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CHLORIDE INJURY TO HASS AVOCADO TREES: A Sandculture Experiment

F. T. Bingham and L. B. Fenn
Professor of Soil Science and Graduate Student, respectively.
University of California, Riverside.

Successful management of avocado orchards in California is complex, demanding thoughtful attention to a host of important operations including that of irrigation and salinity management. A thorough knowledge of tree response to soil moisture and salinity is essential for the development of a realistic management practice because of the avocado tree's extraordinary sensitivity to salinity. The present paper illustrates the hazards caused by excessive chloride; specifically the report contains information on the significance of maintained chloride levels within the root zone, leaf contents and tree response including a limited amount of observations on fruit production. The discussion represents a progress report of a long-term outdoor experiment with Hass avocado trees.

Experimental Procedure

Hass variety avocado trees (one year from graft and on Mexican stock) were transplanted from a commercial nursery in San Diego County to the sandcultures at University of California, Riverside. Each unit (figures 1 and 2) consisted of a large concrete tank, 36" diameter and 40" length, filled with sand to support the transplanted tree, and a second tank counter-sunk in the ground adjacent to the sand tank. The lower tank served as a nutrient solution reservoir. By means of an electric timer, pump, pipe, and a manifold for each unit, irrigations were readily executed as scheduled. The excess solution percolated down through the sand back into the reservoir. In practice, the pumps were regulated to pump 15 minutes at 5 gpm, 3 times a day. Each unit contained a large wind break on the north side. Twenty complete sandculture units were used.

After growing the trees on uniform and complete nutrient solutions for two years, differential treatments of chloride were incorporated into the experiment. After some adjustments based upon preliminary tree response, treatments of 0, 5, 10, 15, and 20 me chloride per liter (me Cl/l) were applied with 4 tree replication. The treatments were made by adding sufficient chloride salts to nutrient solutions which were adjusted to the same total salinity after receiving the chloride salts. As example, the electrical conductivity of all solutions was approximately 3.0 mmhos/cm while the chloride varied from 0 to 20 me/l.

All solutions were renewed every 60 days as a standard practice to prevent a significant depletion in concentration of the components. In between solution changes, the volumes were maintained by frequent additions of deionized water.

Results and Discussion

The principal results of the sandculture experiment are presented in Table 1. General tree response to excessive chloride is illustrated in Figure 3. Leaf symptoms are illustrated in Figure 4.

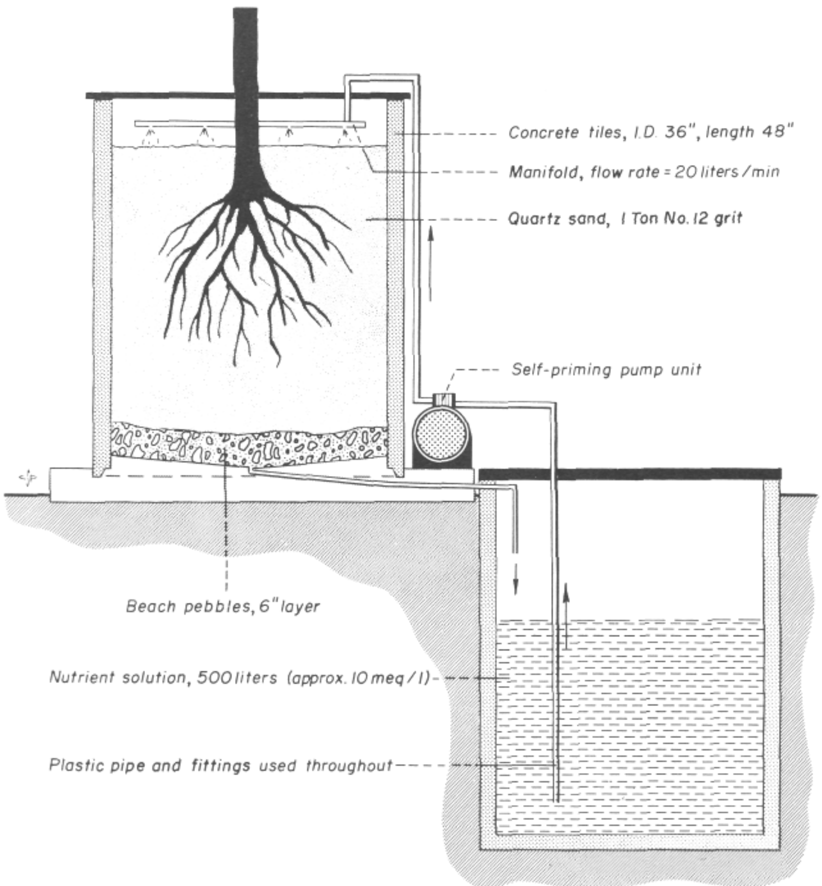


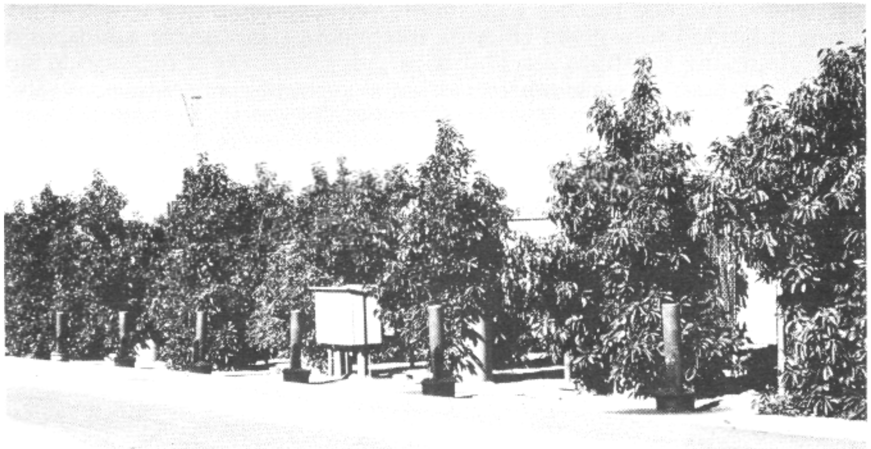
Figure 1. Sketch of the sandculture. Initially all trees were transferred from a commercial nursery to the sandcultures where they were maintained for 2 years on uniform and complete nutrition prior to receiving differential chloride treatments.

TABLE 1. Response of Hass avocado trees to maintained concentrations of chloride in sandcultures (all solutions have some osmotic pressure)

	Substrate Leaf*	Leaf Injury	Trunk Diameter	Growth 1965 Fruit	Relative water uptake
me/l	%Cl		inches	lbs tree	%
0	0.005-0.010	none	4.25	33	100
5	0.15-0.20	none to very	3.66	9	77
10	0.35-0.40	slight	3.34	18	63
15	0.50-0.70	moderat severe	3.25	15	51
20	1.40-1.60	severe	2.96	9	48

* 5-8 month old spring cycle leaf.

Figure 2. Hass avocado trees at 1961 and 1965.



Chloride Absorption: Usually soil salinity builds up throughout the irrigation season, reaching maximum concentration during the early fall months, and of course, winter rains tend to leach the soil. In addition to the above influence, irrigation practices may moderate or intensify salinity; the net result often being fluctuating soil salinity conditions. Thus, at times, the tree may be exposed for relatively short periods to excessive levels of soil salinity. Information on tree responses to soil salinity should include rate of uptake in order for an evaluation of a fluctuating salinity level. For example, Figure 5, a plot of leaf chloride versus period of exposure to chloride in the solution culture, shows that uptake is rapid and reaches a maximum value within 2 to 3 weeks of first being subjected to a given chloride treatment. Also, further additions of chloride to the substrate resulted in an additional rapid increase in uptake. The above data are representative of substrate concentrations ranging from 10 me Cl/l to 15.0 me Cl/l. Similar relations were observed for more dilute chloride concentrations in the substrate. Hence, the grower should attempt to maintain low soil salinity (chloride) throughout the irrigation season. Salt build up in the root zone even for short periods of time, say 2 to 3 weeks, would result in injurious quantities of chloride moving into the plant.

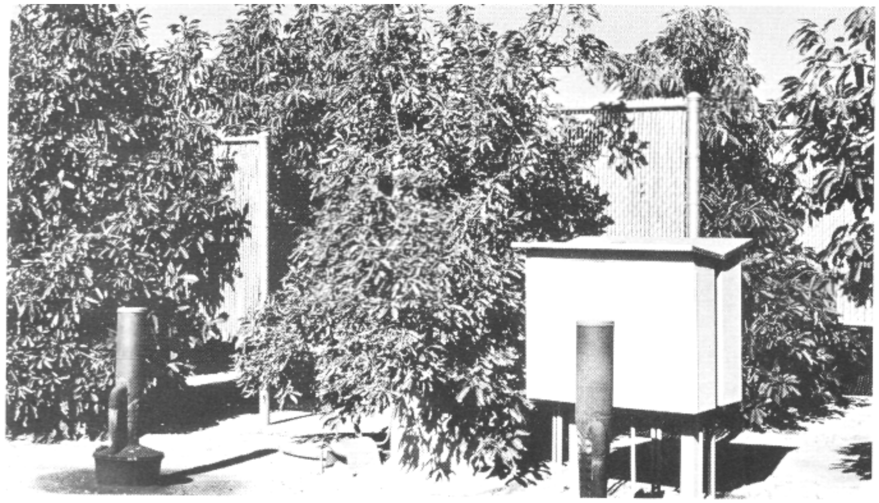


Figure 3. Prolonged effects of high chloride waters on Hass avocado tree growth and appearance. Center tree contains leaf Cl values of 1.2 to 1.5%, shows considerable leaf tip and margin burn and early leaf drop.

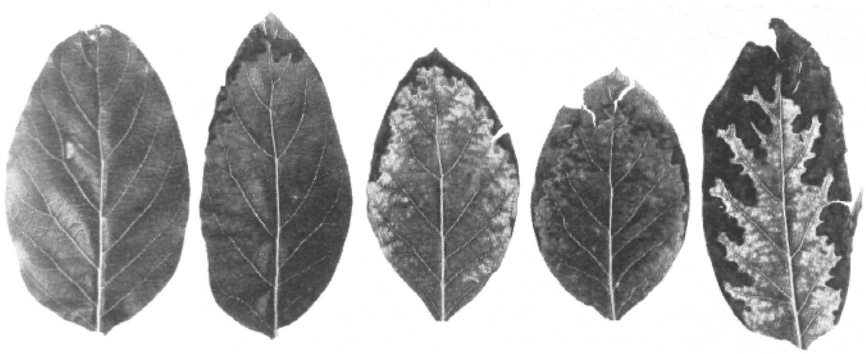


Figure 4. Slight to severe necrosis due to increasing chloride. Progression of symptom is chlorosis to necrosis or margin and tip burn. Hass variety avocado tree leaves.

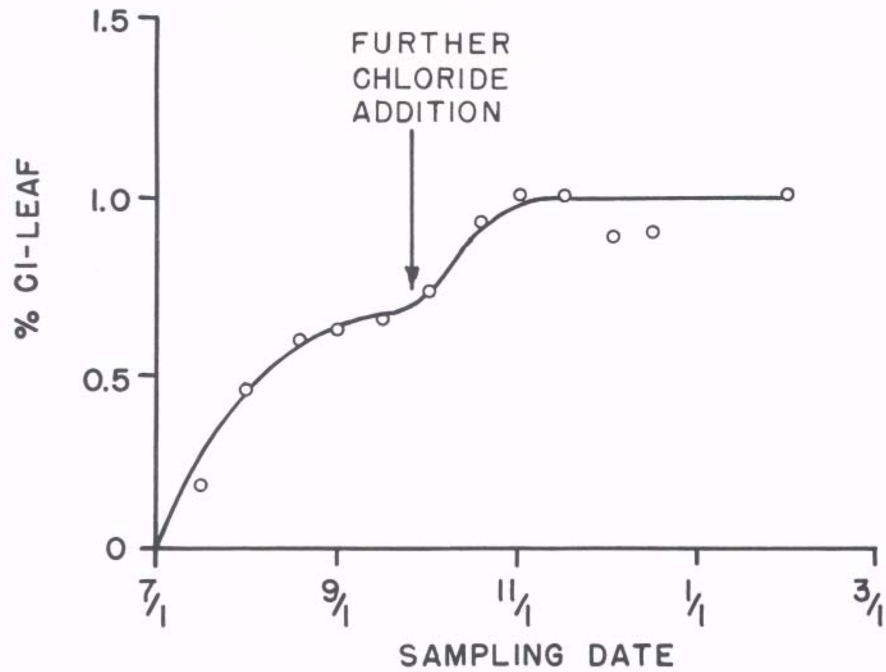


Figure 5. Leaf chloride in relation to time exposed to chloride. Note the rapid uptake of chloride and that the values reach a characteristic level. Note that the avocado does not continuously accumulate chloride.

As for the significance of chloride levels in the root zone, reference to Figure 6 reveals a linear relation between content of chloride in leaf blades or petioles and substrate concentrations up 10-15 me Cl/l. Greater amounts in the substrate resulted in a marked increase in uptake. Note that the blade contains somewhat greater contents of chloride than the petiole. Of concern to the grower is the fact that uptake follows the salinity level, i.e., greater the chloride accumulation in the soil, the greater likelihood of injurious quantities of chloride entering the plant.

Growth Response: Data in table 1 reflect growth restriction in relation to chloride levels in the substrate. Trunk diameter and fruit production data are presented. The photo plates (figures 2 and 3) also illustrate the restrictive effect of chloride on the size of the tree. Compare, for example, the smaller tree to the left of the center panel to adjacent trees (figure 3). Unfortunately, black and white photography does not convey the extent of leaf burn exhibited by the high chloride trees. Treatments of 5- and 10-me Cl/l resulted in reductions of trunk diameter (an expression of growth, comparable to tree size for example) relative to the chloride-free substrate of 15 and 20% respectively. Water consumption similarly shows the 5 me Cl and 10 me Cl trees to use 77% and 63% of the water being used by the control trees. There is no question that these relatively low chloride concentrations in the sandcultures are associated with less growth. The grower might extrapolate the above findings to a reduction in fruit production; however, the current data are not conclusive on this point, merely suggestive of reduced yields.

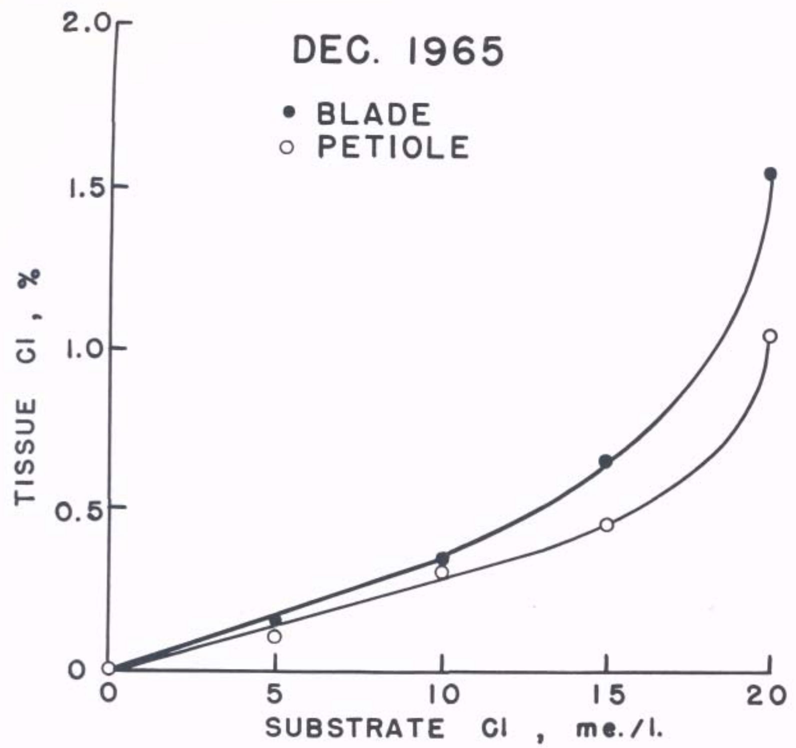


Figure 6. Plant tissue analysis in relation to chloride content of the substrate (nutrient solution).

Chloride Injury Symptoms: There may be considerable variation in symptom expression depending upon stage of development, leaf age, and possibly nutrition, as examples, but a common characteristic is marginal and trip burn which spread inward toward the midrib. Under conditions favoring the development of severe leaf burn, premature leaf drop follows. Figure 4 illustrates the progression of symptoms from chlorosis to necrosis of the tip and margin of leaves. Tree growth is hampered markedly, due in part to less leaves functioning normally in photosynthesis. Figure 3 presents a comparison of a high chloride tree to a normal tree. Note the leaf curl and dwarfed appearance on the Cl tree. These symptoms have been described by other investigators, e.g. Haas (4), Ayers, *et al.* (l), and Embleton, *et al.* (3) to mention a few.

Fruit Production: Thus far, only the 1965 fruit harvest results are available (table 1). As to be expected, considerable variation occurred on a tree to tree basis. However, excessive chlorides reduced tree size markedly, led to extensive leaf burn and leaf drop and very possible reduction in fruit production. No fruit has been set during the 1966 year on the high chloride trees which is in line with the 1965 results. Fruit size, shape, skin texture, and oil content were not affected by the chloride treatments.

Judging from tree performance in the current studies, sustained leaf levels of 0.75% Cl or higher would be associated with reduced growth, severe leaf burn and very possibly reduced yields.

Concluding Remarks

Review of the published accounts on chloride injury specifically for avocados leads to several important conclusions:

1. The avocado tree is unusually sensitive to salinity, chloride, and sodium when compared with other plant species.

2. Soil and leaf analysis criteria for diagnostic purposes are limited even though recognition of chloride tip burn dates back some 30 years to A. R. C. Haas' 1929 publication.

Reliable standards are needed to evaluate irrigation waters, soil and plant tissue analyses. But, in order to have a realistic calibration of chloride analyses with tree responses and in particular fruit production, controlled, long-term experiments are required. The present study is particularly appropriate in that it utilized bearing trees subjected to known quantities of chloride extending over several seasons. Properly designed and executed field experiments would be even more desirable in determining the significance of chlorides but such experiments are difficult to conduct with adequate control. The only recourse available is to evaluate the results of the present experiment in terms of that published earlier by others, taking into account the particular experimental conditions prevailing at the time of observation. As examples, in California, Ayers *et al.* (l), Haas (4), and Embleton *et al.* (3) associated tip burn of Fuerte trees with minimal chloride leaf values ranging from *0.25%* Cl to 0.80% Cl respectively. The above data were not derived from experiments, rather they come from leaf surveys in areas suspected to be under the influence of chloride. Yet, the above observations are consistent with those of the present authors and as such, provide additional assurance while proposing criteria for diagnostic purposes.

TABLE 2. Soil-, water-, and leaf-analyses criteria for appraisal of chloride hazard

Hazard	Soil Saturation Extract me Cl/l	Irrigation water. me Cl/l	Leaf %CI
None	2	2	.25
Definite	2-4	2-4	.25-.75
Severe	4+	4+	.75-1.50

Table 2 contains diagnostic criteria for evaluating chloride hazard in terms of soil, water, and leaf analyses. Regarding soil analysis, the saturation extract technique is commonly used and should be well-suited for chloride provided one realizes that soil chlorides may fluctuate in response to irrigation, water table, rainfall, etc. Nevertheless, the chloride concentration of the saturation extract is approximately 1/2 to 1/4 of the concentration dissolved in the soil solution at sampling time. Assuming a dilution factor of 3, one may extrapolate the sand- culture concentrations to those of the saturation extract (divide by 3). For example, the 10-15 me Cl/l sandculture concentrations which produced definite injury, indicate saturation extract values of 3 to 5 me/l as hazardous. Expressed as ppm Cl on a solution basis, the above approximate 100 to 175 ppm. Similarly, irrigation waters containing over 100 ppm Cl require careful management to avoid undesirable accumulations of chloride in the soil. Regarding leaf analyses, the criteria given in Table 2 appear to be reasonable and realistic. Values in excess of 0.75% Cl would be associated with severe leaf burn, early leaf drop, slower growth and quite possibly, reduced yields. Probably, the tree tolerates a degree of leaf burn without registering reduction in production — the limits are unknown at present.

Acknowledgment

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