SCIENTIFIC RATIONALE AND ECONOMIC INCENTIVE FOR USE OF A WINTER APPLICATION OF FOLIAR UREA IN CITRUS PRODUCTION[1]

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INTRODUCTION

Based on 56 "experiment-years" of citrus data, Embleton and Jones (1974) reported that kilogram for kilogram, foliar-applied nitrogen was as effective as soil-applied nitrogen for fruit production. Maximum nutritionally-attainable yields were obtained with annual nitrogen rates of approximately 0.5 to 0.7 kg per tree for oranges, 0.9 kg per tree for lemons, and 0.5 kg foliar-nitrogen and 1.4 kg soil-applied nitrogen per tree for grapefruit. While these requirements can be met with one annual soil application, limitations on the amount of nitrogen that can be applied in one spray, necessitate three to six foliar sprays each year to provide these levels.

The logical extrapolation that applying nitrogen to the foliage is a more costly management strategy has limited its adoption despite the fact that Embleton *et al.* (1978, 1986) have provided strong evidence that even a program of conjunctive soil- and foliar-applied nitrogen can substantially reduce nitrate ground water pollution without adversely affecting fruit yield, size, and quality.

Results of our basic research suggested that a winter foliar-application of low-biuret urea (LBU) may increase yield, and field results, to date, have demonstrated that LBU applied to the foliage at the rate of 28 lbs N per acre (~0.15 kg N per tree) mid-January ±30 days increased navel orange yield without reducing fruit size each year of a 3-year trial.

BASIC RESEARCH

Since citrus trees flower in the spring in response to low temperatures experienced during the winter, controlled-environment chambers have been used to apply low temperatures in a quantitative manner so that changes in plant growth regulators, carbohydrates, and nitrogen compounds could be monitored in relation to floral intensity. In such experiments, flower number was consistently correlated with the duration of the low-temperature period (Moss, 1969; Southwick and Davenport, 1986; Lovatt *et al.*, 1988a, b). However, no correlation between flower number and the endogenous level of any of several plant growth regulators (Davenport, 1990) nor between leaf concentrations of starch, glucose, total nitrogen, or nitrate (Lovatt *et al.*, 1988b) could be demonstrated. In contrast, there was a significant correlation between the ammonia content of leaves collected 1 week after the end of the low-temperature treatment and both the duration of low-temperature stress ($p<0.01$; $r=0.6$) and flower number ($p<0.0001$; $r=0.8$) (Lovatt *et al.*, 1988a, b).

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To determine whether or not the ammonia accumulating in the leaves of citrus trees subjected to low temperature was physiologically related to floral intensity, 5-year-old rooted cuttings of the 'Washington' navel orange were subjected to short periods of low temperature which do not result in significant flower production. At the end of the treatment period, the ammonia status of the trees was artificially increased with a foliar-application of LBU (Table 1). This resulted in an increase in flower number (Table 1).

Table 1. Effect of LBU (1.5 g per tree) applied to the foliage of 5-year-old rooted cuttings of the 'Washington' navel orange at the end of the low-temperature treatment.

Weeks of low-temperature treatment at 15-18°C for 8 h/day and 10-13°C for 16 h/night	Increase in leaf ammonia content during the first week after transfer to warm temperature as a percent of the control without urea for each treatment	Increase in flower number as a percent of the control without urea for each treatment
4	166%	194%
6	215%	230%

From: Lovatt *et al.*, 1988a.

In addition, foliar LBU increased the proportion of the total flower population borne on leafy inflorescences (shoots bearing leaves and flowers). For example, when 5-year-old rooted cuttings of the 'Washington' navel orange induced to flower by 6 weeks of low-temperature treatment were also given a foliar application of LBU, the number of leafless inflorescences doubled (Table 2), but the number of leafy inflorescences increased 4-fold, increasing the number of flowers borne on leafy inflorescences from 25 to 40% of the total flower population. Furthermore, foliar LBU increased the average number of leaves per inflorescence 3-fold (Table 2). It is well documented for citrus that leafy inflorescences set more fruit that persist to harvest than leafless inflorescences (for a recent review, see Erner, 1989).

Table 2. Effect of LBU (1.5 g per tree) applied to the foliage at the end of 6 weeks of low-temperature treatment on inflorescence type of the 'Washington' navel orange.

	Number of			
Treatment	Flowers borne of leafless inflorescences	Flowers borne on leafy inflorescences	Leaves borne on leafy inflorescences	Vegetative shoots
No urea	290	110	136	112
With urea	615	406	499	51

These results provide the scientific rationale for the idea that a winter foliar application of LBU to commercially-producing citrus trees, in some years, may sufficiently increase the ammonia status of the trees over the level accumulating in response to low winter temperatures to result in increased flowering, fruit set, and yield.

FIELD RESEARCH

LBU was applied to commercially producing 30-year-old 'Washington' navel orange trees on Troyer citrange rootstock on November 14 , December 14, January 14, or February 14 at the rate of 10 lbs LBU (Unocal PLUS® donated by the Unocal Corporation) per 100 gallons H_2O sprayed to the drip point. (The equivalent of 60 lbs LBU per 600 gallons H_2O per acre was used to provide 28 lbs N per acre; ~0.15 kg N per tree.) There were 12 individual tree replicates per treatment to make it possible to detect yield differences at the 5% level (Jones *et al.*, 1957). All trees received 0.5 kg N per tree as LBU applied to the soil each year in November or December.

YIELD RESULTS

For three consecutive years, a winter application of foliar LBU in January or February increased the yield of 30-year-old 'Washington' navel orange trees in terms of both total fruit weight per tree and number of fruit per tree (without significantly reducing fruit size).

A January or February foliar application of LBU increased yield by just over one carton (17 kg, 37.5 lbs) per tree in 1989-90, just under one carton per tree in 1990-91, and by 2.5 cartons per tree in 1991-92, compared to trees receiving only soil LBU.

It is important to note that the increased yield resulting from the winter foliar application of LBU had no negative effect on fruit size in any year of the study. For 1989-90 and 1990-91, the LBU treatment having the greatest number of fruit per tree had the greatest number of fruit with diameters from 7.0 to 8.0 cm (carton sizes 88 and 72); an additional carton per tree in 1989-90 and an additional half carton per tree in 1990-91.

The increase in yield resulting from the winter foliar application of LBU was not a result of improved nitrogen status of the trees. At the end of the three-year experiment, leaf total nitrogen content of the 1991 spring flush leaves collected in September was not significantly different at the 5% level for control trees receiving soil LBU versus trees receiving foliar LBU. Leaf total nitrogen content was between 2.5 to 2.6%. There was no significant correlation between total N and yield.

In Tables 3 and 4, we report the results of a cost-benefit analysis which used the following values: (*i*) The 1989-90 average price of \$3.20 per carton; (*ii*) 15 gallons Unocal PLUS® per acre at \$1.10 per gallon; (*iii*) spray rig at \$25.00 per acre for the highest cost of application; and (*iv*) airplane at \$10 per acre for the lowest cost of application to give the lower and upper end of the range reported as net return in Tables 3 and 4. Our analysis underestimates total and net income because it does not take into account the increase in the number of fruit of carton sizes 72 and 88, which have a high dollar value. Also keep in mind that yields were greatly reduced in the 1990-91 season due to the freeze in December of 1990.

Table 3. Three-year net cumulative increase in packing cartons and in total and net dollar return per acre for trees receiving foliar LBU versus soil LBU.

	Date LBU applied to the foliage			
	November	**December**	**January**	**February**
- Packing cartons	**288**	**319**	**452**	**400**
- Total return	**\$924**	**\$1024**	**\$1451**	**\$1284**
- Net return	**\$814-845**	**\$914-945**	**\$1341-1372**	**\$1174-1205**

Table 4. Average net dollar return per acre per year for trees receiving foliar LBU versus soil LBU.

Date LBU applied to the foliage			
November	December	January	February
$271-282	$305-315	$447-457	$391-402

In each year of this study, the winter foliar application of LBU more than paid for itself (Tables 3 and 4).

CONCLUSION

California citrus growers are proactive. In response to the accusation that the Citrus Industry has contributed to nitrate contamination of groundwater in California, growers decreased the amount of nitrogen applied to the soil and increased the use of foliar nitrogen. Our research results suggest that using low-biuret urea (LBU) as the source of nitrogen and shifting one application of 28 lbs nitrogen per acre to mid-January ±30 days, in some years, may sufficiently augment the ammonia accumulating in response to low winter temperatures to increase flowering and/or fruit set and yield without reducing fruit size, while providing 15 to 30% of the nitrogen required annually. This management strategy is economically viable and environmentally sound.

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