THE INFLUENCE OF BORON NUTRITION ON THE "PETECA" DISEASE IN LEMONS

by

Hasan Bolkan

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"Peteca" and Boron Nutrition

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ABSTRACT

A one-year experiment was conducted in 1964-1965 in a citrus orchard located at Adloun, in South Lebanon, to investigate the influence of B nutrition on the development of "peteca" disease in lemon fruits. Leaf samples were collected during April 1964 from Moughiaizly lemon variety showing no "peteca" symptoms and from Eureka lemon variety showing such symptoms. The leaves were analysed for B, N, NO_3, Mg, Mn, P, Fe, Na, Ca, K. Statistical analysis of the data by the use of "t" test revealed that leaves from Moughiaizly trees were significantly higher in B concentrations and significantly lower in N, NO_3 and K contents as compared to the leaves from Eureka trees.

After the establishment of low B levels in Eureka, a completely randomized experiment with two levels of borax, one level of polybor and a check was designed using 5 replications per treatment. The treatments were applied on July 14, 1964, and on September 23 of the same year, leaf samples were obtained from current season shoots and analysed for inorganic constituent. The data was further statistically analysed using the method of analysis of variance.

The results presented on a dry weight basis indicated that 100 grams of borax per tree, applied to the soil, did not increase the B concentration of Eureka leaves, whereas each of the polybor and borax foliar sprays, at the rate of 250 grams, dissolved in 200 liters of water, significantly increased the B content of the leaves.

To study the development of "peteca" in storage, 10 lemon fruits from each treated tree were collected, placed in wooden boxes

and kept at room temperature for two months.

Observations indicated that the appearance of "peteca" symptoms on fruits kept in storage started after two weeks in all treatments and the development increased throughout the storage period. At the end of the storage, fruits from trees receiving borax soil application showed the least amount of "peteca" symptoms. However, the results were not statistically significant from the check.

During this work, histological studies of fruits were undertaken. Tissues from healthy and diseased fruits were fixed in killing fluid and embedded in paraffin after dehydration in butyl alcohol and absolute alcohol. The tissues then were serially sectioned with a microtome and finally stained in safranin-fast green. Studying the diseased sections with the use of a photomicroscope and comparing them to healthy tissues, revealed thaf the outer epidermis of the rind is absolutely normal without any mechanical injury. The cells under the epicarp layer were dark, dry and shrunken. The diseased area was always found to be located between the epicarp and inermesocarp layers.

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INTRODUCTION

Deterioration of fruits in storage may be caused by organisms found on their surface at harvest and/or by physiological disturbances of the tissues (21). "Peteca", a disease reducing the quality of lemons in storage, appears to be a physiological breakdown of the skin of the fruit (3, 21, 31, 32). Although a considerable amount of research has been conducted to determine the casual agent by Fawcett and Lee (21) and Klotz (32), none has reached a definite conclusion regarding the exact cause. Further, no work has been reported on the influence of B nutrition on the development of "peteca" disease.

In 1962, Weltzien (51) was the first to report "peteca" symptoms on lemons in Lebanon. However, the author recently has found the same symptoms on Shamouty oranges as well.

Skin breakdown has been reported in apple fruits deficient in boron (1, 8, 22, 23). It was felt that B may be responsible for "peteca" as well. For this purpose an experiment was initiated during April 1964 to investigate the influence of B supply on the inorganic leaf composition of Eureka lemon trees and the occurence of "peteca".

REVIEW OF LITERATURE

A. "Peteca" Disease

I. History

Fawcett and Lee (21) stated that "peteca" has been known in California since the lemon industry started, and the name "peteca" was first adapted by R.E. Smith and E.H. Smith in 1911. At the same time Bodartzeff (3) reported that in 1929 when lemons were received in Leningrad, 15 to 20% were found to be affected with "peteca" and rot blotch diseases.

II. Symptoms

"Peteca" is a rind disease of the lemon, *Citrus limon*, occuring in storage. It may occasionally appear on some fruits before they are picked (21, 32). The disease is hastened by low temperature, cool growing seasons and heavy oil spraying (3, 21, 32).

The surface cells of the fruit (the flavedo) at first are normal, showing no apparent mechanical injury. However, the tissues underneath (the albedo) become dry, shrunken and slightly discolored (21, 32). Following this, the flavedo which is still intact sinks down and forms deep, dark spots. Fawcett and Lee (21) and Klotz (32) reported that "peteca" spots resemble early stages of black pit, with the difference that the later has a slight abrasion through which the bacterium entered. Klotz (31, 32) was able to produce experimentally symptoms approximating those of "peteca" and he suggested that anaerobic respiration may be the cause of the disease.

III. Control

The only control measure for "peteca" was found to be proper ventilation in storage and elimination of heavily affected fruits (21).

B. Boron Nutrition

I. Boron Absorption

The uptake of B varies greatly depending on species, varieties, environmental conditions, availability of B and balance with other elements in the soil (17, 22). It is believed that B is absorbed in one of its ionic forms such as $B_4\bar{\bar{O}}_7$, $H_2B\bar{O}_3$, $HB\bar{\bar{O}}_3$ or $B\bar{\bar{\bar{O}}}_3$ and is required by plants in extremely low quantities (47). Sufficient B was found to be absorbed by plants from solutions containing as low as 25 ppm. (22). Eaton (17) stated that B is carried to the leaves by the transpiration stream as an inorganic radical and accumulates as a result of its combination with organic compounds which are not very mobile. In a further statement, he reported that the absorption rate is determined by the characteristics of the absorbing root cells, nature of B compounds in the plant and to a certain degree by the equilibrium existing between mobile and non-mobile forms of B within the plant.

II. Rootstock Effect on Boron Absorption

Boron accumulation in leaves is partly influenced by the rootstock (10, 12, 17, 19, 20). Frost Nucellar Eureka lemon grown on Macrophylla (*Citrus macrophylla*) rootstock resulted in lower concentrations of B in the leaves and a lower incidence of B toxicity as compared to the same variety grown on other rootstocks (19, 20). On the other hand, grapefruit budded on sour orange was found to absorb less B from the soil than when grown on trifoliata orange (10). These results show that the said rootstocks could be used for orchards where B excess is a problem (19).

III. Relationship of Boron to Other Elements

Boron in plants is closely associated with other ions, particularly with cations such as Ca^{++} and K^{+} (43). Drake (15) working with tobacco and corn plants found that B deficiency occured when a certain balance in the intake of Ca and B did not exist. Also plants grown on soils that had high Ca content, such as the alkaline soils, were reported to require more B than those on acid soils (28). According to Gauch (23) increasing the B in soils increases the percentage of soluble and total Ca in the plant. However, Cooper (13) stated that high B treatments decrease the accumulation of B in the leaves.

Reeve and Shive (38) found that as corn and tomato plants absorbed increasing quantities of K, increasing quantities of B were observed as well. Also toxic levels of B in citrus lower Ca and increase K, while low levels increase P and Mg and decreases K.

Muhr (35) stated that insufficient B in soils resulted in higher percentages of N, Mg, Fe and plants receiving high N concentrations require greater amounts of B than those receiving limitted levels.

IV. Function of Boron

The exact role of B in plant nutrition is still obscure (7, 22, 27, 44, 45). It is considered to have a catalytic or enzymatic functions (12, 45). Recent observations suggested that one role of B is the translocation of sugars by forming a sugar borate complex which passes easily through membranes as compared to non-borated, non-ionized sugar molecules (7, 16, 23, 24, 44). Dugger, Humpherys and Calhoum (16) stated that B increases the translocation of sugars in plants by decreasing the enzymatic conversion of glucose-I-phosphate to starch. Thus, an increase in the concentration of glucose-I-phosphate increases the synthesis of sucrose which will be translocated from the site of synthesis of plant tissues. Another possible function of B in plant metabolism is to stabilize the oxidative system (7). Chapman and Kelley (11) reported that B apparently plays a role in cell division, it also appears from the work of Tisdale and Nelson (47) that B has a function in protein synthesis as well.

V. Boron Deficiency in Citrus

Boron deficiency in citrus is more apparent under severe drought conditions, heavy lime applications and irrigation with alkaline water (12, 14, 36). Symptoms may appear on twigs, leaves, roots and fruits (12, 14). Fruit symptoms are characterized by malformation, undersized, excessive drop, thick rind with gum spots and hard areas in the albedo (5, 7, 12, 27, 36, 45). Usually the seeds are shrivelled or entirely missing (10, 36, 45). Early stages of deficiency results in abundant abortion of young fruits, low yield, reduction of juice and low sugar content (10, 36). On the other hand, there is a splitting in the leaves and corking of the main veins, discoloration and curling of the leaf blades to the sides and away from the midrib (5, 11, 17, 30, 32).

Stevens (46) stated that lack of B nutrition causes a cessation of meristematic tissues and die back of new growth. It was also found that the cambium degenerates, the phloem of the vascular bundles breaks down and stops the translocation of sugars in said tissues (14, 25).

VI. Control of Boron Deficiency

The margin between sufficiency and injury of B is very narrow (7, 27). Boron deficiency can be overcome by borax or boric acid applications either to the soil or as a foliar spray (7, 12, 27, 36, 45, 47). However, B is more commonly applied to the soil than as a foliar spray, because it is not fixed in the soil (37). Latimer (33) recommends that pH values, previous B treatments, rainfall, drainage, leaching power and content of organic matter of soil should be studied before borax applications. It was also found that the absorption of borax by plant is dependent upon the amount of water available and texture of the soil (47). Sufficient amounts of borax usually range from 5 to 25 pounds per acre, depending on the environmental conditions (22). One application of either borax or boric acid each year gives satisfactory results (30). Shive (41)and Jones (28) reported that B can be added in large quantities to alkaline soils as compared to acid soils without causing any injury to the plants.

VII. Boron Excess in Citrus

Boron excess in citrus occurs when irrigation water contains more than 0.5 ppm. of B and when high amounts of B fertilizers are supplied to the trees (7, 10, 30). Plants show the B injury first by developing yellowish patches between the veins and around the margins of the older leaves (11, 30). Current season leaves may not show the symptoms until they are several months old, many affected leaves abcise in winter (30). Tip-burn and chlorosis were also found to be characteristic symptoms of B excess (5).

VIII. Control of B Excess

Little work has been reported on the control of B excess. Usually, waters containing more than 2 ppm. of B are considered unfit for citrus irrigation (7, 10, 30). When B content of the irrigation water is high, the best solution is to find another source of water or to use tolerant plants (10). Also excess application of N was found to decrease the severity of injury caused by excess B (7, 28).

MATERIALS AND METHODS

The experiment was conducted in a citrus orchard located at sea level at Adloun, in south Lebanon. The soil type according to the reconnaissance map of Lebanon is a clay soil. The pH of the soil is 8.5 (6). The trees are Moughiaizly and Eureka lemon varieties of the same age (ten years old) budded on sour orange rootstock and set at a distance of five meters. No B fertilizer was applied to the trees, whereas N was applied at the rate of 3 kgs. per tree in the form of NH_4NO_3. In the said orchard "peteca" was only appearing on fruits of the Eureka variety.

In spring of 1964, 10 trees from each variety were used for the preliminary study. Leaves were collected at random from the periphery of the tree (from bearing terminals) and each sample was put in a separate bag (2, 9). Each sample consisted of 30 average and non-diseased leaves. The same day, the leaves from each sample were washed with a detergent by rubbing both surfaces with a sponge, rinsed in tap water , then immersed in 0.1% hydrochloric acid for about 30 seconds and finally washed twice with distilled water. After the excess water was shaken off, the leaves were placed in a paper bag, and dried in a forced draft oven at 70 ∓ 1 C° for 48 hours. The oven dried samples were ground in a Wiley mill with a 40 mesh sieve and the ground material was collected in a screw capped bottle. Prior to weighing of the sample, the bottles with the cap off were kept in the oven at 70 ∓ 1 C° for approximately 6 hours, and then cooled in a dessicator.

Boron and $N\bar{O}_3$ were analysed according to the method suggested by Ulrich and Johnson (49). Nitrogen was determined by the standard

Kjeldahl method (49) and the rest of the elements K, Ca, P, Fe, Mg, Na and Mn were analysed after the procedure described by Toth et al (48). The results were calculated on a dry weight basis and statistically analysed by using the "t" test which gave the critical difference between the two means (34).

After establishing the low B content of Eureka lemon leaves, 20 trees were selected and a completely randomized experiment with two levels of borax ($Na_2 B_4O_7 . 10H_2O$), one level of polybor ($Na_2 O . 5B_2O_3 . 10H_2O$) and a check was designed using 5 replications per treatment. The treatments applied consisted of the following materials.

1. Check - Receiving no B treatment.

2. 100 grams of borax containing 11.26 grams of B applied to the soil by broadcasting over the area occupied by the root zone.

3. 250 grams of borax containing 28.16 grams of B dissolved in 200 liters of water, foliar spray.

4. 250 grams of polybor containing 45.83 grams of B dissolved in 200 liters of water, foliar spray.

All treatments were applied on July 14, 1964 and on September 23, of the same year leaf samples were obtained and analysed as before. The results were computed on dry weight basis and statistically analysed by using the method of analysis of variance (34).

A second attempt was made to investigate the effect of B treatments on the development of "peteca" disease in storage. For this purpose 10 fruits from each of the experimental trees were collected on November 13, 1964. All samples were taken at random from the periphery of the tree within 150 to 200 cms. above the ground. Lemons were brought to the laboratory and each sample was numbered from 1 to 10 with India designer's ink. The samples were placed separately in wooden boxes and stored at room temperature for 8 weeks.

The development of the disease on stored fruits was studied at 5 intervals as follows:

1. November 27, 1964
2. December 10, 1964
3. December 18, 1964
4. January 4, 1965
5. January 11, 1965

Histological study of the fruit tissues was undertaken as well. Materials having the desirable features (about 0.5 cm. thickness of rind from healthy and diseased fruits) were cut into suitable pieces and immersed immediately in formalin-alcohol-acetic acid (killing fluid, about 10 ml. in 15 ml. test tubes). After approximately 48 hours, the material was dehydrated in various concentrations of butyl alcohol and absolute alcohol solutions. The material was kept at least 2 hours in each concentration. Following this, the material was washed with paraffin several times at 53 ∓ 2 °C to release the alcohol odor from the tissue. Then the tissues were fixed in paraffin and placed on wooden blocks. The mounted tissues were serially sectioned with a microtome (ten micra thick) and stained in safranin-fast green as suggested by Saas (40).

The sections were critically studied under a photomicroscope at 8 x 10 x 1.6, 8 x 2.5 x 1.25 and 8 x 2.5 x 1.6 magnifications and microscopic photographs were taken for further evaluations.

RESULTS AND DISCUSSION

A study was conducted to investigate the "peteca" disease of Eureka lemons. Results are reported in sections each pertaining to the subject studied.

I. Comparison Between Inorganic Leaf Composition of Eureka and Moughiaizly Lemon Varieties Under Similar Orchard Conditions.

The results obtained from leaf inorganic analysis prior to application of the treatments are presented on a dry weight basis in Table 1. This Table shows the means of each element studied which were used to see if any significant differences occurred between the two varieties.

It is apparent from studying the data in the said table that leaves from Moughiaizly trees had significantly higher concentrations of B and lower concentrations of N, K, and NO_3^- than leaves from Eureka trees. The remaining elements that were studied were similar in concentrations in both varieties. A possible explanation for high B and low N, K and NO_3^- concentrations in Moughiaizly is that this variety is able to accumulate more B. but less N, K and NO_3^- than Eureka. It also could be a result of the interaction between the sour orange rootstock and the scion, which resulted in substantially higher B but lower N, K and NO_3^- content in the variety Moughiaizly than it does in Eureka.

II. Effect of Boron Application on Inorganic Leaf Composition of Eureka Lemon Variety.

The first aim of this study was to evaluate the effect of B on the inorganic leaf composition of Eureka. For this purpose B was applied to Eureka lemon scion variety budded on sour orange rootstock as follows:

Table 1. Comparison between inorganic leaf composition (D.W.) of Eureka Moughiaizly lemon varieties under similar orchard conditions.

Tree	% K		% Ca		% Na		% P		% Mg		%3		% N		ppm Fe		ppm Mn		ppm B	
No.	M[1]	E[2]	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E
1	1.15	1.86	9.97	9.98	0.221	0.278	0.102	0.111	0.584	0.635	0.194	0.217	1.78	1.92	22.40	16.70	3.20	22.60	230.10	143.30
2	1.37	1.46	9.99	9.40	0.215	0.176	0.109	0.093	0.595	0.635	0.158	0.236	1.48	1.69	29.60	15.00	24.90	13.30	199.10	177.50
3	1.24	1.45	9.00	9.37	0.319	0.169	0.110	0.087	0.636	0.538	0.213	0.225	1.94	1.90	8.70	14.90	31.20	9.90	184.00	163.50
4	1.33	1.36	9.62	8.75	0.267	0.142	0.111	0.093	0.607	0.685	0.143	0.222	1.76	1.88	16.70	21.70	20.40	12.40	180.30	184.30
5	0.96	1.79	11.55	9.66	0.344	0.197	0.136	0.147	0.673	0.608	0.131	0.175	1.67	2.02	14.30	15.00	12.70	21.70	192.60	175.80
6	0.88	2.14	9.84	9.10	0.193	0.198	0.104	0.104	0.601	0.634	0.191	0.172	1.74	1.75	20.80	8.70	31.10	3.50	206.80	189.10
7	1.02	1.43	9.66	8.52	0.181	0.192	0.102	0.104	0.691	0.588	0.150	0.186	1.70	1.66	23.90	12.00	30.70	14.70	200.30	156.00
8	1.25	1.87	10.17	10.55	0.220	0.178	0.105	0.115	0.776	0.505	0.193	0.207	1.67	1.90	33.10	15.70	31.40	31.40	179.00	164.50
9	1.25	1.96	10.18	9.51	0.419	0.236	0.098	0.137	0.637	0.676	0.162	0.217	1.77	2.07	15.70	14.30	22.70	28.70	203.20	195.40
10	1.24	2.24	9.71	11.36	0.263	0.302	0.121	0.153	0.769	0.847	0.183	0.210	1.91	1.96	15.60	25.50	27.70	23.70	195.70	166.70
Mean	1.17	1.76^{++}	9.97	9.62	0.264	0.207	0.110	0.114	0.657	0.632	0.178	0.207^{++}	1.74	1.86^{+}	20.08	15.95	23.60	18.19	197.11^{++}	171.61
			n.s.		n.s.		n.s.		n.s.						n.s.		n.s.			

$^{+}$Calculated "t" significant at 0.05 level.

$^{++}$Calculated "t" significant at 0.01 level.

100 gms. of borax per tree soil application, 250 gms. of borax per 200 liters of water used as foliar spray, 250 gms. of polybor per 200 liters of water also used as foliar spray and a check.

Results obtained from leaf inorganic analysis on the effect of B on the elements studied in the leaves are presented in Tables 2 to 11. These Tables show the data for each element studied, as well as the comparison between the means of each of the four treatments used.

The elements will be discussed separately and the discussion will include the relation of B application and B level in the leaf to each of the elements. Values in the tables were reported as percent dry weight or ppm. dry weight.

Boron: The data in Table 2 show that borax applied to the soil by broadcasting over the area occupied by the root zone did not increase the B content of the leaves 70 days after application, as compared to the check, whereas polybor and borax foliar sprays highly significantly increased the B concentration in the leaves. No statistical differences were observed between the effect of both polybor and borax foliar spray on the B supply to the leaves.

Observations indicate that B absorption is faster and more efficient when supplied as foliar spray than when applied to the soil. Therefore, it can be concluded that under the conditions of this experiment, B can be easily supplied as foliar sprays to Eureka lemon variety when required. These results are in agreement with the findings of Chapman (10). However, Proebsting (37) stated that B is more commonly applied to the soil than as a foliar spray. This could be true under conditions where B is not required immediately by plants as well as in orchards where

Table 2. Boron content of Eureka lemon leaves (ppm. D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms. /200 lt. water, foliar spray
1	96.25	126.28	232.95	181.44
2	157.41	130.46	306.43	258.14
3	124.65	140.66	217.01	201.73
4	96.97	139.08	178.36	223.18
5	137.91	99.53	227.30	232.12
Mean	122.64	127.20	232.41**	213.32**

L.S.D. at 0.05 level 39.91

at 0.01 level 44.18

**Highly significant at both levels

B is not fixed by the soil.

Nitrogen: The application of B to the soil and as foliar sprays did not show to have any effect on leaf N, Table 3. However, Muhr (35) reported that insufficient soil B results in higher percentage of N in leaves.

Under the conditions of this experiment, it could have been that the time elapsed between B applications and leaf sampling was too short to show any effect of B on leaf N.

Nitrate Nitrogen: Studying Table 4 it was found that the $N\bar{O}_3$ content of the leaves was not affected by B supplied either to the soil or as foliar sprays.

The explanation given previously for lack of B effect on N content could be the same for $N\bar{O}_3$.

Iron: As shown in Table 5, there was a tendency for Fe to be present in higher amounts when B supply was high in the leaves. Leaf Fe content was significantly increased with borax and polybor foliar sprays and both treatments were found to induce approximately similar amounts of Fe in the leaves. Borax applied to the soil had no effect on leaf Fe. A possible explanation is that upon the dissolution of borax in the soil, a variety of compounds might have formed which reduced the amount of Fe available to the plant. Also the increase of Fe in the leaves of trees receiving foliar sprays of B could be due to the fact that B increased the availability and mobility of Fe in the plant. On the other hand, borax applied to the soil did not show any effect on leaf Fe which could be due to the poor utilization of B, during the period between application and leaf sampling, by trees.

Table 3. Nitrogen content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms. /200 lt. water, Foliar spray
1	1.98	2.02	1.92	2.03
2	2.05	1.87	1.93	2.02
3	2.07	2.06	1.92	1.90
4	2.34	1.93	1.78	2.05
5	2.10	2.05	2.03	2.05
Mean	2.11	1.99	1.92	2.01

Treatment

Calculated $F.3/12 = 3.30$

at 0.05 level (n.s.)

Table 4. Nitrate Nitrogen content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

		Treatment		
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. / 200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	0.170	0.180	0.140	0.120
2	0.130	0.160	0.120	0.120
3	0.140	0.070	0.120	0.110
4	0.080	0.170	0.110	0.130
5	0.140	0.160	0.160	0.100
Mean	0.132	0.148	0.130	0.116

Treatment

Calculated F 3/12 = 0.666

at 0.05 level (n.s.)

Table 5. Iron content of Eureka lemon leaves (ppm. D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil treatment	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms. /200 lt. water, foliar spray
1	11.34	21.72	32.69	17.41
2	10.33	17.77	23.39	17.27
3	11.75	7.44	17.36	24.81
4	7.50	12.96	24.99	12.03
5	10.39	11.51	11.26	25.77
Mean	10.26	14.28	21.94**	19.46*

L.S.D. at 0.05 level 8.13

at 0.01 level 10.00

*Significant at 0.05 level

**Highly significant

Manganese: The Mn content of the leaves was not affected by B supplied to the trees, Table 6. This indicates that there was no interaction between leaf Mn and B at the applied rates.

Magnesium: Leaf Mg was found to be negatively associated with polybor foliar spray, Table 7. The polybor spray significantly reduced the Mg content of the leaves as compared to the Mg content of plants under no treatment as well as those receiving borax in the soil and as foliar spray.

Previously it was reported in Table 2 that polybor and borax foliar sprays induced equal amounts of B in the leaves, therefore, the reduction of Mg in plant leaves receiving polybor could not be due to the B supply. It is thought that the chemical make up of polybor could be responsible for the said reduction and not to the B supplied.

Phosphorus: Leaf B content was not affected by B supplied to the tree, Table 8. An explanation can be that there was no any interaction between B and P in the leaves at the rates applied.

Sodium: The Na content of the leaves was significantly increased at the 0.01 level with polybor foliar spray and only at the 0.05 level with borax foliar spray, Table 9. The difference could be due to the higher amounts of B supplied in the polybor spray as compared to borax. On the other hand borax applied to the soil had no effect on the Na content of the leaves. A possible explanation is that B was fixed in the soil in a form which was not available to the trees, or under the conditions of this experiment the solubility of borax was slowed down and B was not

Table 6. Manganese content of Eureka lemon leaves (ppm. D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250gms./ 200 lt. water, foliar spray
1	22.69	13.37	14.21	16.07
2	12.91	16.40	18.19	15.94
3	11.75	26.80	10.68	19.30
4	9.00	12.96	19.22	9.02
5	25.98	14.39	14.07	20.04
Mean	16.47	16.78	15.27	16.07

Treatments:

Calculated $F\ 3/12 = 0.096$

at 0.05 level (n.s.)

Table 7. Magnesium content of Eureka lemon leaves (ppm. D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms. /200 lt. water, foliar spray
1	0.702	0.543	0.512	0.590
2	0.639	0.547	0.520	0.585
3	0.727	0.655	0.480	0.758
4	0.743	0.891	0.529	0.602
5	0.714	0.633	0.563	0.465
Mean	0.705	0.653	0.520**	0.600

L.S.D. at 0.05 level 0.109.

at 0.01 level 0.134.

**Highly significant at both levels.

Table 8. Phosphorus content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

		Treatment		
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	0.106	0.104	0.092	0.087
2	0.104	0.074	0.097	0.097
3	0.095	0.096	0.100	0.083
4	0.121	0.110	0.062	0.097
5	0.088	0.104	0.096	0.103
Mean	0.103	0.098	0.089	0.093

Treatment:

Calculated F 3/12 = 1.00

at 0.05 level (n.s.)

Table 9. Sodium content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms. /200 lt. water, foliar spray
1	0.088	0.167	0.182	0.150
2	0.165	0.178	0.161	0.141
3	0.164	0.167	0.171	0.132
4	0.144	0.188	0.246	0.113
5	0.163	0.152	0.149	0.117
Mean	0.144	0.170*	0.182**	0.131

L.S.D. at 0.05 level 0.022.

at 0.01 level 0.027.

*Significant at 0.05 level.

**Significant at both levels.

taken up by the plant in amounts sufficient to affect the Na content of the leaf, Table 2.

Calcium: The data in Table 10 show that Ca concentrations of the leaves was increased with the addition of B. All treatments were found to be highly significant at the 0.01 level. However, they were not significantly different from each other in their effect on Ca contents of the leaves. Although, Ca was found to increase with borax soil application, this increase could not be due to B nutrition because the soil application did not increase the B content of the leaves, Table 2. A possible explanation is that B increased the availability of Ca ions in the soil which could have increased the leaf Ca. This suggests that B applied to the soil had an indirect effect on the leaf Ca content.

Potassium: Leaf K was not affected by B applied to the trees, Table 11. The results indicate that under the conditions of this experiment, no interaction between the added B and plant K was established.

III. Effect of Boron Applications on the Development of "Peteca" Disease.

The results obtained from counting the fruits showing "peteca" on the tree and in the storage are presented as percent affected fruits in Tables 12 to 17. The data in said tables was analysed statistically by using the methods of analysis of variance (34).

Field Observations: Upon examining the lemons on all the trees under experimental conditions during the period extended from November 13 to November 30, 1964 it was found that "peteca" disease appeared in few fruits

Table 10. Calcium content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	7.26	8.36	8.59	7.82
2	7.07	7.49	7.85	8.02
3	7.17	7.44	8.06	7.72
4	7.14	7.90	8.38	7.34
5	6.66	7.19	7.37	7.67
Mean	7.06	7.68**	8.05**	7.71**

L.S.D. at 0.05 level 0.39

at 0.01 level 0.48

**Highly significant at both levels

Table 11. Potassium content of Eureka lemon leaves (% D.W.) as affected by B applications to the trees.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	1.42	1.68	1.17	1.38
2	0.78	1.41	1.34	1.09
3	0.89	1.49	1.00	1.38
4	1.23	1.33	1.93	1.23
5	1.34	1.75	1.71	1.44
Mean	1.13	1.53	1.43	1.30

Treatments:

Calculated F 3/12 = 2.71

at 0.05 level (n.s.)

Figure 1. "Peteca" Disease on Eureka Lemon Fruits.

(Notice the sunken spots on fruit surface) from each of the treatments. Following the appearance of the symptoms, fruits on the tree were infected by organisms causing fruit rot. The infected tissues were studied microscopically and the organisms were identified as green mold, blue mold and Alternaria. The affected fruits were abundantly found on the periphery and lower parts of the trees rather than in the center and upper parts. The observations are in agreement with the findings reported by Fawcett and Lee (21) and Klotz (32).

The data obtained from counting the infected fruits per tree is presented in Table 12. This table shows that the non-treated trees had the highest and trees which received borax applied to the soil had the least amount of fruits showing "peteca". On the other hand, polybor foliar spray had a higher percent affected fruits than the borax foliar spray. However, the treatments were not statistically significant among themselves.

Although the difference between borax applied to the soil and the check were not statistically significant, still borax soil application caused a considerable reduction in the development of "peteca". The lack of statistical significance could be due to the short time elapsed between B application and sampling date.

Laboratory Studies: Ten lemons from each experimental tree were picked in the green stage, placed in wooden boxes and stored at room temperature from November 13, 1964 to January 11, 1965 and studied at 5 intervals.

Symptoms: The first "peteca" symptoms appeared as discolored, slightly sunken areas on the surface of the rind within two weeks following

Table 12. Number of fruits showing "peteca" per Eureka lemon tree counted during November 13 to November 30, 1964.

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	20	11	3	8
2	62	2	55	7
3	None	None	19	33
4	58	None	8	12
5	19	None	35	16
Mean	39.75	2.60	24.00	15.20

Treatments:

Calculated F 3/12 = 2.25

at 0.05 level (n.s.)

storage. A few days later, the surface cells collapsed and dried out, making the spots deeper, clearer and darker, Figure 1. Fruits were misshapen (the healthy portion made an outgrowth) and about 2% of the surface was covered with the disease. These symptoms were similar to those described by Fawcett and Lee (21) and Klotz (32).

Although "peteca" does not cause rot to the fruit, the sunken spots become weak areas and open the way to infection by organisms which are responsible for rotting. These organisms were identified under a microscope as Stemphyllium and Alternaria. One characteristic symptom of secondary infection was that the organisms appeared only on the area where "peteca" first developed and were limited in growth to that area never extending to the healthy tissue.

The Influence of B Supply on "Peteca" Development in Storage: The data in Table 13 show that after 2 weeks of storage at room temperature, the fruits from the check showed the highest and fruits from trees that received borax soil application showed the least amount of "peteca". On the other hand, trees receiving polybor foliar spray had a lesser amount of fruit showing "peteca" as compared to those receiving borax foliar spary. After 4 weeks of storage, the results obtained were similar to those obtained before, with the only difference that polybor foliar spray treatment resulted in higher percent of affected fruits than borax foliar treatment, Table 14. A week later, the check had the highest, followed by borax foliar spray and the borax soil application the least percent affected fruits, Table 15. After 7 weeks of storage, polybor foliar spray resulted in the same percent of affected fruits as did the check, and borax foliar spray produced less than both but more than the borax soil application, Table 16. The results obtained by counting the affected lemon fruits in storage at different intervals did not show statistical difference until one week before the end of storage. At the end of storage, polybor foliar spray treatment had the highest percent of affected fruits which was highly significant at the 0.01 level as compared to borax soil and borax foliar spray treatments. However, the results were not statistically significant from the check.

The trend of fruits from different treatments showing "peteca" was the same as that observed in the field on fruits before picking, Table 12.

Figures 2 to 5 show that the appearance of "peteca" disease on lemons kept in storage started after 2 weeks in all treatments, and the development increased throughout the storage period. Though during the last week of storage the disease developed very rapidly. After 8 weeks of storage, polybor foliar spray almost followed the same pattern as did the check, Figures 2 and 3. Fruits from trees receiving borax foliar spray and soil application showed a slight increase during the first 7 weeks and a rapid increase at the end of storage, Figures 4 and 5.

All through the investigations, there was a good indication that borax soil application slightly reduced the development of "peteca" disease. One possibility for not getting statistically significant results could be due to the small size of the samples taken from each treated and untreated trees.

Boron is known to have a role in sugar translocation in

Table 13. The development of "peteca" disease on Eureka lemon fruits at room temperature, from Nov. 13 to Nov. 27, 1964 (percent affected fruits).

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	20	30	None	20
2	10	None	None	20
3	None	None	10	None
4	30	None	20	None
5	None	None	10	10
Mean	12	6	8	10

Treatments:

Calculated $F\ 3/12 = 0.27$

at 0.05 level (n.s.)

Table 14. The development of "peteca" disease on Eureka lemon fruits at room temperature from Nov. 13 to Dec. 10, 1964 (percent affected fruits).

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	30	30	None	30
2	30	None	10	20
3	None	None	10	None
4	30	None	20	None
5	None	None	30	10
Mean	18	6	14	12

Treatments:

Calculated F 3/12 = 0.48

at 0.05 level (n.s.)

Table 15. The development of "peteca" disease on Eureka lemon fruits at room temperature from Nov. 13 to Dec. 18, 1964 (percent affected fruits).

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar water	Borax 250 gms./ 200 lt. water, foliar spray
1	40	30	None	40
2	30	None	10	40
3	None	None	10	None
4	40	None	20	10
5	None	None	50	10
Mean	22	6	18	20

Treatments:

Calculated F 3/12 = 0.78

at 0.05 level (n.s.)

Table 16. The development of "peteca" disease on Eureka lemon fruits at room temperature from Nov. 13, 1964 to Jan. 4, 1965 (percent affected fruits).

	Treatment			
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms./ 200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar water
1	70	40	40	40
2	40	None	30	40
3	None	None	10	10
4	70	30	40	10
5	20	None	80	10
Mean	40	14	40	22

Treatments:

Calculated F 3/12 = 2.10

at 0.05 level (n.s.)

Table 17. The development of "peteca" disease on Eureka lemon fruits at room temperature from Nov. 13, 1964 to Jan. 11, 1965 (percent affected fruits).

		Treatment		
Replications	Check	Borax 100 gms./ tree soil application	Polybor 250 gms. /200 lt. water, foliar spray	Borax 250 gms./ 200 lt. water, foliar spray
1	100	50	70	40
2	50	None	60	60
3	50	40	50	30
4	90	90	100	60
5	40	20	100	20
Mean	66	40	76**	42

L.S.D. at 0.05 level 28.98.

at 0.01 level 35.65.

**Highly significant at both levels.

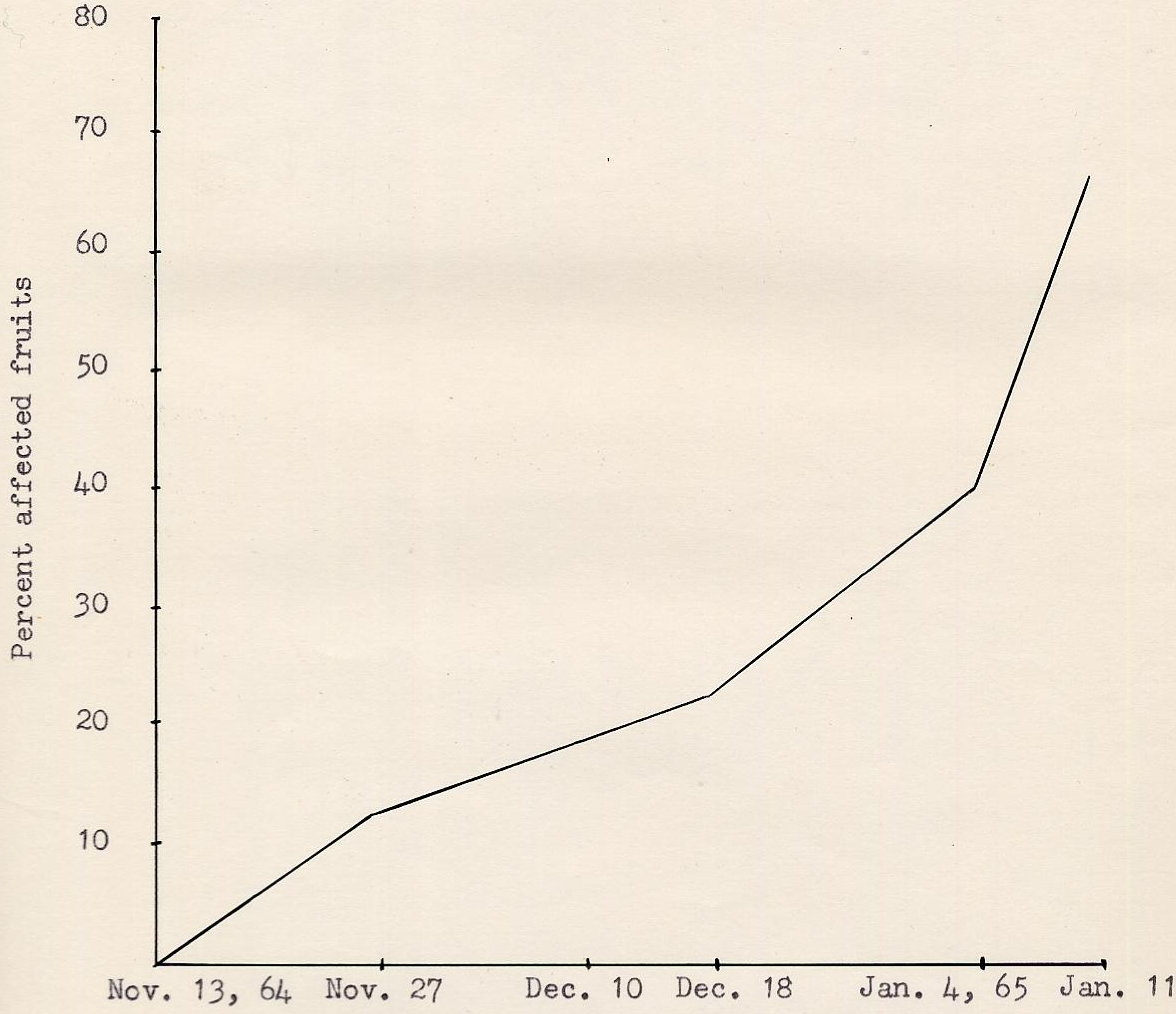

Figure 2. Development of "peteca" in storage on fruits from trees not receiving additional boron.

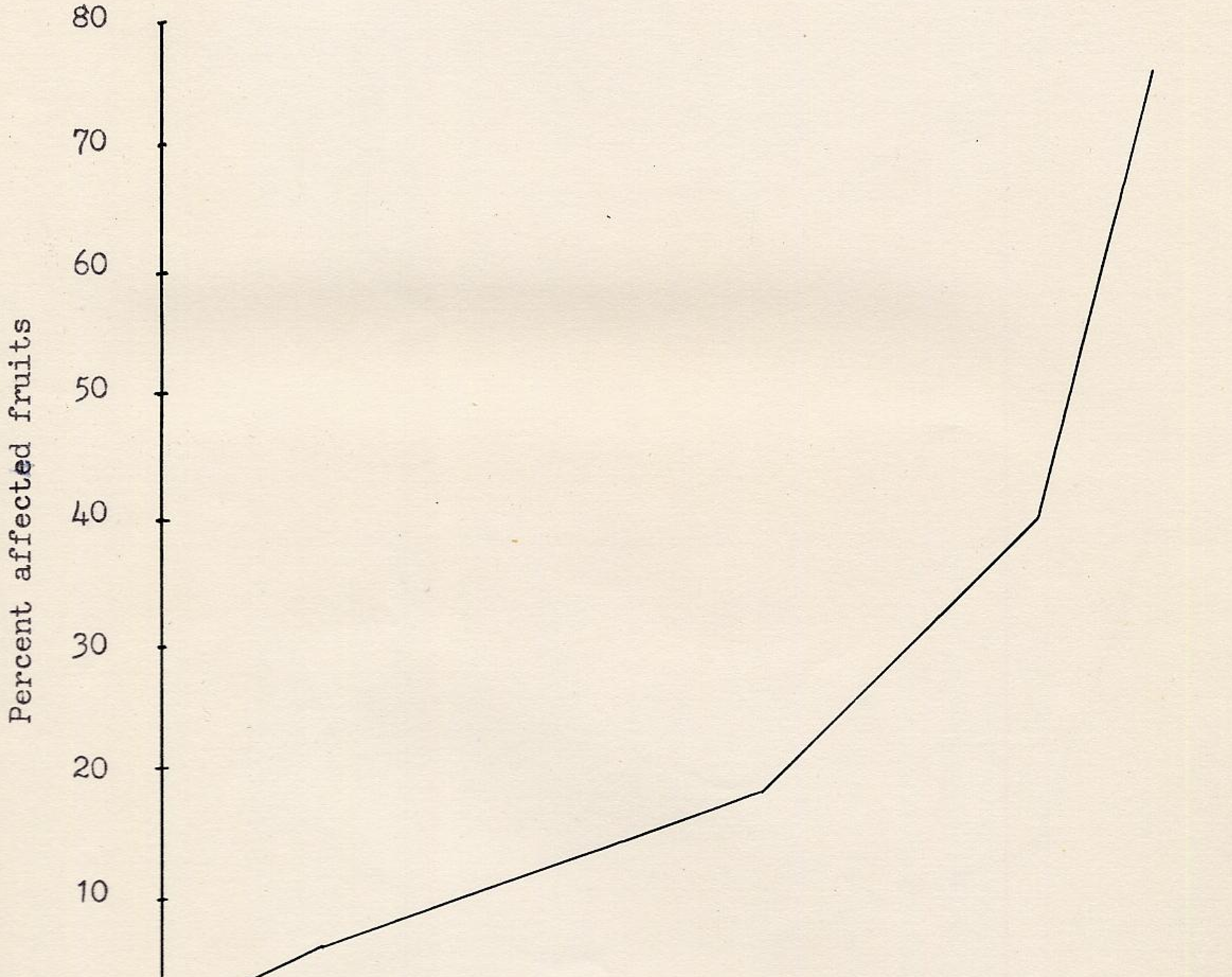

Figure 3. Development of "peteca" in storage on fruits from trees receiving polybor at the rate of 250 gms./ 200 lt. of water, foliar spray.

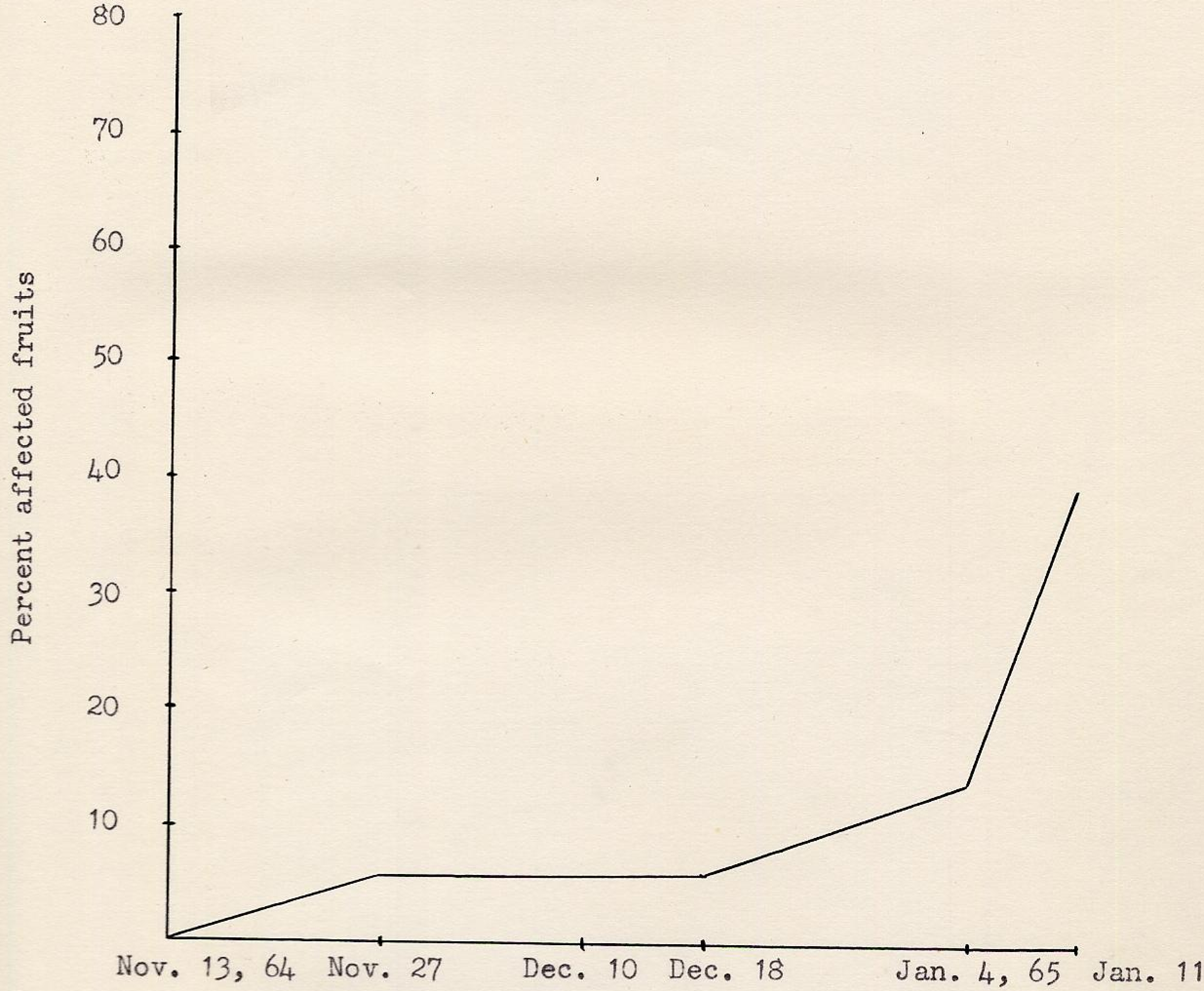

Figure 4. Development of "peteca" in storage on fruits from trees receiving borax at the rate of, 100 gms./tree, soil application.

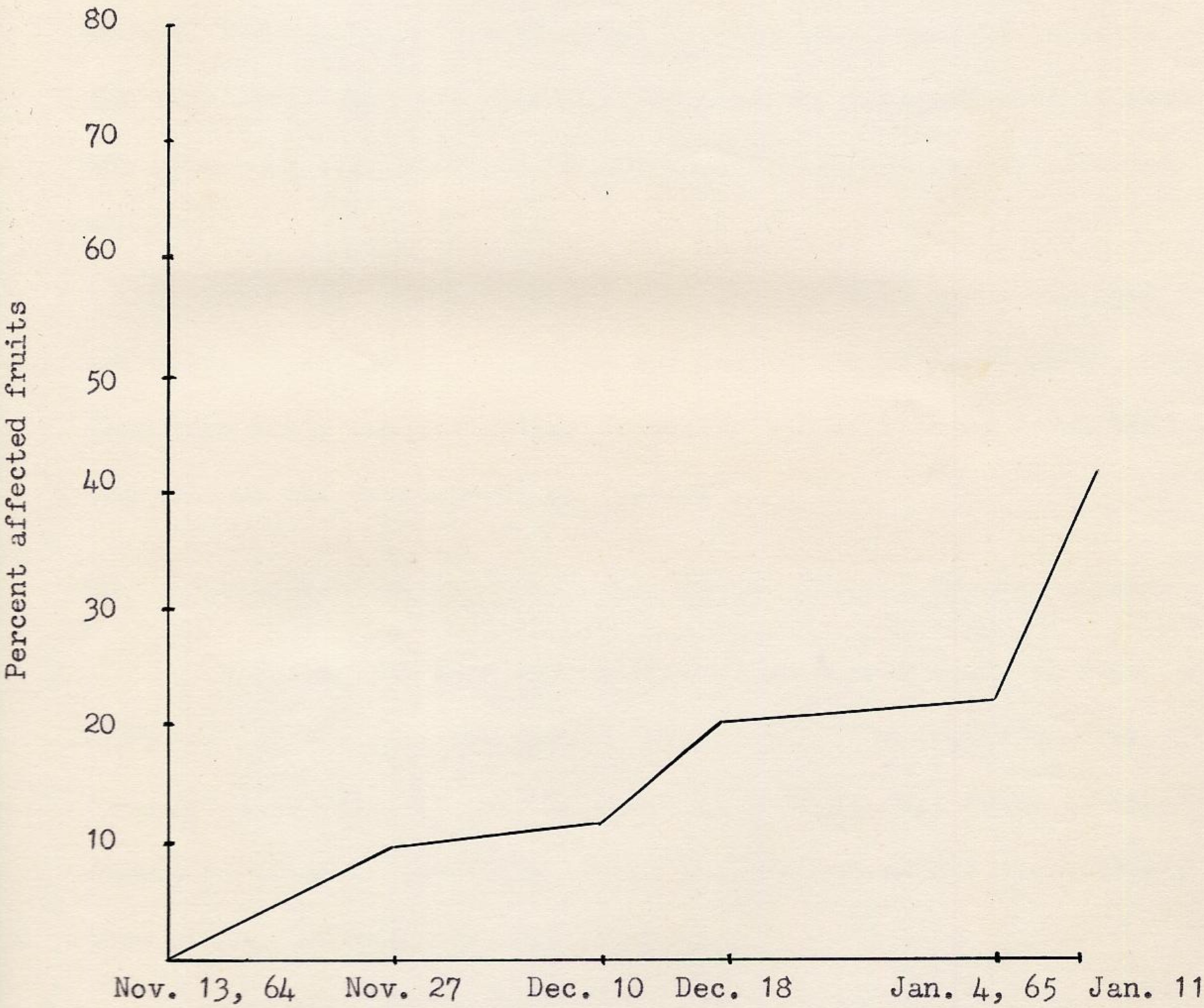

Figure 5. Development of "peteca" in storage on fruits from trees receiving borax at the rate of, 250 gms./200 lt. of water, foliar spray.

protein synthesis and in cell division of plants. It could be that when B was applied to the soil and absorbed by the roots, it did function in one or more of its roles that indirectly influenced "peteca". Only it has to be kept in mind that if B was absorbed by the roots, the amount must have been very small and as such did not show an increase in leaf B content, or the absorbed B could have remained in parts of the tree other than the leaves. Boron in the soil may have increased the uptake of some elements or compounds which indirectly affected "peteca".

From this discussion it seems that if B is to be employed in correcting "peteca" it has to be applied to the soil. However, only a long term study can accurately determine the effects of B supplied to the soil on the development of "peteca".

IV. Histological Studies of Lemon Tissues Showing "Peteca" Symptoms.

Histological work was undertaken on Eureka lemon to study the histology of tissues from healthy fruits and from fruits showing the "peteca" disease. For this purpose the material was fixed in killing fluid, embedded in paraffin, serially sectioned with a microscope and then stained in safranin-fast green.

Studying the sections under the photomicroscope, it was found that the epidermal wall of tissues taken from diseased fruits was normal (Figure 6, section 1) as compared in structure to the outer epidermal wall of tissues taken from healthy lemons, Figure 7, section 1. The outer walls of the epidermal cells were heavily cutinized in both healthy and diseased tissues. However, fruits heavily affected by "peteca" showed a rough epidermal layer as compared

Figure 6. Section from diseased fruit (rind tissue) showing shrunken cells, magnified 384 times.

Figure 7. Section from healthy fruit (rind tissue), magnified 384 times.

Figure 8. Section from diseased fruit (rind tissue) showing rough epidermis and dark, shrunken, dry cells, magnified 384 times.

Figure 9. Section from diseased fruit (rind tissue) showing broken oil glands, magnified 75 times.

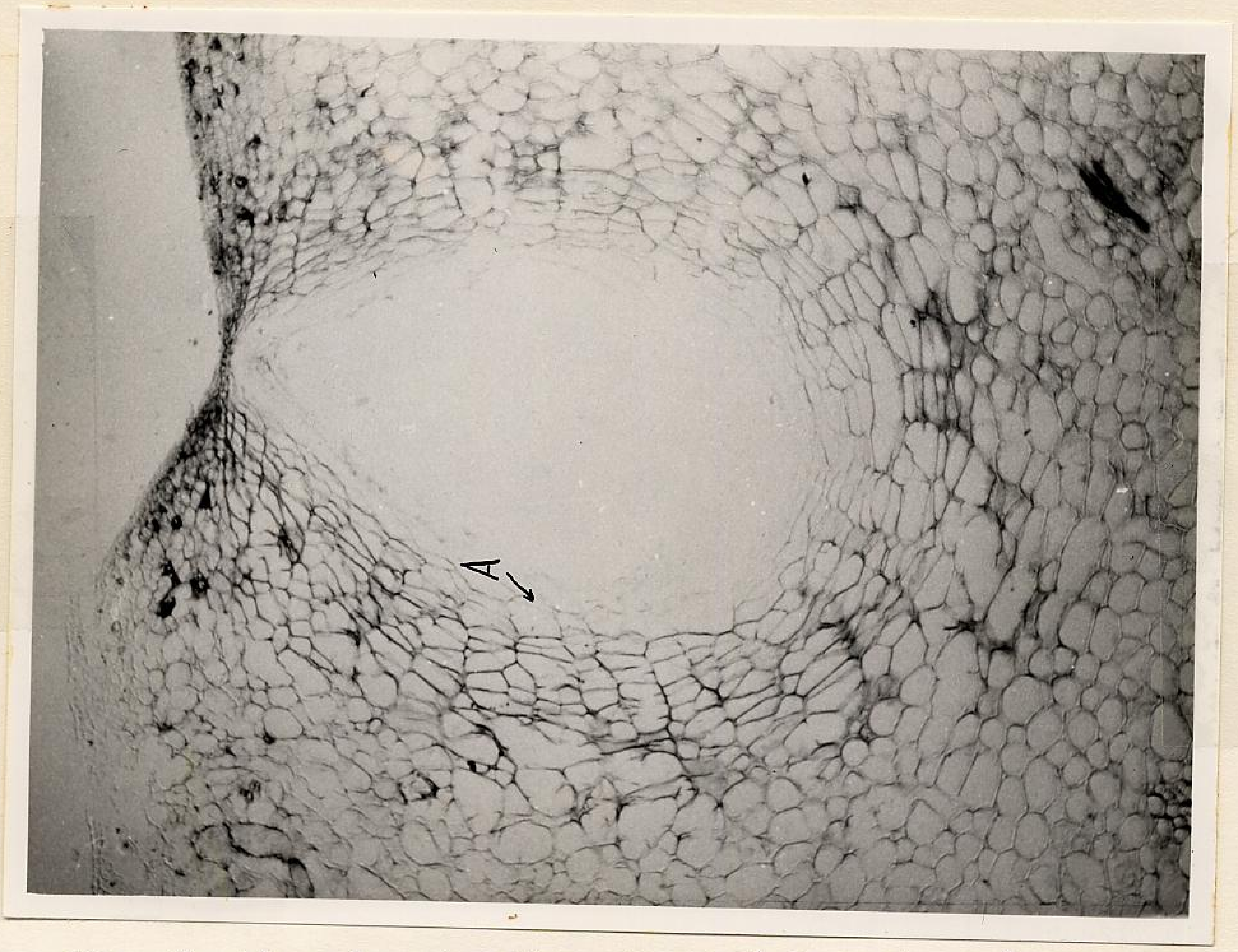

Figure 10. Section from healthy fruit (rind tissue) showing a normal oil gland, magnified 96 times.

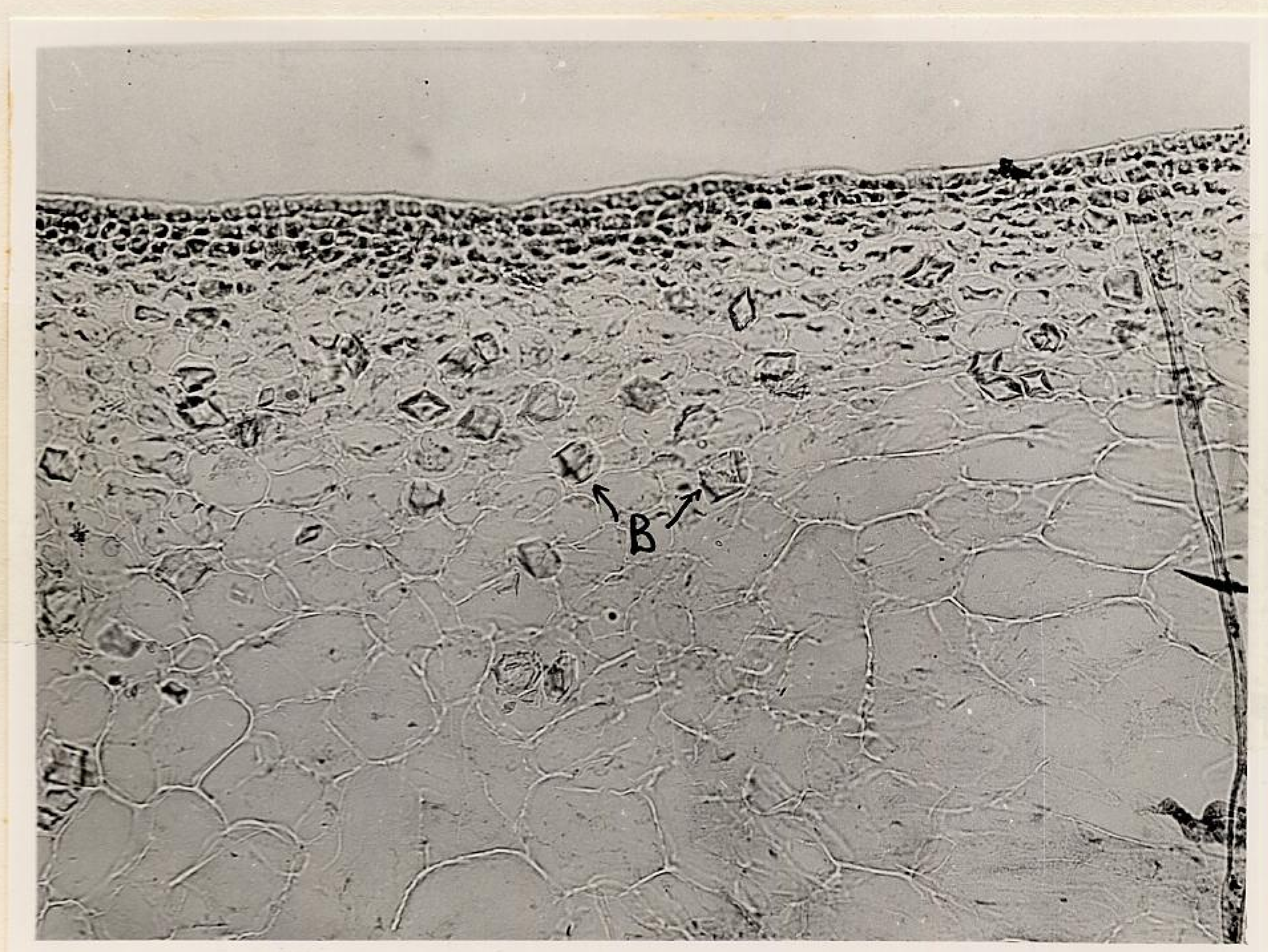

Figure 11. Section from diseased fruit (rind tissue) showing excess calcium oxalate crystals, magnified 75 times.

to healthy ones, Figures 6 and 7, section 1. As the shape of cells contained in the epicarp layer, the diseased tissues had roundish cells (Figure 6, section 2) while healthy tissues had polygonal shaped cells, Figure 7, section 2. The cells from diseased tissues of the hypoderm layer (beneath the outer epidermis) were completely dry, shrunken and dark (Figure 8, section 1) while the healthy tissues had normal cells, Figure 7, section 2. According to Fawcett and Lee (21) surface cells may remain normal in mild cases.

Usually the mesocarp layer was the least affected portion. However, the cells were slightly shrunken as compared to healthy tissues, Figure 8, section 2. On the other hand in heavily affected cases, the cell walls were not clear and the intercellular spaces were missing, Figure 6, section 1.

As shown in Figure 9 (A) cells surrounding the oil glands were broken, whereas in healthy tissues they were normal, Figure 10 (A). Two of the slides prepared from diseased tissues, out of 35 were found to contain higher amounts of calcium oxalate crystals, Figure 11 (B).

From the histological study, it was found that the "peteca" disease of lemons appears to occur beneath the outer wall of the epicarp layer and above the inner mesocarp layer of the peel.

SUMMARY AND CONCLUSIONS

This study was undertaken to investigate the influence of B nutrition on the development of "peteca" disease on Eureka lemons.

A preliminary survey was conducted during April 1964 to compare the inorganic leaf composition of Moughiaizly lemon variety, showing no "peteca" symptoms, and Eureka lemon variety showing such symptoms, both varieties growing in the same orchard. The elements analysed for were B, N, NO_3, K, Ca, Na, P, Fe, Mg and Mn. The results obtained from leaf analyses revealed that leaves from Moughiaizly trees had significantly higher concentration of B and lower concentrations of N, K and $N\bar{O}_3$ than leaves from Eureka trees.

After the establishment of low B level in Eureka lemon leaves 20 trees were selected and B was applied as follows: 100 gms. of borax /tree, soil treatment, 250 gms. of borax/200 lt. of water, foliar spray, 250 gms. of polybor/200 lt. of water, foliar spray, and no B application. Each treatment was replicated 5 times.

By comparing leaf inorganic constituents of treated trees to non-treated trees, it was found that leaf B concentrations were significantly increased with both polybor and borax foliar spray. Whereas, borax applied to the soil had no effect on B content of the leaves. In addition to this, leaf Fe, Mg, Na and Ca concentrations were found to be increased by borax and polybor applications as well.

To study the development of "peteca" and its relation to B, 10 fruits from each experimental trees were stored at room temperature for 8 weeks. At the end of storage it was found that trees receiving polybor foliar spray had the highest and trees receiving borax soil application had the least percent affected fruits. However, none of the results were statistically significant as compared to the check. Similar results were obtained by examining the fruit on the experimental trees.

Histological studies on tissues from healthy and diseased fruits of Eureka lemon were carried out. Upon comparing the structure of diseases tissues to healthy tissues, it was seen that in diseased tissues cells under the epicarp layer were dark, shrunken, dry and had a roundish rather than polygonal shape. Also the cell walls were not clear and the intercellular spaces were missing. The affected area was always found to be below the upper epidermis and above the mesocarp. The studies confirmed that "peteca" disease is a physiological breakdown of the skin.

This work showed that there was no direct effect of B nutrition on "peteca" development. Further investigations are necessary to find the actual cause of "peteca" and the extent of B influence on its development.

LITERATURE CITED

1. Abu-Khall, S.S. 1959. Boron and preharvest drop in apple trees. M.S. thesis. American University of Beirut, Beirut, Lebanon.

2. Barinlage, W.J. and H.A. Thompson. 1962. The effect of early season sprays of boron on fruit set. Proc. Amer. Soc. Hort. Sci. 80:64-71.

3. Bodarzeff, A. 1929. Note on diseases of lemons observed under faulty storage conditions. Rev. Appl. Mycology 9:304.

4. Boyrton, D. 1954. Nutrition by foliar application. Ann. Rev. Plt. Phys. 5:31-54.

5. Bownam, F.T. 1956. Citrus Growing in Australia. Angus and Robertson, Sydney, London, Melbourne, Wellington.

6. Bukhari, M.A. 1960. P and K effects on Valencia orange trees. M.S. thesis. American University of Beirut, Beirut, Lebanon.

7. Chandler, H.W. 1957. Deciduous Orchards. pp. 183-186. Lea and Febiger, Philadelphia.

8. __________. 1958. Evergreen Orchards. pp. 118-120. Lea and Febiger, Philadelphia.

9. Chapman, H.D. 1960. Leaf and soil analysis in citrus orchards. Cal. Agr. Exp. Sta. Manual 25. University of California Berkeley, Davis, Los Angeles.

10. Chapman, H.D. and A.P. Vanselow. 1954. Boron deficiency and excess. Cal. Citrog. 40:455-456.

11. Chapman, H.D. and W.P. Kelley. 1946. The mineral nutrition of citrus. The Citrus Industry. 1:719-725. University of California.

12. Childers, N.F. 1954. Fruit Nutrition. Horticulture publications, Rutger University, New Brunswick, N.J.

13. Cooper, W.C., B.S. Gorton and E.O. Olson. 1952. Ionic accumulation in citrus as influenced by rootstock and scion and concentration of salts and boron in the substrate. Plt. Phys. 27:191-203.

14. Dennis, R.W.G. 1951. Plant Diseases. Philosophical Library, Inc., New York.

15. Drake, M., D.H. Sieling and G.D. Scarseth. 1941. Calcium-boron ratio as an important factor in controlling the boron starvation of plants. Jour. Amer. Soc. Agron. 33:455-462.

16. Dugger, W.M., T.E. Humphreys and B. Calhoun. 1957. The influence of boron on starch phosphorylase and its significance in translocation of sugars in plants. Plt. Phys. 32:364-370.

17. Eaton, F.M. 1944. Deficiency, toxicity and accumulation of boron in plants. Jour. Agron. Res. 69:237.

18. Eaton, F.M. and G.Y. Blair. 1935. Accumulation of boron by reciprocally grafted plants. Plt. Phys. 10:411-424.

19. Embleton, T.W., C.K. Labanauskos and W.P. Bitters. 1962. The influence of certain rootstocks on the concentration of boron, iron, manganese and other elements in lemon leaves and on boron toxicity symptoms. Pro. Amer. Soc. Hort. Sci. 80: 285-289.

20. ________________. 1961. Rootstock effect on boron and other elements in leaves. Cal. Citrog. 47:230.

21. Fawcett, H.S. and Lee H. 1926. Citrus Diseases and Their Control. pp. 441-443. McGraw-Hill Publications. New York.

22. Gardner, U.R., F.C. Bradford and H.D. Hooker. 1952. <u>The Fundamentals of Fruit Production</u>. pp. 195-197. McGraw-Hill Book Company, New York.

23. Gauch, H.G. 1957. Mineral nutrition of plants. Ann. Rev. Plt. Phys. 8:31-64.

24. Gauch, H.G. and W.M. Dugger. 1953. The role of boron in the translocation of sucrose. Plt. Phys. 28:457-466.

25. Haas, A.R.C. and L.J. Klotz. 1931. Further evidence on the necessity of boron for health in citrus. Botanical Gaz. 92:94-100.

26. Haynes, J.L. and W.R. Robbins. 1948. Calcium and boron as essential factors in the root environment. Amer. Soc. Agron. Jour. 40:795-803.

27. Hume, H.H. 1957. <u>Citrus fruits</u>. The Macmillan Company, New York.

28. Jones, H.E. and G.D. Scarseth. 1944. The calcium-boron balance in plants as related to boron needs. Soil Sci. 57:15-24.

29. Jones, R.M. 1950. <u>Microscopical Technique.</u> Paul B. Hoeber, Inc., New York.

30. Kelley, W.P. and S.M. Brown. 1927-1929. Boron in the soils and irrigation waters of Southern California and the relation to citrus and walnuts. Hilgardia 3:445-458.

31. Klotz, L.J. 1929. Red blotch and "peteca" of citrus. Rev. Appl. Mycology 9:238.

32. __________. 1961. Color handbook of citrus diseases, p. 75. University of California, Berkeley.

33. Latimer, L.P. and G.P. Percival. 1943. How much borax can an apple tree tolerate. Proc. Amer. Soc. Hort. Sci. 43:21-24.

34. Le Clerg, E.L., W.H. Leonard and A.G. Clark. 1962. Field Plot Technique. pp. 89-94. Burgess publishing Co., Minnesota.

35. Muhr, G.R. 1942. Plants symptoms of boron deficiency and the effects of borax on the yield and chemical composition of several crops. Soil Sci. 54:55-65.

36. Pratt, M.R. 1958. Florida Guide to Citrus Insects, Diseases and Nutritional Disorders in Color. University of Florida, Agr. Exp. Sta., Gainsville.

37. Proebsting, E.L. 1957. Tree nutrient sprays. Cal. Agr. 11(3):10.

38. Reeve, E. and J.W. Shive. 1944. Potassium-boron and calcium-boron relationships in plant nutrition. Soil Sci. 57:1-14.

39. Reuther, W. 1961. Plant Analysis and Feftilizer Problems. American Institute of Biological Sci., Washington D.C.

40. Saas, J.E. 1961, 3rd ed. Elements of Botanical Microtechnique. McGraw-Hill Book Company, New York.

41. Scott, L.E. 1944. Boron nutrition of the grape. Soil Sci. 57:55.

42. Shear, C.B., H.L. Crane, and A.T. Myers. 1948. Nutrient element balance, application of the concept to the interaction of foliar analysis. Proc. Amer. Soc. Hort. Sci. 51: 319-326.

43. Shive, J.W. 1945. Boron in plant life - A brief historical survey. Soil Sci. 60:41-51.

44. Shok, J. 1957. The substitution of complexing substances from boron in plant growth. Plt. Phys. 32:308-316.

45. Smith, P.F. and W. Reather. 1954. Leaf analysis of citurs. From Fruit Nutrition by Childers. pp. 257-294. Sommerset Press, Somerville. N. Jersey.

46. Stevens, R.H.W. 1938. Carbohydrate metabolism in relation to boron nutrition. Proc. Amer. Soc. Hort. Sci. 36:537-541.

47. Tisdale, S.L. and W.L. Nelson. 1956. Soil Fertility and Fertilizers. pp. 106-108. The Macmillan Co. New York.

48. Toth, S.J., A.L. Prince, A. Wallance and D.S. Mikkelsen. 1948. Rapid quantitative determinations of eight mineral elements in plant tissue by a systematic procedure involving use of flame photometer. Soil Sci. 66:459-466.

49. Ulrich, A. and M. Johnson. 1959. Analytical methods for use in plant analysis. Cal. Agr. Exp. Sta. Bul. 766:62. University of California.

50. Walker, J.C. 1944. Histologic-pathologic effects of boron defficiency. Soil Sci. 57:51-54.

51. Weltzien, H.C. 1963. Plant diseases in the Middle East. Observations in the Republic of Lebanon, 1962. Phytopathogia Mediterranea 2:260.

APPENDIX

Table 18. Analysis of variance for Boron content (ppm. D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 2.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replication	7840.99	4	1960.25	2.88
Treatment	51430.79	3	17143.60	25.23**
Error	8153.93	12	679.44	
Total	67425.71	19		

Treatments:

Observed F 3/12 = 3.49 (5%)

5.95 (1%)

**Highly significant at both levels.

Table 19. Analysis of variance for nitrogen content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 3.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replication	0.02	4	0.050	5.00
Treatment	0.10	3	0.033	3.30
Error	0.13	12	0.010	
Total	0.25	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 20. Analysis of variance for $N\bar{O}_3$ content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 4.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	0.004	4	0.0010	1.11
Treatments	0.002	3	0.0006	0.666
Error	0.011	12	0.0009	
Total	0.017	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 21. Analysis of variance for Fe content (ppm. D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 5.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	111.54	4	27.89	0.80
Treatments	410.78	3	136.93	3.93*
Error	417.77	12	34.81	
Total	940.09	19		

Treatments:

Observed F 3/12 = 3.49 (5%).

*Significant at one level.

Table 22. Analysis of variance for Mn content (ppm. D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 6.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	81.20	4	20.30	0.622
Treatments	9.37	3	3.12	0.096
Error	391.83	12	32.65	
Total	482.40	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 23. Analysis of variance for Mg content (ppm. D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 7.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	0.042	4	0.010	1.428
Treatments	0.094	3	0.031	4.428*
Error	0.092	12	0.007	
Total	0.228			

Treatments:

Observed F 3/12 = 3.49 (5%)

*Significant at one level.

Table 24. Analysis of variance for P content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 8.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	0.0002	4	0.0001	0.50
Treatments	0.0005	3	0.0002	1.00
Error	0.0025	12	0.0002	
Total	0.0032	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 25. Analysis of variance for Na content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 9.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	0.0047	4	0.0018	3.00
Treatments	0.0108	3	0.0036	6.00**
Error	0.0070	12	0.0006	
Total	0.0225	19		

Treatments:

Observed F 3/12 = 3.49 (5%)

5.95 (1%)

**Highly significant at both levels.

Table 26. Analysis of variance for Ca content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 10.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	1.26	4	0.3150	3.94
Treatments	2.55	3	0.8500	10.63**
Error	0.96	12	0.0800	
Total	4.77	19		

Treatments:

Observed F 3/12 = 3.49 (5%)

5.26 (1%)

**Highly significant at both levels.

Table 27. Analysis of variance for K content (% D.W.) of Eureka lemon leaves as affected by B applications to the trees and reported in table 11.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	0.47	4	0.1175	2.17
Treatments	0.44	3	0.1466	2.71
Error	0.65	12	0.0541	
Total	1.56	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 28. Analysis of variance for affected fruits at room temperature with "peteca" from Jan. 5 to Jan. 11, 1965 and reported in table 12.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	5630	4	1407	3.19
Treatments	4760	3	1587	3.60*
Error	5290	12	441	
Total	15680	19		

Treatments:

Observed F 3/12 = 3.49 (5%)

*Significant at one level.

Table 29. Analysis of variance for affected fruits at room temperature with "peteca" from Dec. 19, 1964 to Jan. 4, 1965 and reported in table 13.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	4080	4	1020	2.49
Treatments	2580	3	860	2.10
Error	4920	12	410	
Total	11580	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 30. Analysis of variance for affected fruits at room temperature with "peteca" from Dec. 11 to Dec. 18, 1964 and reported in table 14.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	1330	4	333	1.01
Treatments	775	3	258	0.78
Error	3950	12	329	
Total	6055	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 31. Analysis of variance for affected fruits at room temperature with "peteca" from Nov. 28 to Dec. 10, 1964 and reported in table 15.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	850	4	212.50	1.13
Treatments	275	3	91.67	0.48
Error	2250	12	187.92	
Total	3375	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 32. Analysis of variance for affected fruits at room temperature with "peteca" from Nov. 13 to Nov. 27, 1964 and reported in table 16.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	580	4	145	1.16
Treatments	100	3	33.33	0.27
Error	1500	12	122.25	
Total	2180	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)

Table 33. Analysis of variance for affected fruits before picking with "peteca" from Nov. 13 to Nov. 30, 1965 and reported in table 17.

Source	Sum Sq.	d.f.	Mean Sq.	F. Ratio
Replications	1060.80	4	265.20	0.758
Treatments	2354	3	784.67	2.25
Error	4194	12	349.50	
Total	7608.80	19		

Treatments:

Observed F 3/12 = 3.49 at 0.05 level (n.s.)