Fertigation and Growth of Young ‘Hamlin’ Orange Trees in Florida

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Abstract. One-year-old ‘Hamlin’ orange [Citrus sinensis (L.) Osb.] trees on sour orange rootstock (C. aurantium L.) were used to compare various fertigation frequencies and rates with application of granular materials. In Expt. 1, granular fertilizer was applied five times per year or liquid fertilizer was applied five, 10, or 30 times per year at 0.23 kg N/tree per year as an 8N-3.4P-6.6K formulation. In Expt. 2, an additional treatment of granular and liquid material was applied three times per year, but fertilizer rate and formulation were the same as in Expt. 1. Experiment 3 included the same application frequencies as Expt. 1, but with two rates of N (0.11 or 0.06 kg N/tree per year). Soil samples were taken from each treatment 1, 4, and 7 days after fertigation at depths of 0-15, 16-46, and 47-76 cm for nutrient analyses. Trunk diameter, shoot growth, and tree height were similar for all treatments 8 months after planting in Expts. 1 and 2, while trees in Expt. 3 had significantly less growth at the lower rate. Soil NH$_4$-N and NO$_3$-N concentrations for all liquid treatments within 1 week of fertigation were highest for the five times per year treatment at the 0- to 15-cm depth, but nutrient concentrations of all liquid treatments were similar at the other depths. For most dates and depths, NH$_4$-N and NO$_3$-N concentrations were similar for both fertilizer rates.

In 1988-89, ≈49,000 ha of citrus was planted in Florida (Division of Plant Industry, 1990). During planting, 12% of growers fertilized with liquid fertilizer, while 21% used fertigation alone or in combination with granular fertilizer after planting (Taylor et al., 1989). Fertigation has several advantages over broadcasted granular fertilizers, including effective placement of nutrients and flexibility in application frequency (Ferguson and Davies, 1989). While fertigation is becoming a widely used method for fertilizing young citrus trees in Florida, no information is available concerning optimum rates or frequencies of application.

In previous research on fertilization of young citrus trees, Rasmussen and Smith (1961) found no effect of application frequency of granular fertilizer on growth of newly planted ‘Valencia’, ‘Hamlin’, or ‘Pineapple’ orange trees. Bester et al. (1977) studied application frequency of broadcast urea and liquid fertilizers on newly planted ‘Valencia’ orange trees and found that trunk diameter was the same for trees fertigated six times per year compared with broadcasted fertilizer applied four times per year. However, fertigated trees had higher leaf N and Fe concentrations and received 60% more water than those with the broadcast treatment.

Fertigation frequency and rate may also affect nutrient levels in the soil. Several experiments have been conducted to determine the amount of NO$_3$ losses from leaching. A direct relationship was found between NO$_3$ concentration in a sandy loam soil and the rate of N applied to citrus (Dasberg et al., 1983, 1988) and apple trees (Klein and Spieeler, 1987). In contrast, Rible and Pratt (1977) did not find a significant correlation between amount of N applied and NO$_3$ accumulated or leached. Fellows and Brezonik (1981) found that when using fertilizer rates higher than recommended on citrus trees in Florida, nutrient seepage into Conway and Apopka Lakes was increased, as compared to using the recommended rate. However, rates below those recommended were not tested.

Several factors influence leaching of NO$_3$, including climate, soil type, land use, and rate and source of N. When moderate amounts of N (211 g/tree) were applied to young citrus trees, there was 79% and 89% N recovery of the plant/soil system after 6 and 14 weeks, respectively (Hagihia, 1980). Shallow tilling increased NO$_3$ (Calvert, 1975; Mansell et al., 1980a, 1980b) and NH$_4$ (Mansell et al., 1980b) leaching. However, the latter experiment also showed NH$_4$ concentrations decreased within 1 week after fertigation and irrigation. Meek et al. (1970) found NO$_3$ concentration decreased as the soil solution approached the water table. Nitrate concentrations in the surface water of a well-drained sandy soil were twice as high in the 0- to 60-cm as in the 60- to 120-cm sample depth. “Even greater NO$_3$ concentration differences between the two depths occurred after fertilizer application and were directly influenced by rainfall (Forbes et al., 1974).

Although fertigation has been used for several years, particularly for mature citrus trees, no research has been done in Florida on rate and timing of fertigation for newly planted citrus trees. Our objectives were to determine optimum rates and application frequency of granular as compared to liquid fertilizers and to monitor movement of NO$_3$-N and NH$_4$-N through the root zone of young citrus trees.

Fertigation on a Kanapaha fine sand (Expt. 1). Container-grown ‘Hamlin’ orange trees on sour orange rootstock (=1.5 years in the nursery) were obtained from Southern Citrus Nurseries, Dundee, Fla., and planted in April 1987 on double beds (16.75 m width x 0.60-0.75 m height x 85 m length) at the Horticultural Research Unit near Gainesville, Fla. Soil type was a Kanapaha fine sand (loamy, siliceous, hyperthermic, Grossarenic, Paleaquolls) with a loamy or clayey layer starting 1.2 m below the soil surface and a water table fluctuating between 0.45 to 1.60 m from...
Table 1. Effect of fertilizer rate, type, and application frequency on growth of young 'Hamlin' orange trees 8 months after planting on a Kanapaha fine sand with a hard pan 1.2 m below the soil surface, 1988 (Expt. 3).

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Frequency Trunk diam (cm)</th>
<th>Rate (kg N/tree per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(no./year) (cm)</td>
<td></td>
</tr>
<tr>
<td>Granular</td>
<td>5</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.2</td>
</tr>
<tr>
<td>Liquid</td>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.1</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>2.2</td>
</tr>
</tbody>
</table>

0.11 kg N/tree per year

0.06 kg N/tree per year

All trees received 0.23 kg N/tree per year.

Trees were arranged in a randomized complete-block design consisting of 24 individual tree samples/block (treatment). Therefore, each block constituted a single replicate for each treatment. Trees were spaced 3.4 m within rows and 7.9 m between rows on each double bed.

All trees received the same amount of water, applied either during fertigation or at 20% soil moisture depletion (SMD), as determined using a Troxler 2601 neutron probe ('Troxler, Raleigh, N. C.) (Marler and Davies, 1990). Liquid fertilizer was injected at the end of an irrigation cycle, with all treatments finishing at the same time to reduce nutrient leaching after application. Measurements included preplant soil analysis, tree height and trunk diameter at planting and after each growth flush (three/year) for all trees, and leaf nutrient analysis, and shoot length and number after each growth flush for 10 trees/treatment (Marler and Davies, 1990). Whole-plant fresh and dry weights were taken in Dec. 1987.

Fertigation on an Arredondo fine sand (Expt. 2). Barerooted 'Hamlin' orange trees on sour orange rootstock (=2 years in the nursery) were obtained from Southern Citrus Nurseries and planted in Apr. 1988 at the Fitchfield Farm, Gainesville. Soil type was an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic, Paleuquults). Treatments included granular fertilizer applied three or five times per year or liquid fertilizer applied three, five, 10, or 30 times per year. Fertilizer analysis and rate were the same as in Expt. 1. Trees were arranged in a randomized complete-block design with four blocks of five single-tree replicates per block and spaced 4.6 m within rows and 6.1 m between rows.

All trees received the same amount of water during fertigation and irrigation using 38-liter-h−1 90° microsprinklers located 1 m northwest of each trunk. Trees were irrigated every 2 days during the first 2 weeks of establishment, every 2 to 4 days the next 6 weeks, and at 20% SMD for 1.25 h the remainder of the year. Fertilizer injection times ranged from 7 to 67 min. Tree trunks were wrapped with fiberglass tree wraps to reduce sprouting.

Fig. 2. Fertigation frequency and soil NO3-N concentration 4 days after fertigation using two fertilizer rates \([0.06 (\text{D}) \text{ and } 0.11 (\text{A}) \text{ kg N/tree per year}]\) at three depths under 'Hamlin' orange trees 8 months after planting. (A) 0-15 cm; (B) 16-46 cm; (C) 47-76 cm. Single regression lines represent combined values for both N rates (B, c).

Fig. 3. Fertigation frequency and soil NO3-N concentration 7 days after fertigation using two fertilizer rates \([0.06 (\text{D}) \text{ and } 0.11 (\text{A}) \text{ kg N/tree per year}]\) at three depths under 'Hamlin' orange trees 8 months after planting. (A) 0-15 cm; (B) 16-46 cm; (C) 47-76 cm. A single regression line represents combined values for both N rates (B).

Fig. 4. Fertigation frequency and soil NH4-N concentration 1 day after fertigation using two fertilizer rates \([0.06 (\text{D}) \text{ and } 0.11 (\text{A}) \text{ kg N/tree per year}]\) at three depths under 'Hamlin' orange trees 8 months after planting. (A) 0-15 cm; (B) 1646 cm; (C) 47-76 cm. Single regression lines represent combined values for both N rates.
with 12 single-tree replications per treatment ranged in a completely randomized design on 10 trees per treatment. Trees were ar- ranged with two fertilizer rates (0.11 or 0.06 kg/tree per year) and using individual injectors for each tree from all trees. Shoot number and length were measured as in Expt. 2, except the same as those in Expt. 2. The same mea-
surements were made as in Expt. 3. Barerooted ‘Hamlin’ orange trees on sour orange rootstock (= 2 years in the nursery) were obtained from Southern Citrus Nurseries and planted in Apr. 1988 on double beds (16.75 m width × 0.60-0.75 m height × 85 m length) at the Horticultural Research Unit. Site characteristics were the same as those in Expt. 1. Treatments were applied in a 2 × 4 factorial arrangement with two fertilizer rates (0.11 or 0.06 kg N/tree per year) and four fertilizer application frequencies that included a granular treatment applied five times per year or liq-
 uid fertilizer applied five, 10, or 30 times per year. Fertilizer application procedures, irrigation levels, and tree wraps were the same as those in Expt. 2. The same mea-
 surements were made as in Expt. 2, except that shoot number and length were measured on 10 trees per treatment. Trees were ar-
 ranged in a completely randomized design with 12 single-tree replications per treat-
 ment. Complete randomization was achieved by placing seven irrigation lines down each row and using individual injectors for each

Fertilization at two rates on Kanapaha fine sand (Expt. 3). Barerooted ‘Hamlin’ orange trees on sour orange rootstock (= 2 years in the nursery) were obtained from Southern Citrus Nurseries and planted in Apr. 1988 on double beds (16.75 m width × 0.60-0.75 m height × 85 m length) at the Horticultural Research Unit. Site characteristics were the same as those in Expt. 1. Treatments were applied in a 2 × 4 factorial arrangement with two fertilizer rates (0.11 or 0.06 kg N/tree per year) and four fertilizer application frequencies that included a granular treatment applied five times per year or liq-
 uid fertilizer applied five, 10, or 30 times per year. Fertilizer application procedures, irrigation levels, and tree wraps were the same as those in Expt. 2. The same mea-
 surements were made as in Expt. 2, except that shoot number and length were measured on 10 trees per treatment. Trees were ar-
 ranged in a completely randomized design with 12 single-tree replications per treat-
 ment. Complete randomization was achieved by placing seven irrigation lines down each row and using individual injectors for each

Fig. 5. Fertilization frequency and soil NH$_4$-N concentration 4 days after fertigation using two fertilizer rates [0.06 (A) and 0.11 (B) kg N/tree per year] at three depths under ‘Hamlin’ orange trees 8 months after planting. (A) 0-15 cm; (B) 16-46 cm; (C) 47-76 cm. Single regression lines represent combined values for both N rates (B, c).

Measurements included trunk diameter at 2 to 4 cm above the graft union, height taken at planting and after each growth flush, and leaf nutrient analysis after each growth flush on all trees. Leaf samples were collected from each matured growth flush from the mid-
 shoot and included two to three leaves per tree from all trees. Shoot number and length were measured after each flush on eight trees per treatment.

Nitrate-N and NH$_4$-N concentrations were similar for both rates in all three soil depths, as indicated by a single regression equation, and there was a significant but poor linear correlation only for the 0- to 15-cm depth in response to ap-
 plication frequency (Fig. 1). Four days after fertigation, NO$_3$-N levels were similar in the lower two depths, as indicated by a single regression equation (Fig. 2). However, NO$_3$-N concentrations at the upper depth were significantly higher for the 0.11 kg N/tree per year rate and both rates showed a significant quadratic trend in response to application frequency. Treatments applied five times per year led to higher NO$_3$-N concentrations than the other application frequen-
cies. Nitrate-N concentrations in the upper and lower depths differed significantly with fertilizer rate 7 days after fertigation (Fig.

Ammonium-N concentrations 1 day after fertigation were similar for all application frequencies and both rates for the lower two depths, as indicated by a single regression equation (Fig. 4). However, treatments applied five times per year led to significantly higher NH$_4$-N concentrations compared to 10 and 30 times per year in the 0- to 15-cm depth (P = 0.05, data not shown). Four days after fertigation, NH$_4$-N concentrations dif-
fered at the first depth in response to fer-
tilizer rate and application frequency, as indicated by a significant quadratic trend (Fig.

Seven days after fertigation, NH$_4$-N concen-
trations were similar in response to fer-
tilizer rate (Fig. 5), and the five times per year treatment resulted in significantly higher levels of NH$_4$-N than the other application frequencies for all depths (P = 0.05, data not shown). There was little accumulation or movement of NH$_4$-N past the root zone into the 47- to 76-cm depth within 7 days after fertigation.

Fig. 6. Fertilization frequency and soil NH$_4$-N concentration 7 days after fertigation using two fertilizer rates [0.06 (A) and 0.11 (B) kg N/tree per year] at three depths under ‘Hamlin’ orange trees 8 months after planting. (A) 0-15 cm; (B) 16-46 cm; (C) 47-76 cm. Single regression lines represent combined values for both N rates.

Soil NO$_3$-N and NH$_4$-N concentrations for

<table>
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<th>Data Set</th>
<th>Value</th>
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<tr>
<td>NO$_3$-N (mg/kg soil)</td>
<td>0.11-kg N/tree per year rate</td>
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<th>Data Set</th>
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<tbody>
<tr>
<td>NH$_4$-N (mg/kg soil)</td>
<td>0.11-kg N/tree per year rate</td>
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<td>NH$_4$-N (mg/kg soil)</td>
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</table>

In Expt. 3, leaf nutrients within optimum concentra-
tions were P, K, Mg, Fe, Mn, and B, while those deficient or low were Ca, Zn, and Cu. In Expt. 3, leaf nutrients within optimum concentra-
tions were P, K, Mg, and B, while nutrients low or deficient included N, Ca, Fe, Mn, Zn, and Cu (Koo et al., 1984).
granular materials were <5 and 3 mg N/kg soil, respectively, suggesting that our sampling procedure did not accurately reflect nutrient concentrations in the soil. In this instance, the distribution of the granules was such that the soil sample did not always contain fertilizer, whereas the liquid formulation was evenly distributed over the fertigated area.

Growth of young ‘Hamlin’ orange trees did not depend on frequency of fertilizer application or fertilizer type within the limits of this study, using two soil types and planting systems. Nitrogen applied at 0.06 kg/tree per year significantly limited tree growth, as compared to 0.11 kg/tree per year. Our results are in agreement with those of Rasmussen and Smith (1961), who found no effect of fertilization frequency on growth of young citrus trees using granular materials. Moreover, our optimum rates are within currently recommended rates for granular materials on young citrus trees (Koo et al., 1984). Dasberg et al. (1988) also observed no effect of fertilizer (liquid or granular) on growth of mature citrus trees, provided the trees received equal amounts of water. Concentration of NO$_3$-N and NH$_4$-N at a 0- to 15-cm depth was significantly higher for trees fertigated five times per year as compared to 30 times per year, with no accumulation and movement of these nutrients past the root zone within 7 days of application. Our results indicate that growers have flexibility in choosing their fertilizer programs in the first season after planting, allowing them to adjust fertilizer rates and frequencies according to leaf analyses, water quality, and cultural practices. Properly managed fertigation may also reduce ground water pollution, particularly with nitrates, without compromising growth of young trees. In addition, once the fertigation system is in place, cost of application is considerably less for fertigation than for granular materials (Ferguson and Davies, 1989).

**Literature Cited**


Calvert, D. V. 1975-. Nitrate, phosphate, and potassium movement into drainage lines under three soil management systems. J. Env. Qual. 4:183-186.


