TIME OF APPLICATION OF UREA TO CITRUS FOLIAGE INFLUENCES YIELD, FRUIT SIZE AND SCARRING BY CITRUS THRIPS

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INTRODUCTION:

Foliar-applied urea was demonstrated in the early 1960's to be as efficacious as nine other sources of nitrogen supplied to the soil in maintaining yield of orange trees (Leonard et al., 1961). Embleton and Jones (1974) provided evidence that maximum nutritionally-attainable yields for sweet oranges were obtained with annual nitrogen rates of 0.45 to 0.65 kg per tree, regardless of the method of application. Foliar application of nitrogen fertilizer to citrus has not been widely adopted commercially. Due to the limits in the amount of nitrogen that can be applied in a single application, up to five foliar sprays may be required each year to provide the recommended annual rate of nitrogen, creating the perception that foliar nitrogen fertilization is more expensive because several applications are required to maintain yield. Thus, it is necessary to demonstrate that foliar nitrogen fertilization is cost-effective in order to encourage citrus growers to abandon the use of soil-applied nitrogen in favor of foliar-applied urea.

Earlier results of Sharples and Hilgeman (1969) suggested that urea applied to the foliage at the proper time might have a beneficial effect on yield. They were able to obtain yields of `Valencia' oranges over a 7-year period with only 0.23 kg N total per tree split between two foliar applications of urea, one in February and a second in late April to early May, that were statistically equal to yields obtained with 0.45 or 0.91 kg N per tree as ammonium nitrate supplied to the soil. Similarly, recent research (Ali and Lovatt, 1994) demonstrated that a properly-timed winter prebloom (mid-January or mid-February) application of low-biuret urea to the foliage of the `Washington' navel orange (0.16 kg N per tree) significantly increased yield and fruit number per tree each year compared to control trees receiving soil-applied nitrogen for the three consecutive years of the study. The number of commercially valuable fruit with diameters 6.1 to 8.0 cm increased significantly as yield increased (r^2=0.88). Without taking into account the increase in the number of fruit of packing carton sizes 88 and 72, which have a greater dollar value, and despite the loss in yield due to a freeze in December of year two of the study, the average net dollar return per acre per year for trees receiving foliar low-biuret urea versus soil-applied low-biuret urea was approximately $450 and $400 for applications made in mid-January and mid-February, respectively (Ali and Lovatt, 1992). Consistent with the hypothesis that timing is important, mid-November and mid-December sprays were less effective. Of additional benefit, Embleton and Jones (1978) and Embleton et al. (1986) documented that foliar application of nitrogen substantially reduced nitrate pollution of ground water, even when used to only partially replace soil-applied nitrogen.

Growers in the San Joaquin Valley comprise a majority (59%; 91,000 acres) of California's citrus acreage and have historically used chemicals to control citrus thrips. Broad-spectrum materials such as dimethoate and formetamate, the two main pesticides used over the last 15 years to control citrus thrips are devastating to biological control agents such as *Aphytis melinus* DeBach (Morse and Bellows, 1986), which can be used to control red scale in citrus. Thus, current use of chemicals to control citrus thrips precludes the use of biological control for other insect pests. A non-pesticide strategy to control citrus thrips would aid in converting the San Joaquin Valley to biological control (Luck et al., 1986).

A predacious mite, *Euseius tularensis* (*E. hibisci*) Congdon and McMurtry, a polyphagous natural enemy of citrus thrips, appears to provide some biological control, especially when citrus thrips pressure is light (Tanigoshi and Griffiths, 1982; Tanigoshi et al., 1984, 1985). However, during warm periods after petal-fall, citrus thrips levels can rapidly increase to levels that the predaceous mite has trouble controlling. A selective material that could reduce the level of citrus thrips before or at this time would be helpful. Preliminary results from both laboratory and field experiments provide evidence suggesting that foliar-applied low-biuret urea might be effective in reducing citrus thrips population levels. The only other selective materials presently available for citrus thrips control are sabadilla (Veratran D) and ryania (Ryan 50), both marginally effective botanical baits when mixed with sugar, and the newly registered abamectin (Agir-Mek). Both are in short supply. If, as expected with increased interest in citrus integrated pest management including *Aphytis* releases for California scale control, a moderate number of growers start to use one or both of these materials, supply could not meet demand.

The objective of the present study was to test the hypothesis that foliar urea applied within the period April 1 to June 1 can do triple duty (i) as a "non-pesticide" to control citrus thrips and reduce fruit scarring, (ii) as a "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality, and (iii) as a nitrogen fertilizer by supplying a portion of the nitrogen to be applied in a given year thus reducing the amount applied to the soil. The goal of our research was to determine whether there is an optimal time for foliar application of urea that will successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring that would be cost-effective. If successful, the results of our research will not only improve citrus productivity and grower profits, but will also reduce pollution to the groundwater from nitrate and reduce the amount of chemical pesticides currently used to control citrus thrips.

PROCEDURES:

The research was conducted on 17-year-old `Frost nucellar' navel orange trees on Trifoliate orange rootstock under commercial production by Paramount Citrus in the Ivanhoe area of the San Joaquin Valley. The research was replicated for three years due to alternate bearing.

There were five treatments each replicated as eight randomized blocks (six rows wide by 15 trees long). Data was collected from six individual trees per block for a total of 48 data trees per treatment. Foliar low-biuret urea was applied each year on approximately April 7, April 21, May 5, or May 20 for treatments 1 through 4, respectively. Treatment 5, the control, was Paramount Citrus' current management practice, consisting of soil-applied nitrogen. Total nitrogen analyses were done annually in September on each of the 240 data trees in order to monitor the total nitrogen status of the tree as is currently done commercially and to determine the contribution to total N made by each treatment over the 3 years of the field trial.

Harvest was in March of each year, with harvest for year three scheduled for March 1995. Fruit weight per tree, fruit number per tree, fruit size for all fruit on each of the 240 data trees, and degree of thrips scarring on all fruit on 120 data trees were determined.

RESULTS:

Foliar applications of low-biuret urea consistently raised the NH_3-NH_4^+ content of both the young and mature leaves by 100 to 150 μg per g dry weight leaf tissue, but this increase was only evident for sampling dates 1 to 3 days after the foliar urea application. Eight days after the foliar application of urea, the levels of NH_3-NH_4^+ in either young or mature leaves were not significantly different from the control leaves on the same date or the time zero leaves collected the day before the foliar application of urea.

Total nitrogen content of the leaves for all trees used in the research increased from 2.5% in September 1991 to 2.9% in September 1992. The spring application of low-biuret urea may contribute to the annual nitrogen requirement of the tree, but it was not possible to tell the effect of the urea sprays versus that of the soil-applied N from the leaf analyses provided to us by Paramount Citrus. Individual data trees were sampled in September 1994 in order to be able to detect treatment effects.

The results of the study provided clear evidence that a spring foliar application of low-biuret urea had no negative effect on the population densities of beneficial predatory mite, *Euseius tularensis*. There was no significant difference in the number of predacious mites per leaf for trees on which 500 mites had been released on March 19, 1992, independent of whether these trees were left as controls or were subsequently sprayed with low-biuret urea on the date indicated. The number of mites per leaf was not due to a natural increase in the population by immigration during the course of the study, since the control trees on which no mites were released had significantly lower numbers of mites per leaf on both sampling dates.

Spring foliar applications of low-biuret urea had no statistically significant effect on the population densities of *Scirtothrips citri*. The high degree of variability in the number of thrips in each of the replicate samples made it impossible to detect statistically significant differences due to any of the treatments.

Spring foliar applications of low-biuret urea had no statistically significant effect on fruit scarring determined as either on-tree evaluations of fruit on the outside of the tree in September or evaluation of total fruit per tree at harvest in March. While not significant at the 5% level, it is interesting to note that for both years of the study, the late May (May 20, 1992 and May 25, 1993) foliar application of low-biuret urea resulted in the lowest degree of fruit scarring, especially severe scarring (Table 1). This trend was observed for both the on-tree and harvest evaluations for both years of the study. Although not significant at the 5% level, it is also worth noting that for both years of the study, the second date of foliar application of urea (April 21, 1992 and April 27, 1993) had the highest percent scarring, especially severe scarring. In year two, the mean percent of fruit severely scarred by citrus thrips was significantly less at the 10% level for trees receiving the late May application of low-biuret urea compared to trees receiving the late April application (Table 1). Neither value was significantly different from the control or from trees receiving urea to the foliage in early April or early May.

In the first year of the study, which was an "on" year, there were statistically significant differences at the 5% level between dates of urea application to the foliage in terms of total weight of fruit per tree and the number of fruit of packinghouse carton size 56 (fruit with diameters between 8.1 and 8.8 cm). The date of foliar urea application had no statistically significant effect on other sizes of fruit. The May 20, 1992 foliar application of low-biuret urea had the highest total fruit weight and the highest number of fruit of packinghouse carton size 56. In both cases, the May 20, 1992 low-biuret urea application was statistically better at the 5% level than the April 7 and May 5 spray dates. However, the April 7, April 21, and May 5 treatments were not statistically different from the control at the 5% level. At the 10%

level, the May 20, 1992 foliar application of urea resulted in significantly more total weight of fruit per tree and more fruit per tree of packinghouse carton size 56 than the control and all other treatments, except the April 21, 1992 urea application.

In the second year of the study, which was an "off" year, there was no significant effect at the 5% level on the kg and number of fruit per tree. There was, however, a statistically significant increase in the kg of fruit of packinghouse carton size greater than 56 (fruit with diameters greater than 8.8 cm) for trees receiving the May 25, 1993 foliar application of low-biuret urea compared to the control trees receiving soil-applied nitrogen. Trees receiving the May 25, 1993 foliar application of low-biuret urea had significantly more fruit of packinghouse carton size 56 than trees receiving the early April 13 foliar application of urea.

Repeated Measure Analysis was used to test the effect of the time of foliar-urea application on fruit yield, number and size over the two years of the study. The late May foliar application of low-biuret urea significantly ($P \leq 0.05$) increased yield (kg) and both the kg and number of fruit of packinghouse carton size 56 per tree compared to trees receiving foliar applications of low-biuret urea in early April or early May, but was not significantly different from the control trees receiving soil-applied nitrogen or from trees receiving a foliar application of low-biuret urea in late April (Table 2). There was no significant effect on the kg or number of fruit in any other size category.

DISCUSSION:

Our results suggest that urea will not have much impact in preventing scarring of fruit when thrips pressure is great. The performance of urea in reducing the percentage of fruit scarred by thrips in a light thrips year remains to be determined. The results provide evidence that a properly-timed spring (late May) foliar application of low-biuret urea significantly increased yield by increasing both the weight and number of large-sized fruit (packinghouse carton size 56) with some reduction in the degree of severe fruit scarring by citrus thrips. Trees receiving the late May foliar application of low-biuret urea averaged 11 kg more fruit than the control trees receiving soil-applied nitrogen over the two years of the study. This represents an additional 0.65 17-kg carton of fruit per tree. At a typical planting density of 96 trees per acre, the late May foliar application of low-biuret urea would yield 63 additional cartons per acre. For the cost/benefit analysis, the following values were used: (*i*) price of $8.00 per 17-kg carton despite the fact that the late May foliar application of urea increased the number of fruit per tree of packinghouse size 56 and had no effect on any other fruit size and subtracted $2.29 per carton for packinghouse handling of the extra cartons (per Connelly Melling; Dole) to calculate profit; (*ii*) 56.8 liters (15 gallons) Unocal PLUS per acre at $16.50 per acre; and (*iii*) spray rig application at $25.00 per acre to calculate expenses with all other expenses being the same, although there really is the expense of a soil application of nitrogen to the control trees which was not included. Net return to the grower for the late May foliar application of low-biuret urea was an average of $318 per acre per year.

Table 1. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on the Percent of Fruit at Harvest Severely Scarred by Citrus Thrips.[z]

Date Urea Applied to Foliage	%Severely Scarred Fruit Year 1	$P \leq 0.10$	%Severely Scarred Fruit Year 2	$P \leq 0.10$
early April	20.65	a	11.93	ab
late April	21.99	a	14.03	a
early May	20.89	a	11.09	ab
late May	16.09	a	9.67	b
control-soil applied N	18.94	a	11.08	ab

[z] Average yield for all treatments was 269 ± 13 and 141 ± 4kg fruit per tree in years 1 and 2, respectively.

Table 2. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on Yield for the Two Years of the Study

Date Urea Applied to Foliage	Yield kg/tree	$P \leq 0.05$	56s kg/tree	$P \leq 0.05$
early April	197	b	53	b
late April	210	ab	60	ab
early May	201	b	56	b
late May	215	a	65	a
control-soil applied N	204	ab	60	ab

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