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TRACE METAL NUTRITION OF AVOCADO

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Project Objectives: (1) To evaluate fertilizer application methods and materials for correction of zinc deficiency in Hass avocado. (2) Development of enzyme markers for characterizing trace metal availability in zinc leaf tissues.

Zinc and other trace metal deficiencies are common in many southern California avocado orchards and are suspected to be an important limiting factor in fruit production and tree health (Crowley 1992). Several methods have been developed to correct this problem including foliar applications of zinc sulfate and zinc chelates (Goodall et al., 1979), trunk injections (Whiley et al., 1991), or soil applications of zinc fertilizers to increase zinc availability (Wallihan et al., 1958). However, currently there is no consensus as to which application techniques are the most effective and which materials are best used with the various application techniques. There has also been confusion when treatments recommended for acid soils of San Diego County are used for treatment of calcareous soils in Ventura County. As a result, many avocado growers are employing a variety of techniques with varying success.

To investigate this problem, we implemented a field trial in Ventura County with Hass Avocado. As revealed from our survey of different experimental sites, one particularly important finding during the first year was that almost all of the chlorosis symptoms (yellow and mottled leaf tissue) we observed in the field were due to iron deficiency rather than zinc. Thus despite the perception that zinc is the predominant deficiency problem for avocado in Southern California, we believe that in many cases iron and zinc deficiencies are being confused, with the result that some trees are being incorrectly treated. This does not mean that zinc is no longer a problem, since routine applications are still necessary for maintenance of zinc-sufficient trees on calcareous soils. However, zinc has been routinely applied to orchards for so long that it is seldom deficient anymore in acid soils, and is no longer a common deficiency in commercial orchards in Ventura County.

As shown in this report, the most effective method for supplying zinc to trees appears to be the use of foliar sprays. Nevertheless, an important criterion in evaluating the effectiveness of different zinc fertilizer materials when applied as a foliar spray is to determine whether the zinc that has been applied is active in the leaf tissue, or if it is simply coating the leaves with an unavailable precipitate that becomes incorporated into the waxy cuticle. This can not be distinguished using traditional leaf tissue analyses that only reveal differences in zinc content. Although still in the developmental stage, we believe that one of the best ways to measure the active metal fraction may be to assay the leaf tissue sap for enzyme markers that are dependent on iron or zinc and thereby reflect the internal availability of the metal in the leaf cells. Key enzymes we are investigating include nitrate reductase, polyphenol oxidase, catalase, and peroxidase.

Zinc Application Trials. Eight different zinc treatments were established as outlined in Table 1, using a completely randomized design for the soil treatments and trunk injections, and a block design for the foliar spray applications. The soil and trunk injection treatments were begun in October 1992. Foliar application treatments comparing two commercial zinc materials and the inorganic salt, zinc sulfate, were begun in June 11, 1993. The commercial zinc fertilizers, Zinc Metallosate and Zintrac-8 were used at the manufacturer recommended concentrations (Table 1), and were mixed with a commercial surfactant, SUN IT II (AGSCO, Grand Forks ND) at a rate of 8 oz per 20 gallons. The trees were sprayed by a professional spray rig operator.

Table 1. Schedule of application methods, zinc materials, application rates, and timing for each of the methods evaluated for correction of zinc deficiency in Haas avocado on a calcareous soil in Ventura Co.

Application Method	Zinc Material	Application Rate	Application Timing
Control	N/A	N/A	
Foliar	Zinc sulfate	15 gram / liter	Once per year; applied on 6/11/93
	Zinc Metallosate	11.7 ml / liter	
	Zintrac 8	2.3 ml / liter	
Trunk Injection	Zinc nitrate	10% $Zn(NO_3)_2$ 15 ml/m diameter	One time injection on 10/19/92
Simulated Irrigation	Zinc sulfate	1.75 lb / tree	Quarterly; applied 10/19/92, 1/26/93, 4/14/93, 7/29/93
	Zinc chelate	1.5 oz / tree	
Soil Banding	Zinc sulfate	7 lb / tree	Once per year; applied 10/19/92

Leaf samples were analyzed for zinc, iron, and manganese in January, May, and August 1993. Ten leaf samples were collected from individual trees in each treatment, washed, and acid digested for analysis by flame atomic absorption spectroscopy. National Bureau of Standards apple leaves were included for quality control assurance and yielded results within 2% of reference values.

Results

This experiment revealed clear differences among the zinc fertilizer materials and application methods that were particularly evident at the last leaf sampling date on August 31, 1993. As shown in Table 2, all of the treatments, with the exception of trunk injection, provided some improvement in the zinc content of the foliage. However, the most effective treatments were foliar applications, followed by soil banding of zinc sulfate. The least effective treatments were trunk injection and quarterly applications of chelated zinc or zinc sulfate to the soil.

Table 2. Leaf tissue zinc contents of Haas avocado trees receiving zinc fertilizers applied as a foliar spray to the canopy, or by trunk injection, quarterly irrigation, or soil banding under the canopy dripline.

Treatment		Statistical Analysis	
Application Method	Zinc Material	Mean [z]	Std. Deviation
Control	N/A	48 c	16
Foliar	Zinc sulfate	95 ab	31
	Zinc Metallosate	78 b	19
	Zintrac 8	125 a	31
Trunk Injection	Zinc nitrate	44 c	12
Simulated Irrigation	Zinc sulfate	69 bc	18
	Zinc chelate	59 c	25
Soil Banding	Zinc sulfate	95 ab	45

[z] Different letters indicate a significant difference ($P < 0.05$) by Tukey's HSD.

Foliar Sprays. When applied as a foliar spray, all of the zinc materials tested were effective for increasing foliar zinc content in comparison to the control trees. However, with respect to overall ranking, the zinc oxide material, Zintrac-8, gave the best response, followed by zinc sulfate, and lastly by Zinc Metallosate. The data analysis showed there was no statistical difference between zinc sulfate and Zintrac-8, whereas Zinc Metallosate was significantly less effective than Zintrac-8 ($P > 0.05$ %), and comparable to zinc sulfate.

Given the low cost of zinc sulfate, this material may be the most cost effective for foliar applications. However, further tests are needed to determine how these materials compare in penetrating the leaf cuticle. Another important factor that needs to be evaluated is how different surfactants influence leaf penetration. The surfactant material used in this study, SUN IT II, was effective but has not yet been compared with other commercial products that may alter the ranking of the foliar applied fertilizers.

Soil Banding of Zinc Sulfate. In comparison to the foliar application, the soil-banding treatment in which 7 lbs of zinc sulfate is applied under the canopy dripline appeared to be equally effective when only the statistical means of the data are compared. However, we observed that this treatment provided spotty correction of zinc deficiency, as indicated by the higher standard deviation. Trees amended with this fertilizer had a range of zinc contents from 40 to 193 ppm, whereas trees sprayed with Zintrac-8 had a range from 83 to 179 ppm. The response also appears to be highly dependent on soil properties or irrigation-dependent differences among different orchards. In two other field sites where we are examining trace metal interactions, one orchard showed absolutely no response for trees receiving soil-banded zinc sulfate, (29 ppm Zn in comparison to 32 ppm Zn for the control). In the third site, there was only an intermediate response in which trees provided with soil-banded zinc sulfate had 59 ppm Zn in comparison to 33 ppm for the control. In this last field, values for zinc sulfate amended trees ranged from 35 to 106 ppm versus 22 to 47 for control trees. Thus, even when a response was observed, the uniformity among trees was relatively poor.

Quarterly Applications. Still less effective than soil banding were treatments in which either zinc sulfate or zinc chelate were supplied quarterly in irrigation water. Although the trees received the same total quantity of the zinc sulfate, the response was less than when the trees were provided by the entire 7 lb application in one dose. Trees provided with quarterly applications of zinc sulfate and zinc chelate had 69 and 59 ppm zinc, respectively, which due to the high variation among trees, was not statistically different from the control.

Trunk Injection. At the first sampling date in January 1993 (prior to the foliar application treatments), the leaves were analyzed to determine short term responses for trees that had been fertilized with soil or irrigation applications of zinc, or by trunk injection. At this time, only the trees that had received a trunk injection of zinc nitrate showed a response, suggesting that the other fertilizers applied to the soil in the Fall either were not taken up or were not translocated to the foliage during the winter.

In January, the mean zinc concentration in both control and soil fertilized trees was 38 ppm, although certain individual trees had foliar concentrations as low as 15 ppm and as high as 97 ppm. In contrast, trees that had received trunk injections of zinc nitrate had a mean tissue content of 63 ppm zinc. However, this short term response to trunk injection disappeared after new foliage was produced in the spring, indicating that there was no long term benefit from the trunk injection.

Perhaps a even greater drawback to trunk injection were the resulting open wounds that continued to exude sap through the winter. We were cautious to sterilize the injection needle in 5% sodium hypochlorite (bleach) between trees and, fortunately, no immediate disease problems were observed. However, trunk injection almost certainly increased the susceptibility of these trees to subsequent infections and was considered to be a potentially harmful treatment. A recent publication recommending trunk injection employed zinc injections with phosphonate to simultaneously control phytophthora root rot and correct zinc deficiency (Whiley et al., 1991). Under these circumstances, the treatment may have some merit, but in our experiment was not as effective as foliar application or soil banding of zinc sulfate.

Recommendation. As a final note, one particularly important problem we have encountered that may lead to incorrect diagnosis of trace metal deficiencies is with leaf sampling techniques for trace metal analyses. In repeated random sampling of leaves from individual trees, we have found large and significant differences in trace metal contents for 10 leaf samples and between individual leaves taken from the same tree. This is particularly evident for iron which is not readily translocated from older leaves to the new foliage. Iron deficiency symptoms occur primarily in the new leaf tissue, however, in some cases we also observe localized iron deficiency symptoms within trees in which one or two branches are affected, while the rest of the tree has normal foliage. When 10 leaf samples are collected from around the perimeter of individual trees or even worse, from a group of trees in one area of the orchard, the metal contents are averaged for both iron-sufficient and deficient leaves. The bulk leaf tissue analysis data are thus useless for determining which metals are actually limiting. Given this variability, we strongly recommend that individual samples of similarly affected leaves be collected for analyses to diagnose suspected trace metal deficiencies.

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