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NITROGEN FERTILIZATION OF THE 'HASS' AVOCADO IN CALIFORNIA

What we know and what we don't know.

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SUMMARY:

Nitrogen (N) is one of 17 essential mineral nutrient elements required by avocado trees and all other plants. If deficient, tree growth, leaf expansion, fruit set and fruit size are reduced. In spite of nearly four decades of research, the management of N in avocado groves is poorly understood and recommendations vary widely. So what do we know? We know that nitrogen deficient avocado

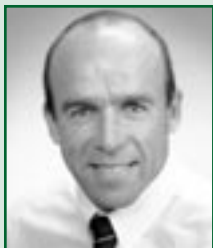
trees respond rapidly to applied N. Generally, the response is in the form of increased yield as well as shoot growth. However, if too much N is supplied, the trees may invest disproportionately in shoots and wood at the expense of fruit and so production may decline. Also, excessive N can result in poor postharvest quality and advanced ripening (Arpaia et al., 1996).

Using available crop nutrient removal data, and estimates of the amount of N lost through leaching and other natural processes, it is estimated that approximately 90 lbs. of N/acre are required each year to produce 11,000 lbs. *continued on page 2*

RESEARCH UPDATE

- ▶ Dr. David Crowley (UC Riverside) recently set out a comprehensive trial at the Stehly Ranch near Valley Center, CA, to examine the effect of saline irrigation water on Hass grafted to 11 different rootstocks. In the future, we hope to identify salt tolerant rootstocks for California orchards through this research.
- ▶ Dr. Mary Lu Arpaia (UC Riverside) has launched a collaborative research project with Jan Delyser and CAC's Merchandising team. They are showing exceptional early results from their retail quality study. In one market, for example, reduced product waste resulting from early recommendations will save an estimated \$ 500,000 in shrinkage per year.

Watch for meeting notices in the AvoGreensheet or log onto www.avocado.org/growers for more information.




From The Editor

Guy Witney, CAC Production Research Program Manager

In the current issue of AvoResearch we have concentrated on the nutrient elements most often discussed in grower circles, namely nitrogen and zinc. The California Avocado Commission (CAC), through our Production Research Program, has a considerable history of investment in research on these two nutrients and we continue to support a nitrogen field study with Dr. Carol Lovatt at UC Riverside. In this issue, researchers have summarized much of what we know about nitrogen and zinc in tree nutrition, as well as providing some information on iron nutrition for completeness.

As with past issues of AvoResearch, we have a pullout insert that can be pinned up or saved. In this issue it is on Avocado Sunblotch Viroid. While many in the grower community know of this threat to our trees, some of the information presented here is likely new to most. Dr. Allan Dodds at UC Riverside is conducting ongoing research into this disease and he provides a great summary of what we now know. Please contact Allan if you feel you are able to help in the program (see details in the insert).

Lastly, Reuben Hofshi, Chair of the Production Research Committee, visits one of the centers of origin of the avocado: Mexico. In this article he extols the advantages of growing 'Hass' avocados in an almost ideal environment and challenges the California industry to use research to take advantage of the great genetic potential of the crop. 

In This Issue

- Nitrogen fertilization of the 'Hass' avocado in California
- Trace metal nutrition of avocado
- Recognizing avocado sunblotch disease
- Hass cultivation in Mexico



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of avocado fruit (110 trees/acre, each producing 100 lbs. fruit). The recommended leaf N concentration for avocados is 2.2% (dry weight).

In Southern California orchards, N can come from several sources. While we often think of fertilizers as being the primary source of N for trees, there are often significant amounts of

supplied to the tree during times when trees are thought to have increased demand (around mid-November and again in mid-April), yield and fruit size was significantly increased. However, this work needs to be repeated over several years and locations to gain confidence in recommending this practice. Currently, the best recommendation is to apply N in several small doses starting in February and ending in November. This supplies the tree through periods of demand while minimizing losses through leaching during winter

include nitrate, ammonia, free amino acid precursors needed for protein synthesis, DNA and RNA, and nucleotides, the nitrogenous precursors of DNA and RNA synthesis. Since N is utilized in the synthesis of DNA, RNA and protein, which are essential for growth, and for the synthesis of hormones that direct cell division (cytokinins) and cell expansion (auxins), growing tissues are affected by N deficiency before existing tissues. Tree growth, leaf expansion, fruit set and fruit size are reduced by a lack of available N. Classic symptoms of N deficiency are pale green leaves and fruit, small leaves and fruit, low yields, reduced tree vigor, and when acute, chlorosis (yellowing) of leaf veins.



Nitrogen deficiency results in pale colored leaves, short leaf life, sparse foliage and reduced fruit yield.

N in orchard irrigation water as well as inherent in some soils. For example, some well waters in the Corona foothills of Riverside County have sufficient N to meet the total demand of avocado trees (M. Arpaia, personal communication). Often overlooked, too, is the contribution of air pollution to the N supply. In the inland valleys with poor air quality as much as 30 lbs. of N/acre are contributed from particulates falling from the air (M. Yates, personal communication). Mulches are becoming a common site in many California avocado orchards and will also add N. It is a good idea to have the carbon/nitrogen ratio of your mulch analyzed and adjust your fertilization program accordingly. It is important for growers to test their irrigation water and soil for available N, as well as do routine leaf analysis to determine tree N status. Using this information, the amount of N needed to be supplied as fertilizer can be estimated.

We don't yet have a good understanding of the best time to apply N. In experiments where extra N was

rainstorms or heavy irrigation (Yates et al., 1993).

To increase the efficiency of applied N and to supply trees during periods of anticipated demand, some work has been done with foliar (leaf applied) sprays. When foliar urea was applied to the spring flush leaves (2/3 fully-expanded), there was a significant increase in leaf N content. In experiments applying urea to the canopy when inflorescences are at the cauliflower stage, there was an increase in yield and fruit size distribution over the control.

Read on if you would like to know more detail on N in the tree, past research and future directions!

THE DETAILS:

Why do avocado trees need nitrogen fertilizer?

N fertilizer applied to avocado trees is predominantly used to synthesize protein. Other N-containing molecules

When nitrogen is applied as fertilizer, where does it go in the tree?

Avocado fruit are not "nutrient cheap." Research done in California, Australia and New Zealand has shown that avocado fruit are a major sink for N. Avocado fruit have the highest protein concentration of commercially produced fruit, including deciduous, subtropical or tropical tree crops (Hall et al., 1980). Whereas other fruit average 0.8% protein on a fresh weight basis (FAO, 1970), avocados routinely exceed 2.3% protein per unit fresh weight (Pearson, 1975; Slater et al., 1975; Hall et al., 1980).

Research in California has shown fruit N concentrations to be between 0.8% and 1.8% on a dry weight basis. Interestingly, fruit N content, like leaf N content, was independent of crop load and N fertilization rate. There is also a significant amount of N stored in the foliage and small branches of avocado trees. We (Lovatt, 1998) dissected an 8-year-old 'Hass' avocado tree on Duke 7 rootstock, which was bearing 148 lbs. fruit. The total N content of the fruit equaled 0.65 lb. Small branches with a total fresh weight of 144 lbs. stored 0.76 lb. N. Leaves and new shoots, which weighed only 55.5 lbs. total, contained 0.44 lb. N. Scaffolding branches, total fresh weight 155 lbs., had 0.33 lb. N. Other parts of the tree (trunk, roots) contained negligible amounts of N.

How much nitrogen fertilizer does a tree need each year?

“Crop nutrient removal” is a method used to calculate the amount of a nutrient taken out of the orchard by the harvested fruit in order to calculate the amount that must be replaced through fertilization to sustain yield. Fertilization rates based on nutrient removal are much improved by also knowing the amount of nutrient required to support annual vegetative growth, the amount of nutrient lost due to abscission of flowers, fruit and leaves, and fertilizer losses due to leaching, volatilization, and microbial action.

Research in Australia provided evidence that an additional 84% more N than that contained by the fruit was required to replace the N lost in fallen leaves and shed flowers and to compensate for N leaching, erosion and fixation (Dirou and Huett, 2001). N requirements for woody tissue and root growth were unknown. Thus, in Australia to produce 10 metric tons fruit/ha/year, a crop replacement rate of 70 kg. N/ha/year is required. This is equivalent to a N fertilization rate of 62 lbs./acre to produce 10,000 lbs. fruit/acre.

Data from California (Lovatt, 1998) was used to calculate an estimated N replacement value for a ‘Hass’ avocado orchard in California. Estimating a 10% loss in leaves each spring, there would be an approximate loss of 0.04 lb. N per tree annually. A 10% increase in vegetative shoot growth, root growth, and storage of N in branches would require 0.15 lb. N per tree. A yield of 100 lbs. fruit per tree would remove 0.43 lb. N at harvest. The amount of N lost due to abscission of reproductive structures during bloom and early fruit set is unknown. Using these values and a planting density of 110 trees per acre, the calculated annual replacement rate for N fertilization would be 68.2 lbs. N/acre in California. Estimating a 30% loss in

N fertilization due to leaching, volatilization, and fixation would require another 20.5 lbs. N/acre. Thus, 88.7 lbs. N/acre would be required each year to produce 11,000 lbs. of avocado fruit per acre. Coincidentally, average yield for the ‘Hass’ avocado in California has been 5,700 lbs./acre for the last 25 years (Arpaia, 1998). In addition, corresponding replacement fertilization for P, K, Ca, Mg and possibly other nutrients would be required annually to maintain the proper balance in the tree’s nutritional status.

When using fertilization replacement values, it is equally important to calculate the amount of N and other nutrients provided in the irrigation water, soil and organic matter. In addition, efforts should be made to reduce the amount of N, and other nutrients, that must be applied by reducing leaching, volatilization, and fixation. Soil and leaf analysis should be performed annually.

We are in the process of experimentally determining replacement values for other nutrients as well as improving the values we have for N. Our goal is

to provide monthly, phenology-based, fertilizer replacement values for developing fruit, vegetative growth and N storage. In the interim, values presented here, while preliminary, are instructive.

When should nitrogen fertilizer be applied?

Whereas there are theories on “right” and “wrong” times to fertilize avocado trees, research quantifying the relationship between critical periods of tree phenology and the effect of application time and amount of fertilizer applied at specific times is still limited.

Embleton et al. (1968) conducted the first research on N fertilization of the ‘Hass’ avocado in California. In a five-year experiment they demonstrated that ‘Hass’ avocado trees had the highest mean yield at the highest annual rate of applied N (4.0 lbs./tree). Mean leaf N concentration was 2.13% for this treatment. Despite the fact that different rates of N fertilization resulted in significant differences in leaf N concentrations, there was no correlation with yield within a given year. Very similar results were obtained by Yates et al. (1993), who found that leaf N levels correlated well with the amount of N applied (0.8 lb. and 1.6 lbs. N/tree/yr.), but not yield.

In a seven-year study initiated with six-year-old ‘Hass’ avocado trees (Embleton and Jones, 1972), four different annual rates of N from 0.2 to 4.0 lbs. per tree were applied by splitting the total N in July and November or in February, July, and November. No treatment affected yield. The results suggested that ‘Hass’ avocado yields were insensitive to N fertilization rates, time of application, and leaf N concentrations in the range between 1.75% and 2.12%.

Lovatt (2001) recently completed a four-year experiment that addressed the question of whether yield of ‘Hass’ avocado could be increased by doubling the amount of N currently applied

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Excess nitrogen may cause excessive vegetative growth at the expense of fruit.

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during specific stages of the tree growth cycles “phenology.” Many California growers divide the total annual amount of soil-applied N fertilizer into small applications made during the period from late January to early November to protect groundwater from potential nitrate pollution. While research has shown that splitting nitrogen into several small doses will in fact reduce the potential for groundwater contamination by nitrates (Yates et al., 1993), there has been concern that the amount of N in the individual applications may be too little to meet the demand of the tree at specific stages of its phenology.

The control in this experiment was the practice of annually applying N as NH_4NO_3 (ammonium nitrate) at 150 lbs./acre in six small doses of N at 25 lbs./acre in January, February, April, June, July, and November. From these six application times, five were selected on the basis of tree phenology and additional N as NH_4NO_3 at 25 lbs./acre was applied at each time for total annual N of 175 lbs./acre. Two phenological stages were identified for which N application at 50 lbs./acre in a single application (double dose of N) significantly increased the four-year cumulative yield (lb. fruit/tree) 30% and 39%, respectively, compared to control trees ($P \leq 0.01$). In each case, more than 70% of the net increase in yield was commercially valuable large size fruit (packing carton sizes 60, 48 and 40). The two phenological stages were: (i) when shoot apical buds have four or more secondary axis inflorescence meristems present (around mid-November); and (ii) anthesis-early fruit set and initiation of the vegetative shoot flush at the apex of indeterminate floral shoots (approx. mid-April). When the double dose of N was applied at either of these two stages, the total pounds and number of large size fruit averaged across the four years of the study was significantly greater than the control trees ($P \leq 0.01$). Application of the double dose of N in April significantly reduced the severity of alternate bearing ($P \leq 0.05$). In this experiment, yield was not significantly correlated with leaf N concentration.

The results of the study suggested that time and rate of N application are factors that can be optimized to increase yield, fruit size, and annual cropping of ‘Hass’ avocado. The best treatments in this study and additional treatments are being tested in a second orchard. Several years of research in multiple orchards are necessary to learn under what climate and orchard conditions these results can be achieved with reliability before a University of California recommendation can be made. The results of the second experiment will contribute to this goal.

Why isn't yield correlated with the leaf nitrogen status of ‘Hass’ avocado orchards in California?

The N fertilization experiments of Embleton et al. (1968), Embleton and Jones (1972), Yates et al. (1993), and Lovatt (2001) were all conducted in alternate bearing orchards. Any treatment that affected yield altered the degree of alternate bearing of the trees. The amount of vegetative growth the tree produced and the amount of stored N the tree used or conserved was also affected. Both the large pool of stored N in avocado branches, and the variation in vegetative shoot growth in relation to yield, buffer the effects of yield on leaf N concentration. Thus, it is not unexpected that yield is not related to leaf N concentration. If your orchard bears unevenly, as most do, it will be difficult to obtain a good correlation between leaf N and yield.

In early fertilization trials when the optimum levels for many nutrients were not known, Embleton et al. (1968), suggested an alternate reason for N leaf content not correlating with yield. That is, in some cases another nutrient may have been in low supply and thus limiting production in spite of adequate available N.

Can nitrogen be supplied to ‘Hass’ avocado trees in California through the foliage?

It is clear that N uptake is more efficient at some times of the year than others. In California, avocado flowering and fruit set are periods of high nutrient demand that frequently occur when soil temperatures are low. Low soil temperature reduces root metabolic activity, solubility of nutrients in the soil solution, and nutrient uptake and transport in the transpiration stream. Foliar fertilization can meet the tree’s demand for a nutrient at times when soil conditions may render soil-applied fertilizers less efficient. For foliar fertilization to be successful, the nutrient must be taken up

by leaves of the crop, or other target organs, and be phloem mobile. Mature leaves of the ‘Hass’ avocado growing in California are very inefficient in taking up N (Nevin et al., 1990). However, inflorescences and young spring-flush leaves do respond to foliar-applied low-biuret urea.

In a three-year experiment, low-biuret urea was applied to the canopy of ‘Hass’ avocado trees (0.35 lb. N/tree) in a commercial orchard during the “cauliflower stage” of avocado inflorescence development (Jaganath and Lovatt, 1998). All trees had optimum nutrient levels based on annual September leaf analysis. The “cauliflower stage” is characterized by elongation of the secondary axes of the inflorescence and late stages of pollen and ovule development within the flowers (Salazar-Garcia et al., 1998). Urea applied at this time significantly increased the number of viable ovules and number of pollen tubes that successfully reached the ovule and increased cumulative yield ($P \leq 0.05$) (Jaganath and Lovatt, 1998). Foliar-applied urea resulted in a net increase in cumulative (three years) yield over the control of 4.4 tons/acre. The increased cumulative yield was accompanied by an increase in the

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number of commercially valuable large size fruit (packing carton sizes 60, 48 and 40). Treatments were cost-effective. Note that due to increased formation of flowers with double pistils, urea should not be applied to orchards with leaf B concentrations >150 ppm.

Urea, as a foliar spray at the "cauliflower stage" of inflorescence development, requires good coverage of the developing inflorescences. Under Southern California conditions, leaves of the 'Hass' avocado do not take up urea at this stage of flower development because they are fully mature (Nevin et al., 1990). In contrast, application of low-biuret urea (22 lbs. N/acre) to spring flush leaves when they were 2/3 fully expanded significantly increased percent leaf N. Leaves at this stage of development have sufficiently thin cuticles and adequate surface area to take up urea effectively. However, it is not known yet if applying urea at this time has a positive effect on yield. These results taken together provide evidence that foliar-applied urea can efficiently meet the demand of the 'Hass' avocado tree for N and/or stimulate specific physiological processes resulting in increased yield and fruit size.

CONCLUSION:

Nitrogen fertilization provides a relatively inexpensive tool that can be used to manage tree vigor, optimize fruit set and size, and reduce alternate bearing. However, it must be emphasized that good stewardship of soil-applied fertilizer and a complete, balanced fertilization program are necessary to realize the potential benefits of N fertilization.

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Measuring fruit yield in one of Dr. Carol Lovatt's nitrogen fertilization field trials.