FERTILIZATION, ROOTSTOCKS, GROWTH AND YIELDS OF YOUNG 'ROHDE RED' VALENCIA ORANGE TREES

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Abstract. **'Rohde Red' valencia orange trees [*Citrus sinensis* (L.) Osb.] on three rootstocks, (*C. volkameriana* Ten. and Pasq., Carrizo citrange [*C. sinensis* (L.) Osb. × *Poncirus trifoliata* (L.) Raf.], or Swingle citrumelo [*C. paradisi* Macf. × *P. trifoliata* (L.) Raf.], were used to determine if annual N rate and application frequency should be adjusted based on rootstock during the first 3-5 yr in the field. Treatments were arranged in a three (rootstock) × three (N rates) × three (N application frequency) factorial experiment with six individual tree replications per treatment. Annual N application rates ranged from 0.30 to 0.60 lb/tree and N was applied in 8, 15, or 60 split applications per year. Rootstock had a significant effect on trunk circumference and yields in all three years with trees on *C. volkameriana* producing the largest trees. The greatest yields generally occurred for trees on *C. volkameriana*, followed by those on Carrizo and Swingle, respectively. The highest N rate increased yields over the two lower rates in year 3 for trees on *C. volkameriana* and Swingle rootstocks, but did not affect yields in year 4. In year 5, the 0.45 and 0.60 lb annual rates increased yields over the 0.30 lb rate for all rootstocks. There was no interaction between rootstock and N rate related to trunk circumference, but there was interaction between N rate and yields. Application frequency had no effect on trunk circumference, leaf N concentration or yields in any year.**

Several studies have been conducted in Florida to determine optimum N rates and application frequencies for newly planted citrus trees. Rasmussen and Smith (1961) found an optimum annual N rate per tree of 0.08 lbs for 1-yr old trees growing on deep, sandy soils. Calvert (1969) observed a higher, broader range of optimum annual rates (0.24 to 0.72 lbs N/tree) depending on soil characteristics for 2-yr old trees growing on the east coast. Willis et al. (1990) found a slightly lower optimum annual rate of 0.23 lbs N/tree for 'Hamlin' orange trees during the first year in the field. In contrast, Guazzelli et al. (1996) observed no effect of N rate on growth the first year in the field, but found an optimum annual rate of 0.37 lbs N/tree for trees in the second year growing on the Ridge. Obreza (1994) observed only a slight effect of N rate on canopy volume of 'Hamlin' orange on Carrizo rootstock for the first 3 yr in the field. However, he found a linear increase in yields as annual N rate increased from 0.21 to 0.84 lbs/tree for yr 4 and 5. Similarly, Davies and Zalman (2001) found no effect of N rate on trunk diameter for young 'Rohde Red' valencia orange trees for the first 3 yr after planting.

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Application frequency generally has no effect on growth of young orange trees in Florida (Davies and Zalman, 2001; Willis et al., 1990). However, in one study growth of 'Hamlin' trees on Carrizo citrange rootstock growing in sandy soils in Florida was greater when fertilizer was applied 30 compared with 5 or 10 times/yr (Willis et al., 1990).

Rootstock has a significant effect on citrus tree growth and yields (Castle, 1987; Wutscher, 1989). For example, scions on lemon type rootstocks are usually more vigorous and productive than those on most citranges, citrumelos, or sour orange rootstocks (Castle, 1987; Davies and Albrigo, 1994 Wutscher, 1989). This difference in vigor is usually not considered when determining fertilizer practices.

Currently, most young citrus trees in Florida are fertilized based on tree age or size without regard for rootstock (Davies and Albrigo, 1994, Tucker et al., 1995). However, Syvertsen and Smith (1996) observed that larger trees on *C. volkameriana* rootstock required higher N rates for optimum growth than smaller trees on sour orange rootstock. They suggested that N rate and application frequency should be adjusted based on rootstock and tree vigor. The objective of this study was to determine if N application rate and frequency should be adjusted based on rootstock for 'Rohde Red' valencia orange trees during the first 3-5 yr in the field.

Materials and Methods

Materials and Methods for part of this study are discussed in detail by Davies and Zalman (2001) but will be repeated in the following sections.

Plant material. Bare-root 'Rohde Red' valencia orange [*Citrus sinensis* (L.) Osb.] trees were obtained from a commercial field nursery (Roland Dilley, Avon Park, FL) and planted in Gainesville, Fla. on 19 May 1995 at 20 ft between rows and 8 ft within rows. Even though trees had been in the field nursery about 2 yr before digging, 1996 was considered as yr 1 in the field and this study focuses on yr 3-5, 1998-2000. Soil type was an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudults). Trees were irrigated every other day for the first 2 weeks after planting using 10 gal/h, 90° pattern microsprinklers located 3 ft northwest of the tree. Soil water deficit was maintained at less than 30% throughout the study, which is the optimum level for young citrus trees in this soil type (Marler and Davies, 1990).

Table 1. Rootstock and trunk circumference of 4- and 5- year old 'Rohde Red' valencia orange trees in Gainesville, Fla., 1999 and 2000.

	Trunk circumference (in)[z]	
Rootstock	25 Jan. 1999	30 May 2000
Swingle citrumelo	3.6 c	4.2 c
Carrizo citrange	4.1 b	5.1 b
C. volkameriana	4.5 a	5.6 a

[z]Mean separation within years by DMRT, $P \leq 0.05$, n = 54. There were no significant effects of N rate or application frequency; thus, all treatments were combined by rootstock (Source: Davies and Zalman, 2001).

Table 2. Rootstock, N rate, and yield per tree of 3-year-old 'Rohde Red' valencia orange trees in Gainesville, Fla, 1998.[z]

	Annual N rate (lb/tree)[y]							
	0.30		0.45		0.60			
	Fruit yield/tree						Mean[x]	
Rootstock	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)
Swingle	2.8 b[y]	2.2 b	5.1 b	2.6 b	12.3 a	5.9 a	6.7 B	3.6 B
Carrizo	8.3 a	4.6 a	10.5 a	5.3 a	15.5 a	8.2 a	11.4 B	6.0 B
C. volkameriana	26.8 b	14.3 b	39.2 b	20.9 b	59.7 a	33.5 a	41.9 A	22.9 A
Mean[x]	12.6 B	7.0 B	18.3 B	9.6 B	29.2 A	15.9 A		

[z]Fruit were harvested 8-12 Mar. 1998.
[y]Mean separation within rows (abc) by DMRT, $P \leq 0.05$, n =1 8. Regression analysis was not used to separate N rates because only three rates were used.
[x]Main effects of N rates and rootstocks (means) (ABC) were analyzed separately by DMRT, $P \leq 0.001$, n = 54. Interaction significant, $P \leq 0.001$.

The irrigation system was designed so that each tree served as an individual replication that was randomly assigned a treatment within each of six blocks as described previously (Marler and Davies, 1990). Treatments consisted of three rootstocks, *C. volkameriana*, Carrizo citrange, and Swingle citrumelo, three annual fertilizer rates (0.30, 0.45, and 0.60lbs/tree), and three application frequencies (8, 15 and 60×/yr). Application frequencies and N rates were chosen based on ranges observed in previous studies (Tucker et al., 1995; Willis et al., 1990). Fertilizer was applied in Mar. 1998 (yr 3), 1999 (yr 4), and 2000 (yr 5) and continued until December of each year. Liquid fertilizer with an 8-N (4% NH_4^+, 4% NO_3^-) 2P-6.6K analysis was applied using Dosatron 2% fixed injectors (Dosatron Intl., Clearwater, Fla.). This fertilizer analysis is typically used for young trees in Florida, although P rate was reduced based on relatively high levels of P in the soil (Tucker et al., 1995). The irrigation system was run for 30 min, after which the fertilizer was injected for 20 to 40 min depending on the treatment. The system was then flushed for 30 min after fertilizer injection.

Measurements. Trunk circumferences were measured on 25 Jan. 1999 and 30 May 2000. Leaf tissue nutrient concentrations were measured in three of the six blocks in September of each year using five spring flush leaves per tree for each of the 27 trees per block (81 trees). The entire experiment was not sampled due to its large size (162 trees). Leaves were prepared and analyzed as described previously (Maurer and Davies, 1993). Fruit were harvested, counted and weighed on 8-12 Mar. 1998 (yr 3); 25-29 Jan. 1999 (yr 4), and 15-18 Feb. 2000 (yr 5).

Experimental design and statistical analysis. Treatments were arranged into a 3 × 3 × 3 factorial experiment in a randomized complete block design consisting of six blocks of 27 trees per block, and six individual trees per treatment (162 trees total). Treatment effects on trunk circumference and yield were determined in years 3, 4, and 5 using ANOVA and Duncan's multiple range test within rootstocks where rootstock and N rate interactions were present. Means were separated using Duncan's multiple range test even though these are quantitative variables which in this instance is statistically and practically warranted (R. Littell, Dept. of Statistics, Univ. of Florida, pers. comm.).

Results and Discussion

Trunk circumference was not affected by N rate or application frequency in 1999 or 200l; however, it was significantly affected by rootstock (Table 1). There were no interactions among treatments. Trees on *C. volkameriana* had the largest circumference followed by those on Carrizo and Swingle, respectively. During the initial 3 yr of this study, the same trends occurred (Davies and Zalman, 2001). Moreover, the same relative differences in vigor among rootstocks have been reported in several citrus growing regions (Castle, 1987). Trees on *C. volkameriana* started out the largest and grew over a larger portion of the season than those on the other two rootstocks (Davies and Zalman, 2001).

Fruit number and weight increased across all rootstocks in 1998 as annual N rate increased from 0.45 to 0.60 lbs/tree

Table 3. Rootstock, N rate and yield per tree of 4-year-old 'Rohde Red' valencia orange trees in Gainesville, Fla, 1999.[z]

	Annual N rate (lb/tree)[y]							
	0.30		0.45		0.60			
	Fruit yield/tree						Mean[x]	
Rootstock	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)
Swingle	144.8 a	47.6 a	136.5 a	49.8 a	151.2 a	54.9 a	144.2 B	50.7 B
Carrizo	92.0 b	33.3 a	117.5 a	44.1 a	113.1 a	40.1 a	107.5 B	39.2 B
C. volkameriana	262.1 a	98.3 a	253.8 b	98.1 a	246.7 a	97.0 a	254.2 A	97.9 A
Mean[x]	166.3 A	59.7 A	169.3 A	64.0 A	170.3 A	64.0 A		

[z]Fruit were harvested 25-29 Jan. 1999.
[y]Mean separation within rows (abc) by DMRT, $P \leq 0.05$, n = 18. Regression analysis was not used to separate N rates because only three rates were used.
[x]Main effects of N rates and rootstocks (means) (ABC) were analyzed separately by DMRT, $P \leq 0.001$, n = 54. Interaction significant, $P \leq 0.001$.

Table 4. Rootstock, N rate and yield per tree of 5-year-old 'Rohde Red' valencia orange trees in Gainesville, Fla, 2000.[z]

	Annual N rate (lb/tree)[y]							
	0.30		0.45		0.60			
	Fruit yield/tree				Mean[x]			
Rootstock	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)	No.	Wt. (lb)
Swingle	61.2 b	28.7 b	93.0 a	42.0 a	66.0 a	31.1 a	73.4 C	33.9 B
Carrizo	130.7 a	55.2 b	130.9 a	56.3 b	156.0 a	67.5 a	139.4 A	59.7 A
C. volkameriana	77.0 a	39.0 b	115.2 a	61.5 a	105.9 a	53.5 a	99.4 B	51.4 A
Mean[x]	89.6 B	41.1 B	113.1A	52.3 A	109.5 AB	50.7 AB		

[z]Fruit were harvested 15-18 Feb. 2000.
[y]Mean separation within rows (abc) by DMRT, $P \leq 0.05$, n =1 8. Regression analysis was not used to separate N rates because only three rates were used.
[x]Main effects of N rates and rootstocks (means) (ABC) were analyzed separately by DMRT, $P \leq 0.001$, n = 54. Interaction significant, $P \leq 0.001$.

(Table 2). In addition, fruit weight and number were significantly greater for trees on *C. volkameriana* than those on Carrizo and Swingle which were similar. However, there was a significant interaction between rootstock and N rate ($P \leq 0.001$). Trees on Swingle showed the greatest increase in fruit weight with increasing N rates followed by those on *C. volkameriana*. Trees on Carrizo showed no significant increase in fruit weight or number with increasing N rates, although means were highest at the highest rate. Nitrogen application frequency had no effect on fruit weight or number (data not shown).

The situation in 1999 was slightly different. Fruit weight and number across rootstocks was not generally affected by annual N rate (Table 3); however, trees on *C. volkameriana* again had greater fruit weight and numbers than those on Carrizo and Swingle which had similar yields. Although the interaction was statistically significant, practically there appeared to be no horticulturally meaningful interaction between N rate and rootstock as was observed in 1998. Occasionally, significant interactions appear in data, but they are not meaningful from a practical standpoint (R. Littell, Dept. of Statistics, Univ. of Fla., pers. comm.). There was again no effect of application frequency on yields (data not shown).

In 2000, there was again an increase in fruit weight and number as annual N rate increased from 0.30 to 0.45 or 0.60 lbs across all rootstocks (Table 4). Fruit weight was greater for trees on *C. volkameriana* and Carrizo than those on Swingle. Fruit number, however, was greatest for trees on Carrizo followed by those on *C. volkameriana* and Swingle, respectively, across all N rates. Thus, fruit on Carrizo were smaller than those on the other rootstocks. In this case, the interaction of rootstock and N rate was significant for all rootstocks ($P \leq 0.001$). Once again, N application frequency had no effect on fruit weight or number (data not shown).

The effects of rootstock on tree growth and yields were similar to those observed in several other studies as summarized by Castle (1987) and Davies and Zalman (2001) using these same trees. However, N rate also had effects on yields. In yr 3, yields fruit weight increased when annual N rate was increased from 0.30 to 0.60 lbs for trees on all three rootstocks, which is in agreement with Syvertsen and Smith (1996) who suggested that N rates should be increased for trees on larger, more vigorous rootstocks.

In year 4, there was no rate effect of N rate on fruit weight or number, but fruit were harvested early (25-26 Jan.) following a freeze on 6 Jan. (min. temp. 20 °F). This early harvest may have biased the results. Again, in 2000 an annual N rate increase from 0.30 to 0.45 or 0.60 lbs/tree increased yields. Obreza (1994) observed a linear increase in yields for 'Hamlin' oranges in Florida as annual N rates increased from 0.21 to 0.84 lbs/tree. We cannot determine optimum N rates for each rootstock in this study because only three rates were used, but in general, the greatest increase in yield occurred as annual rates increased above 0.45 lbs/tree.

There were no significant differences in leaf N concentration related to N rate, application frequency or rootstock (data not shown), suggesting that leaf analysis may not be useful for fertilization scheduling for 3 to 5-yr-old orange trees. Nitrogen application frequency did not affect trunk circumference or yields over the 3 yr of the study. Similarly, application frequency had no effect on trunk diameter during the initial 2 yr in the field (Davies and Zalman, 2001). Willis et al. (1990) also found no effect of application frequency on growth of young 'Hamlin' trees on sour orange rootstock. However, in the same study (Willis et al.,1990) and in studies by Maurer et al. (1995) in Florida and Legaz (1981) in Spain frequent fertilizer application increased growth and yields over less frequent applications. The study by Willis et al. (1990) was conducted in the same location with the same soil type and rootstock (Carrizo) as used in this study. Nevertheless, results clearly showed no effect of N application frequency (up to 60 times/yr) on growth or yields, or any interaction between N rate or rootstock and frequency.

Literature Cited

Calvert, D. V. 1969. Effects of rate and frequency of fertilizer applications on growth, yield and quality factors of young 'Valencia' orange trees. Proc. Fla. State Hort. Soc. 82:1-7.

Castle, W. S. 1987. Citrus rootstocks, p. 361-399. In Rootstocks for fruit crops. R. C. Rom and R. F. Carlson (eds.). John Wiley and Sons, N.Y.

Davies, F. S. and L. G. Albrigo. 1994. Citrus. CAB Intl., Oxon, UK.

Davies, F. S. and G. Zalman. 2001. Nitrogen, rootstocks and growth of young Rhode Red Valencia orange trees. HortScience 36:62-65.

Guazzelli, L., F. S. Davies, and J. J. Ferguson. 1996. Fertilization rate and growth of Hamlin orange trees related to preplant leaf N levels in the nursery. HortTechnology 6:383-387.

Legaz, F., R. Ibanez, P. G. De Barreda, and E. Primo-Millo. 1981. Influence of irrigation and fertilization on productivity of 'Navelate' sweet orange. Proc. Intl. Soc. Citricult. 2:591-595.

Marler, T. E. and F. S. Davies. 1990. Microsprinkler irrigation and growth of young Hamlin orange trees. J. Amer. Soc. Hort. Sci. 115:45-51.

Maurer, M. A. and F. S. Davies. 1993. Use of reclaimed wastewater for irrigation and fertilization of young 'Redblush' grapefruit trees. Proc. Fla. State Hort. Soc. 106:22-30.

Maurer, M. A., F. S. Davies, and D. A. Graetz. 1995. Reclaimed wastewater irrigation and fertilization of mature Red blush grapefruit trees on Spodosols in Florida. J. Amer. Soc. Hort. Sci. 120:394-402.

Obreza, T. A. 1994. Program fertilization for densely-planted 'Hamlin' orange trees. Proc. Fla. State Hort. Soc. 107:47-50.

Rasmussen, G. K. and P. F. Smith. 1961. Evaluation of fertilizer practices for young orange trees. Proc. Fla. State Hort. Soc. 74:90-95.

Syvertsen, J. P. and M. L. Smith. 1996. Nitrogen uptake efficiency and leaching losses from lysimeter-grown citrus trees fertilized at 3 nitrogen rates. J. Amer. Soc. Hort. Sci. 121:57-62.

Tucker, D. P. H., A. K. Alva, L. K. Jackson, and T. A. Wheaton. 1995. Nutrition of Florida citrus trees. Univ. of Fla. Coop. Ext. Ser. SP 169, Gainesville.

Willis, L. E., F. S. Davies, and D. A. Graetz. 1990. Fertilization, nitrogen leaching and growth of young Hamlin orange trees on two rootstocks. Proc. Fla. State Hort. Soc. 103:30-37.

Wutscher, H. K. 1989. Alteration of fruit tree nutrition through rootstocks. HortScience 24:578-584.