

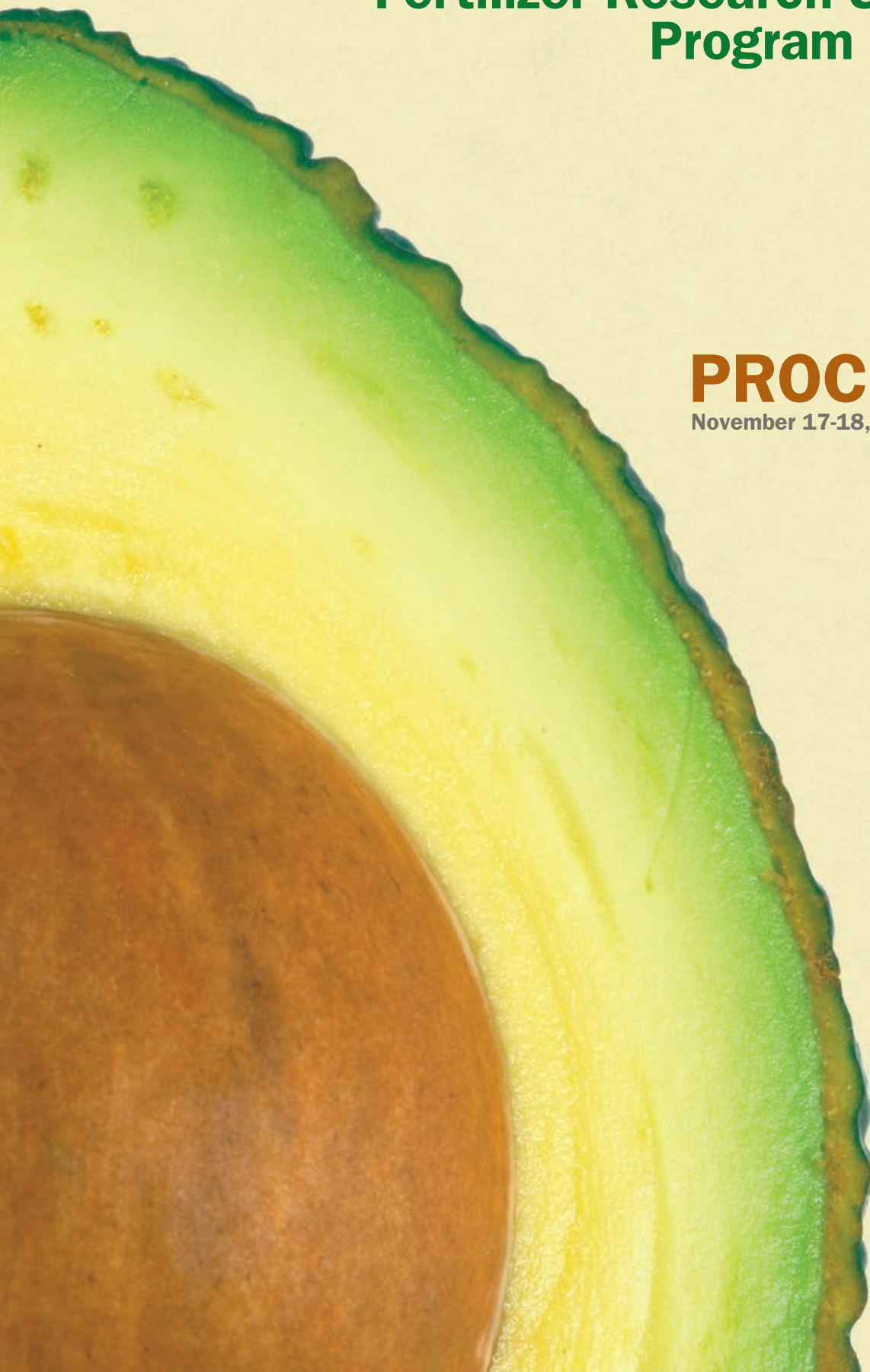
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New Standard for the Effectiveness of Foliar Fertilizers

PROJECT LEADER

Carol J. Lovatt
Professor of Plant Physiology
Department of Botany and
Plant Sciences
4130 Batchelor Hall
University of California
Riverside, CA 92521-0124
(951) 827-4663
carol.lovatt@ucr.edu

COOPERATOR

Jim Bates, CPA
Chief of Financial Operations
Fowler Packing Company
8570 South Cedar Street
Fresno, CA 93725
(559) 834-5911, (559) 281-8446
cfo@fowlerpacking.com

MANDARIN ORCHARD SITE

David Johnson
Ranch Manager
Rustigian Ranch
Corner of Clovis and Central
Fresno, CA 93725
(559) 217-0890
davidjohnson@fowlerpacking.com

INTRODUCTION

Foliar fertilization can meet the plant's demand for a nutrient at times when soil conditions (low temperature, low 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 human health. 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 nitrogen (N) and boron (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. The primary investigator (PI) proposed 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 resulted 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 have replaced soil-applied fertilizer, at least in part, with foliar fertilizer, improving fertilizer efficiency and protecting the environment.

We are testing this theory 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

- 1 Test the efficacy of properly timed foliar-applied ZnSO₄, Solubor-B, urea-N and phosphite-P+K fertilizers to increase Clementine mandarin fruit number, size, and/or quality and increase grower net income.
- 2 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.

DESCRIPTION

1 Test the efficacy of the following fertilizers applied to the foliage at the times specified:

- N [23 pound/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gallon/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.
- Zn [1 pound/acre, ZnSO₄ (36% Zn)] at 10% anthesis in the southwest tree quadrant (SWTQ) to increase fruit set and yield, without reducing fruit size.
- B [1.3 pounds/acre, Solubor (20.5% B)] at 10% anthesis in the SWTQ to increase total yield and yield of commercially valuable large size fruit.
- K and P [0.49 gallon/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.
- N [23 pounds/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.
- K (25 pounds KNO₃/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).

2 Determine the best time to apply the winter prebloom treatments to Clementine mandarin in the San Joaquin Valley, the winter prebloom foliar-applied urea-N and winter prebloom foliar-applied phosphite-P+K were expanded to five treatments as follows:

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] in November.

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] in December.

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] in January.

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gallon/acre, potassium phosphite (0-28-26)] in November.

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gallon/acre, potassium phosphite (0-28-26)] in December.

3 In all treatments, fertilizer rates are based on application in 250 gallons water per 100 trees per acre so that they can be adjusted for application to individual trees.

RESULTS AND DISCUSSION

The starting date of the project was delayed until October 2008 for the following reasons:

- 1 First, the original start date in February 2008 was after the first treatment needed to be applied, i.e., winter prebloom foliar application of urea in January. Thus, the PI would have had no data for this treatment for Year 1 and, thus, this treatment could never have been compared with the other treatments for effects on cumulative yield or effects on yield averaged across the years of the study by repeated measures analyses, an important analysis in an alternate bearing crop which 'Nules' is, ~500 fruit in the off-crop year to >1200 fruit in the on-crop year. The PI also would not have been able to compare the effects of treatments on the alternate bearing index (the calculated measure of the severity of alternate bearing).
- 2 In evaluating potential orchards that growers were willing to make available in February for the initiation of the research, the setting crop yields were very low due to the freeze the

previous winter and, thus, would not have provided a good test of the treatments.

- 3 Based on results obtained with foliar-applied urea in an on-going experiment in Grapevine, California, that suggested that December might be the optimal time apply a winter prebloom treatment instead of January as the PI had proposed, the PI thought the CDFA-FREP project would be best served by applying the urea to separate sets of trees in November, December, and January to make sure there was optimal application time for this cultivar. This new CDFA-FREP project was the perfect time and place to obtain three years of yield data to identify the optimal time for winter prebloom foliar applications of low biuret urea-N and phosphite-P+K to increase flowering and yield. The leadership of the CDFA-FREP agreed. The PI is bearing the expense of the extra trips to make the additional applications, as described above, to do the research in the way that will provide the greatest amount of information of value to the growers. The project is on schedule, but there are no results yet. The harvest for the first year will be in November 2009.

ACCOMPLISHMENTS

The PI has made presentations at the following venues that included information related to this project to educate growers, industry people and other researchers regarding the need to reduce soil-applied fertilizers and the benefits that can be attained using properly timed foliar fertilization:

- Kern County Citrus Growers Meeting, "Plant Growth Regulators on Mandarins," March 25, 2008.
- Tulare County Citrus Growers Meeting, "Plant Growth Regulators on Mandarins," April 17, 2008.
- VI International Symposium on Mineral Nutrition of Fruit Crops, University of Algarve, Faro, Portugal, "Properly Timed Foliar Fertilization Can and Should Result in a Yield Benefit and Net Increase in Grower Income," May 19-23, 2008.
- CDFA-FREP Annual Meeting, "Gauging the Effectiveness of Foliar Fertilizers on Citrus," November 12-13, 2008.
- California and Plant and Soil Science Conference, "Fertilization of Perennial Tree Crops: Timing is everything!" February 3-4, 2009.

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