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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
University of California
4130 Batchelor Hall
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-applied fertilizer 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 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 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. The 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, and 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 $ZnSO_4$, 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

Test the efficacy of the following fertilizers applied to the foliage at the times specified below in comparison with fertilizers applied at 2/3 leaf expansion:

1. N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/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 [1 lb/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 lb/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 gal/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 lb/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 lb KNO_3/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).
7. N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] applied at 2/3 leaf expansion.
8. Zn [1 lb/acre, $ZnSO_4$ (36% Zn)] at 2/3 leaf expansion.
9. B [1.3 lb/acre, Solubor (20.5% B)] at 2/3 leaf expansion.

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:

1. N [23 lb/acre, urea (46% N, 0.25% biuret)] in November.
2. N [23 lb/acre, urea (46% N, 0.25% biuret)] in December.
3. N [23 lb/acre, urea (46% N, 0.25% biuret)] in January.
4. N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] in November.
5. N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] in December.

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 first harvest for our CDFA-FREP-funded research project was in December 2009. All trees produced uniformly good yields (an average of 207 lb of fruit per tree, with a range of 196-220 lb of fruit per tree and an average of 950 fruit per tree, with a range of 863-1016 fruit per tree) (Tables 1 and 2). No treatment significantly increased total yield above that of the

Table 1: Effect of applying foliar fertilizers at key stages of tree phenology in Year 1on yield (lb per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-prebloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May-postbloom (75% petal fall in the Northeast tree quadrant); and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application Time	Total	Packing Carton Size							
			≤ 32	28	24	21	18	15	28-24	28-15
			≤ 2.2 in	2.3-2.4 in	2.4-2.5 in	2.5-2.6 in	2.7-2.8 in	2.8-3.0 in	2.3-2.5 in	2.3-3.0 in
		---- lb per tree ----								
Urea	November	220.0 a[z]	68.8 a	51.4 a	38.8 a	37.5 a	14.3 a	6.8 a	90.2 a	148.8 a
Urea + Potassium Phosphite	November	206.6 a	67.2 a	40.8 abcd	41.0 a	32.4 a	14.6 a	7.9 a	81.6 ab	136.5 a
Urea	December	212.7 a	60.2 a	41.5 abcd	42.8 a	35.7 a	17.0 a	8.6 a	84.2 a	145.5 a
Urea + Potassium Phosphite	December	192.2 a	62.6 a	35.3 cd	29.8 a	33.5 a	16.8 a	9.9 a	65.0 d	125.2 a
Urea	January	220.2 a	69.7 a	49.8 a	38.8 a	39.2 a	12.6 a	6.2 a	88.4 a	146.4 a
Potassium Nitrate	February + May + July	207.7 a	80.9 a	37.9 bcd	28.4 a	31.5 a	16.8 a	5.1 a	66.1 cd	119.5 a
Zinc	April 24 (10% anthesis)	209.9 a	73.2 a	48.1 ab	37.9 a	32.6 a	11.5 a	4.2 a	86.0 a	134.0 a
Zinc	April 13 (2/3 leaf expansion)	208.8 a	69.4 a	45.4 abc	35.1 a	34.4 a	13.9 a	5.7 a	80.3 abc	134.3 a
Boron	April 24 (10% anthesis)	201.5 a	68.3 a	34.2 d	34.6 a	38.1 a	15.9 a	5.1 a	69.0 bcd	127.7 a
Boron	April 13 (2/3 leaf expansion)	214.5 a	71.0 a	43.0 abcd	34.0 a	38.8 a	14.8 a	8.2 a	76.9 abcd	138.7 a
Urea + Potassium Phosphite	April 13 (2/3 leaf expansion)	196.2 a	51.4 a	41.2 abcd	39.9 a	32.4 a	16.5 a	10.1 a	81.1 abc	140.0 a
Potassium Phosphite	May + July	207.2 a	71.9 a	41.2 abcd	36.8 a	30.4 a	18.1 a	5.5 a	78.0 abcd	132.1 a
Urea	July	199.1 a	61.3 a	41.0 abcd	37.5 a	31.3 a	17.4 a	5.5 a	78.5 abcd	132.7 a
Control		205.7 a	56.0 a	40.6 abcd	38.4 a	39.7 a	18.1 a	8.8 a	78.9 abcd	145.3 a
P-value		0.4956	0.8149	0.0931	0.2931	0.9092	0.9343	0.7116	0.0223	0.4204

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at P = 0.05.

untreated control trees. The highest yields as lb and number of fruit per tree were obtained with foliar-applications of low-biuret urea in November or January (220 lb per tree and 1016 and 1010 fruit per tree, respectively, compared to 206 lb and 921 fruit per tree for the untreated control trees).

The majority of the fruit were packing carton sizes 28 to 24 (fruit 2.28-2.5 inches in transverse diameter). The three prebloom foliar-applications of low-biuret urea (November, December or January), the prebloom application of low-biuret urea combined with potassium phosphite (November), and zinc applied to the foliage at 10% anthesis in the SWTQ significantly increased the yield of fruit in these two size categories as lb per tree compared to trees receiving foliar-applied urea combined with potassium phosphite in December, foliar-applied potassium nitrate at dormancy (February), postbloom (75% petal fall in the NETQ) (~May) and during summer fruit growth (July-August), and boron applied to the foliage at 10% anthesis in the SWTQ (P = 0.0223) (Table 1). All other treatments had an intermediate effect on the yield of fruit of packing carton sizes 28 + 24 that was not significant. Interestingly, only the prebloom foliar-application of low-biuret urea (November, December or January) and foliar zinc applied at 10% anthesis in the SWTQ increased the number of fruit of packing carton sizes 28 + 24 per tree compared to trees receiving foliar-applied urea combined with

Table 2: Effect of applying foliar fertilizers at key stages of tree phenology in Year 1 on yield (number of fruit per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-prebloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May-postbloom (75% petal fall in the Northeast tree quadrant); and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application Time	Total	Packing Carton Size							
			≤ 32 ≤ 2.2 in.	28 2.3-2.4 in.	24 2.4-2.5 in.	21 2.5-2.6 in.	18 2.7-2.8 in.	15 2.8-3.0 in.	28-24 2.3-2.5 in.	28-15 2.3-3.0 in.
		no. of fruit per tree								
Urea	November	1016 a[z]	402 a	237 a	164 a	141 a	47 a	19 a	402 a	608 a
Urea + Potassium Phosphite	November	946 a	386 a	188 abcd	173 a	122 a	47 a	23 a	362 ab	553 a
Urea	December	950 a	345 a	192 abcd	181 a	134 a	55 a	25 a	373 a	587 a
Urea + Potassium Phosphite	December	882 a	374 a	163 cd	126 a	126 a	54 a	28 a	289 c	498 a
Urea	January	1010 a	400 a	230 a	164 a	147 a	40 a	18 a	394 a	600 a
Potassium Nitrate	February + May + July	980 a	479 a	175 bcd	120 a	118 a	54 a	15 a	295 bc	482 a
Zinc	April 24 (10% anthesis)	980 a	420 a	222 ab	160 a	123 a	37 a	12 a	382 a	554 a
Zinc	April 13 (2/3 leaf expansion)	970 a	409 a	210 abc	148 a	129 a	45 a	17 a	358 ab	548 a
Boron	April 24 (10% anthesis)	926 a	399 a	158 d	147 a	143 a	51 a	14 a	305 bc	513 a
Boron	April 13 (2/3 leaf expansion)	991 a	420 a	199 abcd	144 a	146 a	48 a	24 a	342 abc	560 a
Urea + Potassium Phosphite	April 13 (2/3 leaf expansion)	863 a	288 a	191 abcd	168 a	122 a	53 a	29 a	360 ab	563 a
Potassium Phosphite	May + July	960 a	417 a	191 abcd	156 a	114 a	59 a	16 a	347 abc	535 a
Urea	July	902 a	351 a	190 abcd	158 a	118 a	56 a	16 a	348 abc	538 a
Control		921 a	328 a	187 abcd	162 a	149 a	59 a	25 a	350 abc	582 a
P-value		0.596	0.8015	0.0931	0.2931	0.9092	0.9343	0.7116	0.0214	0.2288

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at P = 0.05.

potassium phosphite in December, foliar potassium nitrate applied at dormancy (February), post bloom (~May) and during summer fruit growth (July-August), and foliar boron applied at 10% anthesis in the SWTQ (P = 0.0214) (Table 2). Despite the significant positive effect of several treatments on the yield of fruit of packing carton sizes 28 + 24, there was no concomitant effect on the yield of commercially valuable fruit in the combined pool of fruit of packing carton sizes 28 to 15 (2.25-2.95 inches in transverse diameter). Although not significant, the highest yield of fruit of packing carton sizes 28 to15 was achieved with the foliar application of low-biuret urea in November (150 lb fruit per tree, 608 fruit per tree) (Tables 1 and 2). The lowest yield of fruit of packing carton sizes 28 to15 resulted from foliar-application of potassium nitrate at dormancy (February), postbloom (~May) and during summer fruit growth (July-August).

All fruit were of excellent quality and had a high sugar to acid ratio (~ 14). There were no significant treatment effects on any fruit quality parameter analyzed, including rind thickness, average fruit weight, average juice weight per fruit, average juice volume per fruit, total soluble solids (TSS as °brix), acidity (%), or the ratio of TSS:acidity (Table 3).

The second harvest for our CDFA-FREP-funded research project was in December 2010. All trees produced uniform yields (an average of 200 lb of fruit per tree across all treatments, with a range of 183-209 lb of fruit per tree, and an average of 860 fruit per tree, with a range of 757-911 per tree) (Tables 4 and 5). No treatment significantly increased total yield above that of the untreated control trees. The highest yields as lb and number of fruit per tree were obtained with the foliar-application of boron at 10% anthesis (~April):

Table 3: Effect of applying foliar fertilizers at key stages of tree phenology in Year 1 on fruit quality of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January prebloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May-postbloom (75% petal fall in the Northeast tree quadrant); and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application Time	Rind Thickness (inches)	Fruit Weight (ounces)	Juice Weight (ounces)	Juice Volume (pints)	TSS: Acid
Urea	November	0.106 a[z]	5.5 a	10.6 a	0.6 a	14.3 a
Urea + Potassium Phosphite	November	0.122 a	5.8 a	10.6 a	0.6 a	14.7 a
Urea	December	0.110 a	5.6 a	10.6 a	0.6 a	14.2 a
Urea + Potassium Phosphite	December	0.118 a	6.3 a	10.8 a	0.6 a	14.9 a
Urea	January	0.114 a	5.7 a	10.8 a	0.6 a	14.8 a
Potassium Nitrate	February + May + July	0.106 a	5.6 a	10.6 a	0.6 a	14.2 a
Zinc	April 24 (10% anthesis)	0.114 a	5.7 a	11.2 a	0.6 a	15.4 a
Zinc	April 13 (2/3 leaf expansion)	0.122 a	6.1 a	11.6 a	0.7 a	14.6 a
Boron	April 24 (10% anthesis)	0.122 a	5.9 a	10.6 a	0.6 a	14.6 a
Boron	April 13 (2/3 leaf expansion)	0.114 a	5.6 a	10.4 a	0.6 a	14.1 a
Urea + Potassium Phosphite	April 13 (2/3 leaf expansion)	0.118 a	5.9 a	10.6 a	0.6 a	14.6 a
Potassium Phosphite	May + July	0.102 a	5.3 a	10.3 a	0.6 a	14.9 a
Urea	July	0.130 a	5.9 a	10.6 a	0.6 a	13.8 a
Control		0.118 a	6.2 a	10.8 a	0.6 a	14.3 a
P-value		0.5083	0.1462	0.6843	0.6907	0.1919

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at P = 0.05.

208.7 lb and 911 fruit per tree, which was equal in lb per tree to the untreated control but 45 more fruit per tree than the untreated control trees. The next best treatment was low-biuret urea in January at 207.5 lb per tree and 890 fruit per tree. With regard to the yield of commercially valuable fruit per tree (packing carton sizes 28-15, 2.3-3.0 inches in transverse diameter), untreated control trees produced the greatest lb (161) and number (641) followed by low-biuret urea applied in January, but neither treatment had a significant effect on the yield of large size fruit compared to other treatments. There were several significant effects due fertilizer treatment on fruit quality (Table 6). The average weight of individual fruit was significantly reduced below that of the untreated control trees when either boron or low-biuret urea combined with potassium phosphite was applied at the standard application time for citrus foliar fertilization of 2/3-leaf expansion (P = 0.0786). Interestingly, low-biuret urea combined with potassium phosphite applied at this time significantly increased the total soluble solids to acid ratio of the harvested fruit above that of the untreated control trees and all fertilizer treatments except low-biuret urea combined with potassium phosphite applied in November, low-biuret urea applied in January, and zinc applied at 2/3-leaf expansion (P = 0.0782).

Table 4: Effect of applying foliar fertilizers at key stages of tree phenology in Year 2 on yield (lb per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-prebloom; February-dormancy; April-10% anthesis or 2/3 leave expansion as indicated; May-postbloom; and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 2: 2009-2010; the orchard is located in Fresno, CA)

Treatment	Application Time	Total	Packing Carton Size							
			≤ 32	28	24	21	18	15	28-24	28-15
			≤ 2.2 in	2.3-2.4 in	2.4-2.5 in	2.5-2.6 in	2.7-2.8 in	2.8-3.0 in	2.3-2.5 in	2.3-3.0 in
		---------- lb per tree ----------								
Urea	November	199.7 a[z]	48.0 a	37.8 a	31.5 a	37.3 a	24.7 a	11.1 a	69.2 a	142.3 a
Urea + Potassium Phosphite	November	204.9 a	48.7 a	34.0 a	33.6 a	40.4 a	25.7 a	13.9 a	67.6 a	147.6 a
Urea	December	202.6 a	40.7 a	32.7 a	36.7 a	42.3 a	29.3 a	14.8 a	69.4 a	155.8 a
Urea + Potassium Phosphite	December	205.9 a	50.4 a	33.5 a	31.9 a	40.9 a	23.2 a	16.2 a	65.3 a	145.5 a
Urea	January	207.4 a	46.0 a	41.3 a	37.3 a	38.7 a	22.7 a	14.9 a	78.6 a	154.9 a
Potassium Nitrate	February + May + July	204.5 a	43.2 a	34.2 a	36.8 a	38.5 a	28.5 a	12.9 a	71.0 a	150.9 a
Zinc	April (10% anthesis)	194.4 a	45.8 a	30.6 a	37.4 a	27.6 a	26.2 a	16.5 a	68.0 a	138.3 a
Zinc	April (2/3 leaf expansion)	183.0 a	33.2 a	26.1 a	35.1 a	41.9 a	25.4 a	10.3 a	61.2 a	138.8 a
Boron	April (10% anthesis)	204.0 a	52.9 a	40.0 a	37.4 a	37.2 a	20.0 a	10.9 a	77.4 a	145.4 a
Boron	April (2/3 leaf expansion)	208.9 a	50.3 a	39.3 a	39.5 a	40.4 a	22.0 a	12.5 a	78.9 a	153.7 a
Urea + Potassium Phosphite	April (2/3 leaf expansion)	196.1 a	47.0 a	38.0 a	36.5 a	38.3 a	21.1 a	9.2 a	74.4 a	143.0 a
Potassium Phosphite	May + July	198.1 a	48.1 a	27.1 a	33.8 a	41.5 a	28.8 a	10.8 a	60.8 a	142.0 a
Urea	July	199.0 a	38.0 a	32.2 a	36.0 a	44.2 a	20.5 a	16.8 a	68.2 a	149.7 a
Control		208.8 a	40.1 a	36.2 a	49.7 a	42.8 a	22.5 a	10.2 a	85.9 a	161.3 a
P-value		0.9765	0.9024	0.1656	0.3402	0.4925	0.7067	0.5506	0.3341	0.8863

[z] Values in a column followed by different letters are significantly different at the specified P-values by Fisher's Protected LSD test.

Table 5: Effect of applying foliar fertilizers at key stages of tree phenology in Year 2 on yield (number of fruit per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-prebloom; February-dormancy; April-10% anthesis or 2/3 leave expansion as indicated; May-postbloom; and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 2: 2009-2010; the orchard is located in Fresno, CA)

Treatment	Application Time	Total	Packing Carton Size							
			≤ 32	28	24	21	18	15	28-24	28-15
			≤ 2.2 in	2.3-2.4 in	2.4-2.5 in	2.5-2.6 in	2.7-2.8 in	2.8-3.0 in	2.3-2.5 in	2.3-3.0 in
		------ no. of fruit per tree ------								
Urea	November	861 a[z]	278 a	175 a	133 a	140 a	80 a	32 a	308 a	560 a
Urea + Potassium Phosphite	November	878 a	282 a	157 a	142 a	152 a	83 a	40 a	299 a	574 a
Urea	December	851 a	234 a	151 a	155 a	159 a	95 a	43 a	307 a	603 a
Urea + Potassium Phosphite	December	892 a	302 a	155 a	135 a	154 a	75 a	47 a	290 a	565 a
Urea	January	890 a	263 a	191 a	158 a	145 a	74 a	43 a	349 a	611 a
Potassium Nitrate	February + May + July	848 a	279 a	125 a	143 a	156 a	93 a	31 a	268 a	548 a
Zinc	April (10% anthesis)	757 a	192 a	121 a	148 a	157 a	82 a	30 a	269 a	539 a
Zinc	April (2/3 leaf expansion)	824 a	264 a	142 a	158 a	104 a	85 a	48 a	300 a	536 a
Boron	April (10% anthesis)	911 a	291 a	182 a	167 a	152 a	71 a	36 a	349 a	608 a
Boron	April (2/3 leaf expansion)	897 a	304 a	185 a	158 a	140 a	65 a	31 a	343 a	579 a
Urea + Potassium Phosphite	April (2/3 leaf expansion)	856 a	272 a	176 a	154 a	144 a	68 a	26 a	330 a	568 a
Potassium Phosphite	May + July	864 a	251 a	158 a	156 a	145 a	92 a	37 a	314 a	588 a
Urea	July	828 a	218 a	149 a	152 a	166 a	66 a	49 a	301 a	582 a
Control		886 a	228 a	168 a	210 a	161 a	73 a	29 a	378 a	641 a
P-value		0.9306	0.8974	0.1656	0.3402	0.4925	0.7067	0.5506	0.3272	0.7867

[z] Values in a column followed by different letters are significantly different at the specified P-values by Fisher's Protected LSD test.

PRELIMINARY FINDINGS

This orchard has proven to be consistently high yielding. For 'Nules' Clementine mandarin, it is difficult to increase yield further in a heavy crop year. Treatments that are successful typically increase total yield by increasing the yield of small size fruit at the expense of commercially valuable large size fruit (Chao and Lovatt, 2006a, b; 2011). In both years of this study, maximum yield as both lb and number of fruit per tree was of fruit ≤ 2.2 inches in transverse diameter (packing carton size 32 or smaller). Year 2 had a slightly lower average yield than Year 1, 200 versus 207 lb and 860 versus 950 fruit per tree, respectively. The slightly lower yield in Year 2 resulted in 2-fold more commercially valuable fruit of packing carton sizes 18 and 15 (fruit 2.7-3.0 inches in diameter). The goal for a heavy crop year is to increase fruit size. The January winter prebloom foliar-application of low-biuret urea tended to both increase total yield and yield of commercially valuable fruit of packing carton sizes 28-15 (2.3-3.0 inches in diameter). The Year 3 harvest will be in December 2011. At that time, we will statistically analyze fertilizer treatment effects on 3-year cumulative total yield and fruit size distribution (pack out). In addition, we will calculate the 3-year cumulative crop value (US$) to determine if there were significant effects on grower income due to foliar fertilization treatments.

Table 6: Effect of applying foliar fertilizers at key stages of tree phenology in Year 2 on fruit quality of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-prebloom; February-dormancy; April-10% anthesis or 2/3 leave expansion as indicated; May-postbloom; and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 2: 2009-2010; the orchard is located in Fresno, CA)

Treatment	Application Time	Rind Thickness (inches)	Juice Weight (ounces)	Juice Volume (pints)	TSS: Acid
Urea	November	0.1 az	11.9 a	0.7 a	17.9 de
Urea + Potassium Phosphite	November	0.1 a	11.8 a	0.7 a	19.6 ab
Urea	December	0.5 a	12.3 a	0.7 a	18.7 bcde
Urea + Potassium Phosphite	December	0.1 a	12.1 a	0.7 a	18.5 bcde
Urea	January	0.4 a	12.4 a	0.7 a	19.0 abcd
Potassium Nitrate	February + May + July	0.1 a	12.2 a	0.7 a	18.16 cde
Zinc	April 24 (10% anthesis)	0.4 a	12.8 a	0.8 a	18.8 bcde
Zinc	April 13 (2/3 leaf expansion)	0.1 a	11.8 a	0.7 a	19.2 abc
Boron	April 24 (10% anthesis)	0.1 a	12.1 a	0.7 a	18.6 bcde
Boron	April 13 (2/3 leaf expansion)	0.1 a	11.9 a	0.7 a	17.8 e
Urea + Potassium Phosphite	April 13 (2/3 leaf expansion)	0.1 a	11.0 a	0.7 a	20.0 a
Potassium Phosphite	May + July	0.1 a	12.2 a	0.7 a	18.8 bcde
Urea	July	0.4 a	12.6 a	0.7 a	18.5 bcde
Control		0.4 a	12.9 a	0.8 a	18.4 bcde
P-value		0.4654	0.4886	0.4785	0.0782

[z] Values in a column followed by different letters are significantly different at the specified P-values by Fisher's Protected LSD test.

LITERATURE CITED

Boman, B.J. 2002. *KNO_3 foliar application to 'Sunburst' tangerine.* Proceedings of the Florida State Horticultural Society 115:6-9.

Embleton, T.W. and W.W. Jones. 1974. *Foliar-applied nitrogen for citrus fertilization.* Journal of Environmental Quality 3:388-392.

Labanauskas, C.K., W.W. Jones and T.W. Embleton. 1969. *Low residue micronutrient sprays for citrus.* Proceedings of the First International Citrus Symposium 3:1535-1542.

Lovatt, C. J. 1999. *Timing citrus and avocado foliar nutrient applications to increase fruit set and size.* HortTechnology 9:607-612.