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Avocado Leaf Symptoms Characteristic of Potassium, Phosphate, Manganese, and Boron Deficiencies in Solution Cultures

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When avocado leaves are not of a healthy green color and show various symptoms, they frequently possess some peculiarities or characteristics that are of assistance in a diagnosis of the cause of the injury. In the field it is not often feasible to make such a diagnosis without having had a suitable background or training in identifying and relating the symptoms brought about by the deficiency of elements one at a time in artificial solution cultures. The results here reported are designed to be of assistance in the diagnosis of avocado leaf troubles. None of the troubles here reported and artificially produced, have as yet been seen in the field. Familiarity with the results of this study may be of some assistance, should various leaf symptoms at some time in the future make their appearance in avocado orchards.

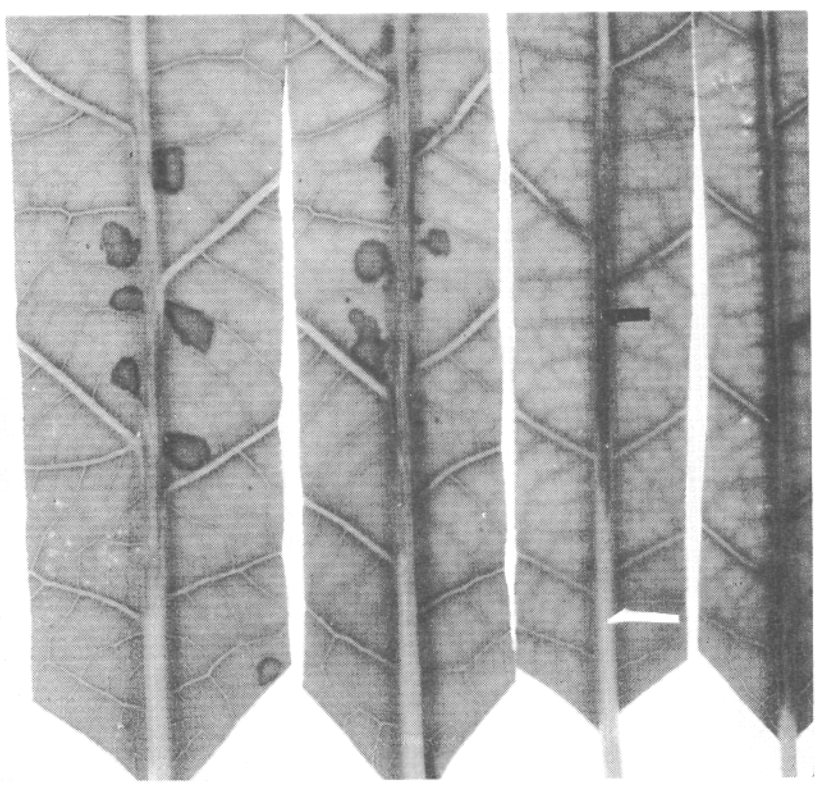

Fig. 3—Potassium deficiency in the leaves of avocado seedlings grown in culture solutions under glasshouse conditions. The leaves are shown bottom side up. The black horizontal line indicates the burning or browning of the main vein, while the white horizontal line indicates the normal healthy color in the vein. Many small scattered burned spots in the leaves are typical of potassium deficiency.

Recently it was possible to study the growth of avocado seedlings in culture solutions under glasshouse conditions where various nutritional factors could the more readily be controlled. Avocado seeds were germinated in river gravel with bottom heat in a propagation chamber where they were grown until the roots were several inches long. The seedlings were thoroughly washed with distilled water and were transferred to jars made of Pyrex glass or to glass carboys that had been cut off at the shoulder. These cultures contained 39 or more liters of nutrient solution prepared from chemically pure or re-purified c.p. salts together with distilled water In this way it was possible to eliminate one element at a time from a culture solution. The food reserves in the seed were of use in enabling the plants to attain a considerable size before the deficiency of a given element became pronounced. One point of technique which is very important should be mentioned, namely, that the pH of the solutions were all frequently adjusted to pH 4.5 by means of dilute solutions of sulfuric acid or calcium hydroxide in order to avoid having a chlorosis resulting from several other causes mask the effects of a deficiency of a single given element. The glass of each culture jar was shielded from the light by means of a light weight tar roofing paper or flat black paint covered with an aluminum-water spar varnish mixture. The cultures were covered with split glass covers on which were placed wood covers bearing adequate supports for the plants. These wood covers were coated with asphalt paint (Gilacoat) and were then coated with water-spar varnish. The seeds of the seedlings were kept barely touching the culture solutions which were frequently renewed.

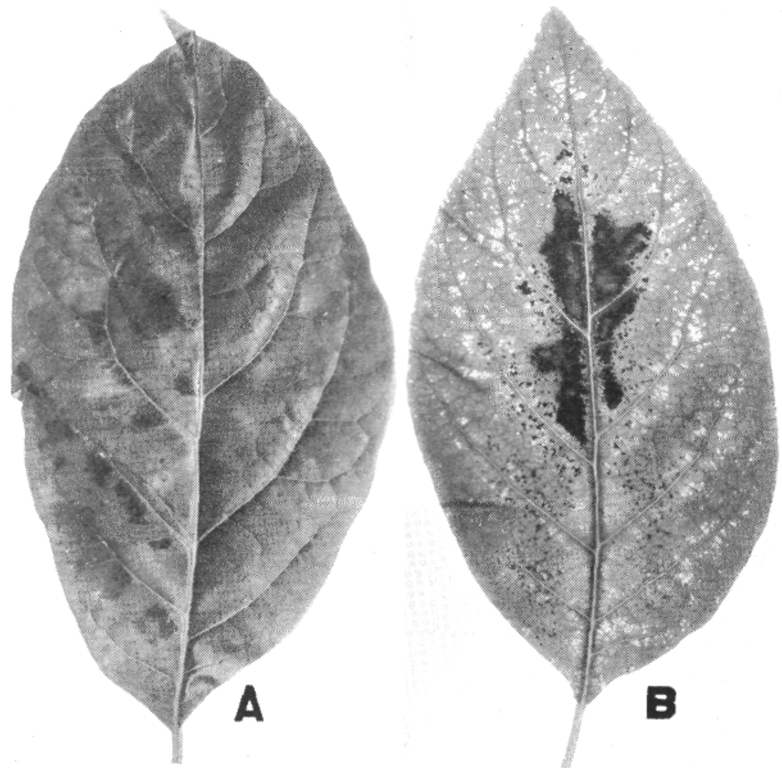

Fig. 1—Phosphate deficiency symptoms in the leaves of avocado seedlings grown in culture solutions under glasshouse conditions: A, left, Initial burning; B, right, Advanced stage of burn with the chlorophyll (green color) of the leaf becoming affected; large dark area in the center of the leaf near the midrib is a brown, burned area.

PHOSPHORUS

Figure 1A shows one of the initial stages of a phosphorus deficiency in Puebla avocado seedlings while figure IB shows an advanced stage. The burning of large portions of the leaf at most any location in the leaf is characteristic of a phosphorus deficiency. This is also true for the leaves of Valencia orange trees budded on Rough lemon or sour orange stocks and grown several years in phosphate deficient solution cultures in an out-of-door wind-protected experimental yard at the Citrus Experiment Station. These symptoms of phosphate deficiency (Haas, A. R. C., Soil Science 42:93-117, 1936; also, 42:187-201, 1936; and Bot. Gaz. 97:794-807, 1936) agree in both citrus and avocado leaves. However, in citrus a phosphate deficiency usually is also accompanied by a dull brownish green coloration in the leaves which has not as yet been sufficiently evident in avocado cultures.

In the avocado seedlings the lowermost and oldest leaves are the first to be affected. The roots generally are severely retarded but new growth continues to be put out and although old roots become dark-colored, they are alive and capable of initiating healthy growth until the deficiency is critical. New leaves may be very slow in their development and may appear as undersized leaves which then burn. When the leaf burn of avocado seedlings in the glasshouse was a general leaf burn, large in extent and not characterized by the burning of the leaf edges or leaf tips, our attention at times has been called thereby to the need of phosphate in certain cultures. The addition of phosphate was followed by a prompt recovery. Phosphate-deficiency burn differs from the burn caused by a chlorine-excess in the general distribution of the burned area, for with phosphate deficiency, large burned areas occur at almost any location in the leaf and not primarily at the tips or margins of the leaves. The chlorophyll of green coloring matter in the leaves may be seriously affected as in figure IB when the deficiency becomes pronounced. Phosphate-deficiency produces a burn in the leaf even when an adequate water supply is available, for phosphate-deficiency burn was produced in plants grown in solutions and in these solution cultures the solutions were brought daily to their original volume with distilled water. In the field it would be important to know whether there was a sufficient supply of soil moisture available, in order not to confuse leaf burn resulting from other causes with that resulting from phosphate deficiency.

POTASSIUM

In certain culture solutions the potassium was omitted and calcium was substituted for potassium. Figure 2 shows the chlorotic areas between the veins and the dropping out of portions of these affected areas. The margins of the leaves were often most irregular. This same type of injury was observed in cultures lacking magnesium. When potassium was omitted from the culture solution there were initially small scattered burned spots in the lowermost (oldest) leaves. These burned spots were usually smaller and more widely distributed than when phosphate was deficient. As shown in figure 3, the main vein in the oldest mature leaves showed burning or a brownish color when viewed from the lower surface of the leaves.

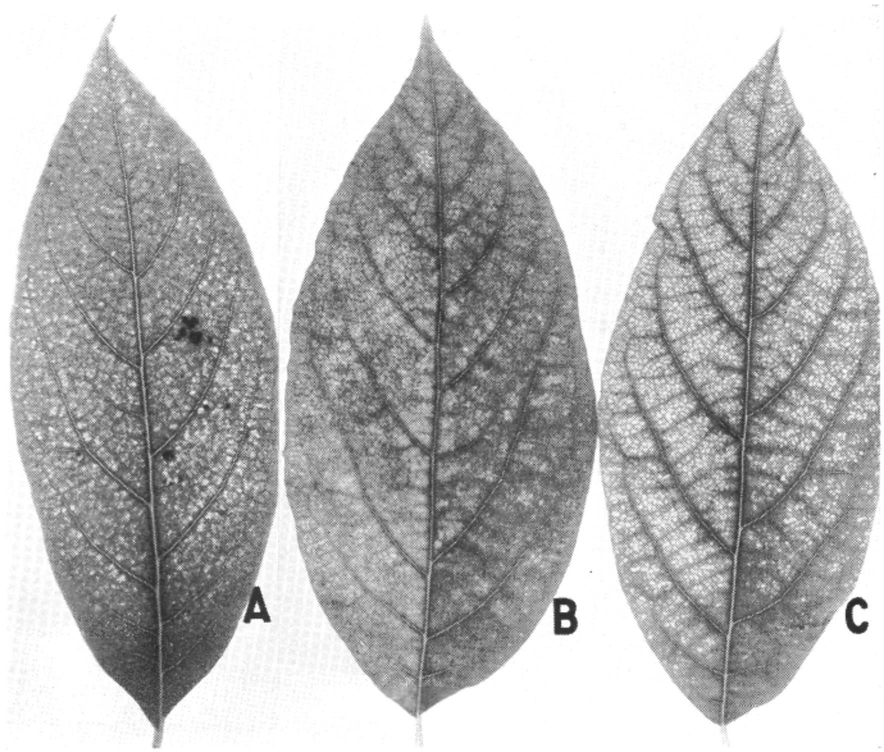

Fig. 4—Manganese deficiency in leaves of avocado seedlings grown in solution cultures under glasshouse conditions: A, Numerous small spots that may burn; B, Chlorotic spots (vein islets); C, Chlorosis nearly complete, chlorophyll (green coloring matter) present largely near the larger veins.

MANGANESE

The deficiency of manganese presents difficulties not found in studies on potassium or phosphate deficiency. The requirements of young plants for manganese are much smaller than those for the major elements. Accordingly, it was necessary to remove the manganese impurities from the so-called chemically pure salts used in preparing the culture solutions. Zinc, copper, boron, and manganese-free iron were present in the culture solution as well as sufficient hydrogen ions (pH 4.5) in order to eliminate these factors in the symptoms produced.

The effects of manganese deficiency on citrus have been studied over a long period of years under controlled conditions. Current experiments with various citrus varieties and avocado seedlings in solution cultures confirm the earlier results. A true mottle is not obtained but rather a chlorosis which in certain stages may resemble a mild or faint mottle which does not respond to zinc. Lack of response of a mottled leaf condition to zinc was observed in citrus in South Africa (Merwe, A. J. v.d. and F. G. Anderssen, Farming in South Africa, Reprint No. 107, Nov., 1937) where it was found that an excess of manganese rather than a deficiency occurred. This discovery in the field confirmed the earlier results (Haas, A. R. C., Hilgardia 6, No. 15, p. 549, 1932) with citrus in culture studies.

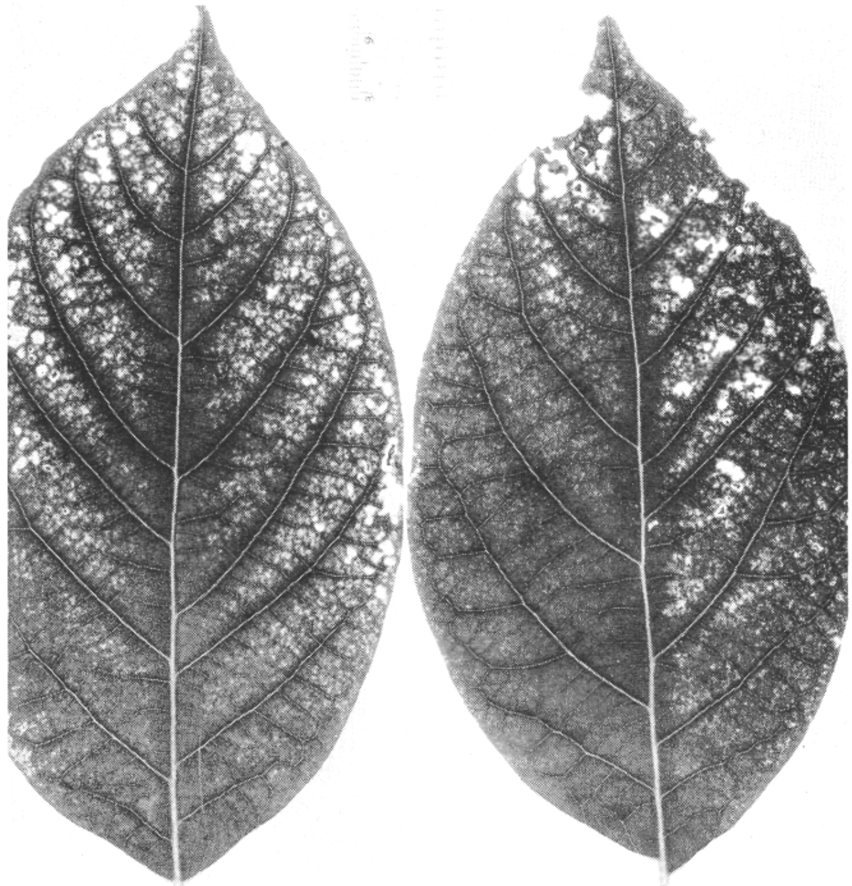

Fig. 2—Potassium deficiency in the leaves of avocado seedlings grown in culture solutions under glasshouse conditions. Some of these youngest leaves become most irregular in outline by the loss of some of the chlorotic tissue. Magnesium deficient leaves have shown a similar appearance.

In addition to the faded out type of mottle, there usually are small spots present in the leaves of citrus which are a reliable characteristic of manganese deficiency. These spots were sometimes found in green leaves known to be deficient in manganese. Yellow spots on leaves grown with a deficiency of manganese have also been reported elsewhere (Bishop, W. B. S., Australian Jour. Exp. Biol. and Med. Sci. 5 (2) :125-141, 1928). Camp and Peech in Florida have emphasized the dull appearance of the leaves and the faint mottle-type of the manganese deficiency symptoms. On a recent visit to Florida the symptoms described as being those of manganese deficiency were seen. The appearance of the leaves is well illustrated by Camp, A. F., and M. Peech (Proc. Amer. Soc. for Hort. Sci. 36:81-85, 1938) and the illustration coincides well with what are considered to be manganese deficiency symptoms in Florida, although the illustration bears certain faint resemblances also to magnesium and phosphate deficiencies. No spots were found. It is hardly likely that manganese deficiency in Florida is very mild everywhere the deficiency occurs at all; rather it is to be expected that at some location very severe deficiency symptoms would also be found. However, thus far these manganese-deficiency leaf spots have not been reported from Florida. Under glasshouse conditions at Riverside all stages ranging from fully green leaves with spots to faintly mottled leaves in all phases of chlorosis with spots or gummy spots were found on shoots produced from healthy appearing branches of cuttings in manganese-free culture solutions. The addition of traces of manganese to the culture solution were followed by the production of healthy green leaves. The manganese deficiency symptoms produced by Chapman, Liebig, and Parker (California Citrograph 24, No. 12, pp. 427 and 454, 1939) conform more closely to the results previously obtained (Haas, A. R. C., Hilgardia 7, No. 4, pp. 181-206, 1932; and Soil Sci. 42, No. 6, pp. 435-443, 1936) than to those of orange leaves seen in Florida. Haas found manganese concentrations ranging from 1.3 to 3.3 p.p.m. in the dry matter of manganese-deficient lemon leaves while Chapman, Liebig, and Parker have since confirmed these results when they reported having found 2 to 4 p.p.m.

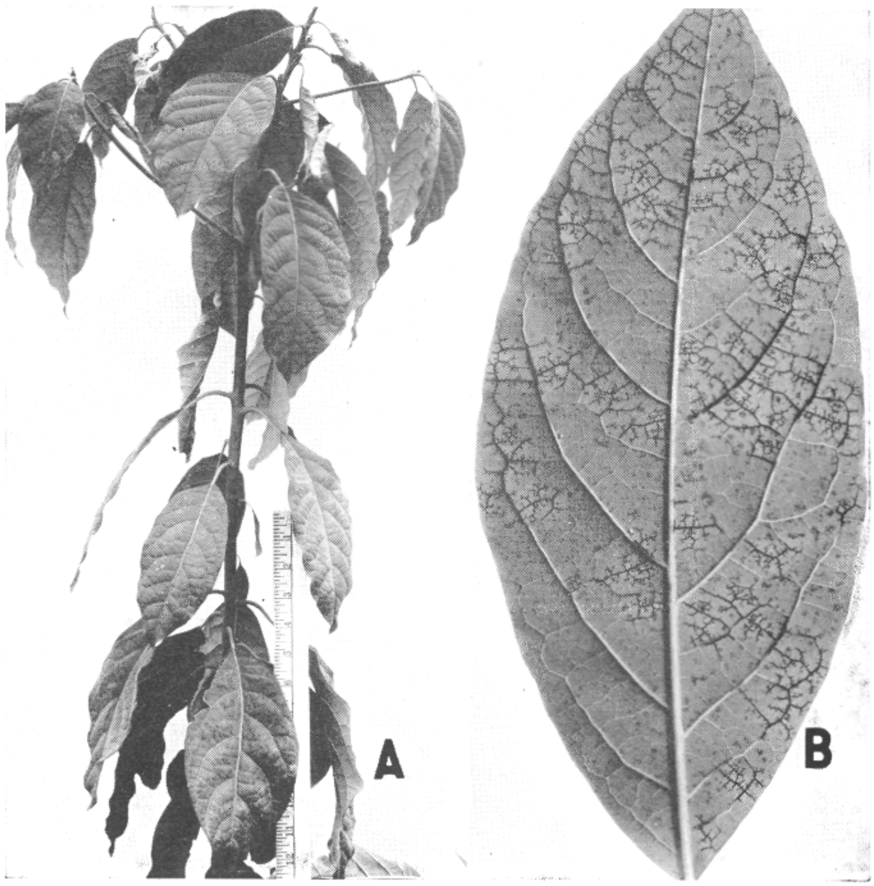

Fig. 5—The effects of a boron deficiency in the culture solution on the growth of an avocado seedling: A, Injury or death of shoot tips and drying up of leaves; B, splitting and corky appearance of veins as seen on the lower surface of an affected leaf.

The content of a given element in leaves may vary from one season to another very markedly because of other factors than the soil. Alternate bearing is one of the chief factors interfering with the establishment of critical values of an element for a diagnosis of various deficiencies. (Lilleland, O and J. G. Brown, Proc. Amer. Soc. Hort. Sci. 36:91-98, 1939; and Cameron, S. H. and G. Borst, Proc. Amer. Soc. Sci. 36:255-258, 1939.)

Haas also found that the absorption of iron, while not prevented by the lack of manganese, was frequently lower in manganese-deficient than in healthy green leaves. Iron and manganese appeared to be related in their effects on plants. That manganese is not involved in the true mottled condition of citrus leaves curable with zinc is seen in results (Haas, A. R. C., Hilgardia 6, No. 15, p. 546, 1932) that showed no difference in the manganese content of healthy and mottled orange leaves.

Figure 4 shows some of the stages through which the leaves of avocado seedlings pass when manganese is deficient. A, shows light colored spots which, as in citrus leaves, may burn; B, shows the tendency for the leaves to become chlorotic and for the areas bounded by the smallest veins (vein islets) to become yellowish; while C finally shows only the larger veins as having much green color adjacent to them, the leaves having become nearly chlorotic. In more advanced stages the yellow spots may gum or burn and the green color may almost entirely disappear from the leaves.

Manganese deficiency is usually associated with marl or soils of high pH and has been reported as being related to oxidation and reduction in soils. Manganese-deficiency spots may occasionally be seen especially in lemon leaves in the field in the early spring cycle when the growth is somewhat chlorotic. In such cases the soil may be unduly wet from the winter rains, the nitrogen may be low and the soil may be high in calcium carbonate. High moisture content in soils materially increases the pH values. Subsequent cycles of growth may be healthy once the soil conditions have been corrected or rather have corrected themselves.

BORON DEFICIENCY

In conducting boron-deficiency experiments with citrus, it was found that there was a tendency for the leaves to show spots and a splitting of the veins and in severe cases a splitting also occurred in the twigs. Gum was found to occur in the peel of the fruit or in the central core and the fruits were hard and irregular in shape. The shoot tips were affected and failed to grow, new growth originating, if at all, from points back of the shoot tips. The leaf vein disturbance in artificial cultures with citrus has not been associated as yet with boron-deficiency as it occurs in citrus in the field in South Africa. However, no difficulty is had in producing leaves with affected veins when boron is omitted from citrus, walnut, or avocado solution cultures grown in the glasshouse or in the open top experiment yard.

Figure 5A shows an avocado seedling in a solution culture in which boron has been omitted. There was a cessation of growth at the shoot tips and many of the young leaves in other such cultures were badly dwarfed or deformed or burned severely while very young. Leaves are seen in figure 5A as having become dry and curled while other nearby leaves are fully expanded. When boron is supplied in trace amounts (0.1 p.p.m. or less), new growth soon is started from buds located back somewhat from the tips of the shoots or back on the trunk itself. Splits, one-half inch or more in length in the shoots or trunk of boron deficient cultures frequently come to our attention and have been photographed. These splits may gum somewhat or may heal over again. Eruptions (blister like) have been seen on some of the twigs. Later it is hoped to study the effects of boron deficiency in avocado fruits.

Figure 5 B shows an avocado leaf bearing marked symptoms as a result of a boron deficiency in the culture solution. The underside of the leaf is shown in the photograph. Splits or cracks appear in the midrib or in the other large veins. The leaves feel somewhat brittle on being crushed.

The symptoms described for the deficiency of the four elements, phosphorus, potassium, manganese, and boron, should prove of greater interest as more of the facts become known.