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THE EFFECTS OF SODIUM ON MATURE AVOCADO TREES

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Although there is descriptive information on visual leaf symptoms and leaf analysis in relation to excesses of soil salinity and alkali (exchangeable sodium), there is no background information which comes from actual experiments carried out with mature trees. The information at hand stems primarily from short-term experiments with seedlings or cuttings under greenhouse conditions (1, 5, 6, 7, 8). In order to have salinity and alkali criteria for evaluation of mature trees, the authors undertook a series of long-term experiments with grafted avocado trees using large outdoor sandcultures. Initially, we investigated the influence of substrate chloride. Observations were made of water relations, chloride uptake and accumulation, resultant leaf symptoms and mineral content, and of fruit production. These results have been discussed in recent articles in the California Avocado Society Yearbooks (3, 4). After the chloride study, the experiment was modified to examine the effects of low to excessive concentrations of sodium in the substrate on bearing avocado trees. The results of this experiment serve as a basis for the present article on sodium injury.

Experimental Procedure

Only a brief description of the sandcultures will be given at this time since details of the facilities and technique used have been published in earlier issues of the California Avocado Society Yearbook (3, 4). Hass avocado trees (Mexican rootstock) were planted (bare root) in large sandcultures, where they were maintained under uniform, complete nutrition conditions for 2 years. Differential chloride treatments were subsequently imposed and maintained for 4 years. These trees were then placed back on uniform, complete nutrition treatment for approximately six months during which time the trees completely recovered from the chloride treatments. At this time, fall 1968, the trees were placed under variable sodium treatments in order to have trees under sodium stress available for observations of sodium uptake and accumulation, development of visual injury symptoms, and characteristics of fruit production. These observations were made over an 18 month period.

Treatments consisted of 4 nutrient solutions replicated 4-fold which were uniform in content of nutrients and total salts and had different SAR values (0, 4, 8, and 12). The SAR value is calculated as follows:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

with all concentrations in meq/l.

Irrigating the avocado trees in the sandcultures with the different nutrient solutions (with SAR ranging from 0 to 12 and sodium concentrations of 0, 12.5, 20.0, and 24.0 meq/l.) thus permitted observations of trees under a range of sodium stress, which in this experiment could be tied to the SAR value. Further, the SAR value can be used to predict the exchangeable sodium percentage (ESP) of soils irrigated with waters of known SAR values. Sodium sensitive plants, such as most tree crops and, in particular, the avocado tree, are injured by sodium when the soil within the root zone contains an ESP value above 4-6%. Hence, response of the sandculture trees under variable SAR treatment is comparable to that observed with trees under field conditions with soil ESP levels of 0, 4, 8, and 12. See the U.S.D.A. Handbook 60 (9) for further discussion of SAR-ESP relations.

Following initiation of differential SAR treatment in November 1968, leaf samples were collected every month for chemical analysis. When possible, only the most recently matured leaf was analyzed. Root samples were collected several times before the onset of leaf injury symptoms. Fruit samples were taken in March 1970 after the trees had been under differential treatment for 15 months to determination of oil content.

Results and Discussion

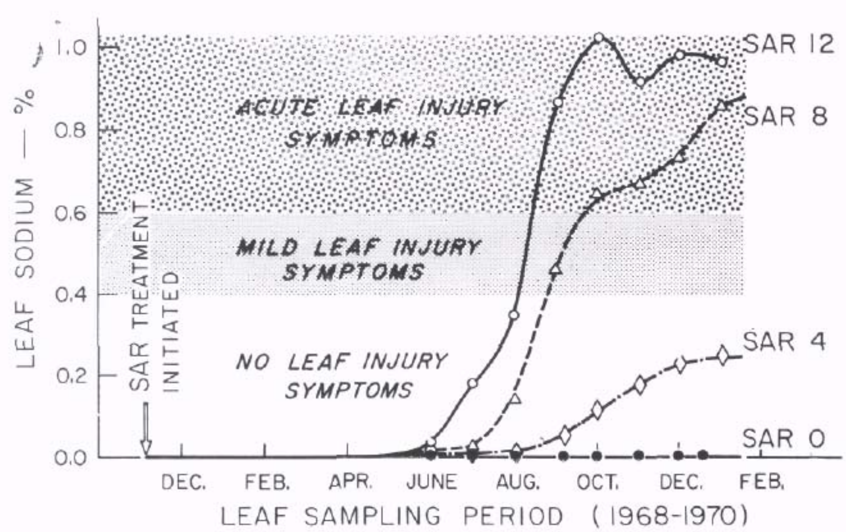

Figure 1. Sodium content of the most recently mature leaf in relation to sampling period and substrate SAR level, and degree of visual injury symptoms (leaf necrosis) associated with treatment or leaf analysis.

Figure 1 shows the accumulation pattern of sodium, as judged by the content of sodium in the leaf in relation to sampling period and SAR treatment. Although SAR treatments were imposed upon the trees in November 1968, sodium did not begin to accumulate in leaf tissue until late spring, 1969. Beginning in June 1969, leaf analysis reflected sodium accumulation which increased to approximately the 1% level for the trees under the SAR 12 treatment. The SAR-4 and -8 treatments produced maximum leaf levels of 0.25% and 0.86% Na, respectively. Severe leaf necrosis and defoliation was observed with the SAR-8 and -12 treated trees, demonstrating that these SAR values were excessive and highly toxic. No injury as judged by leaf burn was detected in the trees irrigated with either the SAR 0 or the SAR 4 solution.

Although little sodium accumulated in the leaves before June 1969, the roots readily accumulated sodium. Root analysis of samples collected in April from trees under SAR-0, -4, -8, and -12 treatments were, respectively, 0.10, 0.56, 0.61, and 0.55% Na. By June 1969, the roots of the same trees contained 0.20, 0.78, 0.80, and 0.95% Na, respectively. The rapid accumulation of sodium in the roots noted above suggests that accumulation of sodium attains a critical level before substantial amounts appear in leaf tissue.

Several conclusions may be drawn from the leaf analysis data plotted in figure 1. Leaf sodium contents of 1 % or higher unquestionably are associated with severe sodium injury, profuse leaf necrosis and defoliation. Possibly 0.4 to 0.5% Na in the leaf is the level associated with a positive but mild development of leaf burn. Values less than 0.2 to 0.3% Na appear to be safe in that trees with leaves containing this amount did not exhibit visual injury symptoms.

Also the sandculture study is highly useful in providing criteria for evaluating SAR values. Apparently, nutrient solutions and probably irrigation waters with SAR values of 8 or higher pose a sodium hazard to the tree. This conclusion is consistent with the results of earlier experiments with avocado seedlings in soils with variable sodium levels (8). Additional background information has been published by Ayers and associates (1, 2), and Haas (5, 6, 7) in the California Avocado Society Yearbook which may be referred to for supporting evidence regarding the avocado tree's sensitivity to sodium.

Fruit production after one season of being under variable sodium treatment (SAR) was eliminated from trees under SAR 8 and SAR 12 treatments. These treatments were obviously severely damaging to the trees, producing profuse leaf burn, high leaf contents of Na (0.8-1.0% Na), followed by defoliation. All fruit was shed by the trees at the onset of leaf defoliation. However, the SAR 0 and SAR 4 treated trees appeared to be normal in all respects; hence we were able to sample fruit in March 1970 from the surviving trees (4-SAR 0 trees and 4-SAR 4 trees) for determination of oil content, and physical characteristics (shape, size, weight, etc.). At time of harvest, the trees had been under SAR treatment for approximately 18 months. No differences were noted in the fruit except for their oil content. Fruit from the SAR 4 treated trees contained substantially higher oil contents than that picked from the control trees (SAR 0). For example, the mean oil contents for the SAR 0 and SAR 4 trees were 15.25% and 18.80%, respectively. While these observations are limited to one season's harvest, they are in agreement with observations of oil content of trees under chloride stress (3, 4). Apparently salt stress, be it from salts in general or from its components such as chloride, sulfate, sodium, etc., hastens maturation of the fruit resulting in higher oil content. There are limits though, above which salt stress is destructive. However, these impressions or conclusions are speculative. Obviously the matter of response of the avocado tree to saline and alkali conditions is only partially understood and considerably more research is needed to establish the spectrum of growth characteristics.

Conclusions

The avocado tree is highly sensitive to sodium. Irrigation waters with SAR values in excess of 4 should be considered hazardous. Soils with exchangeable sodium above 4 to 5% likewise should be considered as having excessive sodium. Leaf levels about 0.4-0.5% are indicative of injury. Sodium levels above 1% are extremely high, definitely indicative of acute sodium toxicity.

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