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IRON CHLOROSIS IN RELATION TO IRRIGATION PRACTICES

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The need for carefully controlled irrigation of citrus trees in some kinds of soils to maintain proper iron nutrition has been recognized for at least 40 years. Generally speaking, iron deficit occurs more often as a result of applying too much water than from applying too little. This fact has given rise to the common idea that the cure for iron chlorosis is to operate at a reduced average content of water in the soil. A frequent recommendation is to irrigate only the alternate middles at any one time and fill in the other middles at the next scheduled irrigation. This procedure may reduce the total water applied by as much as one half, depending on the duration of each run, and has proved beneficial in many orchards.

Good irrigation management is relatively easy in deep, uniform soils that have good structure but problems of iron nutrition seldom occur in such soils. More often, chlorotic trees are found in soils of fine texture and poor structure, or soils having strata with limited permeability to water and air. Stated another way -- this problem arises most frequently in soils for which optimum water management is difficult to describe and to achieve. Each soil profile presents, in some degree, a unique combination of properties that require a tailor made management program.

One orchard situation that we have been concerned with for several years involves a large hillside acreage of avocados, mostly 'Hass' and 'Rincon' varieties, located near Santa Barbara, California. Many of these trees have been subject to severe iron deficiency almost continuously since planting. The soil, Zaca clay, is calcareous throughout and has an excellent crumb structure at the surface; but this structure deteriorates with depth until, at depths of 2 to 4 feet, the soil is so dense that drainage is limited and water saturation is perennial. This report summarizes the soil treatments and irrigation adjustments that have been made to alleviate the iron problem.

Iron Chelates

One obvious possibility was that soil application of iron chelates would correct the problem as it has in several other avocado orchards. Numerous trees were treated with EDDHA-HFe [iron chelate of ethylenediamine di (o-hydroxyphenylacetic acid)] at various rates. Any beneficial effect was so slight that the treatments were discontinued.

Reduced Water Application

In keeping with the program of limited irrigation that has proved so successful in other situations, an irrigation regime was established involving application of 3 acre inches of water per acre in alternate middles, at intervals averaging 8 weeks during the summer irrigation season. The purpose of this reduced rate of water application was to encourage the trees to use water from the subsoil and thus create more favorable conditions there for root development. Over a period of several years under this regime, the iron chlorosis problem became more severe and general tree condition deteriorated substantially. Examination of the soil profile revealed that from the surface down to the dense subsoil the soil was so dry by midsummer that very few roots survived. The subsoil remained saturated, though it may be that more favorable conditions for root development were created in a zone of a few inches at the top of the subsoil. We surmise that growing conditions in this zone fluctuated between winter and summer and. presumably, any roots growing in it during summer deteriorated under saturation conditions during the winter.

Another adverse result of such severely limited application of water is the absence of adequate leaching. By the spring of 1966, enough chloride injury was evident in the leaves that a visual rating for iron chlorosis was difficult. Analysis of soil samples showed the following ion concentrations in the saturation extracts:

	Chloride	*Sodium*	*Calcium*
	milliequivalents per liter		
First foot	1.6	1.7	3.2
Second foot	.9	3.5	3.2
Third foot	2.4	4.7	4.1

Chloride concentrations exceeding 2 me/1 in saturation extract are regarded as hazardous to avocados (1).

Tensiometer-Guided Irrigation

Experience to this point made it clear that the compact, wet subsoil was there to stay and that the trees would have to be rooted in the well-aerated soil above. To do this required an irrigation program that would (i) maintain near-optimum water conditions for root development from the surface to the compacted zone; and (ii) favor slow but continuous leaching to remove salts. In practice, this would involve application of water when the suction in the zone of maximum rooting density reached some prescribed value -- we chose 80 cb (centibars), which is close to the maximum reading that tensiometers can give reliably -- and continuing each irrigation until the suction dropped throughout the zone of water extraction by the roots. It would also involve a method for limiting evaporation of water from the soil surface to encourage root development through the maximum possible depth of soil.

We selected a block consisting of one irrigation unit that contained 18 rows 13 trees long. Seven tensiometer stations were installed in the bottom 5 rows that were to constitute an exploratory experiment. Each station contained 4 tensiometers at respective depths of 1, 10, 20, and 40 inches. Two rows received surface mulch of beanstraw, 2 rows with wood chips, and 1 row not mulched. Starting in May 1966 these 5 rows were irrigated independently of the rest of the orchard. After the mulching materials and the full rooting depth of the profile had been wetted, it was found that the desired conditions were closely approximated by a schedule of 4 hour sprinkler runs at intervals averaging 17 days during the summer season. This represented an increase in total water applied though the exact ratio cannot be determined because the treatment coincided with a change to sprinklers that deliver a larger volume of water.

By the middle of July there was a visible improvement in foliation and colors of the trees receiving this treatment. At the end of September, even the most chlorotic tree in the treated group had developed a complete new set of leaves, moderately green in color, and without any sign of the characteristic iron deficiency pattern.

Periodic inspection revealed that the treated trees had rapidly developed new roots throughout the well-aerated portion of the soil profile, including the zone within an inch or two of the surface.

During the winter of 1966-67 the rainfall distribution was such that soil moisture conditions in the entire area were maintained close to the optimum levels for which the irrigation treatments were designed. By May 1967, chlorosis symptoms were absent from the entire block. During July, however, symptoms began to reappear in many trees that remained under the general irrigation regime. At the end of the 1967 growing season, and on through the winter, severely chlorotic trees were common in the entire area excepting the experimental block, where iron deficiency symptoms were completely absent. Comparison of the photographs in Figure 1 shows the improvement in one tree during the 2 year period 1966 to 1968.

During the late summer of 1967 and early 1968 a series of local problems at the orchard prevented continuation of the experimental irrigation schedule. As of July 1968, all of the trees that had been chlorotic at the start of the experiment were beginning to return to that condition.

Expanded Experiment

On the basis of these results, we laid out a replicated experiment to occupy the entire block, including the establishment of many more tensiometer stations. The main objectives are to include a larger number of chlorotic trees and to provide a better evaluation of the importance of mulching in this situation. In addition, longer term observations are needed on the effect of lower suction values on salt leaching and on the possibility that these conditions may encourage root rot.

Interpretations

In spite of the limited size of the experiment and duration of our observations, certain relationships seem evident. First, the attempt to force the trees to utilize subsoil water resulted in severe water stress and failed to improve the iron nutrition. Second, when proper supply of water was maintained in the surface 2 feet of soil -- where aeration and temperature were also favorable for root development — the trees not only recovered from water stress but obtained an adequate supply of iron, as well. This agrees with previous studies with citrus plants, which showed that when root development was controlled either by water or oxygen supply the level if iron nutrition varied with the rate of root growth (2, 3).

Figure 1. Two photographs of the same avocado tree — Rincon variety — taken two years apart to show response to treatment. Top: Taken at the time mulch was applied to the soil and tensiometer-guided irrigation program was started — May 1966. Note bare twigs and very pale leaves. Bottom: May 1968. Fully foliated and normal leaf color.

The experiment supports the previous findings that proper irrigation management is the best general method presently available to the farmer for favoring good iron nutrition. It also emphasizes the common sense idea that the best part of the profile in which to encourage roots by irrigation is the part that is most favorable in other respects.

The fact that iron-deficient trees often have poorly developed root systems may limit the effectiveness of iron chemicals for correcting the deficiency because it is more difficult to reach the roots with sufficient amount of the chemical. This may be the principal reason for the failure of iron chelate to correct the problem in this orchard, where most of the functional roots were quite deep in the soil.

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