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Guaging the Effectiveness of Foliar Fertilizers on Citrus

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INTRODUCTION

Foliar fertilization can meet the plant's demand for a nutrient at times when soil conditions (low temperature, low soil moisture, pH, salinity) render soil-applied fertilizers ineffective. Thus, foliar fertilization is an effective method for correcting soil deficiencies and overcoming the soil's inability to transfer nutrients to the plant. Nutrients, especially phosphate, potassium and trace elements can become fixed in the soil and unavailable to plants. Applying nutrients directly to leaves, the major organ for photosynthesis, ensures that the plant's metabolic machinery is not compromised by low availability of an essential nutrient. It is important to note that foliar-applied fertilizers of phloem-mobile nutrients are translocated to all parts of the tree, including the smallest feeder roots. Foliar fertilizers reduce the potential for accumulation of nutrients in soil, run-off water, surface water (streams, lakes and the ocean), and groundwater (drinking water supply), where they can contribute to salinity, eutrophication and nitrate contamination, all of which have serious consequences on the environment and humans. Thus, foliar fertilization provides advantages over traditional soil-applied fertilizer and should replace soil-applied fertilizer, at least in part, in crop best management practices (BMPs).

Three problems impede adoption of foliar fertilizers:

1. Not all nutrients are taken up through the foliage and, even if taken up, some nutrients are not phloem mobile. Thus, *a priori* knowledge (research) is necessary to know which nutrients are taken up through the leaves of a specific crop in order to develop a foliar fertilization program. This information is not always available to growers and the lack of information compromises a grower's ability to discern which foliar fertilizers are worth using and when to apply them.
2. Standard leaf analyses do not always show the expected increase in nutrient concentration. This can be due to poor nutrient uptake, but also can result from excellent uptake

and utilization by tissues not sampled (new shoots, stems, roots and especially fruit). Conversely, leaf analyses can give false positive information regarding foliar fertilization. Some foliar-applied nutrients persist in the wax of the leaf cuticle. Thus, if the leaves analyzed are not washed properly, a false high reading will be obtained. Frequently, it is considered sufficient to merely demonstrate that a nutrient applied as a foliar fertilizer is taken up. To do this, leaves are typically analyzed within a short period of time after the fertilizer is applied to the foliage. Whereas this approach may confirm that uptake has occurred, benefits of the application are largely presumed.

3 Rates of foliar fertilizer are typically lower than soil-applied fertilizer, but application of foliar fertilizer can be more expensive, especially if a grower does not own his own sprayer. Tank mixing multiple fertilizers and/or pesticides to save a trip through the orchard can cause negative interactions that reduce efficacy or cause negative effects on plant metabolism, such as the negative effect on yield of the avocado due to the interaction between foliar-applied N and B (Lovatt, 1999). Growers have been proactive in protecting the environment, but with the high cost of fertilizer in general, foliar fertilizers must be proven to be effective for growers to be willing to incur the expense of using them. An improved methodology to evaluate the effectiveness of foliar fertilizer is required. We propose that the only acceptable standard by which to measure effectiveness of foliar fertilizer is a resultant yield benefit and net increase in grower income.

The key to achieving a yield benefit and net increase in grower income is properly timing the foliar application of fertilizer to key stages of crop phenology when nutrient demand is likely to be high or when soil conditions are known to restrict nutrient uptake. For citrus and avocado tree crops, this approach is in contrast to applying foliar fertilizers at the standard time of 1/3- to 2/3-leaf expansion (March), which targets foliage with a thin cuticle and large surface area and only result in yields equal to those attained with soil-applied fertilizer (Embleton and Jones, 1974; Labanauskas et al., 1969). With demonstration that foliar fertilization strategies can be used to increase yield parameters and grower net income with reliability by properly timing their application (Lovatt 1999), growers will replace soil-applied fertilizer, at least in part, with foliar fertilizer, improving fertilizer efficiency and protecting the environment.

Winter prebloom foliar applications of low-biuret urea or potassium phosphite (a form of P [HPO_3^{-2}] readily taken up by leaves and translocated through trees to the roots [Lovatt and Mikkelsen, 2006]) have been shown to increase yield, yield of commercially valuable large size fruit and total soluble solids (TSS) of sweet oranges (*C. sinensis*) (Albrigo, 1999; Ali and Lovatt, 1992, 1994; Lovatt, 1999); when combined, the yield effects are additive (Albrigo, 1999). Use of urea and potassium phosphite in Clementine mandarin (*C. reticulata*) production in Morocco produced similar beneficial yield results (El-Otmani et al., 2003a, b). Application of potassium phosphite in May (during the cell division stage of fruit development) and again in July (at maximum peel thickness, which marks the end of the cell division stage of citrus fruit development) or a single application of urea in July increased the yield of large size 'Frost nucellar' navel orange fruit (*C. sinensis*) (Lovatt, 1999). Fruit size of 'Sunburst' tangerine (*C. reticulata* x *C. paradisi*) was increased with foliar application of potassium nitrate (KNO_3) at dormancy (February), post-bloom (~April) and exponential fruit growth (July-August) (Boman, 2002).

Foliar application of potassium sulfate (K_2SO_4) at the post-shooting stage of banana (*Musa spp*.) increased yield, fruit quality and post-harvest shelf-life (Kumar and Kumar, 2007). Foliar-applied potassium during cantaloupe (*Cucumis melo*) fruit development and maturation improved fruit market quality by increasing firmness, sugar content, and nutritional value through increased beta-carotene, ascorbic acid and K concentrations in the edible flesh (Lester et al., 2007).

For avocado, canopy applications of B or urea-N just prior to avocado inflorescence expansion (cauliflower stage of inflorescence development), significantly increased the number of viable ovules, increased the number of pollen tubes that reached the ovules, and increased yield (Lovatt, 1999). Earlier (bud break) applications were not effective, later (full bloom) applications were intermediate in effect. B is also known to stimulate cell division and increase fruit set and fruit size of many crops, even seedless fruit, and even when leaf analyses indicate B is adequate.

For all cases cited above, proper timing of the foliar fertilizer application was a factor in increasing commercial yield or improving fruit quality parameters, including increased fruit size. Moreover, these results were attained even though the crops were not deficient based on standard nutrient analysis for the crop.

We propose to conduct this research with Clementine mandarin (*Citrus reticulata* Blanco), for which little fertilizer research has been conducted in California. Thus, the results of this project will not only establish the feasibility of using a yield benefit and net increase in grower income as a new methodology for evaluating the effectiveness of foliar fertilizers, but also will provide California Clementine mandarin growers with fertilization practices to improve crop production that are efficient and protect the environment. In addition, CDFA-FREP provides the visibility required to make the benefits of this approach known to researchers and growers of other crops.

OBJECTIVES

To test the efficacy of properly timed foliar-applied $ZnSO_4$, Solubor-B, urea-N and phosphite-P+K fertilizers to increase 'Nules' Clementine mandarin fruit number, size, and/or quality and increase grower net income and, thus, to demonstrate that a yield benefit and net increase in grower income should be the only acceptable standard for evaluating the effectiveness of foliar applied fertilizers.

Thus, the specific objectives are to test the efficacy of the following fertilizers applied to the foliage at the times specified:

1. N (23 pounds per acre, urea [46% N, ≤ 0.25% biuret]) with K and P (0.64 gallons per acre, potassium phosphite [0-28-26]) applied winter prebloom to increase flower number, fruit set and yield, without reducing fruit size, and to increase total soluble solids (TSS) and TSS:acid.
2. Zn (one pound per acre, $ZnSO_4$ [36% Zn]) at 10% anthesis in the southwest tree quadrant (SWTQ) to increase fruit set and yield, without reducing fruit size.
3. B (1.3 pound per acre, Solubor [20.5% B]) at 10% anthesis in the SWTQ to increase total yield and yield of commercially valuable large size fruit.
4. K and P (0.49 gallons per acre, potassium phosphite [0-28-26]) in May and July to increase yield of commercially valuable large size fruit, without reducing total yield, and to increase TSS and TSS:acid.
5. N (23 pound per acre, urea [46% N, ≤ 0.25% biuret]) at maximum peel thickness to increase yield of commercially valuable large size fruit, without reducing yield, and to increase TSS and TSS:acid.

6 K (25 pounds KNO_3 per acre) at dormancy (February), post bloom (~April) and summer fruit growth (July-August) to increase the yield of commercially valuable large size fruit (Boman, 2002). Fertilizer rates are based on application in 250 gallons water per 100 trees per acre so that can be adjusted for application to individual trees.

DESCRIPTION

The research will be conducted in a commercial orchard of bearing 'Nules' Clementine mandarins located near Fowler. Treatments above (1-6), a soil-fertilized control (standard grower practice) (Treatment 7) and a foliar-fertilized (2/3-leaf expansion) control for each fertilizer (ZnSO4, low-biuret urea-N, potassium phosphite-P+K, and Solubor-B above (Treatments 8-12) will be applied to 16 individual 'Nules' Clementine mandarin trees (replications) per treatment in a randomized complete block design (192 data trees).

This research starts in October, at which time we will initiate treatments to determine the optimal time for applying low-biuret urea to the foliage of 'Nules' Clementine mandarin to increase flowering fruit set and yield (November 15, December 15, January 15, or February 15). Starting in early March the orchard will be visited every two weeks to monitor and record tree phenology in order to apply the foliar fertilizer treatments at the proper time each year. Starting at the beginning of June, five average size fruit will be collected from around each of 20 randomly selected trees in the buffer rows every two weeks. Fruit diameter and peel thickness will be measured to determine when maximum peel thickness occurs each year. In September, 40 spring flush leaves from non-fruiting terminals will be collected, processed and analyzed for N, S, P, K, Mg, Ca, Fe, Mn, B, Zn, and Cu by atomic absorption spectrometry and inductively coupled plasma atomic emission spectrometry. In October the time of color break and TSS:acid will be determined. Annually, at harvest in November, treatment effects on yield, fruit size distribution (packout) will be determined using an in-field fruit sizer. A subsample of 100 fruit per tree will be used to determine fruit diameter, peel thickness, color and external peel quality by my lab. A second subsample of 25 fruit per tree will be used to determine fruit weight, juice weight, percent juice, TSS, percent acidity, TSS:acid by the UC Lindcove REC analytical lab. A cost-benefit analysis will be calculated. Cumulative treatment effects on yield parameters will be determined with each successive harvest. The effectiveness of the treatments averaged across two years and three years of the study will also be determined. With each successive set of harvest data, alternate bearing index (ABI = [Year 1 yield - Year 2 yield] ÷ [Year 1 yield + Year 2 yield]) will be calculated for each treatment. In Year 3, treatment effects on ABI for the three years of the study will be determined. All data will be statistically analyzed using the General Linear Model procedure of SAS.

RESULTS AND CONCLUSIONS

The proposed research is scheduled to start in October 2008. Thus, there are no results at this time.

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