California Avocado Society 1993 Yearbook 77: 95-100

Zinc Nutrition of Avocado

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Project Objectives

To evaluate fertilizer application methods and materials for correction of zinc deficiency in Hass avocado.

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. This project was initiated to compare currently recommended treatments that can be used for correction of zinc deficiency in avocado on calcareous soils.

Project Description

During the first year of this project, a fertilizer field trial experiment was installed in Ventura County in an orchard planted with Hass avocado. From our observations and soil tests of this and other affected areas, zinc deficiency symptoms occur in highly localized patterns within the orchards, suggesting that there may be specific soil or irrigation factors associated with zinc deficiency. All of the affected areas contained highly calcareous soils, which is consistent with low zinc availability and which would also lower the availability of iron and manganese. Because of a problem in locating one contiguous site uniformly affected by zinc deficiency, three separate sites were selected for our experiments. All three sites are under commercial management by ProAg Inc. The largest site, Field 1 (Winchester), is located on a hillside overlooking the Las Posas and Santa Rosa Valleys and contains 132 trees within an area where more than half of the trees are visibly affected by zinc deficiency symptoms. Field 2 (Wildgoose) and Field 3 (Warwar) contain 50 and 46 affected trees, respectively, and are located within a few miles of Field 1.

Baseline analyses conducted prior to implementing the experiment showed that there was considerable variability in the zinc, iron, and manganese contents of the foliage for individual trees (Progress Report, Year 1). The normal sufficiency ranges for these elements in avocado are: zinc (30-150 ppm), iron (50-200 ppm), and manganese (30-

500 ppm). In comparison to these normal values, the mean foliar zinc contents in Fields 1, 2, and 3 were 45, 33, and 43 ppm, respectively, which fall in the low to moderately sufficient ranges for zinc. Many trees were below the sufficient range with some trees having values for zinc as low as 11 ppm, indicating severe deficiencies (less than 20 ppm). Field 1 was used for the primary experiment comparing the different zinc treatments, whereas Fields 2 and 3 were reserved for an experiment examining trace metal interactions.

Prior to starting the zinc treatments, all of the trees in Field 1 were amended with chelated iron and manganese fertilizers to correct any problems with these trace elements. Iron and manganese were supplied as Fe-EDDHA (6% Fe) and Mn-EDTA (12% Mn) using the commercial products, LIBFER (Fe-EDDHA) and LIBREL (Mn-EDTA) provided by Allied Colloids. Eight different zinc treatments were then imposed as outlined in Table 1 using a completely randomized design for the soil treatments and a block design for the foliar spray applications.

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

Application Method	Zinc Material	Application Rate	Application Timing
Control	N/A	N/A	
Foliar	Zinc sulfate Zinc Metallosate Zintrac 8	1 5 gram / liter 11. 7 ml/liter 2.3 ml/liter	Once per year; applied on 6/1 1/93
Trunk Injection	Zinc nitrate	10% $Zn(NO_3)_2$ 1 5 ml/m diameter	One time injection on 10/19/92
Simulated Irrigation	Zinc sulfate Zinc chelate	1.75 lb/tree 1 .5 oz/tree	Quarterly; applied 10/19/92, 1/26/93, 4/14/93, 7/29/93
SoilBanding	Zinc sulfate	7 Ib/tree	Once per year; applied 10/19/92

Year 2 Results

Leaf samples were collected from individual trees and analyzed for zinc, iron, and manganese in January, May, and August 1993. Results of the foliar analyses demonstrated clear differences among the zinc fertilizer materials and application methods that were readily apparent at each of the sampling dates and particularly at the last sampling date in August 1993. Differences in the efficacy of individual treatments were statistically analyzed using SYSTAT, with mean separation by Tukey's HSD.

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 any response (data not shown). This suggests that fertilizers applied in the fall either were not taken up or were not translocated to the foliage during the winter months. The mean zinc concentration in 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, or approximately 40% increased zinc, demonstrating that this method is an effective and quick remedy for correcting zinc deficiency. However, as shown in later analyses, this method provides only short term correction and has other serious drawbacks.

Foliar application treatments were begun on June 11, 1993, using a commercial spray rig to apply three different zinc fertilizers. The commercial chelated fertilizer materials, 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 to achieve thorough leaf coverage with minimal runoff from the canopy. Leaf samples collected on May 11, 1993, one month prior to the foliar application, had a mean content of 30 ppm zinc. One month after the foliar application (July 29, 1993), the foliar leaf content of zinc had increased from 30 ppm to 78, 124, and 95 ppm for Zinc Metallosate, zinc sulfate, and Zintrac-8, respectively. These results demonstrate that foliar applications of any of the zinc materials provided highly effective treatment of zinc deficiency.

Final comparisons of all of the treatments were made at the last leaf sampling date for 1993, taken on August 31 during the normal leaf sampling period used by commercial testing laboratories. 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. Nonetheless, there were very clear differences among the treatments that allow us to make specific recommendations as to which methods and materials are most effective.

Among the different treatments we compared, the most effective method for correcting zinc deficiency was foliar application, while the most disappointing methods were trunk injection and soil irrigation with zinc sulfate or zinc chelate. 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 their overall ranking, the chelated zinc 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 was comparable to zinc sulfate. Given the low cost of zinc sulfate, this may be the most cost effective. However, further tests are needed to determine how these different 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.

Table 2. *Leaf tissue zinc contents of Hass 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	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 be	18
	Zinc chelate	59 c	25
SoilBanding	Zinc sulfate	95 ab	45

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

In comparison with the foliar application, the soil banding treatment in which 7 Ibs 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 in the three test sites. In Field 2, absolutely no response was observed for trees receiving soil banded zinc sulfate, which had foliar Zn contents of 29 ppm in comparison to the 32 ppm for the control trees. In Field 3, there was only an intermediate response with soil banded zinc sulfate amended trees having 59 ppm Zn in comparison to 33 ppm for the control. In this field, minimum/maximum range values for zinc sulfate amended trees ranged from 35 to 106 ppm versus 22 to 47 for control trees. Thus as noted in Field 1, even when a response is observed the uniformity is relatively poor.

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 Ib 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.

Interestingly, while trunk injections of zinc nitrate gave a very rapid response for elevating the foliar zinc content, this response completely disappeared by the end of the first season. This may be due to the timing of the injection, which was performed in October 1992. During the winter, the older leaves which had shown the response senesced and were replaced by the new spring foliage which did not benefit from the injection. Thus, there is no long term benefit of the trunk injection. This treatment method also left open wounds on all of the major scaffold limbs which exuded sap throughout the winter and spring. 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 this treatment 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, trunk injection was not as effective as foliar application or soil banding of zinc sulfate.

During the coming year, we will continue to apply and monitor the effectiveness of these different fertilizer materials and will characterize which treatments have the greatest long term cost-benefit. For example, we anticipate that trees supplied with soil banded zinc sulfate may have elevated foliar zinc levels that persist for several years in soils where positive responses are observed. Now that the trees have been established at different zinc levels, we will also attempt to determine potential fruit yield losses and reduction in photosynthetic efficiency that result from zinc and other trace metal deficiencies. Lastly, assays are needed to determine the efficacy of different foliar applied materials and surfactants and their ability to improve internal zinc availability as opposed to coating the leaves with unavailable zinc precipitates. To this end, we will focus on the development of marker enzyme assays for monitoring iron, zinc, and manganese bioavailability in the leaf tissue.

Acknowledgments

The authors would like to thank Sam McIntire and Steve Fox of ProAg Inc. for their helpful cooperation in this project, Albion Laboratories for assistance with nutrient analyses, Allied Colloids Inc. for supply of chelated iron, zinc, and manganese fertilizer materials, and AGSCO Inc. for providing the test surfactant for foliar applications. This research was supported by a grant from the California Avocado Commission.

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