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Zinc Nutrition of Avocado

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Abstract:

In this research we have shown that most but not all of the currently used zinc fertilizer materials and application methods are effective for fertilization of avocado trees located on a calcareous soil. One of the simplest and most effective methods is the banding of zinc sulfate (7 Ibs per tree) in the sprinkler-wetted soil zone under the tree canopy. Zinc sulfate may also be applied on a quarterly basis through the irrigation water, which has the advantage of being less labor intensive than distributing zinc sulfate fertilizer by hand under individual trees. In comparison to zinc sulfate, zinc chelates applied quarterly through the irrigation line involved much lower quantities of zinc (6 grams of Zn/tree vs. 1,200 g for zinc sulfate), but in our experiment did not significantly increase the foliar zinc concentrations. Other treatments investigated foliar fertilization using zinc metalosate, zinc sulfate, and zinc oxide. On a per unit zinc basis, zinc metalosate was the most effective foliar fertilizer, but less expensive zinc sulfate also gave a good response. The third fertilizer material, zinc oxide (Zintrac-8) was shown to precipitate on the leaf surfaces and most of it could be removed by an acid wash of the foliage. In addition to uptake by the foliage, a potential problem with any of the foliar applied materials is their restricted translocation in the tree after application to the outer canopy. Relatively very small quantities were shown to be taken up by the outer canopy, which would be diluted to trivial levels if translocated to the inner canopy, fruit, and roots, all of which also require zinc. Given the present uncertainty on foliar materials, soil or irrigation-water applications of zinc sulfate represent the most reliable methods for zinc fertilization of avocado.

Zinc (Zn) deficiencies are common in many subtropical areas where avocados are grown, and are suspected to be an important limiting factor in fruit production and tree health (13, 4). Deficiencies of Zn are typically associated with calcareous soils in which availability of the metal is limited by its extremely low solubility at alkaline soil pH. Under these circumstances, applications of inorganic fertilizers such as Zn sulfate result in temporarily increased availability until the metal precipitates out of solution as the poorly soluble oxide. Zinc deficiencies have also been reported to occur in acid, sandy soils that have low total Zn contents, and in warm, semiarid regions that typically have low soil organic matter. In these cases, the Zn is relatively soluble, but is leached out of the surface soil occupied by the feeder roots. Thus the strategies that should be used for correction of Zn deficiency depend largely on the soil pH, and perhaps also on the amount of organic matter available to form metal complexes (9, 16). Other factors that influence Zn deficiency are high levels of nitrogen and phosphorus fertilizers (9) and seasonal fluctuations in leaf micronutrient content (2, 10) that may be related to irrigation and climatic factors affecting root growth and nutrient uptake.

Foliar symptoms of Zn deficiency are manifested in the new leaf tissue by a reduction in leaf size and by development of “mottle leaf”, which is characterized by interveinal leaf yellowing caused by impaired chlorophyll synthesis. Other symptoms include shortened internode length on the branches, reduced fruit size, and in Hass avocado, the production of round, misshapened fruit. The critical level of Zn in the leaf tissue has been established at 20 $\mu g \cdot g^{-1}$ leaf dry weight (6), with 30 to 150 $\mu g \cdot g^{-1}$considered to be normal. Using traditional sampling methods with bulk samples collected from the entire orchard, Zn deficiencies are not always easily diagnosed, since affected trees frequently occur in clustered groups where the soil is calcareous, or on trees that have feeder roots damaged by Phytophthora root rot (18). In some instances, visual leaf yellowing symptoms attributed to Zn deficiency may also be confused with iron deficiency, which produces somewhat similar leaf symptoms and can occur simultaneously on calcareous soils. As a result of this confusion and the historical problem with Zn deficiency, avocado growers have employed a variety of methods with inconsistent success, or may fertilize an entire orchard to correct a deficiency that is apparent in only a few highly visible trees.

Several methods have been developed to correct Zn deficiency including foliar applications of Zn sulfate and Zn chelates (11, 6), trunk injections (19), or soil applications of Zn fertilizers (17, 5). Presently, there is no consensus as to which method is the most effective, particularly for orchards on calcareous soils, or which materials are best used with the various application techniques. Foliar application of Zn fertilizers by helicopter is currently one of the more common methods used in southern California because of the difficulty of the terrain. However, there is concern as to whether the foliar Zn fertilizers are actually taken up into the leaf tissue, and secondly, whether the Zn that is absorbed by leaves in the outer leaf canopy is translocated to the other tree parts including the inner canopy, the developing fruit, and the feeder roots below ground (8). In some instances, avocado trees have been observed to produce small, round fruit typical of Zn deficiency even after the foliage has been treated with foliar Zn (20). Moreover, after the leaves have been coated with extracellular zinc, it becomes even more difficult to diagnose a deficiency using leaf analysis. To better investigate this particular problem and determine the relative efficacy of different methods for Zn fertilization, we established a field trial on a commercial orchard planted with Hass avocado that compared Zn fertilizers and application methods, analysis methods, and the influence of surfactants on uptake of Zn from different fertilizer materials.

Materials and Methods

A mature avocado orchard (>15 years old) planted with Hass avocado on Mexican root stocks was selected after a survey of Zn deficient orchards throughout Ventura County, California. The orchard, under commercial management, was located on a moderately sloping (15 - 30%) hillside on the Las Posas Hills adjacent to the Santa Rosa Valley. The soil on this site was characterized as a Soper loam containing free calcium carbonate, which was 60 to 150 cm deep over conglomerate rock. Surface soil (0 - 20 cm) pH values ranged from 7.8 to 8.0 and were buffered by 0.1 to 3% soil carbonate content. Patchy areas containing free calcium carbonate were associated with visibly chlorotic trees that were subsequently determined to be both iron and Zn deficient. At the start of the experiment, all of the trees were permanently numbered and mapped, and baseline nutrient analyses were conducted using leaf samples from individual trees. To eliminate possible problems with iron and manganese deficiencies, the trees were subsequently fertilized with iron-EDDHA (Libfer 6% Fe) and manganese-EDTA (12% Mn) at 142 and 57 g per tree, respectively, using a banded application 0.3 to 1.5 m from the trunk.

The experimental design involved a completely randomized design for the soil- and irrigation-applied materials, and a block design for the foliar treatments. The Zn materials included soil- or irrigation-applied Zn sulfate (36% Zn); irrigation-applied Zn-EDTA; trunk injection of Zn nitrate (3.5% Zn); and foliar applied Zn sulfate, Zn oxide (Zintrac-8, 40% Zn), or Zn Metalosate (6.8% Zn). Application methods and timing were based on recommended procedures previously developed by farm advisors and commercial applicators, or were recommended by the manufacturers of the various compounds. Soil-applied materials were placed in a 1 meter wide band in the mini-sprinkler irrigation wetted zone 0.5 to 1.5 m from the base of the trunk. Irrigation-applied Zn fertilizer was dissolved in water and applied to the entire sprinkler-wetted soil zone using a watering can. Trunk injection was accomplished using a propane gas powered gun inserted into a pre-drilled 6 mm diameter hole at the base of each of the main scaffold limbs. Injections were conducted early in the morning during the period of active leaf transpiration to reduce back pressure and facilitate rapid uptake into the tree limbs. Foliar fertilizers were applied to runoff using a gasoline powered, 200 gallon spray rig operated at ground level by a professional licensed applicator.

Eighteen replicate trees were randomly assigned to each treatment for the soil- and irrigation-applied materials, and 12 trees in individual blocks were used for the foliar applications. Replicate numbers were reduced to 12-16 trees for some treatments following an orchard thinning in 1993. Foliar analyses on individual trees were conducted yearly to monitor the efficacy of each treatment and the degree of variation that occurred between individual trees using the different fertilization methods. A second experiment conducted at the University of California Agricultural Experiment Station in Riverside examined the effects of three different surfactants used in combination with each of the foliar spray fertilizers. In this second experiment, all of the materials were applied in April 1994 to newly expanded Hass avocado leaves.

Leaf washing procedures used for routine analyses of soil- and foliar-fertilized trees analyzed from August 1992 to August 1993 followed industry standard procedures (3) that utilize a soap and water wash with a soft brush, followed by a tap water and 3 deionized-water rinses. In the foliar fertilization experiment conducted in 1994 to examine surfactants, more stringent procedures were tested in which leaves were washed in a dilute soap and water solution, followed by a tap water rinse and a final 0.1 N hydrochloric acid wash. The leaves were then rinsed in deionized water, after which subsamples from individual acid-washed leaves were further treated with a 60 minute wash in hexane to remove Zn associated with wax on the leaf cuticle. Subsequent procedures developed from the leaf washing experiments employed a dilute soap and water wash followed by a tap water rinse, a deionized water rinse, a 60 second acid dip, and three deionized water rinses for analyses of all leaf samples collected from the main field experiment in 1994.

In the main field experiment, foliar leaf analyses were conducted on bulk samples of 10 to 25 leaves for individual trees. A companion experiment conducted in 1993 also examined the zinc, iron, and manganese concentrations for 20 individual leaves collected from 4 different trees to ascertain the appropriate sample size required for minimizing variation in bulk samples collected from individual trees. Using a sample size statistical formula, it was determined that for most trees a minimum of 25 leaves per tree was required to generate a mean value with a 10% error. Samples were analyzed using an atomic absorption flame spectrophotometer. Reagent blanks and apple leaves (SRM 1515, National Inst. of Standards and Technology) were included with each analysis for quality assurance.

Measured values for the standard reference materials were generally within 5% of the reported concentrations.

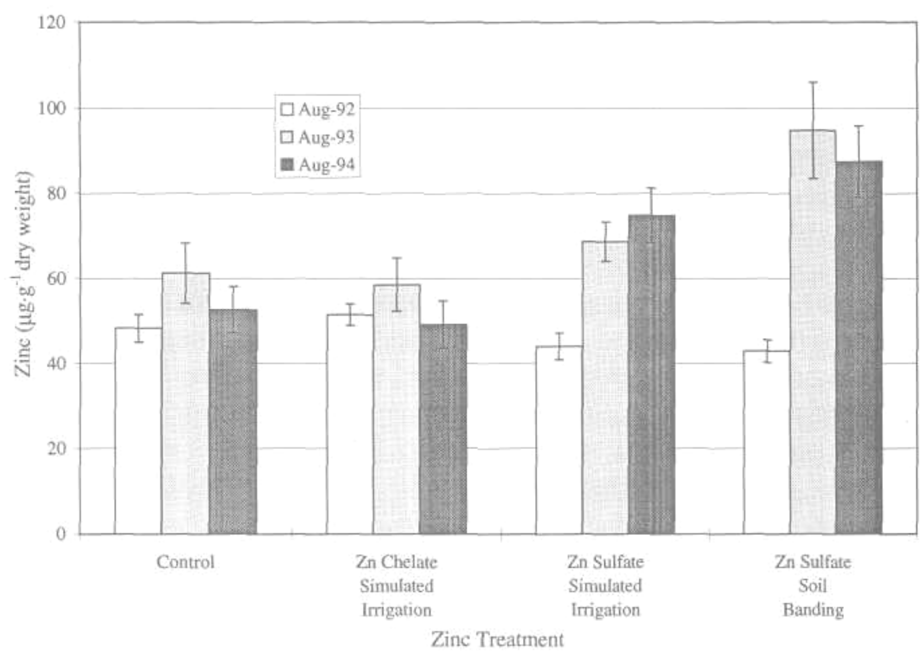

Figure 1. *Foliar zinc contents of Hass avocado trees fertilized with soil-or irrigation-water applied zinc fertilizers. Data for 1992 are for trees prior to fertilization. Zn-EDTA applied at manufacturer's recommended rate of 42.5 g per tree on a quarterly basis. Zinc sulfate applied in the irrigation water at 794 g* $ZnSO_4$ *per tree, quarterly, or as a single application of 3.2 kg per tree in February (4).*

Results and Discussion

Prior to implementing the field experiment, the mean foliar zinc concentration for all of the trees was ca. 45 $\mu g \cdot g^{-1}$, although several individual trees were Zn deficient. This variability in foliar Zn concentrations within an orchard is typical of both zinc and iron deficiency problems and appears to be associated with localized high calcium carbonate concentrations in calcareous soils. Leaf analysis data shown in *Figure 1* for August 1992 are for the trees in each treatment prior to fertilization, whereas the values for August of 1993 and 1994 are after fertilization. Data for trees receiving soil applications of Zn fertilizer were analyzed separately for trees containing low, intermediate, and high Zn concentrations to determine whether deficient and sufficient trees responded uniformly to the treatments.

Trunk Injection. The trunk injection treatment was tested only one time in the fall of 1992 and gave a short term response in which foliar Zn concentrations transiently increased from 40 to 65 $\mu g \cdot g^{-1}$ in the spring, but dropped to control levels by the following August. The 6 mm holes that were drilled into each of the major scaffold limbs healed very slowly and continued to exude sap for several months. This was judged to be a potentially dangerous treatment that could allow introduction of *Phytophthora* into the wounds, which is opportunistically associated with trunk wounding and de-suckering in California avocado orchards. The treatment was therefore discontinued.

Soil or Irrigation Application of Zn Fertilizers. Among the three soil and irrigation treatments, the least effective and most expensive was Zn chelate applied at the relatively low rate of 43 g Zn-EDTA/tree recommended by the manufacturer. Trees fertilized with this latter material were no different than unfertilized control trees *(Figure 1).* One reason for this result may be displacement of Zn from the chelate by calcium (12), which was present in large quantity in the soil as calcium carbonate. In comparison, Zn sulfate applied at an annual rate of 3.2 kg $ZnSO_4$ per tree, either quarterly as a simulated irrigation or annually as a single soil application, increased foliar Zn concentrations to 75 and 87 $\mu g \cdot g^{-1}$, respectively. One concern was whether the most zinc-deficient trees would respond similarly to those that had normal levels of zinc, or were impaired in their ability to acquire Zn as a result of local soil site factors. However, the response proved to be similar for trees in both the low and normal Zn status categories, which had Zn concentrations ranging from 71 to 109 $\mu g \cdot g^{-1}$ after the first fertilizer application. A second application of fertilizer in 1993 resulted in no significant increase in Zn concentrations. Trees that had high levels of Zn greater than 50 $\mu g \cdot g^{-1}$ at the start of the experiment generally showed no significant response to fertilizer additions, with the exception of those receiving Zn sulfate by soil banding, which increased to 103 $\mu g \cdot g^{-1}$ in 1993 and decreased the following year to 61 $\mu g \cdot g^{-1}$. This suggests that avocado may regulate Zn uptake to maintain levels between 50 and 100 $\mu g \cdot g^{-1}$ in the foliage.

An important consideration with long term use of the soil treatments is the total quantity of Zn that is being applied. After two successive applications, 2.4 kg of actual Zn had been applied per tree, which in a 10 meter square area is equivalent to 144 $\mu g \cdot g^{-1}$ Zn in the upper 10 cm of soil. Continued annual applications may exceed the legally allowable quantities anticipated under future EPA regulations for heavy metal contamination of soil (presently 1000 $\mu g \cdot g^{-1}$ in US, 400 $\mu g \cdot g^{-1}$ in Europe). During the next two years, the longevity of the soil fertilizer treatments will be monitored to determine the frequency of fertilizer application that is necessary to maintain adequate foliar Zn contents. Other options once the Zn has been applied to the soil would be to lower the surface soil pH by application of granular sulfur or use of acidic nitrogen or phosphorus fertilizers supplied with the irrigation water.

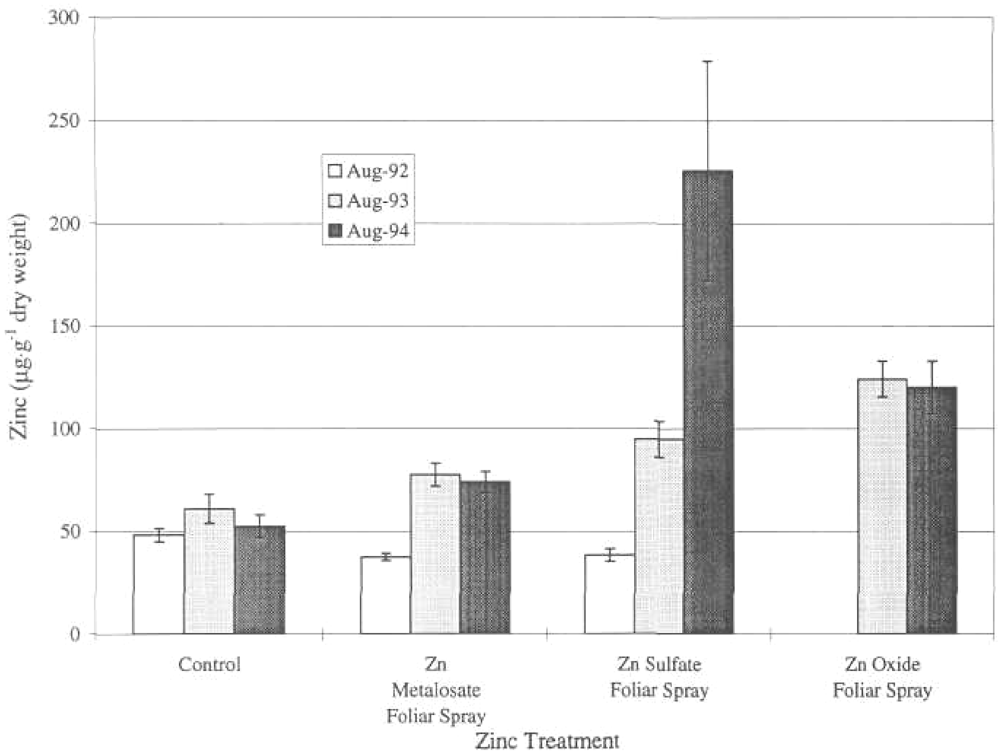

Figure 2. *Foliar zinc contents of Hass avocado trees after foliar application of zinc metalosate (0.8 g Zn/liter), zinc sulfate (5.4 g Zn/liter), and zinc oxide (0.9 g Zn/liter). All sprays were applied to the canopy to near runoff using a commercial spray applicator from ground level. The surfactants, Sun-It™ and Kinetic™, were used in 1993 and 1994, respectively.*

Foliar Sprays. Foliar application of zinc sulfate (15 g/liter, 5.4 g actual Zn), zinc oxide (Zintrac-8, 2.3 ml/liter, 0.9 g actual Zn), and zinc metalosate (11.7 ml/liter, 0.8 g actual Zn) all resulted in an increase in foliar Zn content *(Figure 2)* to levels that should ameliorate any deficiency. Zinc oxide was the most effective on a per unit zinc-applied basis, but is suspected to have poor penetration into the leaf tissue. In 1993, using a commercial surfactant, Sun-It™, mean foliar Zn contents were measured at 75 ppm with Zn metalosate, in comparison to 100 and 125 ppm for zinc sulfate and zinc oxide, respectively. In 1994, a different surfactant, Kinetic™, with better dispersion properties was used. Tissue Zn contents were similar to those measured in the previous year for zinc metalosate and zinc oxide, but the effectiveness of zinc sulfate was increased by more than two-fold such that leaf Zn content was ca 220 ppm.

Summary

Although foliar application is presently one of the most common zinc-fertilization methods used by avocado growers in California and, based simply on foliar analysis of the treated leaves, appears to be as effective as either soil- or irrigation-applied Zn materials, there is not yet any rigorous evidence that this method is effective for correcting Zn deficiency in avocado. If foliar-applied Zn is not translocated in avocado (8), deficiencies may still persist in the newly developing fruit, the inner leaf canopy, and the feeder roots, even though the outer canopy has been treated. Given the present uncertainty as to whether foliar-applied Zn fertilizers are taken up in quantities that would be significant for satisfying the Zn requirement of the entire tree, our results suggest that soil application of Zn may be the most reliable method for correcting Zn deficiency in avocado. This may be accomplished using Zn sulfate in a band applied under the irrigated, sprinkler zone of the canopies of the deficient trees, or simply by addition of solubilized Zn sulfate in the irrigation line.

Literature Cited

1. Alva, A.K., and D.P.M. Tucker. 1992. Foliar application of various sources of iron, manganese, and zinc to citrus. Proc. Fla. State Hort. Soc. 105: 70-73.
2. Bingham, FT. 1961. Seasonal trends in nutrient composition of Hass avocado leaves. J. Amer. Soc. Hort. Sci. 78: 149-160.
3. Chapman, H.D., and P.F. Pratt 1978. Methods of Analysis for Soils, Plants, and Waters, University of California Press.
4. Crowley, D.E. 1992. Soil fertility and the mineral nutrition of avocado. Circular No. CAS-92/1. Publication produced and distributed jointly by the California Avocado Development Organization and The California Avocado Society. 26 p.
5. Embleton, T.W., and E.F. Wallihan. 1966. Soil applications of zinc for avocados. Calif. Avoc. Soc. Yrbk. 50: 87-93.
6. Goodall, G.E., T.W. Embleton, and R.G. Platt. 1979. Avocado fertilization. University of California Coop. Ext. Bull. 2024.
7. Hsu, H.H. 1986. The absorption and distribution of metalosates from foliar fertilization, p. 236-254. In: H. DeWayne Ashmead (ed.). Foliar feeding of plants with amino acid chelates. Noyes Publications, Park Ridge, N.J.
8. Kadman, A., and E. Lahav. 1978. Experiments with zinc supply to avocado trees. Proceedings of the 2cnd International Colloquium on Plant Analysis and Fertilizer Problems., Auckland, New Zealand.
9. Labanauskas, C.K., T.W. Embleton, and W.W. Jones. 1959. Fertilizer effects upon micronutrient nutrition in avocado. Yearbook Calif. Avoc. Soc. 43: 96-99.
10. Labanauskas, C.K., T.W. Embleton, W.W. Jones, and M.J. Garber. 1961. Seasonal changes in concentrations of zinc, copper, boron, manganese, and iron in Fuerte avocado leaves. Proc. Amer. Soc. Hort. Soc. 77: 173-179.
11. Lee, B.W. 1973.The efficacy of aerial applications of zinc to avocado trees. [Nutritional deficiencies]. Calif AvocadoSocYearbook 56:121-123.

12. Norvell, W.A., and W.L. Lindsay. 1969. Reactions of EDTA complexes of Fe, Zn, Mn, and Cu in soils. Soil Sci. Soc. Amer. J. 33: 86-91.

13. Piccone, M.F., and A.W. Whiley. 1985. Recognize boron and zinc deficiency in avocado. Queensland Fruit and Veg. News: 19-20.

14. Sah, R.N., and R.O. Miller. 1992. Spontaneous reaction for acid dissolution of biological tissues in closed vessels. Anal. Chem. 64:230-233.

15. Shazly, S.A. 1986. The effect of amino acid chelated minerals in correcting mineral deficiencies and increasing fruit production in Egypt, p. 289-299. In: H. DeWayne Ashmead (ed.). Foliar feeding of plants with amino acid chelates. Noyes Publications, Park Ridge.

16. NJ.Srivastava, O.P. and B.C. Sethi. 1981. Contribution of farmyard manure on the buildup of available zinc in an aridisol. Commun. Soil Sci. Plant Anal. 12:355-361.

17. Wallihan, E.F., T.W. Embleton, and W. Printy. 1958. Zinc deficiency in the avocado. Calif. Agric. 12: 4-5.

18. Whiley, A.W., K.G. Pegg, J.B. Saranah, and P.W. Langdon. 1987. Influence of Phytophthora root rot on mineral nutrient concentrations in avocado leaves. Aust. J. Exp. Agric. 27: 173-177.

19. Whiley, A.W., K.G. Pegg, J.B. Saranah, and P.W. Langdon. 1991. Correction of zinc and boron deficiencies and control of Phytophora root rot of avocado by trunk injection. Aust. J. Exp. Agric. 31: 575-578

20. *Personal communication:* Francis, Len; Research Coordinator, California Avocado Society.