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FOLIAR FERTILIZER APPLICATION DECREASES 'VALENCIA' FRUIT QUALITY

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Abstract. **Three foliar applications of 6% 3N:18P$_2$O$_5$:18K$_2$O liquid fertilizer in December to 35-year-old 'Valencia' (*Citrus sinensis* L.) on rough lemon (*C. limon* L. Burm. f.) during the 1985/86 crop year increased fruit size and weight, but reduced juice content and total soluble solids. Fruit from sprayed trees was greener than fruit from unsprayed trees. Concentrations in the leaves of P, K, Mn, and Zn increased in response to foliar applications. Seven-year-old 'Valencia' on Cleopatra (*C. reticulata* Blanco) trees were sprayed three times with low-biuret urea in December 1996. Fruit quality analysis of five composite samples of five fruit per tree in May 1997 showed that the fruit from urea-sprayed trees was larger, heavier, and greener, but that juice content, total soluble solids, and solids/acid ratios were lower in fruit from urea-sprayed trees. There was no significant difference in yield.**

Foliar application of nutrients is a longstanding practice in fruit crops, especially when soil applications are not effective because of soil characteristics or to avoid groundwater contamination (Swietlik and Faust, 1984). It has also been reported as effective in cold protection (Kim and Ko, 1996). Nutrient sprays have been used extensively in California to apply macro-and microelements. In Florida, mostly microelements have been sprayed on the leaves, although recently there have been efforts to extend the practice to macroelements (Davies, 1997). Foliar application of urea (230 g [0.5 lb] N/tree/year) as the sole source of nitrogen had no effect on fruit quality in 3 of 4 years when compared to no-N and soil applications ranging from 450 to 3630 g N/tree/year. In one year the urea-sprayed trees had fruit quality equal to the trees receiving no N, with a decrease in quality with increasing N application (Sharples and Hilgeman, 1969). Urea sprays in January and February increased production of 'Washington' navel orange in California, but fruit quality was not determined (Ali and Lovatt, 1994).

High levels of N applied to the soil increased green rind color, rind thickness, and juice acidity (Reitz and Koo, 1960), phosphorus enhanced green rind color and juice content and lowered total soluble solids (Smith et al., 1949; 1963), and potassium increased zinc, rind thickness, green rind color, and juice acidity (Smith and Rasmussen, 1959). In two attempts to test the effectiveness of nutritional leaf sprays in increasing cold hardiness, results were inconclusive for lack of severe freezes in the test years. The tests provided an opportunity, however, to investigate the effects of nutritional leaf sprays on the appearance and the quality of the fruit of the tested trees.

Materials and Methods

In a 35-year-old grove of 'Valencia' orange on rough lemon rootstock near Babson Park, Florida, four randomly selected rows of 28 trees each were sprayed with 6% of a 12N:6P$_2$O$_5$:6K$_2$O liquid fertilizer (Liquid Flomix) on May 23 and July 29, 1985 with an air-blast sprayer. The nitrogen consisted of a 1:3 mixture of NH$_3$ and urea. Four unsprayed rows served as control, the grove received standard care with 224 kg/ha (200 lb/acre) of N and K$_2$O split in two applications, a microelement spray in the spring, pest control sprays, chemical weed control, and microsprinkler irrigation. Sixty-leaf samples were collected from each test row in May before treatment, in July after the first foliar spray, and in December after three additional foliar applications of 6% of a 3N:18P$_2$O$_5$:18K$_2$O formulation on October 2 and December 4, 1985. The December 4 application was repeated on December 10 because of heavy rain immediately after spraying the trees. Zinc and Mn (2.27 kg [5 lb] Zn and 1.7 kg (3.75 lb) Mn per 1893 L [500 gal]) were added to the October spray. The leaf samples were washed in detergent solution, ground to 20 mesh after drying at 70°C (158°F) and ashed at 450°C (842°F). Calcium, Mg, Fe, Mn, Zn, Cu, and Mo were determined by atomic absorption on the ash dissolved in 5% HCl, K and Na by flame emission, S turbidimetrically and P and B colorimetrically. Nitrogen analysis was by micro-Kjeldahl. Two 30-fruit samples per test row were collected on April 9, 1986, fruit weight, diameter, rind thickness, and rind color were recorded and the juice extracted with a motor-driven reamer. Comparisons in the past have shown that 5% to 10% less juice is extracted by this procedure than with a commercial juice extractor. Total soluble solids were determined with a temperature-compensated refractometer and total acids by titration of 10 ml of juice in 90 ml of water with 0.1560 N NaOH.

In a block of 64 seven-year-old 'Valencia' orange on Cleopatra mandarin rootstocks near Leesburg, Florida, alternate trees (36) were sprayed with 0.75% low-biuret liquid urea on December 6, 13, and 23, 1996, using a motor-driven handsprayer. Twenty-eight unsprayed trees served as controls. The trees were grown with 224 kg/ha (200 lbs/acre) of N and K$_2$O per year split into three applications and micro sprinkler irrigation. On May 27, 1997, five fruit per tree were collected for five composite samples from the treated and untreated trees for fruit analysis by methods described above. Fruit from 10 random trees from each treatment was harvested and the yield per tree was recorded. Significance of differences between sprayed and unsprayed trees was determined using the t-test.

Results and Discussion

The 1985/86 experiment was suggested by a fertilizer distributor who thought that one of his groves which had been sprayed

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with liquid 3N:18P_2O_5:18K_2O fertilizer withstood the 1983 freeze

Table 1. Fruit quality of 'Valencia' orange sprayed with N-P-K in 1985 and with urea in 1996.

Treatment	Fruit dia. (cm)	Fruit wt. (g)	Rind thickness (mm)	Juice content (%)	TSS (%)	Total acids (%)	TSS/TA ratio	Fruit color[z]	Juice color (color no.)
				Babson Park - 1985					
NPK spray	7.9	255	5.5	39.6	9.8	0.82	12.2	8.0	38.9
Unsprayed control	7.6	232	5.3	42.4	10.4	0.99	10.7	8.6	39.1
Stat. sig. (p = 0.05)[y]	*	*	ns	*	*	ns	ns	*	ns
				Leesburg - 1996					
Urea spray	7.7	232	4.1	40.9	10.3	0.57	18.2	8.5	38.5
Unsprayed control	7.3	212	3.7	45.2	12.0	0.61	19.8	9.6	38.3
Stat. Sig. (p = 0.05)	*	*	*	*	*	ns	*	*	ns

[z]Fruit external color according to color tables in USDA Technical Bulletin 753, "Seasonal Changes in Florida Oranges." The higher the number, the better the fruit color (7 = G, 8 = H, 9 = I).
[y]t test.

better than adjoining groves. The spray treatments were applied according to his recommendations. The treated trees had somewhat less freeze damage in the December 1985 freeze, but the damage was light and the difference was not very pronounced. Fruit quality analysis in April 1986 (Table 1) showed that the foliar fertilizer applications increased fruit size and fruit weight, but reduced the juice content and total soluble solids and the fruit was significantly greener than the fruit from unsprayed trees. Total acids and juice color were unaffected.

The effects observed agree with most of the results reported from soil-applied N, P, and K experiments. All three elements enhanced green fruit color (Reitz and Koo, 1960; Smith et al., 1959; 1963) and the foliar applications gave the same response. Phosphorus applied to the soil increased juice content (Smith et al., 1963) but the N-P-K sprays had the opposite effect in the Babson Park experiment (Table 1). Leaf levels of P and K increased in response to the foliar sprays, but N levels did not (Table 2). Urea sprays in California also failed to increase concentration of N in the leaves (Ali and Lovatt, 1994). The addition of Mn and Zn to the foliar spray in October resulted in higher analysis values for these elements in December (Table 2), but there were few other differences in microelements between sprayed and unsprayed trees. As with soil application of P (Smith et al., 1949) foliar application lowered total soluble solids (Table 1). N-P-K leaf sprays increased fruit size, but did not affect rind thickness and total acids (Table 1).

The results of the Leesburg experiment were similar to those from Babson Park although only urea was applied there (Table 1). Again, fruit from sprayed trees was larger and heavier, the rind was significantly thicker and greener, as reported in response to soil application (Reitz and Koo, 1960); there was no difference in total acids. Juice content, total soluble solids, and the solids/acids ratio of fruit from unsprayed trees were higher than of fruit from urea-sprayed trees. Spraying urea only decreased juice content and total soluble solids and increased green fruit color more than the N-P-K sprays in Babson Park. As in Babson Park, there was no difference in juice color (Table 1). Yield per tree was slightly, but not significantly, higher with urea sprays (2.05 ninety-pound [40.8 kg] boxes per tree vs. 1.87 boxes per tree, t = 0.58). The results show that the urea sprays reduced the pounds solids production per tree by 15%. A report of production increases in response to urea sprays in California did not include fruit quality analysis. As pounds solids production is the most important factor in Florida, the apparent reduction of solids by urea sprays should be considered when making decisions on nitrogen application.

Table 2. Analysis for 14 elements of leaves before and after spraying with N-P-K liquid fertilizer in the experiment near Babson Park, 1986.

	Percent (d.w.)						ppm (d.w.)							
Treatment	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	Cl	B	Mo
							April 1986 (before treatment)							
Sprayed	2.66[z]	0.143	1.63	2.23	0.278	0.231	279	34	11	25	8	310	54	1.6
Unsprayed	2.64	0.135	1.64	2.51	0.302	0.228	367	34	8	24	9	332	54	1.7
Stat. Sig. (p = 0.05)[z]	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
							July 1986							
6% 12-6-6	2.73	0.144	1.78	2.41	0.362	0.247	342	51	15	21	9	326	87	2.4
Unsprayed	2.68	0.124	1.67	2.94	0.366	0.249	441	46	26	32	9	359	88	2.4
Stat. Sig. (p = 0.05)	ns	*	ns	ns	ns	ns	ns	*	*	*	ns	ns	ns	ns
							December 1986							
6% 3-18-18	2.81	0.208	1.61	2.43	0.312	0.303	590	51	38	19	8	677	115	1.7
Unsprayed	2.78	0.137	1.33	2.56	0.341	0.262	687	47	19	17	8	642	132	1.5
Stat. Sig. (p = 0.05)	ns	*	*	ns	ns	ns	*	*	*	*	ns	ns	ns	ns

[z]t-test.

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ENHANCING DEVELOPMENT OF IMPROVED ROOTSTOCKS BY TISSUE CULTURE PROPAGATION AND FIELD PERFORMANCE OF SELECTED ROOTSTOCKS

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Abstract. **A recently established Cooperative Research and Development Agreement between the USDA and Twyford International to develop micropropagation procedures for new hybrid rootstocks promises to significantly expand the range of germplasm that can be effectively used as rootstocks for citrus, and accelerate testing and release of promising selections. Micropropagation of rootstock cultivars makes it possible to rapidly obtain thousands of uniform plants from a few buds of source material through tissue culture, regardless of whether the original source has fruit, seed, or comes true-to-type from seed. Many citrus relatives and hybrids that previously could not be used as rootstocks because they did not grow uniformly from seed can now be rapidly and uniformly propagated. Micropropagation has other potential advantages, including promoting the rapid distribution of new cultivars and encouraging the production of healthy and high quality plants. Outstanding performance in two field trials is reported for several new hybrid rootstocks for which efficient micropropagation procedures are being developed.**

Introduction

Profitability of citrus production in Florida is limited by the rootstock. Efforts to develop improved citrus rootstocks are limited by genetic traits that are available in the usable germplasm. One important trait for citrus rootstocks that has generally been critical in determining acceptability of rootstocks for commercial use is nucellar embryony, a type of apomixis. Common commercial propagation of citrus utilizes seed propagated rootstock liners that are genetically identical to the source tree because of nucellar embryony. Species or hybrids that do not produce at least 80-90% apomictic seeds have usually been excluded from testing as citrus rootstocks, and avoided as parents in making new hybrid rootstocks because of this reliance on seed propagation. Even when selections that are not highly apomictic have been tested as rootstocks, variation in tree performance due to genetic variability in the seedling liners has been a serious negative trait.

Advances in methods for vegetative propagation of citrus rootstocks through tissue culture (micropropagation) have now made it possible to economically produce large numbers of genetically identical plants from rootstock selections regardless of the natural mode of reproduction. After a short acclimation period in soil, these plants from tissue culture can be budded and grown as though they were seedling rootstocks. Although some types of tissue culture manipulations can produce genetic changes, selection of proper conditions for micropropagation can maintain genetic mutations at levels that are comparable to those observed in rootstock seedlings and scion budwood of common commercial cultivars.

Several new rootstocks that are currently under advanced testing by the USDA appear very promising for commercial use. Most of these new rootstocks can be effectively seed propagated. However, micropropagation may be useful in propagating these rootstocks because plants in culture can easily be maintained free of disease, multiplication is unaffected by seasonal variations, and the system facilitates rapid increase and distribution of new cultivars even when sufficient seed is not available. Also, there are other new rootstocks under development that are difficult or impossible to propagate by seed and are even more suitable for micropropagation.

Diversity of Rootstock Germplasm

The rootstocks currently used in Florida citrus production are not genetically diverse. Nearly all rootstocks in commercial use are composed of genetic material from six species (Table 1). About 90% of Florida citrus trees are growing on rootstocks that are mandarin (*Citrus reticulata* Blanco) or hybrids between trifoliate orange (*Poncirus trifoliata* [L.] Raf.) and sweet orange (*C. sinensis* [L.] Osbeck) or grapefruit (*C. paradisi* Macf.). The number of sex-