Optimum Nitrogen Rate for Fertigated Young Navel Orange Trees in Arizona

Ayako Kusakabe*, Scott A. White, James L. Walworth, Glenn C. Wright, and Thomas L. Thompson

Soil, Water and Environmental Sciences, University of Arizona, Tucson, AZ 85721

Additional index words. *Citrus sinensis*, microsprinkler, fertigation frequency, yield, leaf N, residual soil NO_3

A field experiment was conducted during 1999–2002 in central Arizona to evaluate effects of N application rate and frequency on fruit yield, leaf N concentration, and residual soil N of 3- to 6-year-old 'Newhall' navel oranges (*Citrus sinensis* L. Osbeck) on Carrizo citrange (*Porcirus trifoliate* x *C. sinensis*) rootstock. Trees were grown in a calcareous fine sandy loam and were well-watered, producing a small positive leaching fraction. The experiment included non-fertilized control plots, and factorial combinations of three fertigation frequencies (27, 9, and 3 applications per year) and three N rates (68, 136, or 204 g/tree per year = 0.15, 0.30, 0.45 lb) from urea ammonium nitrate (32–0–0) applied through microsprinklers. Maximum yields occurred at interpolated N rates of 105 to 153 g/tree per year (= 0.23 to 0.34 lb) for the fourth to the sixth growing seasons. These rates were equivalent to only 17% to 34% of currently recommended N rates for flood-irrigated citrus grown in Arizona. Fruit size and juice quality were not affected by N rate or fertigation frequency. Leaf N concentrations were above 2.7% at yield-maximizing N rates. Highest concentrations of residual soil NO_3 resulted from the highest N rate. Fertigation frequency did not significantly affect residual soil NO_3. Optimum N rates for young microsprinkler-irrigated 'Newhall' navel orange trees in Arizona were much lower than the currently recommended N rates.

Citrus production depends greatly on inputs of irrigation water and N fertilizer to obtain optimum tree growth, fruit yield, and quality. This is especially true in Arizona, where sandy soils with a pH of 8.0 to 8.4 and low levels of native soil organic matter of less than 1% (USDS, 2006) are commonly irrigated by flood or furrow irrigation. Escalating water costs and declining water availability are prompting growers to adopt alternative production practices, such as microsprinkler irrigation in place of conventional surface flood irrigation. Microsprinklers offer the potential for higher application efficiency of water than flood irrigation (Smajstrla et al., 1991) and make it possible to use high frequency fertigation with small doses of liquid fertilizers. This allows the precise control of irrigation water and water-soluble nutrient applications as fertigation (Boman and Obreza, 2002). Nutrient losses can be reduced when microsprinkler fertigation is properly managed (Paramasivam et al., 2000).

Existing N fertilization guidelines for young citrus trees grown in Arizona begin with N at 0–230 g/tree per year (0–0.5 lb) in year 1 after planting and increase to a maximum of N at 450–910 g/tree per year (1.0–2.0 lb) in the sixth year (Doerge et al., 1991). Newly planted microsprinkler-irrigated navel orange trees in central Arizona, receiving a fairly small fraction of the current N recommendation rate, had N uptake efficiencies less than 6% and 25% of the N fertilizer applied during first and second growing seasons, respectively. In each subsequent growing season, the N uptake efficiencies showed a steady decline as the N fertilizer rates were increased from N at 45 to 90 g/tree per year (0.1–0.2

lb) or N at 68 to 136 g/tree per year (0.15–0.3 lb; Weinert et al., 2002). This implied that N application rates currently recommended for young, non-bearing flood-irrigated navel oranges can be substantially reduced for microsprinkler-fertigated citrus during the first 2 years after planting (Weinert et al., 2002). Since there is little other information on the response of young fruit-bearing citrus to microsprinkler N fertigation in the desert Southwest, additional research is needed to refine existing N fertilization guidelines for use with microsprinkler systems.

More than 80% of citrus tree roots are located within the top 30 cm (12 inches) of sandy Florida Entisols (Paramasivam et al., 2000). Due to the limited root zone depth of citrus trees in these soils, it may be important to increase fertigation frequency to lower individual application amounts in order to minimize NO_3 leaching. Lower N rates and increased fertigation frequency also may enhance nutrient-use efficiency and tree productivity while minimizing NO_3 leaching (Alva and Paramasivam, 1998; Alva et al., 1998). This, in turn, could enhance growth, fruit yield, quality, and economics of production. The objective of this field experiment was to evaluate effects of N rate and frequency on fruit yield, leaf N concentration, and residual soil N of micro-sprinkler-fertigated 3- to 6-year-old 'Newhall' navel oranges on Carrizo citrange rootstock in fine sandy loam Arizona Entisols. Our research findings in the desert Southwest may also contribute to nutrient management strategies in sandy Florida soils, particularly during the dry spring months.

Materials and Methods

'Newhall' navel orange trees budded onto Carrizo citrange rootstock were grown on 3 × 6 m (10 × 20 ft) centers in a calcareous fine sandy loam Entisol (USDA, 2006; ~50% sand) having a pH of 8.0 to 8.4 and <1.0% organic matter at the University

*Corresponding author. Current address: University of Florida, IFAS, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred, FL 33850. Email: ayako@ufl.edu; phone: 863-956-1151, ext. 1292.

of Arizona Citrus Agricultural Center, Waddell. The study was initiated when the trees were planted in Mar. 1997. From then until Dec. 1998, the first two growing seasons, the trees received factorial combinations of three fertigation frequencies and three fertilizer N rates (Weinert et al., 2002). Treatments were arranged in a randomized complete-block design with five rows. Each row had a total of 20 trees, which represented 10 different treatments and contained two trees per treatment, including a non-fertilized control. There were no buffer trees between treatments. The experiment consisted of factorial combinations of fertigation frequencies of 27, 9, or 3 applications per growing season and three total N rates: N at 68, 136, or 204 g/tree per year (0.15, 0.3, or 0.45 lb). All N was applied as urea ammonium nitrate solution (UAN-32–0–0) through the irrigation system. All trees received identical irrigation management. One pressure-compensating, 300° microsprinkler (Maxijet, Dundee, FL) was located 5 cm from the north side of the trunk of each tree. Total irrigation water applications (relative to the wetted area) were 530 mm (21 inches) during 1999, 1490 mm (59 inches) during 2000, 1800 mm (71 inches) during 2001, and 3350 mm (132 inches) during 2002. Irrigation was applied every 4 to 12 d, depending on when tensiometer readings reached 30 cbars, during the 4 years of this study. The N fertilizers were applied to each treatment using a Dosatron fertilizer injector (Dosatron Products, Sunnyvale, FL). Data presented here are from the third to sixth growing seasons after planting (1999–2002). Thirty spring-flush leaves on nonfruiting branches were randomly collected from each plot in September of each year. Fruit was harvested in December or January during the fourth to sixth growing seasons. Soil samples were collected in December or January during the third to fifth growing seasons. Detailed irrigation management and routine leaf, fruit, and soil sampling and analyses are described in Kusakabe et al. (2006).

Results and Discussion

Fruit yield and quality. No fruit were harvested during the third growing season (1999). In general, fruit yield, fruit quality, and juice quality during the fourth though the sixth growing seasons were not significantly affected by fertigation frequency but did change as the trees developed (data not shown). Koo (1980) reported that when fertilizers were applied via fertigation, the total acid (TA) in juice was low, and the total soluble solids to acid (TSS:TA) ratio was higher compared to dry fertilizer applications. Overall, our results indicated relatively high TSS, lower TA, and higher TSS:TA ratio compared to those of mature 'Valencia' orange trees under trickle irrigation reported by Koo (1984). Nevertheless, variations in N rates and fertigation frequency did not significantly affect fruit and juice quality over the three harvests (Jan. 2001, Jan. 2002, and Dec. 2002).

During the fourth though the sixth growing seasons, maximum predicted yields from quadratic response equations were 10 kg/tree (0.25 box), 19 kg/tree (0.5 box), and 30 kg/tree (0.75 box), respectively (Fig. 1A–B). During the sixth growing season only, yield was significantly ($P < 0.05$) increased by fertigation frequency (Fig. 1B). During this season, yield of the 153 g (0.34 lb) per tree/year, the treatment receiving 27 fertigations was double the amount of trees receiving only 3 and 9 fertigations per growing season. This may be explained by the likely higher N-use efficiency with more frequent fertigation (lower application of N). The maximum predicted yields occurred at N rates of 114 g (0.25 lb) per tree/year for the fourth, 105 g (0.23 lb) per tree/year for

the fifth, and 153 g (0.34 lb) per tree/year for the sixth growing season (Fig. 1A–B). Considerably less N fertilizer was applied to the trees under microsprinkler irrigation compared to current Arizona N recommendations, which are 110–450 g (0.2–1.0 lb) per tree/year for the fourth and the fifth growing seasons, and 450–910 g (1.0–2.0 lb) per tree/year for trees more than 5 years after planting (Doerge et al., 1991). Thus, the yield-maximizing N rates in this experiment were equivalent to only 17% to 34% of currently recommended N rates. One contributing factor could be the relatively low yields, and thus the low amount of N removed by the crop. Based on average citrus fruit N content (Doerge et al., 1991), N removal in harvested fruit at the maximum predicted yields was 18, 35, and 52 g (0.04, 0.08, and 0.11 lb) per tree during the three successive harvests, respectively. The low optimum N rates agree with previous research from Florida (Alva and Paramasivam, 1998; Syvertsen and Smith, 1995) and Arizona (Weinert et al., 2002) that showed that N rates currently recommended for flood-irrigated citrus can be reduced for microsprinkler-irrigated citrus.

Leaf nitrogen concentrations. During the fourth, fifth, and sixth growing seasons, leaf N concentrations were significantly increased by N rate (Fig. 2). Frequency or frequency × N rate interactions, however, did not significantly affect leaf N concentration (data not shown). Leaf N concentrations were significantly increased ($P < 0.01$) by fertigation frequency only during the third growing season, prior to the trees yielding any fruit (data not shown). In the third season, leaf N concentrations in all treatments remained above 30 mg·g^{-1} (3.0%), well above 27 mg·g^{-1} (2.7%), which is the generally accepted upper critical leaf N concentration (Fig. 2; Kallsen, 2003; Sauls, 2002; Tucker et al., 1995). During the fourth, fifth, and sixth fruit-bearing seasons, all fertilized trees contained adequate N for growth. In addition, leaf N concentration in the unfertilized trees was similar to that of the fertilized trees except in the fifth season. Likewise, there was no indication that the unfertilized trees grew less than the fertigated trees, as trunk diameters were not affected by treatments (data not shown). The generally high N status of the unfertilized trees (except in fifth season) was probably due to remobilization of the sufficient internal N reserves for tree growth (Weinbaum and Van Kessel, 1998; Weinert et al., 2002). Leaf N levels did tend to decline after the third growing season as tree canopies developed and yielded fruit. Leaf N concentrations at yield-maximizing N rates were, however, above the critical upper leaf tissue N rate of 27 mg·g^{-1} (2.7%) (Fig. 2; Kallsen, 2003; Sauls, 2002; Tucker et al., 1995). It is important to note that all fertilized trees were adequately supplied with N for all 4 years, according to accepted leaf tissue concentration standards for bearing trees. These standards may be too low for non-bearing trees.

Residual soil NO$_3$. Residual soil NO$_3$ distributions showed important differences among treatments (Fig. 3). In general, when the N fertilizer rate was 136 g (0.30 lb) per tree/year, little residual NO$_3$ was present in soil. In contrast, application of 204 g (0.45 lb) per tree/year usually resulted in substantial amounts of residual NO$_3$ across the three fertigation frequencies. Residual soil NO$_3$ in unfertilized controls was less than 9 mg·kg^{-1} (9 ppm) throughout the soil profile during the three seasons. During the fourth growing season, residual soil NO$_3$ was lower than during the other two seasons, with soil NO$_3$ <7 mg·kg^{-1} (7 ppm) due to heavy rains (data not shown). This likely resulted in substantial NO$_3$ leaching below the sampling depth. However, as in the third and fifth seasons, NO$_3$ concentrations were highest at the higher N rates (Fig. 3).
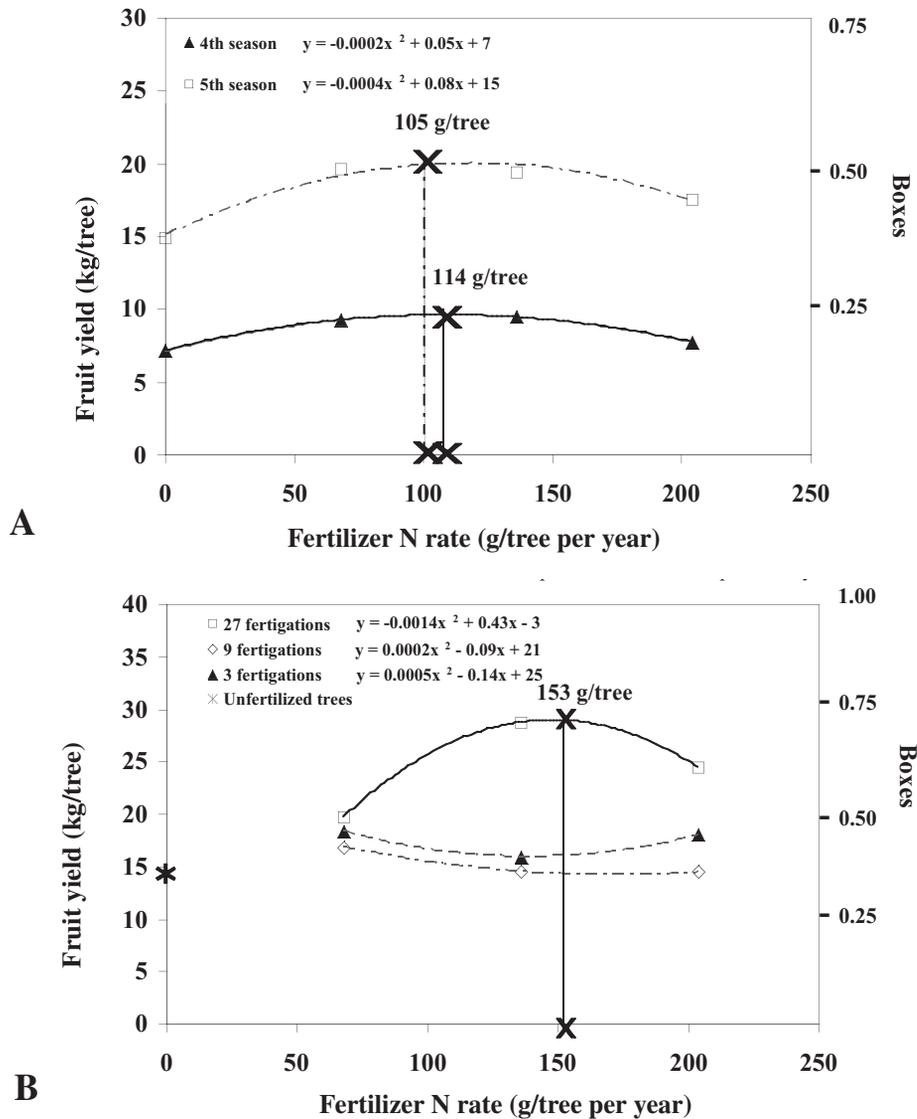
Fig. 1. Fruit yield of 'Newhall' navel orange trees in response to N fertilizer rates (**A**) during the fourth and the fifth growing seasons; and (**B**) among three fertigation frequencies (27, 9, or 3 fertigations per growing season) during the sixth growing season. The x-intercepts denote maximum predicted yield.
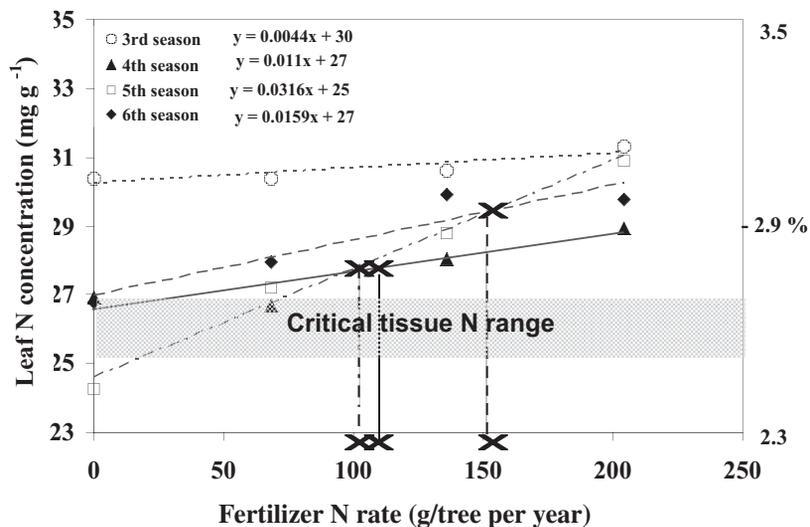

Fig. 2. Effect of N fertilizer rates on leaf N concentration of 'Newhall' navel orange trees during the third through the sixth growing seasons. The x-intercepts denote N rate at the maximum predicted yield.
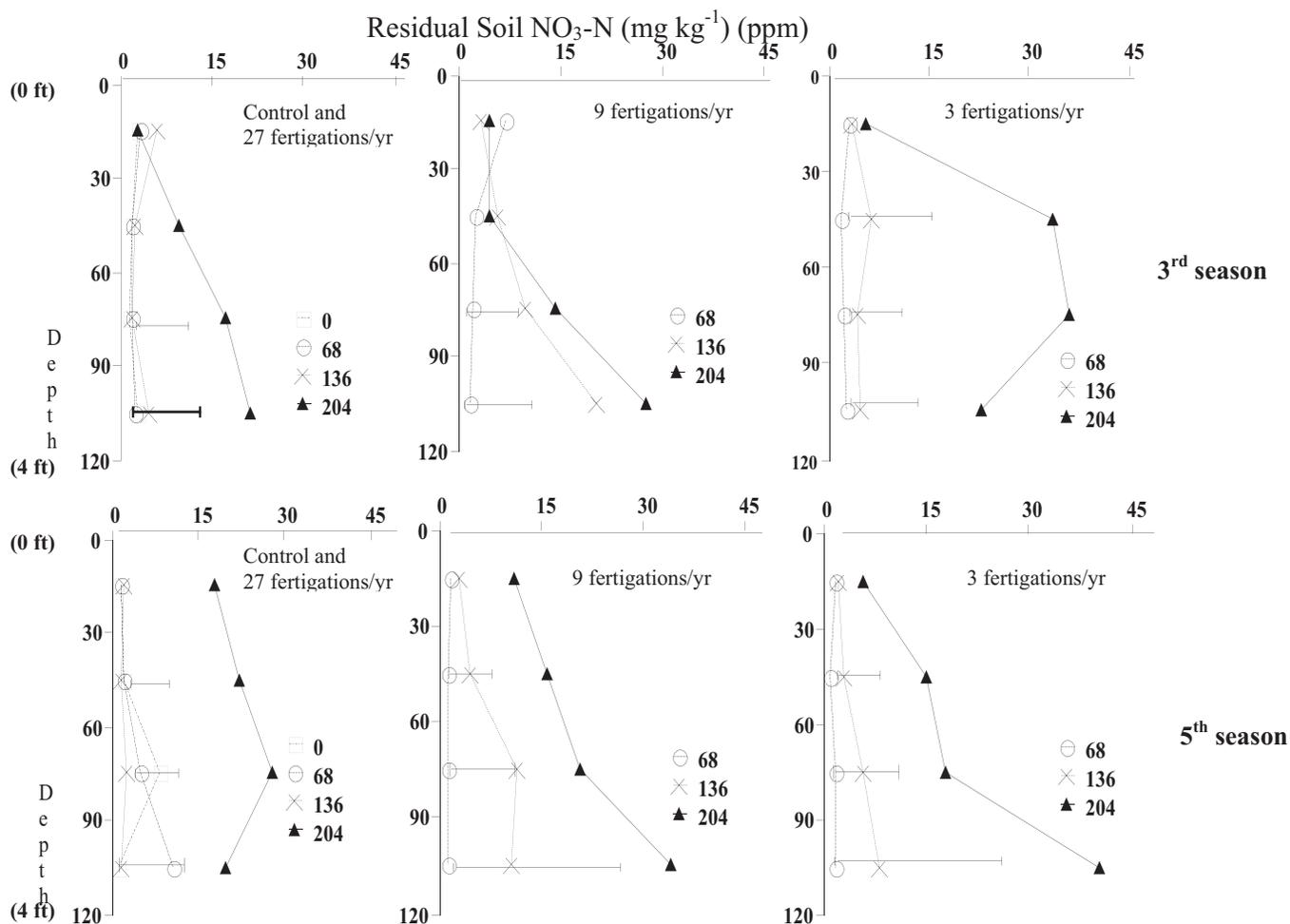
Fig. 3. Soil residual NO$_3$-N concentrations among control plots and three fertigation frequencies (27, 9, or 3 fertigations per growing season) for 'Newhall' navel orange trees during the third through the fifth growing seasons. Error bars, where shown, indicate significant differrences (*P* < 0.05) according to Duncan's multiple range test.

During all three seasons, fertigation frequency did not significantly affect residual soil NO$_3$. This implied that within a given N rate, the sandy loam soil with a pH of 8.0–8.4 and low organic matter was able to retain soil N even at the lowest fertigation frequency (highest concentrations of N) in this low rainfall climate when using efficient irrigation management. Under Florida conditions in the sandy soils, fertigating 1-year-old 'Hamlin' orange trees only 5 times per year resulted in higher soil NO$_3$ in the top 15 cm of soil compared to weekly or 9 monthly fertigations (Willis and Davies, 1991). Alva at al. (1998) also found that increased fertigation frequency minimized NO$_3$ movement under microsprinkler-irrigated mature 'Valencia' orange trees. In our experiment, however, N rate was much more important than fertigation frequency for determining concentrations of residual soil NO$_3$.

Conclusions

We evaluated the response of 3- to 6-year-old microsprinkler-irrigated 'Newhall' navel orange trees to various N rates and fertigation frequencies. The yield-maximizing N rates corresponded to 17% to 34% of currently recommended N rates. Thus, optimum N rates for microsprinkler-irrigated navel oranges in Arizona are lower than the currently recommended N rates developed for flood irrigation. Fruit and juice quality was not significantly affected by N rate or fertigation frequency. Leaf N concentrations at yield-maximizing N rates were consistently above the critical upper leaf tissue N concentration of 27 mg·g^{-1} (2.7%). Thus, the application of N at rates well below currently recommended rates did not compromise the N status of these trees. Highest residual soil NO$_3$ concentrations resulted from the highest N rate.

Literature Cited

Alva, A.K. and S. Paramasivam. 1998. Nitrogen management for high yield and quality of citrus in sandy soils. Soil Sci. Soc. Amer. J. 62:1335–1342.

Alva, A.K., S. Paramasivam, and W.D. Graham. 1998. Impact of nitrogen management practices on nutritional status and yield of Valencia orange trees and groundwater nitrate. J. Environ. Quality 27:904–910.

Boman, B.J. and T.A. Obreza. 2002. Fertigation nutrient sources and application considerations for citrus. Univ. of Florida Coop. Ext. Serv. UF/IFAS Bul. Circ. 1410.

Doerge, T.A., R.L. Roth, and B.R. Gardner. 1991. Nitrogen fertilizer management in Arizona, University of Arizona. College of Agr., Rpt. No. 191025.

Kallsen, C. 2003. Fall leaf tissue samples important for maintaining citrus growth, fruit quality and yields. Univ. of California Coop. Ext. Internet: posted at <http://cetulare.ucdavis.edu/pub/Subtropics%20Fall%2003.pdf> (verified 24 Apr. 2006).

Koo, R.C.J. 1980. Results of citrus fertigation studies. Proc. Fla. State Hort. Soc. 93:33–36.

Koo, R.C.J. 1984. Effect of trickle irrigation and fertigation on fruit production and juice quality of 'Valencia' orange. Proc. Fla. State Hort. Soc. 97:8–10.

Kusakabe, A., S.A. Scott, J.L. Walworth, G.C. Wright, and T.L. Thompson. 2006. Response of microsprinkler-irrigated navel oranges to fertigated nitrogen rate and frequency. Soil Sci. Soc. Amer. J. 70:1623–1628.

Paramasivam, S., A.K. Alva, and A. Fares. 2000. An evaluation of soil water status using tensiometers in a sandy soil profile under citrus production. Soil Sci. 165:343–353.

Sauls, J.W. 2002. Texas citrus and subtropical fruits: Nutrition and fertilization. Internet: posted at <http://aggie-horticulture.tamu.edu/citrus/nutrition/L2288.htm>.

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.S. Harrison, F.T. Izuno, D.J. Pitts, and F.S. Azsueta. 1991. Efficiencies of Florida agricultural irrigation systems. Univ. of Florida Coop. Ext. Serv. UF/IFAS Bul. BUL247.

Syvertsen, J.P and M.L. Smith. 1995. Nitrogen leaching, N uptake efficiency and water use from citrus trees fertilized at three N rates. Proc. Fla. State Hort. Soc. 108:151–155.

Tucker, D.P., A.K. Alva, L.K. Jackson, and T.A. Wheaton. 1995. Nutrition of Florida citrus trees. Univ. of Florida Coop. Ext. Serv. UF/IFAS Bul. SP169.

USDA. 2006. Official series description—Gilman series. USDA. Available online at <http://www.2.ftw.nrcs.usda.gov/osd/dat/G/GILMAN.html>.

Weinbaum, S. and C. Van Kessel. 1998. Quantitative estimates of uptake and internal cycling of ^{14}N-labeled fertilizer in mature walnut trees. Tree Physiol. 18:795–801.

Weinert, T.L., T.L. Thompson, and S.A. White. 2002. Nitrogen fertigation of young navel oranges: growth, N status, and uptake of fertilizer N. HortScience 37:334–337.

Willis, L.E., F.S. Davies, and D.A. Graetz. 1991. Fertigation and growth of young 'Hamlin' orange trees in Florida. HortScience 26:106–109.