Nitrogen Nutrition and Growth of 'Hamlin' Orange Nursery Trees on Swingle' Citrumelo Rootstock

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Summary. **Two experiments were conducted with container-grown 'Hamlin' orange trees [*Citrus sinensis* (L.) Osb.] on 'Swingle' citrumelo [*C. paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.] rootstock to study the effects of N rate on plant growth in the nursery. Treatments consisted of 12, 50, 100, or 200 mg N/liter per tree applied once a week by drip irrigation. Commercial media was used and soil water content was maintained at container capacity. In Expt. 1, fertilization at 200 mg·liter^{-1} resulted in greater scion growth, trunk diameter, and total leaf dry weight compared to the other rates. In Expt. 2, fertilization at 100 and 200 mg·liter^{-1} resulted in greater scion growth," trunk diameter, and leaf and stem dry weights compared to lower rates, but no differences were observed between the two highest rates. Trees that received 12 and 50 mg·liter^{-1} were stunted and leaves were chlorotic. Therefore, the optimum calculated N rate for 'Hamlin' nursery trees on 'Swingle' citrumelo rootstock, based on critical level analysis, is 155 to 165 mg·liter^{-1}.**

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Nutrition is one of the most important aspects of citrus nursery tree production in Florida. Granular fertilizers and fertigation are used commonly in nurseries; however, fertilizer programs are changing constantly based on grower preference and tree prices. Fertilization and nutrition are extremely variable aspects of citrus nursery tree production in Florida. Different fertilizer formulations (granular or liquid), frequencies, rates, and analyses are used for seedlings and budded, container-grown, and field-grown trees. Within individual nurseries, growers constantly change fertilization programs to reduce production time and costs.

Nitrogen rates, in particular, are excessively high. A survey of Florida greenhouse and field citrus nurseries showed that the annual fertilizer application rates were 1182 to 3245 kg·ha^{-1} (Castle and Rouse, 1990). However, mineral analysis of plants showed that only 5% to 20% of the N applied could be found in the leaves of 'Valencia' orange trees grown in container nurseries. Fertigation is used widely in greenhouse nurseries at 200 to 400 mg N/liter per application per tree, or >1000 kg·ha^{-1} per year. Several studies have suggested that N reserves rather than applied fertilizer support early scion growth of recently budded trees and that optimum rates (<50 mg·liter^{-1}) vary with rootstock and growing media (Lea-Cox, 1989; Maust and Williamson, 1991).

Citrus nurserymen in Florida use a wide range of N rates for their container-grown trees in the greenhouse. In addition, trees on 'Swingle' citrumelo rootstock grow more slowly than those on other rootstock, particularly during times of low soil temperature, suggesting that optimum N rates may differ also. Nevertheless, 'Swingle' is the most widely propagated rootstock in Florida, accounting for 51.3% of the registered trees in 1992–93 (Bureau of Citrus Budwood Registration, 1993). Our objective was to determine the N rate that produced the greatest tree growth in the greenhouse using 'Hamlin' orange on 'Swingle' citrumelo rootstock.

Materials and methods

Experiment 1. For Expt. 1,400 bare-root 'Swingle' citrumelo liners were obtained from a commercial nursery and planted on 25 Feb. 1992 in 10 × 10 × 35-cm plastic citripots containing a commercial medium. The medium was composed of 1 perlite : 1 peatmoss (v/v) and contained 8.71 kg of limestone and 0.083 kg of superphosphate/m^3. Liners were budded with 'Hamlin' orange on 3 Mar., 7 and 11 Apr., and 3 and 6 May 1992. Several budding dates were used because of initial differences in trunk diameter among the liners. Average height of liners at budding was 30 cm. Twelve days after budding, the rootstock above the bud was looped over and tied to the tree base to force the bud.

Liquid fertilizer (8N–0P–8K; 4% NH_4^+, 4% NO_3^-, 8% KC1) was applied beginning 27 Apr. 1992 until the trees were harvested on 21 Jan. 1993. The experiment was terminated at that time because trees had grown considerably and treatment differences were quite pronounced. Treatments consisted of 12, 50, 100, and 200 mg N/liter applied per tree once a week to groups of 100 plants each. Fertilizer rates were chosen based on previous studies in Florida (Maust and Williamson, 1991) and to ensure a wide range of rates. Fertilizer was applied using a 2% fixed injector (Dosatron International, Clearwater, Fla.). The fertilizer was injected for 7 min. The last 2 min of

Table 1. Effects of N fertilizer rates in the nursery on total scion length, scion diameter, and leaf N concentration of containerized 'Hamlin' orange trees on 'Swingle' citrumelo rootstock (Expt. 1)[z].

N (mg·liter^{-1})	Total scion length[y] (cm)	Scion diam (mm)	Leaf N (% dry wt)
12	10.1	2.8	2.4
50	9.1	3.1	2.5
100	11.0	2.9	3.0
200	19.1	3.4	2.9
Regression	L***	NS	L***

[z]*Means of 25 trees/treatment.*
[y]*Data analyses was performed on* **log** *of the original values of scion length.*
[NS,*,**,***]*Nonsignificant or significantat P <0.05, 0.01, or 0.001, respectively; L = linear.*

Table 2. *Effects of N fertilizer rates in the nursery on dry weight of leaves, stems, and roots of containerized 'Hamlin' orange trees on 'Swingle' citrumelo rootstock (Expt. 1)*[z].

	Dry wt (g)					
			Rootstock			
N	Scion[y]			Lateral	Tap	
(mg·liter^{-1})	Leaf	Stem	Stem	roots[x]	roots	Total
12	1.21	0.32	4.03	4.03	3.28	12.88
50	1.06	0.25	3.72	3.18	3.10	11.31
100	1.10	0.31	4.94	4.18	3.69	14.21
200	2.45	1.52	4.56	4.12	3.53	16.19
Regression	L***	L***	C*	C*	NS	L**

[z]*Means of 25 trees/treatment.*
[y]*Data analysis was performed on log of the original values of scion leaf and stem dry weights.*
[x]*Includes all except tap roots.*
NS,*,**,****Nonsignificant or significant at* P *<0.05, 0.01, or 0.001, respectively; L = linear, C = cubic.*

irrigation was used to flush the system and reduce fertilizer deposition in the lines. Trees were irrigated every 2 days for 1 h to replenish water lost to transpiration and to return the media to container capacity. No nutrient leaching was observed under these conditions at this irrigation rate and frequency because of high transpiration. Water quality was good, averaging 0.35 ds^{-1}, and no salinity damage occurred. Water was applied using one 3.8-liter/h drip emitter per container.

Maximum day temperature was 33C and minimum night temperature was 15C from 25 Feb. until 18 July. Then the daytime temperature was lowered to 25C to reduce spray burn associated with spider mite control. Copper deficiency symptoms appeared on a few plants in late August. The symptoms became more severe in late December, so trees were sprayed with a 0.5% copper sulfate solution on 13 Jan. 1993. Lateral shoots were removed as soon as they emerged to develop trees with a single stem.

Any damaged and stunted trees were removed. From the remaining trees, 25 representatives were selected at random from each treatment for final measurements and data analyses. To avoid biased results, this subsample was used to reduce variability due to time of budbreak. Five to ten 4-month-old leaves were collected from each tree for N analysis at harvest. Leaves had been previously tagged to determine their age. Total scion length and scion trunk diameter 2.5 cm above the bud union were measured. The trees then were harvested and separated into leaves, scion stems, rootstock stems, lateral roots, and tap roots. The fresh weight of the above tree parts was recorded immediately after harvest. Plants were then oven-dried at 70C to reach a constant weight, and dry weight was measured.

A randomized complete-block design with 25 single-tree replications per treatment was used. Data were analyzed statistically using regression analysis. Where necessary, data were log-transformed before analysis.

Experiment 2. For Expt. 2,100 'Swingle' liners were obtained from a commercial nursery on 15 Feb. 1993. Liners were planted in the same medium and containers as described in Expt. 1. Rootstock were budded with 'Hamlin' orange on 13 Apr. 1993. The buds were forced 16 days later by cutting off the rootstock seedling directly above the bud. Tops were removed in this study because looping had caused variations in time of budbreak in Expt. 1. The same fertilizer rates as in Expt. 1 were applied from 13 Apr. to 22 Sept. 1993. The experiment was terminated at this time because treatment effects were pronounced. Greenhouse temperatures were maintained between 23C at night and 32C during the day.

Scion trunk diameter was measured 2.5 cm above the bud union, and tree height was measured from the planting surface to the tip of the scion stem. The distance from- the medium surface to the bud union was similar for all trees. Individual shoot lengths were measured for each flush of each tree. Trees were harvested on 22 Sept. 1993 and separated into scion leaves and stems (by growth flushes), rootstock stem, lateral roots, and tap roots. Dry weight was determined as described in Expt. 1.

Leaf N analysis was performed as described in Expt. 1. A randomized complete-block design was used with 25 single-tree replications per treatment. Data were analyzed using regression analysis. Optimum N rate was calculated using critical-level analysis (Maust and Williamson, 1991).

Results and discussion

In both experiments, tree growth (as measured using trunk diameter, shoot growth, and shoot and stem dry weight) generally increased linearly with increasing rates (Tables 14). In Expt. 1, there was an abrupt increase in growth between the 100- and 200-mg·liter^{-1} rates (Tables 1 and 2). In Expt. 2, the increase was generally linear (Tables 3 and 4). Trees that received 100 or 200 mg·liter^{-1} had four growth flushes, those receiving 50 mg·liter^{-1} had three flushes, and those receiving 12 mg·liter^{-1} had only two growth flushes per season (Table 5). Optimum N rates were calculated for each experiment using critical-level regression analysis (Maust and Williamson, 1991). Calculated optimum rates were 155 to 165 mg N/liter per application. This rate is equivalent to 3.6 to 3.8 g N/tree per year. Leaf N concentration also differed with N rate. Trees that received 100 or 200 mg·liter^{-1} had higher leaf N levels than those that received 12 or 50 mg·liter^{-1} for both experiments (Tables 1 and 3). Levels of all other nutrients were similar (data not shown).

Table 3. *Effects of N fertilizer rates in the nursery on tree height, scion diameter, and leaf N content of containerized 'Hamlin' orange trees on 'Swingle' citrumelo rootstock (Expt. 2)*[z].

N (mg·liter^{-1})	Tree ht (cm)	Scion diam (m)	Leaf N (%)
12	30.7	3.0	1.7
50	38.9	3.5	1.9
100	45.6	4.2	2.5
200	46.6	4.3	2.8
Regression	L***	L***	Q***

[z]*Means of 25 trees/treatment.*
NS,*,**,*** *Nonsignificant or significant at* P *0.05,0.01, or 0.001, respectively; L = linear, Q= quadratic.*

Table 4. *Effects of N fertilizer rates in the nursery on dry weight of leaves, stems, and roots of containerized 'Hamlin' orange trees on 'Swingle' citrumelo rootstock (Expt. 2)*[z].

N	Scion		Rootstock			
(mg·liter^{-1})	Leaf	Stem	Stem	Lateral roots[y]	Tap roots	Total.
12	1.72	0.57	3.94	4.63	2.99	13.86
50	2.49	1.00	4.69	4.89	4.02	17.10
100	4.23	2.19	4.74	4.74	4.30	19.86
200	4.91	1.99	4.72	4.72	4.71	21.37
Regression	L***	L***	L**	NS	L***	L***

[z]Means of 25 trees/treatment.
[y]Includes all except tap roots.
NS,,**,***Nonsignificant or significant at P ≤ 0.05, 0.01, or 0.001, respectively; L = linear.*

Table 5. Effects of N fertilizer rates in the nursery on dry weight of different growth flushes of containerized 'Hamlin' orange trees on 'Swingle' citrumelo rootstock (Expt. 2)[z].

N	Leaf scion									
(mg·liter^{-1})	Flush 1		Flush 2		Flush 3		Flush 4		Total	
12	0.94	0.25	0.94	0.39	---[y]	---	---	---	1.88	0.64
50	0.92	0.30	1.29	0.61	1.42	0.43	---	---	3.63	1.34
100	1.03	0.49	1.59	0.80	1.71	0.48	2.34	0.53	6.67	2.30
200	1.10	0.57	1.73	0.77	2.27	0.58	2.92	0.50	8.02	2.42
Regression	L*	L***	L***	L***	L*	NS	NS	NS	L***	L***

[z]Means of 25 trees/treatment.
[y]No growth flush occurred.
NS,,**,***Nonsignificant or significant at P 50.05, 0.01, or 0.001, respectively; L = linear.*

Our optimum N rates were considerably higher than those of previous studies (Chapman and Liebig, 1937; Lea-Cox, 1989; Maust and Williamson, 199 1), probably due to differences in planting medium and rootstock. Chapman and Liebig and Maust and Williamson used sand culture that was flushed of nutrients daily, and Lea-Cox used pine bark planting medium. These studies suggested that optimum N concentrations in the planting medium were <50 mg·liter^{-1}. In contrast, this study suggests that higher rates are needed for optimum growth in a commonly used commercial planting medium of peatmoss and perlite. It is likely that nutrients are complexed more strongly in this medium than in sand and are less available to the tree. Rootstock are known to affect leaf N levels, and rootstock responses also differed among studies (Wutscher, 1974). The previous studies by Maust and Williamson and Lea-Cox were done using 'Cleopatra' mandarin, 'Carrizo' citrange, or rough lemon rootstock. 'Swingle' citrumelo rootstock used in this study is more likely to have nutrent-deficiency problems and stops growing earlier and at higher temperatures than these other rootstock. Thus, it is likely that optimum N rates also may differ for 'Swingle'.

Citrus nursery operators who grow trees in the greenhouse in commercial planting medium can increase tree height, trunk diameter, and dry weight by applying 155 to 165 mg N/ liter weekly. Higher rates will increase growth further, but may not be cost-effective. It is important to maintain water content of the planting medium at container capacity. We did not have problems with salt accumulation and leaf damage, even though leaching did not occur. Nurseries with water high in salts may have to be irrigated more heavily to remove salts and may need higher N rates. The optimum rates used here are considerably lower than those currently used in many nurseries in Florida (200400 mg·liter^{-1}), thus suggesting that current rates may be reduced without decreasing tree growth. There is considerable interest in Florida in reducing N rates to decrease the potential for nitrate pollution of groundwater. There is also a strong suggestion that N rates may have to be altered depending on the rootstock used.

Literature Cited

Bureau of Citrus Budwood Registration. 1993. Annual **report: Rootstock** used for registered nursery trees. Bur. of Citrus Budwood Registration, Div. of Plant Ind., Florida Dept. of Agr. and Consumer Serv., Winter Haven.

Castle, W. S. and J.J. Ferguson. 1982. Current status of greenhouse and container production of citrus nursery trees in Florida. Proc. Florida State Hort. Soc. 95:4246.

Castle, W.S. and R.E. Rouse. 1990. Total mineral content of Florida citrus nursery plants. Proc. Florida State Hort. Soc. 103:42-44,

Chapman, H.D. and *G.F. Liebig. 1937.* The effects of various nitrate concentrations on the growth and composition of sweet orange seedlings. Proc. Soil Sci. Soc. Amer. 2:359-365.

Chapman, H.D. and G.F. Liebig. 1940. Nitrate concentrationand ion balance in relation to citrus nutrition. Hilgardia 13:14 1–1 73.

Lea-Cox, J.D. A. 1989. Macroelement nutrition of container-grown citrus nursery stock in pine bark substrates. MS thesis. Univ. of Natal, Pictermaritzburg, South Africa.

Maurer, MA. and F.S. Davies. 1993. Use of reclaimed water for irrigation and fertigation of young 'Redblush' grapefruit trees. Proc. Florida State Hort. Soc. 106:22-30.

Maust, B.E. 1992. Nitrogen nutrition of containerized citrus nursery plants. MS thesis. Univ. of Florida, Gainesville.

Maust, BE. and J. G. Williamson. 1991. Nitrogen rate effect on growth of containerized citrus nursery plants. Proc. Florida State Hort. Soc. 104:191-195.

Wutscher, H. K. 1974. Rootstock and mineral nutrition of citrus, p. 97– 113. In: L. K. Jackson, A. H. Krezdorn, and J. Soule (eds.). Proc, 1st Intl. Citrus Short Course, 24-29 Sept. 1973. Univ. of Florida, Gainesville.

nation for ripeness. The amount of injury caused by the compression bruises on the pulp and peel of the bananas was rated on a scale of 1 to 5, with 1 = none and 5 = severe. The percentage of overall peel scarring included any other injury such as abrasion. Starch loss was evaluated using a starch-staining technique (Blankenship, 1993). Fruit firmness was measured using a 0- to 500-g tip on a McCormick Dynamometer (resembling an Effigi firmness tester) on peeled fruit.

The humidity combinations produced bananas significantly different in peel color, firmness, and percentage overall scarring (Table 1). Peel color was most affected by humidity after gassing; 95% RH resulted in greener bananas. Bananas in high humidity before gassing but 65% RH after gassing responded like bananas that had been in constant 65% RH. Bananas that had been in 65% RH before gassing but were ripened in 95% RH responded like fruit that had been in constant 95% RH. Fruit firmness decreased as peel color became more yellow; bananas in higher ripening humidities had slightly firmer fruit. Starch rating was not significantly affected by any treatment. Percentage overall peel scarring was most affected by humidity during ripening. Bananas ripened in 65% RH showed about double the overall scarring as bananas ripened in 95% RH. Ripening in 75% RH gave intermediate results. Bananas that had been held in 65% RH before ripening, but then ripened at a high humidity, compared favorably with bananas that had been held in constant high humidity.

The pulp and peel injury caused by compression bruising was generally not significantly different among the humidity treatments, regardless of when the injury took place (data not shown). In the few instances in which a significant difference was found, the 95% RH treatments produced less-visible injury. The effect of humidity on compression bruising was inconsistent. Banks (199 1) found that freshly harvested bananas held in 95% RH had more resistance to bruising. However, even in Banks' study, the results were significant only on the second day of 3 days tested. Akkaravessapong et al. (1992) found no significant effect of humidity on compression injury. It appears that RH does not have a great or consistent effect on visible compression injury and probably is not of commercial significance.

We feel that the best humidity recommendation for bananas after transport is to keep the fruit at a constant high humidity of 95% RH, particularly during the ripening cycle. It does not appear that a brief period of lower humidity before gassing causes a decline in quality, as long as ripening humidities are high. High humidity may delay ripening slightly, but the advantage of reduced scarring outweighs this small delay. From our studies, it does not seem necessary to reduce humidity during ripening to avoid disease problems, and this practice may be detrimental to overall fruit quality.

Literature Cited

Akkaravessapon., P., D. C. Joyce, and D. W. Turner. 1992. The relative humidity at which bananas are stored or ripened does not influence their susceptibility to mechanical damage. Scientia Hort. 52:265–268.

Banks, N.H. and M. Joseph. 1991. Factors affecting resistance of banana fruit to compression and impact bruising. J. Sci. Food Agr. 56:315-323.

Blankenship, S.M., D.D. Ellsworth, and R.L. Powell. 1993. A ripening index for banana fruit based on starch content. Hort-Technology 3:338–339.

Chiquita Brands. no date. Your guide to greater profits. Chiquita Brands, Cincinnati.