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MINERAL NUTRITION OF AVOCADOS

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Much research has been conducted on mineral nutrition of avocados with some studies spanning a period of many years; however, there are still many areas which have not been satisfactorily explored. New information opens the door for a multitude of questions which emphasize the limits of our present knowledge, so mineral nutrition research is just as important today as in the past.

Since many nitrogen compounds are petroleum derivatives, the recent energy crisis has increased fertilizer prices and further accentuated the difficulties encountered by growers because of worldwide inflation. Additionally, avocados have traditionally been grown in choice, expensive land where a high return per hectare is essential to the grower. Fortunately, the present demand for avocados and resulting high prices have tended to offset high production costs and has encouraged many new plantings, particularly in the U.S.

Criteria for Efficient Fertilizer Use

Tissue (leaf) analysis offers the best means for diagnosing mineral nutrition problems and ultimately monitoring fertilizer use in the field, despite difficulties in its interpretation, particularly of some microelements. Soil analysis for assessing rates of application and fertilizer type has taken a subsidiary position to leaf analysis. It is still useful to confirm extreme cases of under-fertility or over-nourishment but does not detect changing fertility in the soil and therefore is of no help in determining immediate fertilizer needs. Leaf analysis, on the other hand, gives concentrations of nutrients in the plant which can be utilized effectively if we know the range of nutrient levels at which the plant functions best for maximum yield performance.

Most nutrient levels reported for avocado leaves are values from orchard surveys where fertilizer rates and yields were not recorded precisely. Other leaf analysis values have originated from nutrient cultures studies with young seedlings, which cannot be used for diagnosing fertilizer needs of producing trees. Thus, we do not have standard leaf values for most cultivars which can be related to fruit production and quality. Embleton *et al.* (14) conducted the only study where a curvilinear relationship was obtained between leaf nitrogen (N) and fruit yield. Their work with 'Fuerte' included known rates of N received by the trees. Similar work with other elements and cultivars has been conducted in other areas but meaningful results have been difficult to obtain. The long-term nature of this research makes it susceptible to the vagaries of the weather, the effects of biennial bearing and other factors which complicate collection of precise yield data.

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Factors Affecting Nutrient Uptake by Avocado Roots

Many factors affect the ability of avocado roots in forage for essential elements in the soil. Soil aeration is one of the most important since avocado roots are highly intolerant of water-saturated conditions. The avocado ranks perhaps first among tropical fruit trees in the need for in able, well drained, deep soils. Heavy soils with their accompanying problems of excessive water and low aeration weaken the roots and predispose the plant to infection with such soil borne fungi as *Verticillium* and *Phytophthora cinnamomi.* The first may cause only a setback in the tree's growth, but the second may ultimately kill the tree. Excessive water and insufficient soil aeration reduces the number of feeder roots and weakens the remaining ones, lowering their capacity for obtaining soil nutrients and moisture. A vigorous root system in a well-drained soil is essential for productive avocado trees.

Factors other than poor drainage which damage avocado roots include subfreezing or extended unseasonal low temperatures, saline soils, cultural practices such as continuous use of rotary hoes which destroy surface roots and herbicides, such as bromacil, which are phytotoxic, particularly in sandy soils. The first 2 factors are most serious since they cannot be manipulated or controlled effectively. The others occur as a result of misinformation or mismanagement.

Mineral Requirements

Iron

The ideal soil pH for avocado trees is 5.5-6.5. Avocado trees are susceptible to iron (Fe) deficiency under conditions higher than pH 7.0 because calcium (Ca) is the dominant cation in such soils, creating conditions where Fe becomes fixed in forms unavailable to the roots of the plant. The resulting lime-induced chlorosis is perhaps more critical to avocados on a worldwide scale than to any other fruit crop. Most tropical and subtropical commercial avocado areas, particularly the drier ones, have a high incidence of neutral to alkaline soils where Fe chlorosis is a major problem.

The only possibility for control of Fe chlorosis is by soil applications of Fe chelates, since applications by foliar sprays have not been successful on a commercial scale. There are many chelates available but few are really effective under alkaline or calcareous conditions. One of the most effective is the ferric chelate of ethylenediamine di-(o-hydroxyphenyl acetic acid) or FeEDDHA, known commercially as Sequestrene 138®. This product has been used experimentally and commercially since about 1955 and has proved to have a higher stability under calcareous conditions than any other chelate. Rates of application vary in effectiveness with the degree of alkalinity and size of the lime particle in the soil. Rates of 50-400 g of Seq. 138® per tree have been used to achieve the desired results in different soils. The optimum rate depends on size of tree, degree of chlorosis and soil type and should be determined experimentally in each location. Trickle irrigation is perhaps the most convenient and efficient way to apply FeEDDHA because it goes directly to areas of the soil where there is a proliferation of roots. A surfactant should be added to the water to facilitate dissolution since the chelate is a fine powder and difficult to wet.

Young avocado trees growing and rapidly forming new tissue perhaps benefit most from periodic preventive applications of iron chelates, particularly if the soil is neutral or slightly alkaline. Once chlorotic leaves have matured it becomes increasingly difficult to correct the problem as these leaves react very slowly, if at all, to FeEDDHA.

Nitrogen and Potassium

Nitrogen and potassium (K) are of major significance in avocado nutrition in terms of the amounts needed and of overall importance. Nitrogen is more likely to become deficient than K in orchards where supplemental fertilization is not employed. Most soil N is stored in organic matter. This important component is very susceptible to oxidation in tropical and subtropical climates. Thus, N must eventually be replaced through fertilization regardless of the original fertility.

There are few soils in the warm climates where K is critically deficient, particularly if it is of volcanic origin. However, close attention should be given to K levels in leaves because the soils in some areas, such as Florida, may be quite deficient in this element. A heavy avocado crop removes considerable amounts of K from the tree and cultivars such as 'Booth 8' which tend to overbear may decline or even die after a heavy crop. Potassium levels below 0.35% in 5-7 months-old leaves are considered dangerously low. In these cases some growers apply several sprays of 1% K nitrate to prevent the ultimate collapse of the tree, a practice which needs further research. Potassium deficiency symptoms are not uncommon in Florida, especially with prolific cultivars. Potassium deficiency symptoms appeared after 8 years in trees receiving no K in the fertilizer in an experiment conducted in Homestead. Visual symptoms of N deficiency (leaf levels below 1.0%) appeared in the same soils after only 3 years in trees receiving no N.

Embleton *et al.* (13, 14) found that in 'Fuerte', leaf N levels below 1.6% and higher than 2.0% were associated with a drop in fruit production. This relationship has not been obtained for other cultivars in spite of the amount of nutritional work conducted in many avocado production areas. It is assumed that each avocado cultivar has its own correlation between leaf N and yield, although this remains to be confirmed by research. It is important to know, particularly with today's fertilizer prices, the point at which N becomes counterproductive.

The optimum relationships between leaf N and K and fruit production in the majority of avocado cultivars have yet to be found. This information has been established only for 'Fuerte' in California and this cultivar is a rather unreliable performer, even in the best climates. It is fair to assume that relationships of N and K to yield will be different, with perhaps more amplitude in other cultivars, particularly the more productive ones.

A good rule of thumb in areas where leaf analyses are difficult to obtain would be to use a maximum of 1.5-1.7 kg of elemental N per tree per year for very infertile soils. The amount of elemental N should be decreased accordingly for soils of increasing fertility and depth in relation to the performance of the cultivar in other areas. Blanket recommendations for K are more difficult to make without leaf analysis information, but fortunately it is less likely to be deficient or to become so as rapidly as N.

Phosphorus

This element is well known to be essential for young vigorous plants but its relative importance declines as the tree growth rate slows down. Thus, the amount of phosphorus (P) needed for trees in production is relatively small. This has been clearly demonstrated in Florida's infertile, calcareous soils of the Homestead area where fruit production of 'Lula' and 'Booth 7' has not declined appreciably after 15 years without P applications to the soil. Leaf levels of P in these trees have not declined below 0.1 2% (5-7-month-old leaves) which may be considered perhaps low but not an indication of deficiency. Phosphorus in calcareous soils tends to accumulate, becoming available to the plant very slowly but apparently in adequate amounts. Table 1 shows what some authors consider adequate leaf levels for P and other elements. Until we have more refined information we could assume that under commercial conditions a safe measure should be to not allow leaf P to drop below 0.08%.

Table 1. Elemental leaf levels from selected references in the literature. Most intermediate ranges are not associated with yield performance.

			Range					
Cultivar	Element	Culture	Deficient	Low	Intermediate	High	Toxicity	Reference
Fuerte	N %	Field	1.2	1.6	1.6-2.0	2.0	-	13,14
Lula	N %	Field	-	-	1.68	-	-	47
Lula	N %	Field	-	-	1.24	-	-	47
Fuerte	P %	Field	-	0.065	0.065-0.20	-	-	16
Hass	P %	Field	-	-	0.147-0.163	-	-	15
Lula	P %	Field	-	-	0.16	-	-	47
Lula	Ca %	Field	-	-	1.22	-	-	47
Hass	Mg %	Sand	0.15	0.15-0.25	0.25-0.50	-	-	6
Hass	Mg %	Field	-	-	0.32-0.50	-	-	15
Lula	Mg %	Field	-	-	0.26	-	-	47
-	Fe ppm	Field	26.0-40.0	-	50.0-80.0	-	-	7
-	Zn ppm	Field	4.0-15.0	-	50.0	-	-	52
-	Mn ppm	Field	-	-	70.0	-	-	40
Hass	Mn ppm	Field	-	-	56.0-66.0	295-568	-	35, 36
Fuerte	Cu ppm	Field	-	-	4.0-11.0	-	-	38
MacArthur	Cu ppm	Field	-	-	6.0-10.0	-	-	17
-	B ppm	Solution	2.7-18.0	-	12.0-37.5	-	-	26
Fuerte	Cl %	Solution	-	-	0.04	0.47	1.07-1.62	3
Fuerte	Cl %	Field	-	-	0.19-0.33	-	0.46-1.36	4
-	Cl %	Field	-	-	0.07-0.23	-	0.22-1.48	10
Fuerte	Na %	Field	-	-	0.02-0.04	-	0.37-1.56	4,5
-	F ppm	Controlled	-	-	5.0-17.0	-	195-1,027	9
-	Ba ppm	Field	-	3.0	5.0-12.0	17.0	-	9

Zinc

On a worldwide basis zinc (Zn) and Fe are very critical microelements because the avocado is very susceptible to their deficiency. Symptoms of Zn deficiency are observed in acid soils from which it is easily leached at a low pH and in calcareous soils in which it is fixed in unavailable forms. Early deficiency symptoms are mottled, narrow, disproportionately small leaves at the terminals, usually light green or chlorotic in color. Leaf margins are necrotic and internodes are shortened in advanced cases.

Zinc deficiency symptoms are similar to those of Fe in that once they appear, malformed leaves do not regain normal shape and size after corrective measures are applied, thus prevention is of prime importance. Two annual foliage sprays of Zn sulfate (1.5-2.5 kg in 400 liters of water plus, a surfactant and hydrated lime as a neutralizer) will prevent the problem from appearing in areas where deficiencies are likely to occur. Timing is not critical but sprays should be applied when the foliage is plentiful and mature. Soil applications of Zn are ineffectual in alkaline or calcareous soils, but are practical in acid soils or where steep terrain prevents ground sprays. Chelated Zn applied through drip irrigation is practical and economical. In the calcareous soils of Florida where deficiencies of Fe, Zn and manganese (Mn) are likely to occur, good results are obtained by combining the chelates of these elements in small quantities and applying them periodically through the drip irrigation system.

Other Elements.

Deficiencies of other elements are not frequently observed in avocado orchards. However, symptoms of Mn deficiency are common in Florida, but the problem is not considered critical since its correction and prevention are quite simple and are accomplished in a similar manner as mentioned for Zn. It has been postulated that this deficiency accelerates the appearance of leaf senescence, thereby shortening their productive life.

Magnesium deficiency in avocado orchards is so uncommon that this element can be placed in the same category with Ca and sulfur (S) which are considered critical only in exceptional cases.

Excesses of Some Elements and Salts

There is good evidence indicating that copper (Cu) from fungicidal sprays can accumulate in toxic amounts in calcareous soils. This problem has been found in South Florida in circumstances suggesting that Cu toxicity is serious *per se* and also contributes to the Fe chlorosis problem of avocado groves. Unusually high amounts of Cu have been found on the exterior surfaces of 'Lula' avocado roots. This cultivar needs additional sprays of Cu because of its higher susceptibility to scab (*Sphaceloma perseae*) and shows, as a rule, a higher incidence of Fe chlorotic trees than any other cultivar.

Excesses of salts such as chlorides (Cl) and sodium (Na) are more difficult to control in the soil. They usually occur in drier areas where there is insufficient rainfall for adequate leaching and where the irrigation water may also contain considerable amounts of salts.

The avocado tree is particularly sensitive to Cl and Na since it tends to absorb and accumulate them more readily than most other fruit trees. An excess of Cl shows up as tip and marginal burns of older leaves, ultimately causing defoliation. Sodium toxicity symptoms are interveinal leaf burn compounded with twig dieback in extreme situations.

Sodium is perhaps the more damaging.

Recent work in Israel has indicated that of the 3 races, West Indian avocados are more tolerant to the toxicity of these 2 elements and to Fe chlorosis. Consequently, seedlings of cultivars such as Waldin', which is the traditional rootstock in Florida, should be used in most areas with these problems.

Prospects for the Future

Broad recommendations for the use of most elements in avocado orchards are fairly well established. However, the finer points of nutrition for optimum production and efficient fertilizer use are still being investigated. Newer approaches are being taken, particularly with the advent of drip irrigation and fertigation (periodic application of soluble fertilizer in the irrigation water) where preliminary results have shown that it is possible to lower formerly recommended rates without lowering yields appreciably. At present, research is being conducted in many areas to determine the full extent of the possibilities of fertigation. This method would permit more precise and timely application of nutrients and considerable savings in the amount of fertilizer and in the labor to apply it.

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