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# TOTAL SULPHUR CONTENT AND ITS EFFECT ON AVOCADO LEAVES

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***SUMMARY***

Fertilizers, irrigation waters, and soil areas frequently contain sulfates in considerable amounts that are readily absorbed by avocado roots from the soil solution. The element sulfur, -while considered essential for plant growth, may become injurious when present in excessive amounts in plant tissue. By means of sand and soil cultures, it was shown that excessive concentrations of total sulfur in avocado leaves resulted in a loss of green color and severe marginal leaf burn. The leaf content of magnesium tended to increase to varying degrees, as the concentration of calcium sulfate in the nutrient solution or soil mixture increased the content of calcium and total sulfur in the leaves. Leaves affected by excessive total sulfur (determined as total $SO_4$) accumulation are frequently found in orchard trees where the additional effects of other injurious elements such as sodium and chlorine intensify further the leaf damage. The elimination of sulfur-containing materials as far as possible from an avocado orchard, unless nutritional sulfur-deficiency or a high pH occurs, should benefit avocado tree response.

An inorganic element such as sulfur is considered essential in small amounts for the growth of most plants and is undoubtedly necessary for healthy growth in avocado trees. When, however, a large or an excessive concentration of sulfur-products occurs in the leaves of avocado trees, the leaves lack the appearance of health.

Use is commonly made of calcium sulfate in order to secure an improvement in the drainage of certain soils. Frequently soil areas are impregnated with high concentrations of sulfates. Irrigation waters may contain high concentrations of sulfates and in many cases sodium may be relatively low and calcium very high, and it is in such cases that the high content of calcium sulfate is often too lightly regarded. Calcium sulfate has a relatively high solubility and is readily absorbed by avocado roots.

Preliminary tests were first conducted with sand cultures in order to determine the effects of calcium sulfate on the growth and composition of avocado seedlings. A Topa Topa (Mex.) avocado seedling was planted out-of-doors on May 1, 1951, in each of three-gallon-capacity well drained sand cultures. The nutrient solution consisted of distilled water containing (ppm): K, 185; Mg, 102; $SO_4$, 21.6; $NO_3$, 718; and $PO_4$, 105, respectively. A concentration of 0.2 ppm of boron, manganese, zinc and iron, 0.25 ppm copper and 3 ppm aluminum constituted the minor elements used. Calcium was added to the nutrient solution in the form of $CaSO_4.2H_2O$ in order to obtain the following

concentrations of calcium: 0, 20, 40, 60, 80, and 159 ppm, respectively, whereas with the 21.6 ppm sulfate in the base nutrient the ppm of sulfate applied in the nutrient ranged from 21.6 to 403.2, the same as shown in table 1 for a second experiment.

The calcium concentrations found in the dry matter of the mature leaves when harvested on January 20, 1953, were: 2.008, 2.213, 2.462, 2.576, 1.719, and 1.665 per cent, respectively, whereas the magnesium percentages were: .641, .650, .833, .874, .725, and .643 per cent respectively. At the two highest calcium sulfate concentrations, the percentages of calcium and of magnesium decreased in the dry matter of the leaves. It was observed that although the concentration of magnesium in the applied nutrient solution was the same for each culture, the percentages of magnesium tended to be increased to a certain extent by the increased calcium sulfate. The leaves at the low calcium and low sulfate range were burned, perhaps from the low calcium supply, whereas in the higher calcium range the leaves also were burned, perhaps from the high sulfate range.

This injurious effect of an increase in the sulfate supply in this out-of-door experiment warranted a repetition of the experiment with cultures in the glasshouse where better control of climatic factors could be obtained. A Topa Topa (Mex.) avocado seedling - was planted in each of five three-gallon capacity crocks of sand (provided with drainage). The cultures were grown from October 18, 1951, to March 18, 1953.

The nutrient solution contained (ppm): K, 185; Mg, 59.4; Na, 80; $SO_4$, 21.6; $NO_3$, 718; and $PO_4$, 105, respectively. The solution also contained 0.2 ppm boron, manganese, zinc, and iron, 0.25 ppm copper, and 3 ppm aluminum, respectively. To this nutrient was added the following concentrations of calcium in the form of $CaSO_4.2H_2O$: 0, 20, 40, 80, and 159 ppm, respectively, which produced a total sulfate content of 21.6; 69.6, 117.6, 213.6, and 403.2 ppm, respectively, (table 1). At the 80 ppm Ca and 213.6 ppm $SO_4$ the growth of the seedlings showed an increased growth, but the leaves showed a severe loss of green color and the appearance of considerable margin leaf-burn.

Table 1

Concentrations of calcium and sulfate in the nutrient solutions applied to Topa Topa (Mex.) avocado seedlings in 3 gallon capacity sand cultures and their effect on plant growth and leaf composition.

| Total in the applied nutrient | | Leaves, fresh wt., gms. | Trunk, fresh wt., gms. | Roots, dry matter, gms. | Per cent in dry matter of leaves | | |
|---|---|---|---|---|---|---|---|
| Ca | $SO_4$ | | | | Ca | Mg | Total S as $SO_4$ |
| 0 | 21.6 | 96 | 68 | 30 | 1,223 | .458 | .171 |
| 20 | 69.6 | 92 | 66 | 36 | 1.416 | .624 | .249 |
| 40 | 117.6 | 93 | 87 | 36 | 2.122 | .759 | .316 |
| 80 | 213.6 | 117 | 112 | 68 | 2.028 | .742 | ,314 |
| 159 | 403.2 | 93 | 86 | 56 | 1.738 | .714 | .312 |

Table 1 shows the percentages obtained from duplicated determinations of Ca, Mg, and total S as $SO_4$ in the dry matter of the leaves at the termination of the experiment, and shows the percentages as increasing in the first three cultures. As the leaves matured in each culture, there was some loss of color and marginal-burn even at the lowest

concentration used, probably again the result of calcium deficiency, plus the absorption of sodium and in the higher concentrations (figure 1) probably from excessive sulfate, the sodium absorption, and these coupled with the possible effect of concentration of the nutrient solution. In table 1, the percentages of total S as $SO_4$ in the dry matter of the leaves remained steady once the 40 ppm Ca and 117.6 ppm $SO_4$ concentration in the applied nutrient solution was exceeded.

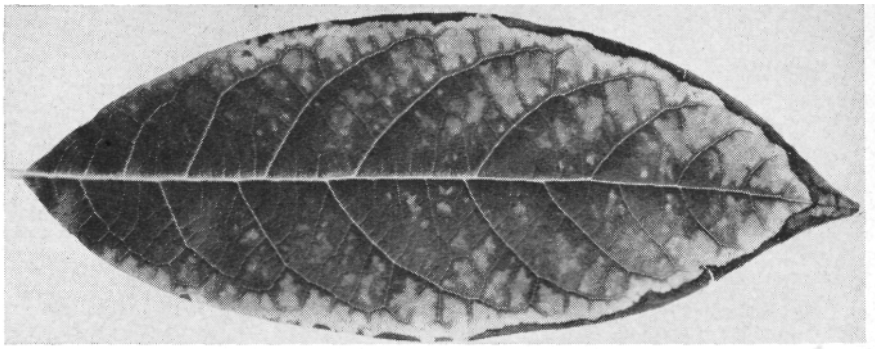

Fig. 1. *Effect of high sulfate concentration in sand cultures on the loss of green color in avocado leaves and the extent of marginal leaf burn.*

In order to eliminate most of the several nutrient factors that possibly affected the sand cultures was the final use of well drained soil cultures with various percentages of calcium sulfate ($CaSO_4.2H_2O$) mixed with the soil and the uniform application of the same nutrient solution to each culture. Two-gallon capacity crocks were used and a Caliente (Mex.) avocado seedling was planted in each soil culture of one group and a Hass (Guat.) avocado seedling was planted in each soil culture of a second group. The cultures were grown in the glasshouse from April 15, 1952, to January 21, 1953, without the addition of minor elements. The nutrient solution consisted of 1.5 times the amount of stock solutions A, B, and C used in Hoagland's nutrient solution or: K, 276; Mg, 81; Ca, 239; Na, 11; $NO_3$, 1078; $SO_4$, 324; $PO_4$, 158; and Cl, 15 ppm, respectively. This is a nutrient solution which when applied to soil cultures had resulted in excellent growth of avocado seedlings.

Only the mature and lowermost leaves that never were in contact with the nutrient or soil solution were collected for chemical analysis. Beginning at the 12.5 per cent calcium sulfate-soil mixture, the mature leaves began to show a loss of green color in the leaves of both the Caliente (Mex.) and Hass (Guat.) avocado seedlings. The severity of the injury increased at the higher concentration-soil-mixtures as shown in figure 2.

Table 2

Effect of various concentrations of calcium sulfate ($C,SO_4.2H_2O$) in soil cultures upon the growth and the average of duplicate determinations of leaf composition of Caliente (Mex.) and Hass (Guat.) avocado seedlings grown with similar nutrient applications.

| Culture No. | $CaSO_4.2H_2O$ mixed with culture soil (per cent) Caliente (Mex.) | Hass (Guat.) | Trunk length (inches) Caliente (Mex.) | Hass (Guat.) | Per cent in dry matter of leaves Caliente (Mex.) Ca | Mg | Total S as $SO_4$ | Hass (Guat.) Ca | Mg | Total S as $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 57 | 58 | 1.405 | .520 | 0.397 | 2.311 | .658 | 0.462 |
| 2 | 6.25 | 6.25 | 59 | 44 | 2.412 | .642 | 1.137 | 2.530 | .720 | 1.148 |
| 3 | 12.5 | 12.5 | 65 | 84 | 2.393 | .576 | 1.775 | 2.762 | .836 | 1.373 |
| 4 | 25.0 | 25.0 | 60 | 36 | 2.624 | .644 | 1.298 | 2.328 | .622 | 1.008 |
| 5 | 37.5 | | 39 | | 2.571 | .694 | 0.440 | | | |
| 6 | 50.0 | 50.0 | 51 | 49 | 2.895 | .788 | .0.595 | 2.180 | .682 | 0.715 |
| 7 | 62.5 | 62.5 | 58 | 3 | 2.515 | .833 | 0.723 | 2.274 | .729 | 0.602 |

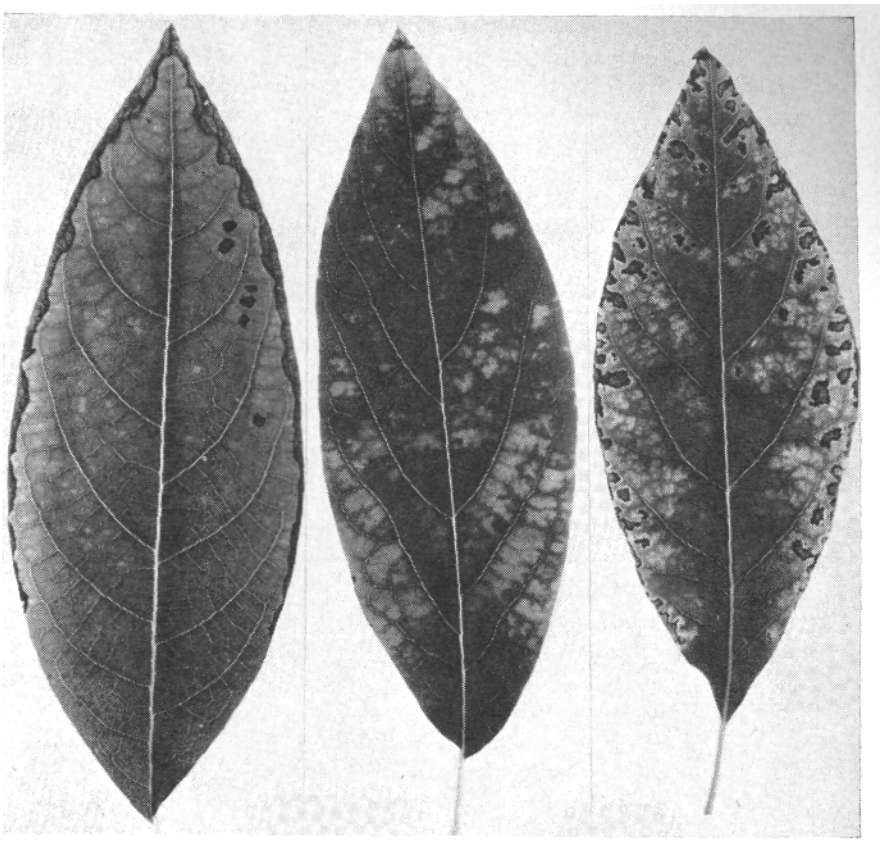

Fig. 2. *Effect of high concentrations of sulfate (as $CaSO_4.2H_2O$ mixed with the soil) upon the loss of green color and accompanying burn in the leaves of Caliente (Mex.) and Hass (Guat.) avocado seedlings. Injury began at the 12.5 per cent calcium sulfate concentration in both sets of cultures. Left to right: Caliente, Caliente, and Hass avocado leaves, respectively. Photo taken October 2, 1952.*

In table 2, the trunk growth of the Caliente (Mex.) avocado seedlings generally was not interfered with by the mixing of $CaSO_4.2H_2O$ with the soil prior to planting and the

application of an excellent nutrient solution accompanied by good drainage. With the Hass (Guat.) avocado seedlings, the trunk growth was by far the best in the control culture No. 1 in table 2.

With no calcium sulfate mixed with the soil (culture No. 1 in table 2) the dry matter of the leaves of the Caliente (Mex.) avocado seedling contained a relatively lower Ca, Mg, and total S as $SO_4$ content than the dry matter of comparable leaves of the Hass (Guat.) avocado seedling. At the 12.5 per cent calcium sulfate-soil mixture, the dry matter of the leaves of the Hass (Guat.) avocado seedling contained its maximum content of Ca, Mg, and total S as $SO_4$ whereas with the Caliente (Mex.) avocado seedling, only the total S as $SO_4$ percentage had reached its maximum. The higher percentages of calcium sulfate-soil mixtures did not appear to appreciably retard the Caliente (Mex.) avocado leaf absorption of calcium and considerably increased the absorption of magnesium as seen in table 2.

The maximum total S as $SO_4$ values shown in table 2 for avocado soil cultures are not unlike those frequently found in leaves of avocado trees grown under orchard conditions and there is a close resemblance between the leaf-burn and loss of green color produced in these soil cultures and in leaves seen in the field.

For example, in the Santa Paula area, the dry matter of avocado leaves of the Rincon (Hyb.) variety showing severe leaf burn (tip and marginal) and loss of green color was found to contain 1.371 per cent of total S as $SO_4$. Similarly in the same area, leaves badly affected as above and of the Hass (Guat.) variety contained 1.202 per cent of total S as $SO_4$ in their dry matter. The severe tip burn which *is* an additional symptom in these leaves was no doubt the result of a content of 0.345 per cent of chlorine in the dry matter of the Rincon (Hyb.) avocado leaves and 0.493 per cent of chlorine in the dry matter of the Hass (Guat.) avocado leaves.