1997 California Avocado Research Symposium pages 9-12
California Avocado Society and University of California, Riverside

Correction of Zinc Deficiency in Avocado

Final Report for Project Year 4 of 4

David E. Crowley
Department of Soil and Environmental Sciences,
University of California, Riverside, CA

Cooperating Personnel: Woody Smith

Benefit to the Industry

This project has provided avocado growers with practical information on trace metal fertilization that is necessary for maintaining the productivity and health of avocado trees. During the first three years of the project, fertilization methods using soil or foliar applications of zinc fertilizer were evaluated. In 1996, soil factors associated with trace metal deficiencies in avocado were studied to determine the cause for zinc deficiency and whether it can be corrected by cultural practices. Basic research was also conducted to determine the reason for avocado's unusually poor ability to acquire trace metals on calcareous soils. Results of these latter studies should prove particularly useful for identification of root stocks that are efficient in trace metal uptake. Lastly, research on the interrelationship of nitrogen fertilizers and avocado trace metal nutrition was conducted to determine whether acid-forming fertilizers may be used to enhance zinc uptake in high pH soils.

Objectives

Examine the influence of nitrate- or ammonium-based nitrogen fertilizers on trace metal uptake by avocado.

Introduction

Previous research on avocado and other tree crops has suggested that trace metal deficiencies may be antagonized by interactions with macronutrients including nitrate-nitrogen fertilizers, high soil phosphorus, and low levels of soil organic matter. Conversely, trace metal nutrition of avocado may improved by potassium fertilization or possibly by use of acid-forming nitrogen fertilizers that increase the solubility of metals in soil. In our prior research, we showed that application of zinc through the irrigation water was effective for increasing zinc uptake by avocado (Crowley et al., 1994, 1996). However, in many soils where zinc deficiency occurs, there are frequently extremely high levels of extractable zinc which are apparently not available to avocado (Crowley and Smith, 1996). This inability to mobilize soil zinc may be due in part to the relatively weak root stress response in avocado, which in trace metal efficient plants would normally operate to acidify the rhizosphere and increase the solubility of iron and zinc

(Manthey and Crowley, 1997). Recently, some growers have begun experimenting with acid-forming fertilizers to increase the availability of iron and zinc. Research conducted during this final project year examined whether this practice is actually effective for improving trace metal uptake by avocado when grown in a high pH, calcareous soil where trace metal deficiencies most commonly occur.

In high pH soils where almost all plants are faced with deficiencies of iron and other trace metals, many dicotyledonous plants respond by releasing hydrogen (H^+ ions) from the root tips to acidify the soil surrounding the root (the rhizosphere), and by release of electrons to reduce oxidized ferric iron to the more soluble ferrous ion (Bienfait, 1985, Bienfait et al., 1985). Although this has been best studied in relation to iron deficiency, the pH-lowering component of this response results in greatly increased solubility of all trace metals (100-fold for Zn and Mn, and 1000-fold for Fe, for every unit decrease in pH). However, the ability of plants to lower the rhizosphere pH is strongly inhibited by the presence of bicarbonate which buffers the soil pH (Venkatraju and Marschner, 1981), and is also affected by the source of nitrogen that is provided to the plant (Marschner and Romheld, 1983). These nitrogen effects can be explained by the ion balance that plants maintain in order to energize the cell membrane for nutrient uptake. The uptake of ammonium nitrogen (NH_4^+) across the root cell membrane is balanced by simultaneous transport of a hydrogen ion (H^+) to maintain the membrane electrical potential of the root cell, thereby lowering the pH of the soil. Conversely, uptake of NO_3^- is balanced by release of OH^- ions, which increases the soil pH and causes trace metals to precipitate out of solution (Figure 1).

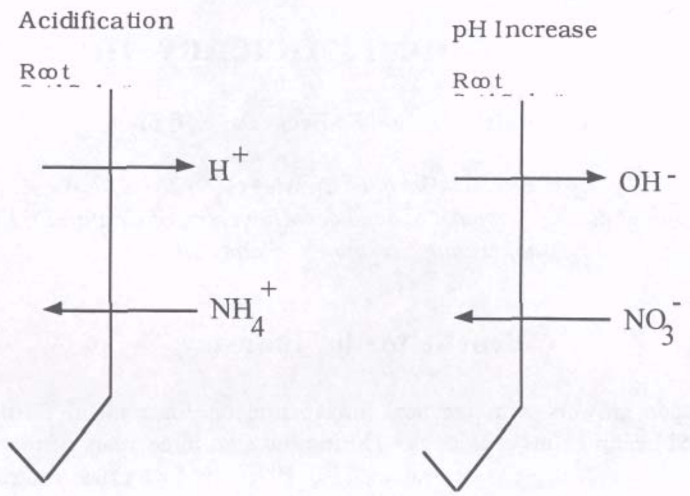

Figure 1. Effect of nitrogen supply as ammonium (NH_4^+) or nitrate fertilizer on acidification (left) or pH increases (right) in the rhizosphere soil solution.

Recently it has been shown that supply of nitrate fertilizers to avocado causes iron-deficiency chlorosis in avocado, presumably by decreasing the solubility of iron in the rhizosphere (Bar and Kafkafi, 1992). This phenomenon has not been examined in the field, but suggest that nitrogen fertilizer practices can be better optimized to enhance trace metal availability. To evaluate the influence of nitrogen fertilizers on trace metal uptake, we conducted a greenhouse experiment using a calcareous, iron-limiting soil in which we will applied nitrogen as $CaNO_3$ NH_4SO_4, N-phuric™ (urea-sulfuric acid), and sulfur-coated urea. We hypothesized that supply of $CaNO_3$ would inhibit uptake of Fe and Zn by the avocado seedlings in comparison to trees provided with NH_4SO_4 or with N-phuric. One potential pitfall of the NH_4SO_4 treatment was that ammonium is readily oxidized to nitrate by nitrifying microorganisms in neutral pH soils. A possible solution would be to use nitrification inhibitors such as Dwell or N-serve, but these materials are very expensive. Another alternative would be to use a slow-release ammonium fertilizer, sulfur-coated urea. In addition to limiting problems with nitrification, nitrate leaching, and alkalization of the rhizosphere, sulfur associated with the fertilizer granules is oxidized to sulfuric acid, which should also increase trace metal availability. N-phuric is another logical choice for supply of ammonium nitrogen and acidification and is currently used by some avocado growers for this purpose. When applied at intervals in the irrigation water, N-phuric may not undergo rapid nitrification prior to diffusion to the plant roots.

Methods

A greenhouse experiment was conducted using 1 year old avocado tree seedlings which were individually transplanted into 2-gallon containers filled with a calcareous soil (pH 7.2-7.5). A factorial design was used in which trees were either fertilized or nonfertilized with trace metals (Fe, Zn, Mn), and were provided with nitrogen fertilizers as follows: ammonium sulfate, N-phuric, sulfur coated urea, calcium nitrate, and a nonfertilized control. There were 20 replicate trees per treatment for a total of 200 trees. Trees receiving the nitrogen fertilizers were fertilized monthly with 50 mg/kg soil N.

During the course of the experiment, leaf tissue chlorosis was monitored using a SPAD chlorophyll meter. Tree growth was measured as height and stem diameter. Leaf tissue analyses were performed for each replicate tree using the most recently expanded leaves. Leaf samples were taken immediately after transplanting, at 6 months, and at 1 year at which time the experiment was taken down.

Results and Discussion

Leaf tissue analyses data showing the effects of nitrogen fertilizers on avocado trees grown with or without additional trace metals are shown in Figures 2 and 3 for trees sampled at 6 months. In comparison to the control trees which did not receive any nitrogen fertilizers, addition of nitrogen in any form resulted in an increase in iron deficiency chlorosis and reduced tissue iron concentrations (Figure 2), but had no significant effect on leaf zinc concentrations. As predicted, nitrate fertilizer had the greatest inhibitory effect on iron uptake, but the overall inhibitory effect of N fertilization on trace metal uptake was unexpected. One possible reason for this effect may be a reduction in root growth and short tip root numbers in trees receiving N fertilizers. The inhibitory effect of N fertilization on trace metal uptake was also observed in trees which were additionally fertilized with chelated metals, although these trees had normal trace metal contents and were not detrimentally affected by N fertilization as were N-fertilized trees without trace metals. Data for the one year leaf samples are still being analyzed at the time of this report.

The results suggests that N fertilizers in general caused decreased uptake of trace metals and that this effect was most severe for nitrate fertilized trees without supplemental trace metals, which showed extreme iron chlorosis. On the other hand, fertilization with ammonia based fertilizers had no strong beneficial effects for correcting trace metal deficiencies as compared to simply providing supplemental trace metals as a separate fertilizer. Nitrogen fertilizers applied at these levels did not provide any measurable increase in biomass over the 1 year period as compared to nonfertilized control trees, and by the end of the experiment resulted in significant reductions in root growth and visible symptoms of salt damage to the plant leaves. This suggests that avocado seedlings are not highly responsive to N fertilization, and that overfertilization with nitrogen may contribute to salinity damage and decreased trace metal uptake.

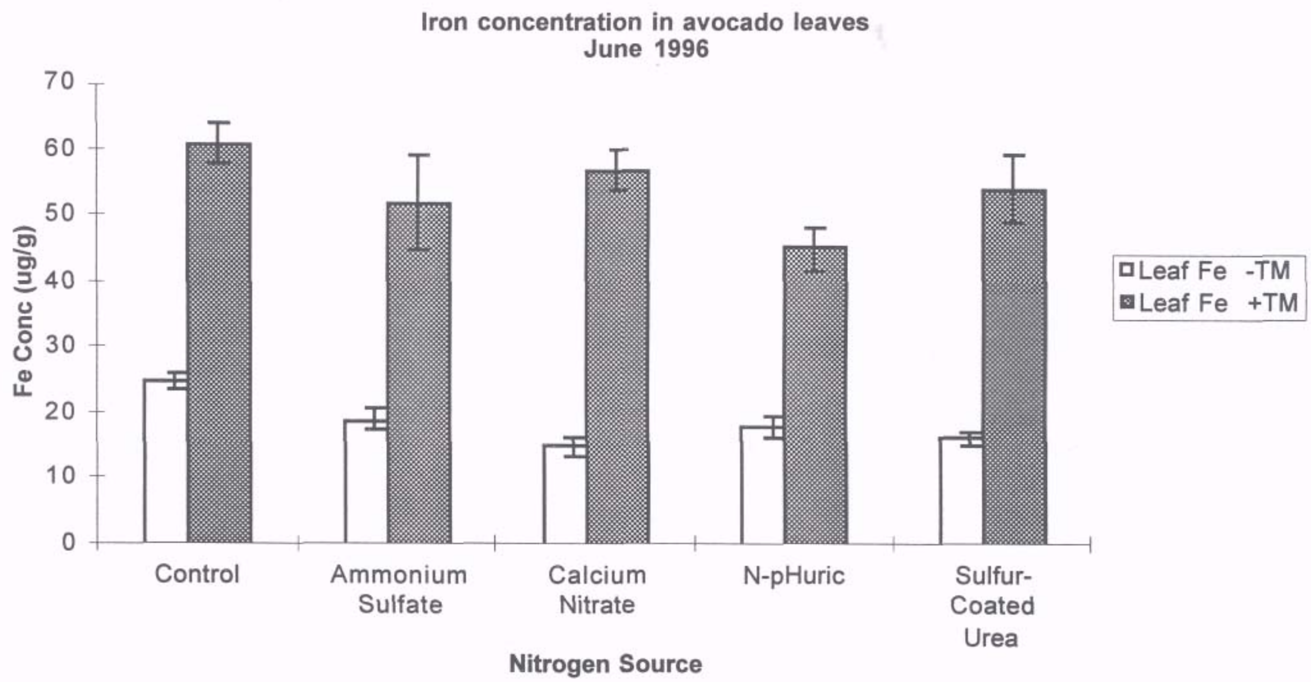

Figure 2. Leaf iron contents for trees fertilized with different nitrogen fertilizers when grown with (+TM) or without (-TM) supplemental trace metals. Nitrogen fertilizers added monthly at 50 mg/kg soil. Chelated metals added once at the beginning of the experiment at 100 mg/kg soil.

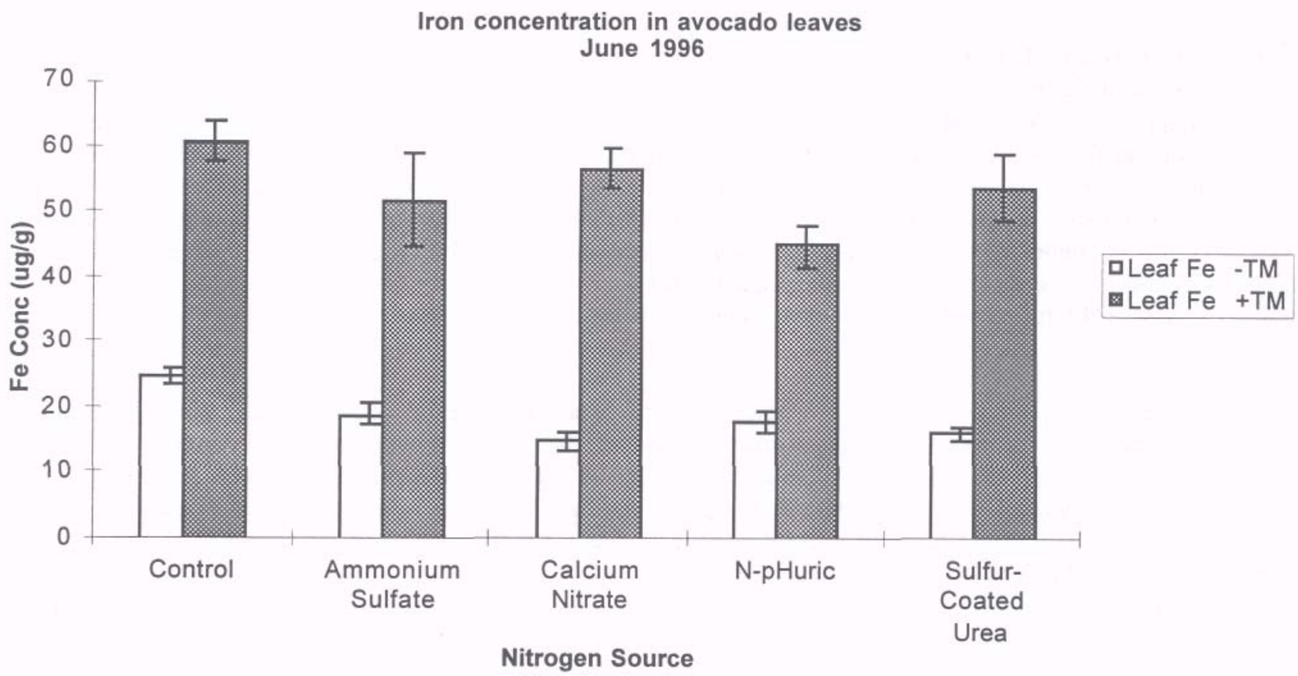

Figure 3. Leaf zinc contents for trees fertilized with different nitrogen fertilizers when grown with (+TM) or without (-TM) supplemental trace metals.

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