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Boron Content of Avocado Trees and Soils

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Introduction

Most plants have been shown to require boron in small amounts for their healthful nutrition, while slightly larger amounts of boron frequently are quite toxic.

Recent studies, with avocado seedlings in culture solutions containing an inadequate supply of boron, have shown that growth becomes seriously interfered with. Various symptoms are produced that vary with the growth condition occurring at the time the need for boron becomes most acute. As in most physiological disorders there may be not only one but several symptoms, any one of which considered alone may not characterize the true nature of the disorder. Even with the application of the required element to the nutrient medium, there is no assurance of the recovery of the plant unless there is a sufficient degree of availability of the added substance for the nutritional requirements.

Chemical analyses of plants, especially leaves, are often resorted to in determining the causal nature of physiological disorders. Such plant analyses have superseded the use of soil analyses; however, their correct interpretation frequently is no easy matter and requires the full and proper coordination of every available resource that can contribute data of any kind upon the disorder in question.

Boron-Deficiency Studies

Seed were obtained at the Citrus Experiment Station and were grown in plaster sand at 75°-80° F in the propagation frames. The seedlings were hardened just prior to the appearance of leaves. When about a foot high, the plants were transferred to the culture solutions in 12-gallon containers with the plants suspended in such a way that the base of the seed barely touched the surface of the solution.

Chemical Determination of Boron in Plants

The boron determinations in these and other avocado plants were made by the use of a very accurate turmeric method later to be reported elsewhere. Initially only the total boron was determined, but subsequently the water-soluble as well as water-insoluble fractions were also determined and showed good agreement with the values obtained for total boron. The boron tests were in every case carried on in duplicate with a blank accompanying each group of ten determinations.

Briefly, the addition of calcium hydroxide was made prior to the ashing of the plant material. The ashing was done in silica dishes over the Fisher burners without air-ventilation at the base of the burner. The water-soluble salts were removed by filtration into a 100-cc flask and the ash residue that contained carbon was heated again until white. The addition of weak HCl to dissolve the ash was continued during the second filtration into the original flask until very slight acidity was obtained as indicated by the clearing of the solution. Aliquots of 5 to 10 cc were usually adequate for the colorimetric boron determination.

The boron analysis of various lots of avocado seed is given in Table 1. Approximately two-thirds of the boron in avocado seed is water-soluble.

TABLE 1
Avocado seed collected at the Citrus Experiment Station

Variety	No. of seeds	Date	Seed	Water-soluble boron in dry matter	Water-insoluble boron in dry matter
				p.p.m.	p.p.m.
Fuerte	6	April 30, 1931	Without seed coats	10.42	5.36
Fuerte	10	April 13, 1931	Without seed coats	8.23	4.02
Benik	5	April 14, 1931	Without seed coats	8.30	4.46
Benik	4	May 29, 1931	Without seed coats	9.66	5.05
Mexicola	1	Oct. 1, 1942	With seed coats	21.07	12.80
Dickinson	1	Oct. 1, 1942	With seed coats	11.36	8.46
Linda	1	Oct. 1, 1942	With seed coats	11.72	5.45
Anaheim	1	Oct. 1, 1942	With seed coats	16.89	7.45

The relatively large amount of boron present in the seed favors considerable growth in the cultures lacking added boron and enables one to observe the growth as it undergoes a gradual boron deficiency during the production of the various growth cycles.

TABLE 2
Boron content of avocado seedlings grown in culture solutions lacking boron

Sample	Boron in dry matter: water soluble	Boron in dry matter: water insoluble	Tree condition
	(p.p.m.)	p.p.m.	
47 Leaves	6.2	12.0	Dying back of terminal leaves and twigs
32 Leaves	8.18	6.17	
Leaves	6.15	8.35	Vein splitting on the under side of the leaves
Leaves	11.33	9.75	No leaf symptoms
Trunk and branches	7.06	3.61	Swelling and staining of trunk
Leaves	6.49	8.59	Slight deficiency symptoms; grown in a large aluminum container
Trunk and branches	8.19	5.38	
Roots	8.96	12.26	
Leaves	2.76	6.26	Severe deficiency symptoms
Trunk	2.00	4.40	
Trunk	3.74	5.85	
Roots	4.90	9.45	
Leaves	37.57	20.00	Healthy control trees

Table 2 gives the boron content of healthy avocado seedlings grown in culture solutions containing 0.1 part per million of boron. When boron was omitted from the culture solution, the boron content of the leaves was greatly reduced as compared with those grown in the control cultures and the symptoms of the physiological disorder resulting from a lack of boron became very conspicuous.

Fig. 1.—Severe boron deficiency in avocado seedlings grown in culture solutions lacking boron. Multiple buds give rise to new dwarfed shoots.

Boron-Deficiency Symptoms

One of the most characteristic symptoms of a boron deficiency is the gradual destruction of the meristem or growing points. In figure 1 is shown not only the injured terminal growing point but also the retardation or death of the growing points of the newly produced and dwarfed auxiliary death of the growing points of the newly produced and dwarfed lateral shoots. The death of the plant therefore proceeds from the most distant youngest portions back toward the base of the trunk.

The leaves of affected shoots become burned and distorted as shown in figure 2 and the growth of the newly-formed leaves soon comes to a stand-still. The midrib and other veins on the lower surface of the leaves frequently are corky and split as shown in figure 3. In many cases of severe boron deficiency there were splits an inch or more in length in the trunk bark.

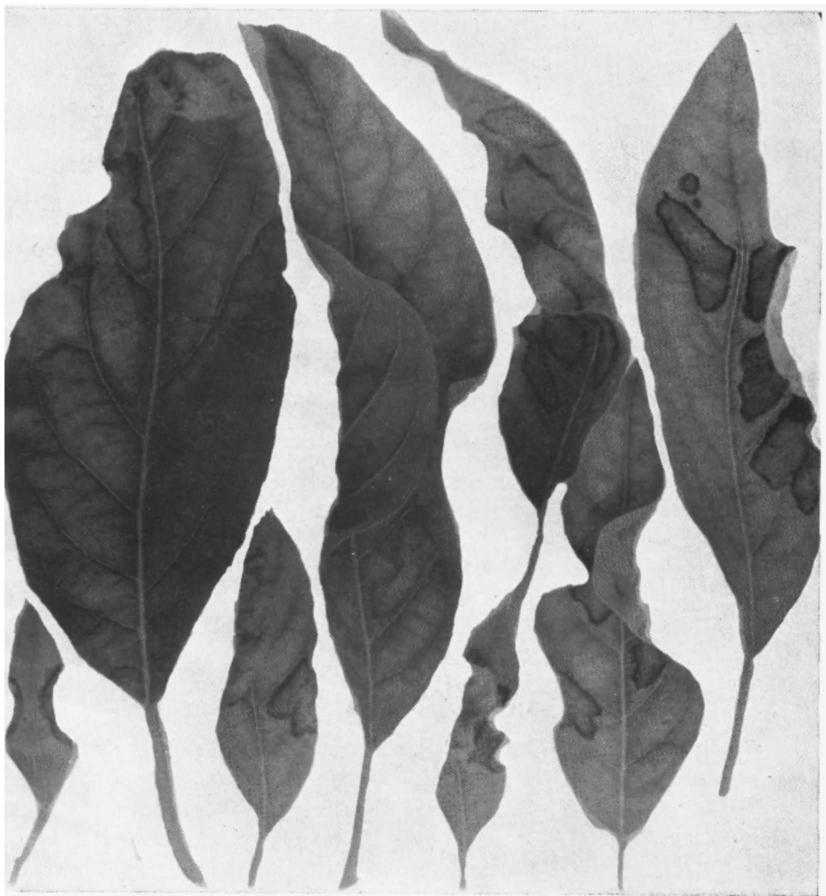

Fig. 2.—Burned and distorted leaves on terminal shoots of avocado seedlings grown in culture solutions lacking boron.

In some of the boron-deficient cultures the terminal portion of the trunk and some of the shoots showed swellings (figure 4) which when cut open revealed pithy or corky pockets stained with a brown resinous-like color. All of these symptoms are secondary when considered with the primary effect on the growing points.

When the terminal growth had ceased and the multiple buds were unable to produce any but very greatly reduced growth, boron was added to some of the culture solutions without renewing the solution. In a very short time healthy new growth proceeded from below the injured terminal portions and the further recovery of the plant was rapid as was revealed by later photographs not shown here.

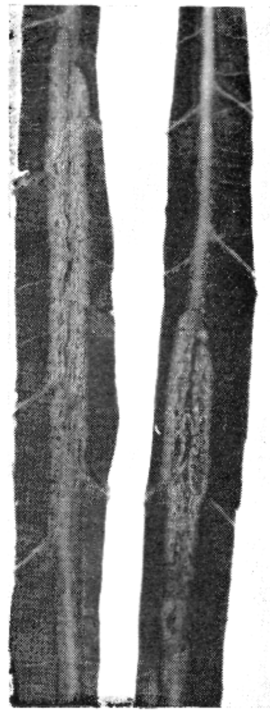

Fig. 3—Corky and split midribs on the lower surface of the leaves of avocado seedlings grown in culture solutions lacking boron.

The root systems of healthy avocado seedlings are white at first and gradually become light brown with age as seen on the left in figure 5. As the effects of a boron deficiency become severe, the root system ceases growing and darkens considerably. Finally the fine roots disintegrate. This was the condition of the roots shown on the right in figure 6. Boron was then added without renewing the culture solution and soon healthy white roots were in increasing evidence as shown on the right in figure 6. The new roots originated in the older and less seriously affected portions and became very numerous as recovery became more complete.

Boron In Orchard Trees

The avocado trees at the Citrus Experiment Station represent quite a number of varieties growing under the same soil and cultural conditions and were utilized as one source of material for this study.

Leaves

The collected leaves were considered mature and were rapidly washed individually in running distilled water. After removal of the excess moisture by shaking, the leaves were dried at 65° C in a ventilated oven and were finely ground in a Wiley mill.

The boron content of avocado leaves is given in table 3. A large proportion of the boron present is insoluble in water. The indications are that the avocado leaf continues to accumulate boron long after it is mature. There is every reason to believe that the water-insoluble boron is available to a certain **N** extent for the use of the plant. When — HCl was used as the solvent instead **10** of distilled water, the Fuerte avocado leaves of December 22, 1937 (R6, T1,2) showed only 8.61 p.p.m. insoluble in the acid as against 23.90 p.p.m. insoluble in distilled water; similarly the Mexicola avocado leaves of December 22, 1937 (R8, T5,6) showed only 7.68 p.p.m. insoluble in the acid as compared with 23.15 p.p.m. insoluble in distilled water.

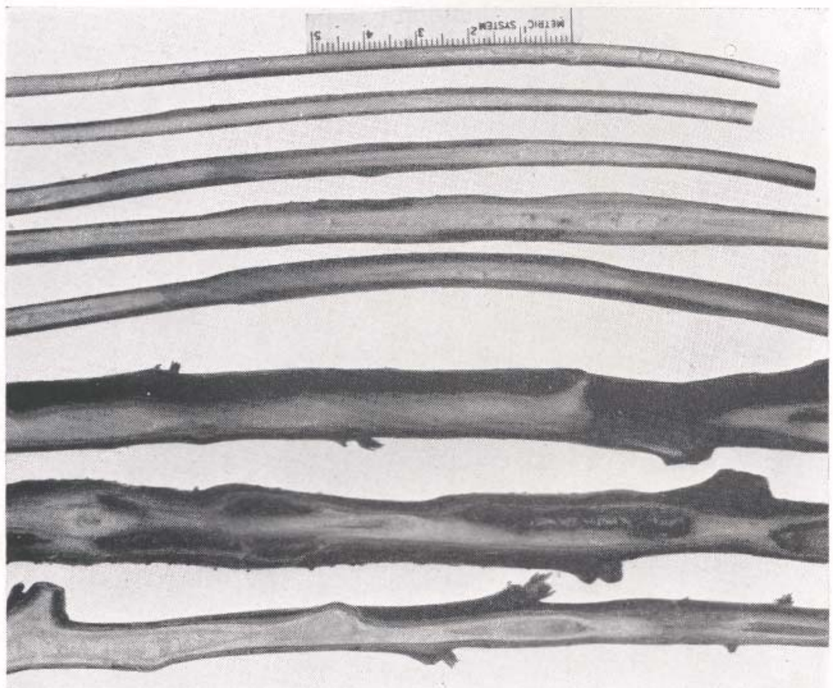

Fig. 4—Swellings of trunk (three lower pieces) and of shoots of avocado seedlings grown in culture solutions lacking boron. The pieces have been cut open to show the pithy pockets and the brown resinous-like color.

Fruit Pulp

Few, if any, analyses are available in regard to the boron content of avocado fruits. Table 4 shows the boron content of the pulp of fruit samples each consisting of one to six or more fruits. The data show the higher boron content in the tip half over that in the stem half and in the higher content in the outer portion over that found in the inner portion.

TABLE 3
Mature avocado leaves

Variety	Date and place of collection		Tree	Water-soluble boron in dry matter (p.p.m.)	Water-insoluble boron in dry matter (p.p.m.)
		C.E.S.			
Fuerte	April 30, 1931;	Riverside	R6T2	11.99	15.25
Fuerte	Dec. 22, 1937;	"	R6T1,2	14.03	23.90
Puebla	April 20, 1931;	"	R3T1	6.93	12.11
Puebla	April 28, 1931;	"	R7T2	6.11	12.42
Puebla	Dec. 22, 1937;	"	R7T1,2	10.10	21.70
Blake	April 30, 1931;	"	R7T3	7.49	16.67
Blake	Dec. 22, 1937;	"	R7T3,4	9.43	19.14
Spinks	April 28, 1931;	"	R8T6	25.38	18.86
Benik	April 30, 1931;	"	R4T2	15.27	16.85
Northrup	Dec. 22, 1937;	"	R6T15	15.33	11.18
Ganter	Dec. 22, 1937;	"	R7T5,6	15.45	25.05
Anaheim	Dec. 22, 1937;	"	R10,T2,3	12.60	19.25
Dorothea	Dec. 22, 1937;	"	R9,T12	12.44	20.78
Ward	Dec. 22, 1937;	"	R10,T5	22.15	25.30
Mexicola	Dec. 22, 1937;	"	R8,T5,6	14.37	23.15
Queen	Dec. 22, 1937;	"	R6,T3,4	18.35	22.60
Dickinson*	Dec. 22, 1937;	"	R7,T7,8	19.96	23.02
Nabal*	Dec. 22, 1937;	"	R4,T14	33.35	29.45
Fuerte	Dec. 8, 1937;	Corona		12.41	15.93
Puebla	Dec. 8, 1937;	Corona		13.31	14.75

* Trees injured by cold.

TABLE 4
Pulp of avocado fruits collected at the Citrus Experiment Station

Variety	Portion of pulp	Total boron in dry matter (p.p.m.)
Fuerte	Stem half	48.63
	Tip half	79.50
Fuerte	Stem half	55.40
	Tip half	83.82
Fuerte	Stem half	52.91
	Tip half	95.11
Fuerte*	Inner half	60.59
	Outer half	66.67
Puebla*	Inner half	62.56
	Outer half	75.76
Kashlan* (Immature)	Inner half	117.60
	Outer half	132.40
Tiger*	Inner half	64.53
	Outer half	71.66
Dorothea	Inner half	61.71
	Outer half	72.30
Mexicola	Slices stem to tip end	42.40
Mexicola	Slices stem to tip end	36.58
Linda*	Whole	37.70
Linda*	Whole	43.00
Linda	Slices stem to tip end	57.60
Linda	Slices stem end to seed	37.64
Linda	Slices seed to tip end	61.15

* Midway between stem and tip halves.

Fruit Skin

In removing the skins from the ripened fruit pulp, care was taken to remove all pulp fragments with a brush under running distilled water. The excess water was shaken away and the remaining moisture was blotted away with filter paper prior to the drying of the skins at 65° C in a ventilated oven.

Table 5 gives the boron content found in the skins of fruits. The determinations were made because of the frequent reference to a boron deficiency in the cracking of celery, cherries and other plant tissues. It is seen that the skin of avocado fruits contains considerable boron. Skins of the fruits of the Puebla variety crack badly at times at the tip or blossom end. These data are of interest in that the skins of the Puebla fruits used in this study contained less soluble boron in the tip than in the stem halves while the converse was found in the skin of fruits of the Fuerte variety.

TABLE 5
Skins of avocado fruits collected at the Citrus Experiment Station

Variety	No. of fruit	Portion of skin	Water-soluble boron in dry matter (p.p.m.)	Water-insoluble boron in dry matter (p.p.m.)
Fuerte	4	Stem half	62.42	46.83
		Tip half	90.63	79.94
Fuerte	3	Stem half	94.50	76.54
		Tip half	111.38	131.00
Fuerte	3	Stem half	113.75	71.63
		Tip half	117.00	72.00
Puebla	6	Stem half	83.30	47.30
		Tip half	53.38	31.50
Puebla	1	Stem half	105.80	50.99
		Tip half	58.37	48.56
Puebla	2	Stem half	111.50	69.85
		Tip half	63.88	52.59
Puebla	2	Stem half	101.80	78.43
		Tip half	57.72	55.50
Puebla*	2	Stem half	98.00	43.30
		Tip half	141.38	88.00
Ward	4	Stem half	30.40	25.66
		Tip half	30.68	21.29
Ganter	4	Stem half	87.25	62.63
		Tip half	77.75	65.17
Linda	1	Stem half	23.40	25.45
		Tip half	18.83	24.42
Kashlan (Immature)	3	Stem half	18.58	13.75
		Tip half	25.12	14.45
Dorothea	5	Stem half	97.90	69.59
		Tip half	116.38	91.94
Anaheim	1	Stem half	70.88	37.40
		Tip half	53.13	52.75
Tiger	6	Stem half	18.38	14.10
		Tip half	24.04	14.85
Dickinson	1	Stem half	41.45	18.20
		Tip half	69.44	25.25
Topa Topa	1	Whole	87.20	39.70
Puebla	4	Whole	66.85	39.63
Mexicola	6	Whole	110.00	43.40

* Seedling; long fruit; grown by Professor W. T. Horne of the Division of Plant Pathology

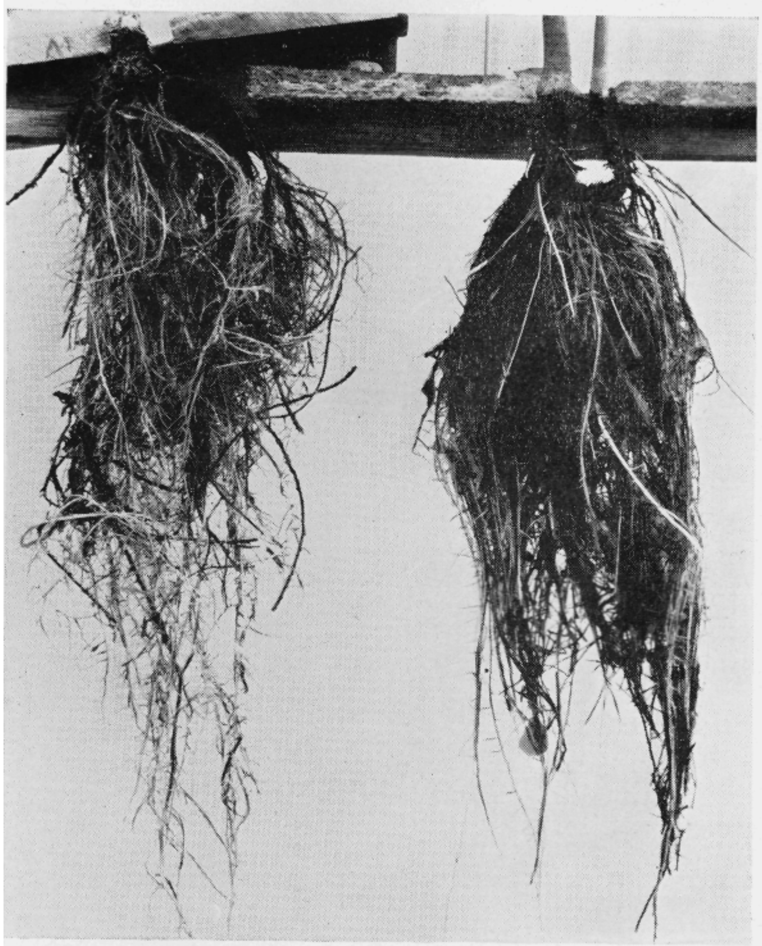

Fig. 5.—*Right:* Root system of avocado seedling shown in *Figure* 1. Note the dark, disintegrating roots that resulted from a lack of boron and the healthy white roots becoming evident as the initial recovery progressed after boron was added to the unrenewed culture solution.
Left: Root system of an avocado seedling grown in a culture solution that never was lacking in boron.

Orchard Soils

The discovery[1] that olive trees in Butte County, California, respond when sufficient boron is made available to the tree, has brought an interest in the question as to whether avocado orchards in some areas might benefit from applications of boron to the soil, especially when such areas are subject to decline.

Briefly, the available boron was determined in a water extract of the soil (1 to 2 soil-water ratio). Twenty grams of soil was boiled with 40 cc distilled water for 5 minutes under a reflux condenser and the dissolved boron was determined in the filtered extract. Many such analyses were made with soils of most citrus areas in southern California and will be reported elsewhere.

TABLE 6

Water-soluble boron in soils of avocado orchards (boron calculated on an air-dry soil basis)

Orchard location	Depth of sample	Boron (1 to 2 soil-water ratio) (p.p.m.)
Griswold, La Habra, Orange County	0"- 6"	1.39
	6"-12"	0.72
	12"-24"	1.26
	24"-36"	0.79
	36"-48"	0.72
Maag, Capistrano, Orange County	0"-12"	1.28
	12"-24"	1.56
	24"-36"	1.48
Native avocado soil, Guatemala	6"	0.51
	12"	0.38
	18"	0.35
	24"	0.24
	30"	0.10
	36"	0.48
Jobe, Covina Highlands, L.A. County	0"-12"	1.30
	12"-24"	1.28
Hazzard, Vista, San Diego County	0"- 6"	0.67
	6"-12"	0.56
	12"-24"	1.11
	24"-36"	1.62
Smith, Vista, San Diego County	0"- 6"	0.98
	6"-12"	0.49
	12"-24"	0.56
	24"-30"	0.94
Huntalas, Vista, San Diego County	0"- 6"	1.35
	6"-12"	1.21
	12"-24"	0.72
	24"-36"	1.01
Avocado tree decline, Vista, San Diego County	0"-12"	0.28
	12"-24"	0.46
Kepner, Escondido, San Diego County	0"-12"	0.63
	12"-24"	0.68
	24"-36"	0.59
Ross, Escondido, San Diego County	0"-12"	2.27
	12"-24"	0.61
	24"-36"	1.14
	36"-48"	2.53
McDonald, Fallbrook, San Diego County	0"- 6"	2.58
	6"-12"	1.48
	12"-24"	0.94
	24"-36"	1.32
Webster (Winterwarm) near Fallbrook, San Diego County	0"- 6"	2.01
	6"-12"	1.23
	12"-24"	0.82
	24"-36"	0.94
Anthony, Fallbrook, San Diego County	0"- 6"	2.47
	6"-12"	1.33
	12"-24"	1.73
	24"-36"	0.88
Calavo Gardens, Mt. Helix, San Diego County	0"-12"	0.51
	12"-24"	1.63
	24"-36"	0.85
	36"-48"	0.88

In table 6 are given the values obtained for the water-extracted, boron calculated on an air-dry soil basis. For comparison, boron determinations were also made on soil obtained[2] from a boron-responsive olive orchard in Butte County. For the 0"-12" depth (1 to 2 soil-water ratio) the boron extracted amounted to 0.12 p.p.m. when calculated on an air-dry soil basis. For the soil of an as yet non-responsive Navel orange orchard, nearby the olive orchard in Butte County, the boron extracted (0"-16" soil depth) at the 1 to 2 soil-water ratio amounted to 0.13 to 0.16 p.p.m. (air-dry soil basis).

In table 6 the parts per million of boron (air-dry soil basis) are also given for a native Guatemalan soil (largely organic) in which large trees made healthy growth. The boron extractable from the soil of a declining orchard was relatively low (though adequate) in the first 12 inches of soil and the second foot of soil also contained adequate amounts. At both depths the soil was extremely heavy. The boron value for the Kepner orchard soil was among the lowest found in the orchard soils studied and is without doubt quite adequate. The available boron in the avocado orchard soils of southern California cannot be said to be inadequate. Unreported data for the citrus orchard soils are in agreement with those reported for the soils of avocado orchards.

Summary

The growth of avocado seedlings in culture solution was seriously interfered with when boron was inadequate. The boron found in the leaves was greatly reduced when severe symptoms were evident. Injury to the meristem or growing point of the terminal growth was one of the first boron-hunger signs. Additional symptoms were the corking and splitting of veins and trunk, the burning and the distorting of the new leaves and the swelling of young twigs with brown staining of the wood. The young roots disintegrated as the plant died back from the tips.

The boron content (water-soluble and water-insoluble portions) of the leaves, fruit pulp and skin of orchard trees of different varieties growing in the same soil was studied and the possible relationship of boron to blossom (tip) end cracking of certain fruits was referred to.

The possibility that some avocado orchard soils may be deficient in available boron was explored. No evidence of a boron deficiency has been found thus far in avocado orchard soils.

These soil samples were kindly sent to me by Mr. H. P. Everett, County Agricultural Agent for Butte County.

1. Everett, H. P., Olive die-back work. Calif. Agr. Col. Ext. Ser. Progress Rpt., 3 pp. mimeo. October 1942.

Scott, C. E., H. Earl Thomas and Harold E. Thomas, Boron deficiency in the olive. Phytopath. 33 (no. 10): 933-942, 1943.