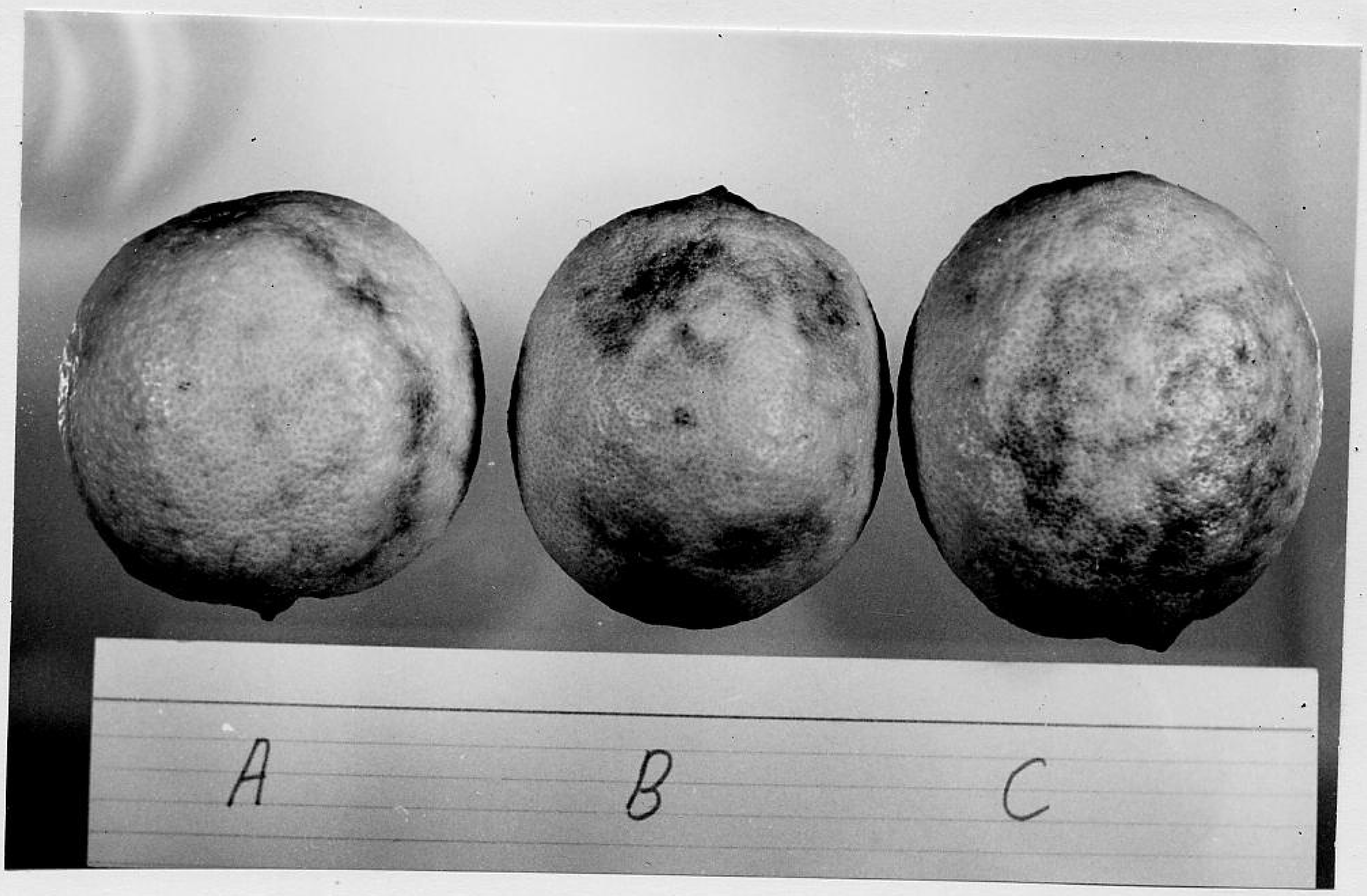

Figure 7. Eureka lemon fruits showing three different patterns of Peteca; A, semicircular band; B, circular band; C, full circular-pitting.

Figure 8. Cross sections of Eureka lemon fruit with Peteca symptoms. Symptoms appear only in the peel.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

A study was conducted to investigate the relation between B and the Peteca disease of lemons.

Borax spray toxicity tests were made in May, 1965 on a Cleopatra mandarin and 2 sour orange trees. The tests demonstrated that a foliar drip-spray of 250 g Borax/100L water, followed 27 days later by a 500 g Borax/100L spray was safe to use.

On April 9, 1965 a leaf B analysis was made for trees that had received a soil application of 100 g Borax each, 11 months before and also for control trees. The analysis showed that after 11 months there was still no increase in leaf B due to the above treatment.

On June 17, 1965 an experiment using Eureka lemon trees on sour orange rootstocks and following an RCB design composed of 6 treatments and 5 replicates was carried out. The treatments were: 1) Control, 2) 150 g Borax/tree soil application, 3) 500 g Borax/100L water, foliar drip-spray, 4) 200 g Borax/tree soil application, 5) 250 g Borax/100L water foliar drip-spray repeated on September 9, 1965, and 6) 375 g Polybor/100L water drip spray. Leaves from the experimental trees were harvested on June 22, July 23, and October 14, 1965. The leaves were analyzed for the following: N, P, K, Mg, Mn, Fe, B, Na, Ca, and NO_3^- .

It was found that the foliar sprays significantly increased B and in one case Fe. There was also a trend for the B foliar sprays to increase Fe, Mg, and Mn content of leaves in general. At the rates used Borax soil applications had no significant effect on any of the inorganic leaf constituents analyzed for.

None of the B treatments applied had any effect on the incidence of Peteca on unpicked fruit. No Peteca developed on fruits stored for 5 months from the January 29, 1966 harvest, irrespective of the treatments.

Calcium was found to be much higher in the leaves during June and July than in October. Peteca was found to occur mainly on fruits which developed in the former two months which with August are the hottest months of the year when there was a stress for water. Peteca was found to develop naturally on fruits from resistant late varieties which matured very early.

Injections of 1 ml and 0.5 ml citric acid into the fruit axis and the rind respectively caused the appearance of stylar-end rot symptoms. The injection of saturated NaOx into the fruits in a like manner produced symptoms in the peel similar to those of Peteca, notably a water-soaked area which later sink down forming a pit. These symptoms appeared in the Peteca-resistant late varieties such as Mughaizly as well as in Eureka lemon fruits. It was also observed on trees which had been top-worked to Mughaizly that the Eureka fruits from the original scion were yellow and had Peteca whereas the Mughaizly fruits were still green and Peteca-free.

An analysis of fruits with Peteca symptoms and fruits of the same varieties without any symptoms showed Ca to be higher in the rind of the diseased fruits.

It was concluded from the above results that Peteca is most probably a Ca disturbance brought about by the shallow soil and lengthened interval between irrigations during the hottest months of the year. For Peteca to occur, the fruit must be in a critical period of its development during the aformentioned adverse growing conditions. It is mainly for this reason that the late developing varieties were not affected by Peteca. Calcium is thought to bring about the symptoms by either one or both of the following mechanisms: 1) Calcium becomes unavailable to cell walls by forming CaOx or a similar compound resulting from the reaction of Ca with an organic acid. Calcium uptake is reduced by water stress in the soil which at the same time increases organic acids in the fruit. 2) Calcium can cause an imbalance in some other nutrient essential for fruit growth. Thus if a deficiency is induced by Ca, growth may be stopped in certain parts of the fruit resulting in Peteca. In this case the pitting would be due to a cessation of growth in one part of the rind while the surrounding areas continue to grow.

Recommendations

The following recommendations can be made based on the results of the present work:

1. To increase leaf B a 500 g Borax/100L water, foliar drip-spray can be effectively used.

2. In storing lemons of the Eureka variety it is advisable that they be of the January harvest which does not develop Peteca after picking.

3. To reduce the occurrence of Peteca the irrigation interval should be shortened back to 15 days or less in July and August.

4. It is possible to topwork Eureka lemon trees to the resistant Asasly and Mughaizly variety which will remain Peteca-free.

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APPENDIX

Table 34. Analysis of variance for the Fe content of Eureka lemon leaves (ppm dried weight basis) collected on October 14, 1965, as reported in Table 7. This is an example of the statistical analysis for the RCB design.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F	F 0.05	F 0.01
Replication	4	13,663.533	3,415.883	5.896[xx]	2.87	4.43
Treatments	5	10,556.267	2,111.253	3.644[x]	2.71	4.10
Error	20	11,586.067	579.303			
Total	29	35,805.867				

[x] Significant at the 0.05 level.

[xx] Significant at the 0.01 level.

Standard deviation $= \sqrt{\frac{579.3 \times 2}{5}} = 15.23$

$t_{0.05}$ for error d.f. = 2.09 $\quad LSD_{0.05} = 2.09 \times 15.23 = 31.83$

$t_{0.01}$ for error d.f. = 2.85 $\quad LSD_{0.01} = 2.85 \times 15.23 = 43.41$