TRACE METAL NUTRITION OF AVOCADO

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A. Zinc deficiency
Typical leaf zinc deficiency symptoms. Note the chlorosis (yellowing) between veins and the reduced leaf size (top).

B. Iron deficiency
Iron deficiency symptoms on new growth. Iron deficiency and zinc deficiency are easily confused.

SUMMARY

It is easy to confuse zinc and iron deficiency symptoms, so growers should rely on annual leaf analysis. Also, it is essential for avocado growers to know their soil pH, and soil iron and zinc levels before embarking on a fertilization program. For zinc, best results are with soil application through fertigation or banding, and there is no apparent advantage to using chelated zinc. For iron fertilization, the best solution is to use soil applied Sequestrene 138, an iron chelate. It is highly stable and can last for several years recycling many times to deliver more iron to the roots. It is important not to mix trace metal fertilizers with phosphorus fertilizers.

INTRODUCTION

Avocados require many different nutrients for growth that include both macro and micronutrients. Macronutrients such as nitrogen, potassium and phosphorus are generally provided as fertilizers. Micronutrients are those nutrients that are essential for plant growth and reproduction, but are only required at very low concentrations. Most micronutrients, or trace elements, are involved as constituents of enzyme molecules and other organic structures. Zinc and iron are important trace elements required for plant health. Zinc is an important component of a number of key metabolic enzymes as well as influencing protein synthesis, carbohydrate and auxin metabolism and membrane integrity. Iron plays a key role in the process of respiration and the manufacture of chlorophyll for photosynthesis.

Most trace elements are normally available in soil in sufficient quantities. When trace element deficiencies do occur, it is usually the result of chemical conditions in the soil that make metal elements insoluble and unavailable to the plant. This is especially true with zinc and iron that have very limited solubility at pH 6 or above. Trace metal deficiencies may also be caused by certain chemical reactions that occur in soils containing lime or that are irrigated with water containing high amounts of bicarbonate. Poor soil drainage and root disease can also be contributing factors that will limit the growth of feeder roots that are responsible for metal uptake. An understanding of which factors are causing a trace metal deficiency can be helpful in determining the best method to correct the problem, and whether or not the trees should be treated with a trace metal fertilizer.

Very often trace metal deficiencies are indicated by the appearance of leaf yellowing or, in the case of zinc, by the development of small round fruit. The first step in treating trace metal deficiencies is to determine exactly which metal micronutrients are limiting since both iron and zinc deficiencies can cause similar foliar symptoms. Although zinc deficiency is often considered to be the most common trace metal deficiency in Southern California, iron deficiencies are actually much more common. In both cases, the leaves show chlorosis (yellowing) that is caused by problems with chlorophyll synthesis ***(Figures A and B)***. Another possibility is that trees showing leaf chlorosis may simultaneously have both zinc and iron deficiencies, in which case both problems need to be corrected at the same time. For zinc, normal leaf levels should range between 20 to 40 ppm. Leaf deficiency symptoms will occur when the foliar zinc concentrations fall below 15 - 20 ppm. Iron deficiencies on the other hand occur at leaf concentrations below 35 - 50 ppm, although in some cases trees may show iron deficiency symptoms at much higher leaf concentrations. This latter problem is due to the uptake of bicarbonate from the irrigation water, which inactivates the transport of iron in the leaf tissue. In addition to problems caused by irrigation water, bicarbonate ions can also be produced in the soil when calcium carbonate (lime) dissolves and generates HCO_3^- ions. In situations where soils contain high levels of lime, it may be nearly impossible to correct trace metal deficiencies since the problem is not due to metal availability, but is instead a physiological problem in the plant tissue (Crowley and

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Smith 1996). Fortunately, this problem usually occurs only in "hotspots" in the orchard, which attract attention but are not indicative of conditions throughout the orchard. In some cases, iron deficiency symptoms may even occur on one side of a tree but not on the other, which is due to root growth into lime pockets in the soil.

METHODS FOR CORRECTION OF TRACE METAL DEFICIENCIES

Under normal conditions, avocado trees will use naturally occurring organic matter-metal complexes that will solubilize zinc and iron and other metals and hold them in a form that can be taken up by the roots. These naturally occurring metal complexes are very effective in low pH soils. However, in situations where avocados do not obtain sufficient quantities of metals by natural processes, or where absolute quantities of the metals are limiting, such as in sandy soils, a variety of methods have been developed to correct trace metal deficiencies. These methods include foliar applications of zinc sulfate and zinc chelates (Goodall et al., 1979), trunk injections of trace metals (Whiley et al., 1991), or soil applications of zinc and iron fertilizers (Wallihan et al., 1958). When trace metal fertilizers are applied to the soil, they can be applied as metal chelates or as various metal salts such as zinc sulfate, zinc oxide, iron sulfate, and iron chloride. All of these materials can be applied directly to the soil or may be injected into the irrigation water. In general, chelated metal fertilizers are more expensive than metal salts but can be used in smaller quantities since they retain their solubility after they are added to soils. In contrast, inorganic metal salts will remain in solution only for a short time and will then precipitate into soil minerals that are no longer available to the tree. Metal chelate fertilizers can include many different chemicals that are usually referred to by their abbreviated names and include EDTA (ethylene-diamine-tetra-acetic acid), DTPA (diethylene-triamine-pentaacetic acid), or EDDHA (ethylene-diaminedi (o-hydroxyphenylacetic acid). All of these materials are water soluble, but it is important to choose the right one since they have different abilities to form stable metal complexes depending on the soil pH. For example, EDTA prefers to chelate calcium rather than iron or zinc at neutral to alkaline pH (pH > 7.0). In higher pH soils, iron and zinc chelated with EDTA will eventually be displaced by calcium and the metal ions will no longer be available to the tree. On the other hand, the metal chelator DTPA is relatively stable with zinc at high pH and may also be used to supply copper and iron. For iron fertilization, the best chemical is EDDHA (Sequestrene 138). This metal chelator is highly stable and can last for several years in the soil since it recycles many times to dissolve more iron in the soil and deliver it to the roots. The applied amount of a trace metal fertilizer depends on the type of fertilizer material as well as the severity of the deficiency. Chelates are generally provided in amounts of 1.4 to 1.8 oz. per tree, although in some cases much higher quantities may be required if the trees are located on a calcareous soil or a lime "hotspot."

With metal salts such as zinc sulfate or zinc oxide, it is much easier to apply too much fertilizer, as these materials are relatively inexpensive and have traditionally been recommended in excessive quantities. Available zinc is measured as the amount that can be extracted using DTPA under standardized laboratory test conditions, and represents only a fraction of the total zinc that is present in the soil. Embelton and Wallihan (1966) recommended the use of zinc sulfate at a rate of 7 lbs. per mature tree. This application was to be repeated every three years. However, if the standard recommendation is followed, the total zinc levels in the soil are instantly elevated to greater than 150 ppm under the tree after a single application of the fertilizer. These levels will quickly decline as the fertilizer precipitates out as new soil minerals, but will still maintain a very high level for one or two years. In contrast to the 150-ppm levels reached after fertilization, most plants have been found to require only 0.5 to 1 ppm of DTPA extractable zinc for normal growth (Soil Testing Plant Analysis Handbook, 1990) and plants such as peanut may even be poisoned when zinc concentrations exceed 36 ppm (Borkert et al., 1998). After reviewing soil analysis reports from commercial labs that were generated for avocado orchards in San Diego County, we found that many avocado orchards now contain DTPA extractable zinc concentrations that range between 100 to 200 ppm, or more than 100 times the normal levels that are needed by plants. Not only is this excessive, but if more zinc is applied, it may eventually accumulate to levels that exceed the legally allowable quantities for soil contamination under U.S. EPA regulations (presently 2800 ppm in U.S., 200 ppm in Europe). There is also the possibility that avocado tree roots might be temporarily damaged by excessive fertilization, although this has not yet been investigated. Growers should, therefore, augment their annual leaf analysis for zinc with soil analysis to minimize an excessive build-up of zinc in the soil.

FIELD EVALUATION OF FOLIAR AND SOIL APPLIED FERTILIZERS

To evaluate the currently recommended methods of zinc fertilization and better determine how much zinc is needed, we conducted a three-year experiment in Ventura County to compare different zinc formulations and application methods (Crowley et al., 1996). Results of these experiments showed that for soil applied fertilizers, zinc sulfate was the most effective while zinc chelates were the least effective and most expensive. Trees fertilized with the zinc chelates at the manufacturer's recommended rate were no different than unfertilized control trees.
In comparison, zinc sulfate (7 lbs. $ZnSO_4$ 36% per tree) applied either as a quarterly simulated irrigation or annually as a single soil application, increased foliar zinc contents to 75 and 90 ppm, respectively. However, as reviewed above, this concentration is excessive and much lower quantities could probably be used to adjust the leaf tissue contents to levels between 20 and 40 ppm. In this experiment, we also examined foliar applications of zinc sulfate or zinc oxide and an organic complexed zinc fertilizer, zinc

metalosate. In general, all the foliar applied materials appeared to be effective based strictly on foliar tissue analysis. However, with foliar applied fertilizers there is considerable difficulty in determining how much of the zinc actually penetrates the leaf tissue versus how much remains on the leaf surface where it can be detected by tissue analysis but is of no use to the plant. In our study, this problem was particularly evident with zinc oxide, which was easily washed from the leaf surface using a diluted hydrochloric acid. Previous research also has shown that there may be problems with translocation of foliar applied zinc (Kadman and Lahav 1978). If this is true, then when the tree is sprayed, the leaves that come into direct contact with the spray may have sufficient zinc, but the rest of the canopy as well as roots and fruit may still have deficiencies that could affect their growth and physiology.

To further investigate this question, we carried out experiments similar to those that were conducted in Israel by Kadman and Lahav (1978), in which radioactive zinc was used as a tracer to follow zinc uptake and translocation. In our research, zinc was applied as a 1-cm spot to either the top or bottom of newly expanded leaves. Using photographic film and another method (liquid scintillation counting) to quantify the movement of the radioactive zinc, we showed that virtually all of the applied zinc sulfate remained in the spot where it was applied and that only a small amount (around 5%) moved out into the leaves above and below the treated leaf (Crowley et al., 1996). Similar results were obtained with both zinc metalosate and zinc EDTA. We also examined a number of surfactants with a range of chemical properties to determine if these materials would increase leaf zinc penetration. In general, surfactants were beneficial for spreading the zinc over the leaf surface, but resulted in only a small increase in uptake. Altogether, our results suggest that all of the tested materials are only effective in treating the outer leaf canopy that comes in direct contact with the foliar spray and are probably of little benefit to the rest of the tree.

RECOMMENDATIONS

Leaf tissue analysis provide the most valuable tool for diagnosing trace metal deficiencies. It may be worthwhile to test different areas in the orchard before deciding to treat the entire orchard with a fertilizer. Many groves located on calcareous soils may contain “hot spots” where trees will show iron and zinc deficiencies that are not easily corrected using fertilizers or foliar applications. If there are only a few affected trees, it may be best to either spot treat these trees, or accept the fact that these trees will have metal deficiencies.

An orchard that is producing 10,000 lbs. of fruit per acre will remove 220 grams (~ 1/2 lb.) of actual zinc per acre per year. At the present time, zinc fertilizers tend to be excessively used. For example, it is a common practice in San Diego County to apply 6 lbs. of zinc sulfate (36%) every five years to mature trees. This is equal to 47 pounds of actual zinc per acre per year or nearly 100 times more than that which is removed. Consequently, many avocado orchard soils are probably being over-fertilized. If leaf tissue analysis reveal that zinc deficiencies are occurring in the orchard, the grower should keep good records to monitor how the orchard has responded to the zinc fertilizer and thereby determine the amounts that should be applied annually as a standard maintenance program. The exact response to zinc or iron fertilizer will vary from orchard to orchard depending on the soil pH, organic matter levels, soil texture, and salinity. Although zinc fertilizers have traditionally been applied during the winter months when no other fertilizers are applied, our research clearly shows that soil applied fertilizers are taken up best during the period of new root growth in the spring and early summer.

If fertilization is necessary, a good starting level is 3.5 ounces of actual zinc per tree. Many growers apply liquid zinc sulfate in one or two applications per year at a rate between 7 to 30 gallons per acre per year. The recommended rate given above(3.5 oz./tree) translates to 17 gallons of liquid Zn sulfate (12% Zn) per acre for orchards planted at a density of 110 trees per acre. Following application of the fertilizer in the spring, leaf analysis should be taken in the period between late August and early September. The amount of fertilizer to apply the following spring can then be adjusted according to the tree response that was obtained the previous year. In our experience, trees that contain greater than 50 ppm Zn will show little or no response to additional fertilizer even when it is applied in high quantities.

Commercially formulated liquid zinc sulfate fertilizers are sold by the gallon and contain 12% zinc by weight. The liquid is kept at pH 4 - 5 to keep it in solution and to permit better availability to the trees. In addition to the premixed liquid fertilizers, liquid zinc fertilizers also can be prepared using the powder form of zinc sulfate, which is very soluble. However, this material is exothermic and can be mixed in small amounts only. Solid zinc sulfate is 36% zinc by weight and has low solubility in its granular form. This is the reason it is used for soil banding.

A variety of methods can be used to apply the fertilizers. Banding fertilizers are effective for spot treating areas in the orchard, but are also expensive since they must be hand applied. There is also a greater tendency to apply excessive quantities that result in very high immediate concentrations that diminish over the next five to six years as the zinc or iron precipitates into insoluble minerals that cannot be extracted by the DTPA soil test. Although not yet tested, there is concern that very high levels of zinc that occur in the soil immediately after banding may be inhibitory to root growth. Repeated soil application treatments may also lead to accumulation of total zinc to hazardous levels. Thus, the best way to apply zinc and obtain the greatest fertilizer use efficiency is to apply it in smaller amounts at more frequent intervals. This can be accomplished by injecting the trace metal fertilizer into the irrigation water. However, if fertigation is used, zinc and iron fertilizers should never be mixed with phosphorus fertilizers as this will result in precipitation of

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zinc or iron phosphate in the irrigation line, that will cause plugging of the irrigation emitters. Foliar fertilizers can be applied to new leaf tissue, but so far they appear to have very limited efficacy as compared to other methods. In general, soil applications are preferred to foliar application since the trace metals can be absorbed by the roots and translocated throughout the tree and into the developing fruit.

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