

Managing Yield with Foliar Fertilization

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California citrus growers have long been proactive in their efforts to reduce the potential for nitrate pollution of groundwater by reducing their use of soil-applied nitrogen fertilizer. This review was undertaken to assist citrus growers in making decisions about the use and timing of foliar-applied low-biuret urea.

Embleton and Jones (1974) provided evidence that maximum nutritionally attainable yields for sweet oranges annually required between 0.45 and 0.60 kg N/tree, regardless of fertilization method. Despite this, foliar nitrogen fertilization was not widely adopted commercially due to the limits in the amount of nitrogen that can be applied in a single application, necessitating a minimum of three

sprays each year to supply the recommended annual rate of nitrogen. In contrast, earlier results of Sharples and Hilgeman (1969) suggested that urea applied to the foliage at the appropriate time might affect yield beneficially. For seven years, 'Valencia' orange trees receiving only 0.23 kg N/tree split between two foliar applications of urea, one in early February and a second in late April-early May, produced yields that were statistically equal to those obtained with much higher rates (0.45 or 0.91 kg N/tree) of ammonium nitrate applied to the soil. The objective of our research has been to identify specific times in the phenology of the navel orange tree, during which a single foliar application of low-biuret urea at 0.16 kg N/tree (28 lbs. N/acre) would increase yield and/or fruit size sufficiently to make foliar nitrogen fertilization cost effective. The overall goal was to help

growers to replace soil-applied nitrogen with foliar nitrogen fertilization and thus, reduce the potential for nitrate pollution of the groundwater.

The efficacy of single foliar application of low-biuret urea during one of three phenological stages was tested in four different commercial navel orange orchards. The effect of applying urea to the canopy at pre-bloom (prior to or during flower initiation) or at full bloom was quantified with the objective of increasing fruit set and yield in two orchards located in southern California, where yields average 30 tons per hectare (California Agricultural Statistics Service, 1991). The effect of a later foliar application of urea at maximum peel thickness of the fruit was tested with the goal of increasing fruit size in two orchards in the San Joaquin Valley of California, where yields average 60 tons per hectare (California Agricultural Statistics Service, 1991).

In general, low-biuret urea applied during the period from flower initiation through fruit set significantly increased yield without reducing fruit size, whereas applications made at the end of the cell division stage of fruit development significantly increased fruit size without affecting yield. On a calendar basis for California, applications of low-biuret urea made in mid-January to mid-February had a more significant effect on yield than later sprays, but late sprays made in mid-June to mid-July are more effective in increasing fruit size than increasing yield.

Winter Pre-bloom

For the three successive harvests, from 1990 through 1992, Ali and Lovatt (1994) successfully increased fruit set and yield of the 'Washington' navel orange with a winter pre-bloom application of low-biuret urea applied to the foliage to the point of run-off at a final concentration of 0.5 percent N (as Unocal Plus, 20 percent N, 0.1 percent biuret), to provide 0.16 kg N/tree (28 lbs. N/acre) (Table 1). Control trees received 0.5 kg N/tree as urea (granules, 0.25 percent biuret) applied to the soil in winter (November to January). Single foliar applications of urea were made on Nov. 15, Dec. 15, Jan. 15 or Feb. 15. Each set

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of trees received only one foliar application of urea. The foliar applications made on Jan. 15 or Feb. 15, the approximate time of irreversible commitment to flowering and flower initiation for the southern California orchard in which the research was conducted (Lord and Eckard, 1987), increased yield significantly for all three years of the study (≤ 0.05). Foliar-applications of urea made on Nov. 15 or Dec. 15 increased yield in two of the three years (≤ 0.05). Yield increases were not accompanied by a decrease in fruit size. As the kg fruit per tree increased in response to foliar-applied urea, the number of fruit of commercially valuable size (packing carton size 88 and 72, transverse diameter 7.0-8.0 cm) also increased, but not significantly (Table 1).

Yield increases were not due to improved nitrogen status of trees receiving a foliar application of low-biuret urea and all trees had optimum levels of N (2.5-2.6 percent) and other nutrients throughout the experiment according to annual September leaf analyses. There was no significant relationship between tree nitrogen status and yield. Time of foliar urea application was a significant factor affecting cumulative yield. In each

Table 1: Effects of a winter pre-bloom foliar application of low-biuret urea on yield of the 'Washington' navel orange, three-year average and net cumulative yield. ^z

Month Urea Applied	Yield (kg/Tree)	Fruit No./Tree		Net Cumulative Yield (tons/ha)
		All Sizes	7.0-8.0 cm	
None (control)	85 b ^y	542b	172 a	—
November	102 a	657 a	188 a	12.2
December	103 a	661 a	211 a	12.6
January	113 a	761 a	190 a	20.6
February	107 a	708 a	198 a	16.4
Significance	$P \leq 0.001$	$P \leq 0.01$	NS	ND

^z Ali and Lovatt (1994).

^y Means within a column followed by different letters are significantly different by Duncan's multiple range test at ≤ 0.05 . NS Non-significant at ≤ 0.05 and ND statistical significance not determined.

year of this study, the winter pre-bloom foliar application of low-biuret urea was cost-effective and resulted in a significant increase in net dollar return to the grower (Ali and Lovatt, 1992). January or February foliar-applied urea resulted in net increases in yield over the control of 20.6 and 16.4 tonnes/ha/3 years, respectively.

Yield increases obtained with winter pre-bloom foliar applications of low-biuret urea in southern Africa for a num-

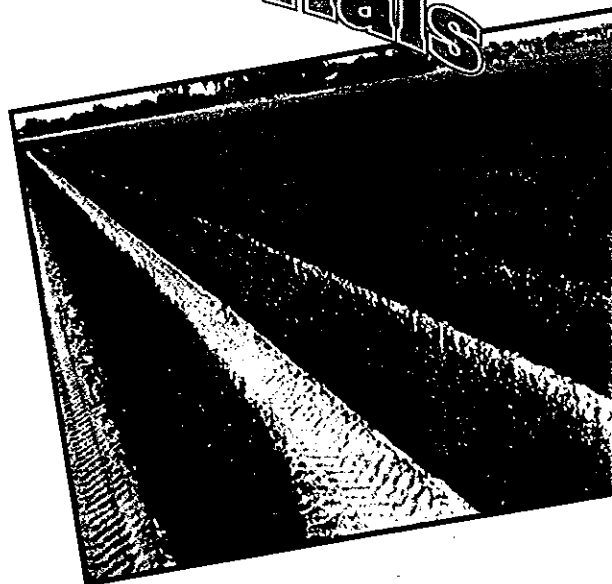
ber of different Citrus species led to the universal adoption of the treatment (Rabe, 1994). In southern Africa, two urea applications are made 10 to 14 days apart for trees at less than 2.6 percent N (leaf analysis in southern Africa is for leaves behind a fruiting terminal), a single urea application is made to trees between 2.6 percent to 2.7 percent N, and no urea is applied to trees at greater than 2.7 percent N, depending on the cultivar and whether it is an "on" or "off"



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crop year (Dr. Etienne Rabe, personal communication).

At the 50th Anniversary of the Indian River Citrus Seminar on March 5, 1997, Dr. Gene Albrigo reported in his presentation titled "Foliar Application of Major Elements for Flowering and Fruit Set" that a winter pre-bloom foliar application of low-biuret urea (0.16 kg N/tree; 28 lbs. N/acre) significantly increased flower number, fruit set, and yield of 'Valencia' orange. In his presentation, Albrigo also reported that a winter pre-

bloom foliar application of phosphorus as phosphite (Nutri-Phite 0-28-26 at the rate of 2.6 qts./acre) also increased 'Valencia' orange flower number, fruit set and yield. In addition, Dr. Albrigo subsequently reported that both treatments increased total soluble solids significantly at harvest.

We are currently determining the upper limit in percent leaf N above which a winter pre-bloom foliar application of urea is without benefit in increasing yield in navel oranges in California. In addition, we are testing

whether a winter pre-bloom foliar application of potassium phosphite might offer an alternative means to increase yield in a high N orchard.

Full Bloom

At full bloom low-biuret urea (as Unocal Plus, 20 percent N, 0.1 percent biuret) was applied in sufficient water to fully cover the foliage of 'Washington' navel orange trees at a final concentration of 1.3 percent N to provide 0.16 kg N/tree (28 lbs. N/acre). All trees had optimum levels of N (2.4-2.5 percent) and other nutrients throughout the experiment according to annual September leaf analyses. The treatment significantly increased yield by 25 kg and 217 fruit per tree in the "on" year (≤ 0.10), but not in the "off" year. As yield increased so did the number of commercially valuable large-size fruit of packing carton sizes 88 and 72 (transverse diameter 7.0-8.0 cm). The treatment resulted in a net increase in yield over the control of 7 tonnes/ha/2 years. The full bloom foliar application of urea was cost-effective and resulted in a net increase in dollar return over the control. The ability of a full bloom application of low-biuret urea to increase yield in an "on" but not an "off" crop year was confirmed in a second orchard in the San Joaquin Valley.

Maximum Peel Thickness

Approximately one week or three weeks past petal fall low-biuret urea (as Unocal Plus, 20 percent N, 0.1 percent biuret) was applied in sufficient water to fully cover the foliage of 'Frost nucellar' navel orange trees at a final concentration of 1.5 percent N to provide 0.16 kg N/tree (28 lbs. N/acre). Both treatments significantly increased the number of large-size fruit (transverse diameter 8.1-8.8 cm) in a single, but different, year of the three-year study (≤ 0.05). In an attempt to improve the efficacy of the treatment, the time of maximum peel thickness for navel oranges from southern coastal California to the northern citrus region of the San Joaquin Valley was experimentally determined for both "on" and "off" crop years. Maximum peel thickness marks the end of Stage I, the cell division stage of fruit development. Our objective was to apply urea to the foliage at this time to extend the length of the cell division period to increase fruit size without increasing fruit set.

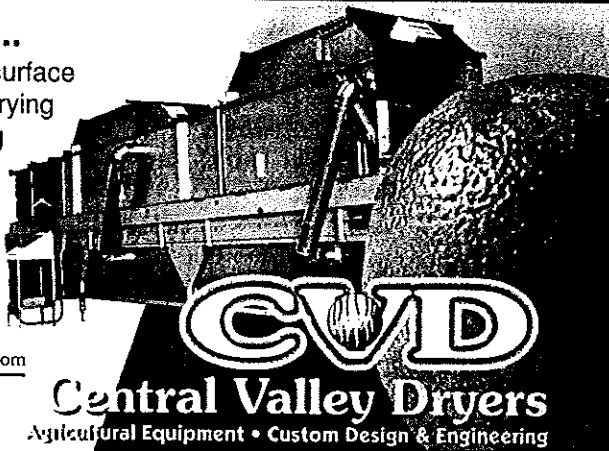
Maximum peel thickness occurred between June 17 and July 27. Based on this result, low-biuret urea (granules, 46 percent N, 0.25 percent biuret) was applied to fully cover the foliage of

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'Frost nucellar' navel orange trees at a final concentration of 1.5 percent N to provide 0.16 kg N/tree during mid-May, mid-June or mid-July. This study included phosphorus, another nutrient that would be in high demand during cell division and a nutrient known to increase fruit quality by increasing kg soluble solids/ha and the ratio of total soluble solids to acid in the juice (Embleton et al., 1973). Phosphorus was applied to the foliage as potassium phosphite (Nutri-Phite, 0-28-26) at a rate of 6 L/ha in mid-May or mid-July or as two applications at 4.6 L/ha in mid-May and mid-July. All trees had optimum levels of nitrogen (2.8 percent) and other nutrients according to annual September leaf analyses. The July application of urea and the double application of potassium phosphite in May and July significantly increased the number of commercially valuable large-size fruit (transverse diameter 6.9-7.4, 7.5-8.0, and 8.1-8.8 cm, packing carton sizes 88, 72 and 56, respectively) from 51 percent of the total fruit on the tree for the control to 60 percent and 63 percent of the total fruit on the tree for the two treatments, respectively (Table 2).


The increase in fruit size was not due to a reduction in yield. These two treatments resulted in higher kg (non-significant) and number of fruit (≤ 0.10) per tree. The double application of potassium phosphite also significantly increased total soluble solids (≤ 0.001) and the ratio of total soluble solids to acid (≤ 0.01) by early November compared to control fruit. By Nov. 4, fruit from trees receiving the two foliar applications of potassium phosphite had a ratio of 8.1 compared to a ratio of 7.2 for control fruit. Total soluble solids (≤ 0.04) and the ratio of total soluble solids to acid (≤ 0.01) remained significantly higher in fruit from trees treated with potassium phosphite than control fruit 30 days later.

The ability of foliar applications of urea or potassium phosphite at maximum peel thickness to increase fruit size every year remains to be determined. It also remains to be determined whether winter pre-bloom applications of urea and potassium phosphite can be used sequentially and/or in combination at pre-bloom and at maximum peel thickness to significantly increase both yield and fruit size.

Conclusion

Flowering in citrus is promoted by low temperature or water-deficit stress. Our previous research provided evidence that foliar urea applied during or at the end of the low-temperature or water-deficit period increased citrus flowering by elevating the ammonia status of the tree above a critical threshold and by partially replacing the stress required for flowering (Lovatt et al., 1988a, b; Ali and Lovatt, 1995; Hake, 1996). In addition, foliar-applied urea also increased the polyamine content, growth rate, and size of developing citrus fruit, as well as their potential to set (Lovatt et al., 1992; Corona, 1994).

A winter pre-bloom foliar application of urea would be best used to increase flowering, fruit set and yield in years when there is insufficient cold weather (or water-deficit stress in areas where bloom is induced by drought) to result in a strong bloom, when trees are going into an "off" bloom, or when trees are low in nitrogen (Rabe, 1994) or nutrient deficient due to low soil temperature as indicated by yellow leaves in winter or early spring. Flowering and fruit set, which would be expected to have a high



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Table 2. Effect of low-biuret urea and potassium phosphite applied to the foliage of 'Frost nucellar' navel orange in July or May and July, respectively, on yield and number of fruit per tree of packing carton sizes 88, 72, and 56.

Treatment	kg fruit/ Tree	Number of Fruit/Tree	Number of fruit per tree of packing carton size z				
			88	72	56	88+72	88+72+56
Control	126	487b ^y	51 b	83 b	113 b	134 b	247 b
Urea (July)	148	629 a	81 a	140 a	156 a	222 a	378 a
Potassium Phosphite (May and July)	150	621 a	84 a	140 a	166 a	224 a	390 a
Significance	NS	P≤0.10	P≤0.10	P≤0.05	P≤0.10	P≤0.05	P≤0.05

^z Packing carton sizes 88, 72 and 56 correspond to fruit with transverse diameters 6.9-7.4, 7.5-8.0, and 8.1-8.8 cm, respectively.

^y Means within a column followed by different letters are significantly different by Duncan's multiple range test at ≤0.05 or ≤0.10.

nutrient demand, occur when soil temperatures are low. Soil temperatures are generally less than 15 C from January to April in citrus growing areas of California (Hamid et al., 1988). Winter and spring foliar fertilizer applications likely increase fruit set and yield because of limited availability of nutrients essential for flowering and fruit set due to reduced transpiration and/or nutrient

acquisition by roots when air and/or soil temperatures are low. Clearly in some years in some orchards there will be no benefit from a winter pre-bloom foliar application of urea.

Yield increases in an "on" crop year resulting from a full bloom foliar application of urea likely result from satisfying the increased demand for nitrogen by the heavy crop load. The mechanism by

which urea or potassium phosphite applied to the foliage at maximum peel thickness increased fruit size remains to be determined, as well as whether the treatment will prove effective over multiple successive years. The increased ratio of total soluble solids to acid in juice of fruit from trees treated with foliar sprays of potassium phosphite is the reported response of citrus fruit to

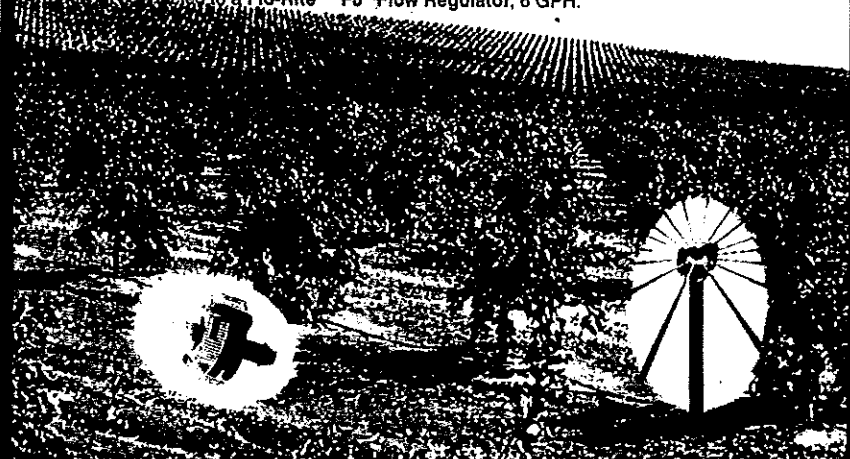
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increased phosphorus nutrition (Embleton et al., 1973).

The results of our research identified three stages in the phenology of the citrus tree when foliar applied urea-N can be used to increase yield or fruit size. Each foliar urea application provided 25 to 33 percent of the annual N required by sweet oranges for maximum yield (Embleton and Jones, 1974). The treatments were cost-effective and reduced the potential for nitrate pollution of the groundwater. The results clearly demonstrate the importance of timing in the application of foliar fertilizer in order to achieve a desired goal.

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Fukumoto Navels

continued from page 4

Gonzales has noticed that excitement over the Fukumotos seems to have waned. Foamy bark rot, he says, may have spooked growers away from Fukumotos. Or it could be something else, he speculates.

"Maybe we have too much of an early navel. Now there is a lot of excitement about late summer navels," Gonzales says.

Zuckerman says typically he sees a rush on a new variety by innovative growers wanting to try something different.

"That interest usually lasts a couple of years. Then the interest usually dips off for a couple of years until people see how the fruit performs in terms of production and returns to the grower. The biggest question is yield per tree; in Japan it was not a good producer," he says.

Zuckerman says Becks are still a popular variety.

"Right now growers are wanting Becks because they know it. We know what the Beck will do year after year. It's a good producer; it produces early and has large fruit," he says.

So far, it looks like Fukumotos may fit right in there side by side with Becks. Like the Beck variety, Fukumotos are more than good looking - it's about earliness and a good tasting piece of fruit. Only time will tell if it all pans out. □

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