Proc. Fla. State Hort. Soc. 59:138-145. 1946.

SYMPTOMS EXHIBITED BY AVOCADO TREES GROWN IN OUTDOOR SAND CULTURES DEPRIVED OF VARIOUS MINERAL NUTRIENTS

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A knowledge of the symptoms of malnutrition exhibited by plants supplied nutrient solutions that were complete except for a single element has been found helpful in diagnosing nutritional troubles that appear in plants in the field. Although the responses of plants in general to severe deficiencies of the known essential mineral elements tend to follow established patterns, there are sufficient differences in the expresion of deficiency symptoms by different species to make it desirable to establish as completely as possible the responses peculiar to each of the important economic plants. Our knowledge of the responses of the avocado to mineral deficiencies is meager.

Haas (2) has reported the symptoms characteristic of potassium, phosphorus, manganese, and boron deficiency exhibited by avocado seedlings grown in solution culture in the greenhouse in California. Zinc deficiency symptoms in the avocado as they appear in the field have been described by Parker (4) in California and by Ruehle (5) in Florida. Ruehle and Lynch (6) have reported that avocado "dieback" was corrected by copper sulfate, though they suspected that the symptoms of this disease may have involved more than copper deficiency alone.

Two varieties of avocado, Taylor and Lula, were used in the present investigation. The yearling trees were removed from boxes of soil in which the seedling rootstocks had been grafted, washed, and planted in 8-gallon crocks of washed white sand (St. Lucie subsoil). The Taylor trees were maintained in the sand cultures for over two years; the Lula trees for about 18 months. One set of Taylor cultures (8 trees) was supplied with the following nutrient solutions: complete, minus phosphorus, minus potassium, minus magnesium, minus manganese, minus boron, minus zinc, minus iron. Duplicate sets of Lula cultures (total of 20 trees) were supplied the same solutions as the Taylor trees and, in addition, minus copper and low nitrogen solutions. The complete nutrient solution used was Hoagland's (3), and in the solutions lacking one element suitable substitutions were made. Fresh nutrient solution was added in varying amounts and at intervals varying from weekly to daily, depending upon size of tree, upon season, and primarily upon the rate at which the pH[1] of the solution in the culture vessel changed. The cultures were flushed out before each addition of nutrient solution, usually with rain water, but when this was not available, with tap water. The pH of the flushed leachate, which was not re-used, varied from about 3.6 to about 6.5.

DEFICIENCY SYMPTOMS

It is not certain that all of the symptoms of malnutrition displayed by the trees described here are characteristic of specific deficiencies. Until the results described below are confirmed by more extensive work, they should be considered as tentative. In the main, however, the symptoms of malnutrition described here are similar to those that have been established by extensive work on other plants. The symptoms displayed by the two varieties, Taylor and Lula, were practically identical, but because the Taylor cultures were maintained for a longer period than the Lula cultures and showed more pronounced symptoms, most of the illustrations are of the variety Taylor.

Plate 1. Taylor avocado trees grown in sand cultures supplied with the following nutrient solutions; No. 11, complete; No. 12, minus magnesium; No. 13, minus zinc; No. 14, minus manganese.

Nitrogen. The trees grown in the low nitrogen cultures were badly stunted, the bark was reddish brown, and the spring-flush shoots short and thin. The immature leaves on elongating shoots were amber to an abnormally bright red color. The mature leaves were very small, stiff, and yellowish green. In summer and fall the old spring-flush leaves gradually burned from the tip toward the base and finally were abscised when nearly all of the blade had burned. The appearance of Lula leaves from the complete and low nitrogen cultures is shown in plate 3, J and K.

Phosphorus. The general appearance of a Taylor tree that was suffering severe phosphorus deficiency is shown in plate 2, No. 15, and that of a single leaf in plate 3 E. The tree was stunted, and the number of leaves on the plant was greatly reduced as a result of abscission of the older leaves. The leaves were smaller than normal and distinctly rounded. The leaf blades were stiff and leathery. Soon after reaching maturity the leaves became dull brownish green in color. This bronzing, or change of color to dull brownish green, was the most distinctive symptom of phosphorus deficiency observed. Many of the twigs lost all of their leaves and died back to larger branches. Some of the leaves, as they aged, burned at the tips and margins. When the cultures were dismantled, it was found that the phosphorus-deficient trees were making almost no new root growth, and the old roots, though alive, were black rather than the normal light brown in color. While the root systems in most of the cultures showed signs of malnutrition, only those of the phosphorus-deficient plants displayed symptoms that were distinctive.

Potassium. The first symptom of deficiency observed in cultures lacking potassium was the development of somewhat narrowed leaves of slightly subnormal size. Soon after the leaves reached maturity, they became very deep green. Later the intensity of green color decreased. By late summer the leaves of the spring flush showed numerous small, light-brown specks scattered over the leaf. As the leaves aged, the brown specks coalesced into large, irregular, reddish-brown areas of dead tissue between the large veins, along the margins, or at the tip (plate 3 F). The trees were badly stunted, and on severely deficient trees the twigs were very thin and some of them died back during the winter (plate 2, No. 16).

Magnesium. No symptoms of deficiency were observed during the first season of growth in the cultures lacking magnesium. The trees were as large as those receiving complete nutrient solution (plate 1, No. 12). By midsummer of the second season the Taylor tree deprived of magnesium was making less vigorous growth than the control, and the leaves were a lighter green. By September the leaves were greenish yellow over the entire area of the leaf except for a slightly deeper green along the midrib and large veins. In late fall and winter the leaves became yellow, and small, brown, dead lesions appeared scattered over the entire leaf blade. The appearance of a magnesium-deficient leaf is shown in plate 3 B. Magnesium deficiency symptoms did not appear on the Lula trees. This would suggest that, in the avocado, magnesium must become very low before the leaves show obvious deficiency symptoms.

Manganese. Immature leaves did not show symptoms of manganese deficiency, but as soon as the leaves matured, many of them developed yellow areas between the veins. These interveinal yellow areas were at first almost separate from each other, and at a glance appeared as two rows of yellow spots running parallel to the midrib. With aging of the leaves, the yellow areas coalesced somewhat, though the area along the larger veins remained green. The appearance of a leaf in an advanced stage of manganese deficiency is shown in plate 3 D. There was no apparent dwarfing of the tree or leaves. The manganese-deficient Taylor tree is shown in plate 1, No. 14.

Zinc. No symptoms of malnutrition appeared in the Lula cultures, and no sign of malnutrition appeared until midsummer of the second season in the Taylor culture. Then a few leaves showed slight mottling. By September pronounced yellowing between the veins had developed on many of the leaves. Parker (4) described the initial symptoms of zinc deficiency in the avocado as yellow areas between the veins. The pattern of yellowing on the Taylor tree was more diffuse than the pattern that is typical of zinc deficiency in citrus. The leaves were normal in size (plate 3 C) and never developed the recurved midrib and trough-shaped leaves described by Ruehle (5) as typical of leaves suffering severe zinc deficiency. The trees in the minus-zinc cultures attained normal size (plate 1, No. 13).

Possibly the symptoms of malnutrition observed on the Taylor tree represent the early stages of zinc deficiency, but the characteristics described above lead us to believe that probably they resulted from some other disorder.

Iron. The first visible sign of iron deficiency was the appearance of leaves with yellowish-green color between the veins and narrow areas of darker green along the veins. These leaves were of the spring flush. The summer-flush leaves were reduced in size, with blades thin and delicate, and when immature they were a very pale yellow, or almost white, with, little or no difference in color between the areas along the veins and those between the veins. As these leaves matured, the areas along the veins became green. In late summer and fall the most severely chlorotic leaves began to burn at the tips and along the margins. The early stage of leaf burn on a chlorotic leaf is shown in plate 3 G. On some shoots all oí the leaves burned badly. By late fall these shoots were defoliated and dying back from the tips (plate 2, No. 18).

Boron. The spring flush of growth of the trees in the cultures deprived of boron was not quite so vigorous as that of the controls. The internodes were slightly shortened and, as compared with the controls, there was a slight increase in the number of lateral shoots produced. The leaves were not quite so dark green as those of the controls, and some leaves were slightly dwarfed. In the summer flush of growth striking signs of boron deficiency appeared. The new shoots were very short, and the leaves at the tips of these shoots were greatly reduced in size and were yellowish green in color. Some time after reaching maturity, many of the leaves burned at the tips and margins and finally were prematurely abscised. The internodes near the tips of these partly defoliated shoots were much shortened and the axillary buds were greatly swollen. giving the shoots a knobby appearance. Typical shoots of Taylor and Lula from control and from boron-deficient cultures are represented in plate 4. By fall the bud scales, which were enlarged, had burned at the tips, and some of the terminal buds were dead. The abscission of leaves progressed from tip to base of shoots, and some shoots died back several inches from the tips. After the short new terminals lost their leaves, some of the axillary buds grew into extremely short shoots with small, yellow, scale-like leaves that soon burned and died. During the first season of boron deficiency there was little dwarfing effect, but by the end of the second season the Taylor tree was appreciably stunted (plate 2, No. 17).

Copper. The cultures deprived of copper developed, during the growing season of 1945. very dark green foliage and slightly S-shaped shoots. Camp and Fudge (1) state that in citrus the first sign of approaching copper deficiency is the development of unusually dark green foliage and the production of S-shaped shoots. Ruehle and Lynch (6), in describing symptoms of severe copper deficiency that appeared in young avocado trees in the field, presented photographs of trees that had S-shaped shoots, though they did not specifically state that this is a characteristic symptom of copper deficiency in the avocado.

Since the copper-deficient cultures apparently received enough copper, supposedly fron: impurities in the chemicals, water or sand, or from some other source, to prevent the appearance of symptoms of severe deficiency, it is uncertain whether the development of dark green leaves and the slight tendency to produce S-shaped shoots observed here should be considered characteristic early symptoms of copper deficiency in the avocado.

Ruehle and Lynch (6) described the development of a severe multiple bud condition and dieback of the shoots of their copper deficient avocado trees. Their photographs showing this condition bear at least a superficial resemblance to our illustration of boron deficiency. Therefore, under field conditions, it may be difficult to distinguish between multiple buds and dieback caused by a deficiency of copper and the condition caused by a deficiency of boron, and caution should be exercised in diagnosing these deficiencies without additional criteria.

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Plate 2. Taylor avocado trees grown in sand cultures supplied with the following nutrient solutions: No. 15, minus phosphorus; No. 16, minus potassium; No. 17, minus boron; No. 18, minus iron.

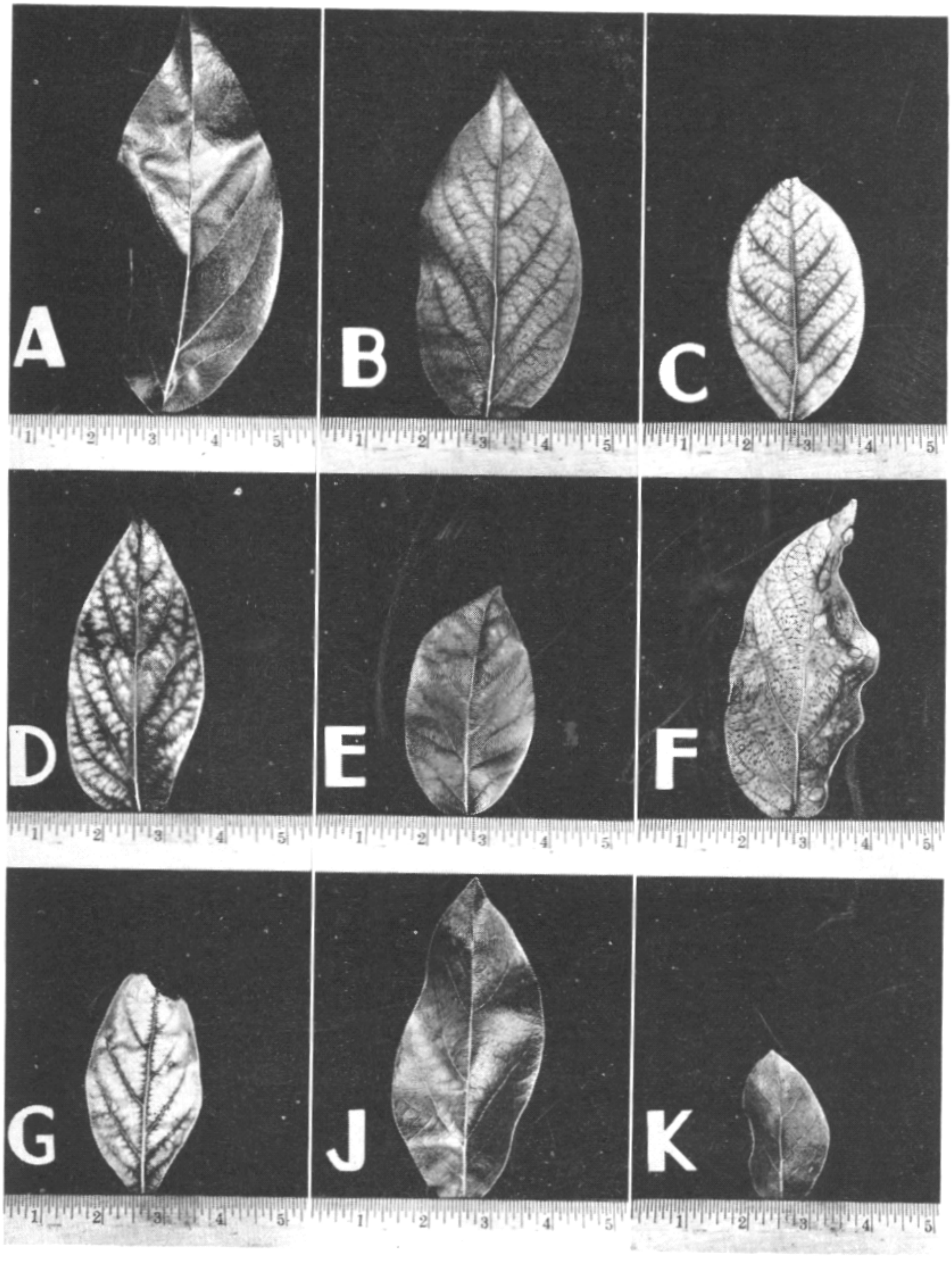

Plate 3. Taylor avocado leaves from plants grown in sand cultures and supplied with the following solutions: A, complete; B, minus magnesium; C, minus zinc; D, minus manganese; E, minus phosphorus; F, minus potassium; G, minus iron; J, Lula avocado, complete; K, low nitrogen.

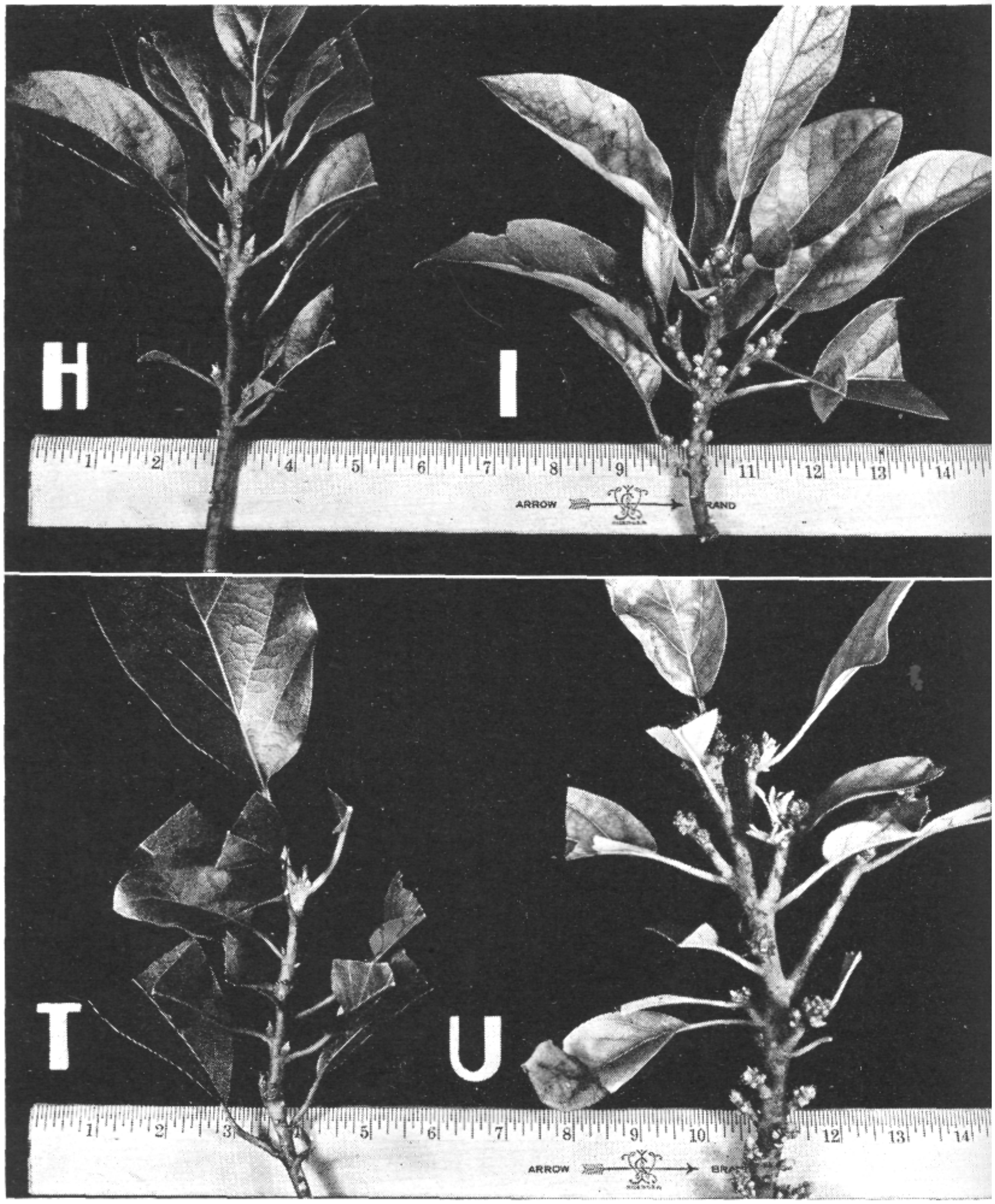

Plate 4. Taylor and Lula avocado shoots from complete and minus-boron cultures; H. Taylor, complete; I, Taylor, minus boron; T, Lula, complete; U, Lula, minus boron.