Table 3. Plant height of young 'Sunburst' tangerine trees as affected by nitrogen rate[z]

	Plant Height[y] (ft.)	
	1/2 N	N
Feb., 1988	3.50 ± 0.25	3.29 ± 0.26
Oct., 1988	5.67 ± 0.38	5.61 ± 0.32
March, 1989	6.28 ± 0.33	6.24 ± 0.39
Oct., 1989	7.62 ± 0.50	7.51 ± 0.57
April, 1990	7.82 ± 0.76	7.74 ± 0.61
Oct., 1990	8.25 ± 0.51	8.37 ± 0.73

[z]One half (1/2N) and full N rate in 1988 and 1989 was 0.66 and 1.32 lbs N/tree/year, respectively.
One half (1/2N) and full N rate in 1990 was 0.52 and 1.05 lbs N/tree/year
[y]Mean of 24 paired samples per treatment ± standard deviation.
No significant differences according to t test at 5% level.

tilizer rates lower than many growers currently use produce adequate growth of young trees.

Young 'Sunburst'/sour orange trees have produced medium to heavy crops, with one report of 88 fruit/tree produced after 2 1/2 years (2). Trees in this experiment did not bear until they were 4-years old because of cold damage. Reduced fertigation rates reported in this paper may be adequate to stimulate growth of nonbearing young 'Sunburst' trees for years 2-4, especially when cold damage has been sustained, but may be inadequate if a crop is set. Leaf analysis (Table 4) also indicated that N, P, Mn and Zn levels in years 2 and 3 of the experiment were in the low to deficient range, with nitrogen being deficient for both 1/2 and full N treatments in year 3 when a crop was produced.

The impact of citrus fertilization practices on the quality of ground and surface waters and the development of more economical production practices to minimize energy and capital inputs are becoming increasingly important.

Table 4. Mineral composition of young 'Starburst' tangerine leaves as affected by nitrogen rate[zy]

Element	1/2N 1989	1/2N 1990	N 1989	N 1990
N (%)	2.50	1.90[x]	3.05	1.90[x]
P (%)	0.12	0.14	0.13	0.12
K (%)	1.48	0.90[x]	1.46	1.02[x]
Ca (%)	3.61	5.03	3.17	4.67
Mg (%)	0.34	0.41	0.30	0.38
Mn (ppm)	18.50[x]	22.00[x]	20.00[x]	24.00[x]
Zn (ppm)	13.00[x]	2.40[x]	12.00[x]	3.00[x]
Cu (ppm)	9.50	17.00	9.00	29.00
Fe (ppm)	58.50	89.00	49.00	93.50
B (ppm)	30.00	37.50	34.00	41.00

[z]One half (1/2N) and full N rate in 1988 and 1989 was 0.66 and 1.32 N/tree/year, respectively.
One half (1/2N) and full N rate in 1990 was 0.52 and 1.05 N/tree/year.
[y]Mean of 2 samples consisting of 100 4- to 6-month old spring flush leaves taken from 24 tree/treatment
[x]Low to deficient.

Reduced fertigation rates for young citrus trees can significantly reduce such inputs.

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FERTILIZATION OF FREEZE-DAMAGED 'HAMLIN' ORANGE TREES

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Abstract. **Six-year-old 'Hamlin' orange trees (*Citrus sinensis* [L.] Osbeck) were fertilized at 0, 2.5, 5.0 or 7.5 pounds of granular material (10N-4.3P-8.3K plus minors) in three applications/year following the freeze of 23 Feb. 1989. Free damage reduced the canopy size about 50%. By October 1989, leaf N, Zn and Mn were at deficient levels for all treatments. Levels of all other elements were within low to acceptable ranges. However, no differences in tree growth and appearance were observed among treatments. The experiment was repeated following the freeze of 25-26 Dec. 1989. Freeze damage reduced canopy size from 50 to as much as 90%. Trees were fertilized three times in 1990 using an 8N-0.86P-6.6K-0.4Mg formulation at the same rates as in 1989. Tree appearance and growth again were similar for all treatments, and leaf N levels were deficient only for 0 and 2.5 lb rates. Therefore, mature nonbearing citrus trees have the capacity to store and mobilize nutrients from the trunk, limbs and roots and require low levels or no fertilization following a freeze where severe wood damage occurs. Alternatively, it may be necessary to apply N only along with a foliar application of minor elements.**

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Severe freezes of 1983, 1985 and 1989 have killed or damaged over 200,000 acres of citrus trees in Florida. The December 1989 freeze alone caused the loss of over 85,000 acres of citrus trees (3). Moreover, many trees are damaged by freezes to varying degrees which may include partial or complete defoliation, twig dieback, or major limb damage. Several opinions exist as to how partially damaged citrus trees should be rehabilitated; in particular, how fertilizer programs should be adjusted to compensate for leaf or wood losses. Recommendations for freeze-damaged mature citrus trees in California are to avoid fertilization following early season freezes until damage is assessed and to apply reduced rates following late season freezes (8). In contrast, in Texas no fertilizer is applied to severely damaged trees (Swietlik, personal communication) and citrus trees damaged during the December 1983 freeze showed no freeze-related nutrient deficiencies except for Mn (7). Similarly, Lawless in Florida (6) observed that nonfertilized freeze-damaged 'Pineapple' orange trees recovered as rapidly as fertilized trees following the freeze of 1940, although no provision was made to compensate for the extent of canopy damage. Current recommendations suggest applying 10 to 20% more N where complete defoliation occurs and a normal crop is anticipated, but a reduction in fertilizer rates where wood damage occurs (4). The general recommendation has been to reduce rates in proportion to the amount of wood damage, viz, 50% for 50% damage, 30% for 30% damage, etc. These recommendations are based on the fact that mature citrus trees store a considerable amount of nutrients in the wood (7) and that citrus roots dieback after a freeze when severe wood damage has occurred (Swietlik, unpublished). Furthermore, no fruit will be produced the following season. Therefore a reduction in fertilizer rate is justifiable. Nevertheless, no replicated field experiments have been conducted in Florida to support these recommendations and Florida recommendations differ from those of Texas and California. The objective of this study was to compare regrowth and leaf nutrient levels of moderately to severely freeze-damaged citrus trees.

Materials and Methods

A one-acre block of 'Hamlin' orange trees on sour orange rootstock was planted in June 1983 at the Fifield Research Farm in Gainesville, FL. Soil type is an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic, Paleaquults). Trees were spaced 20 feet within and between rows. Irrigation and cold protection were provided by 90° 23-gal hr^{-1} Maxijet® microsprinklers located 3 feet northwest of the tree (2). Trees were fertilized as currently recommended (5) and received pesticide and nutrient sprays as necessary. Trees were frozen back to about a 2-foot height during the 25 Dec. 1983 and 21 Jan. 1985 freezes but had obtained heights of 6 to 8 feet prior to the 23 Feb. 1989 freeze. Trees had flushed by this time due to higher than normal temperatures. During the freeze of 1989, minimum sheltered air temperature at 4.5 feet reached 19°F, all new growth was killed and the canopy size reduced by 40 to 50%. Trees had not received a fertilizer application before the freeze.

Following the freeze, the block was divided into four blocks of 28 trees each. Trees were hand pruned removing all dead wood to a height of 4 to 5 feet. A granular fertilizer (10N[5.0% NH_4^+, 5.0% NO_3^-]-4.3 P-8.3K-0.4Mg-0.29Mn-0.08Cu-0.0006B) was applied to each block at 0, 2.5, 5.0 or 7.5 lbs of material per tree per application in three applications per year. Trees were rated subjectively in March, July and October and leaf samples were collected from fully expanded, mature nonfruiting shoots in October for each block. This preliminary study was intended to be observational and no other quantitative data were collected.

The 25-26 Dec. 1989 freeze caused extensive wood damage. Minimum sheltered air temperatures at 4.5 feet were 14°F with durations below 32°F of over 50 hr. The lower portion of the canopy was protected using 90° 23-gal hr^{-1} Maxijet® microsprinklers located 3 feet northwest of the trees. Because of the variable amount of cold protection provided by the irrigation system, amount of canopy (wood) damage varied from 50% to 90% (where emitters became inoperative) within each block. Consequently, the fertilizer study was repeated, but in this case the four rates were applied randomly to trees with varying degrees of damage within each block. Each block contained 3-5 trees having 40-60% or 70-90% canopy damage. Since the block effect was not significant, each treatment was comprised of 12-15 individual tree replicates. Trees were again pruned in March to remove dead wood and 0, 2.5, 5.0 and 7.5 lbs of an 8N(4.0% NH_4^+, 4.0% NO_3^-)-0.86P-6.6K-0.4Mg fertilizer was applied in March, June and October. A foliar application of Zn, Mn, Cu and B was made in April after the new growth flush was fully expanded. Visual ratings were made in April, June and November and trunk circumferences measured in May, July and October. Leaf samples were taken in June and October on fully expanded, mature leaves from nonfruiting shoots. Neutron probe tubes were installed in each block to monitor soil moisture status and trees were watered when soil moisture depletion reached 50%. Water was applied for 3 hr per application using 90° 23-gal hr^{-1} Maxijet® microsprinklers.

Results and Discussion

There were no visual differences in tree vigor or appearance during 1989 related to fertilizer treatment (data not shown). Leaf nutrient levels, however, were deficient for N, Fe, Mn and Zn (5) (Table 1). Levels of other nutrients were generally within acceptable ranges (5). In 1990

Table 1. Effects of fertilizer rate on leaf nutrient levels of freeze-damaged 'Hamlin' orange trees, October, 1989.

Fert applied (lbs/tree/appl)[z]	N	P	K (%)	Ca	Mg	Fe	Mn	Zn (ppm)	Cu	B
0	1.90	0.20	1.74	1.34	0.27	41	18	17	6	28
2.5	2.00	0.19	1.66	1.46	0.32	38	16	17	7	31
5.0	2.00	0.23	1.76	1.33	0.32	38	14	17	6	31
7.5	1.80	0.20	1.68	1.40	0.33	41	17	18	6	30

[z]Fertilizer was broadcast by hand in March, July and October, 1989. Fertilizer analysis was 10N(5.0% NH_4^+, 5.0% NO_3^-)-4.3P-8.3K-0.4Mg-0.29Mn-0.08Cu-0.006B.

Table 2. Effects of fertilizer rate on freeze-damaged 'Hamlin' orange trunk circumference and visual rating, 1990.

Fertilizer applied (lbs/tree/appl)[z]	Time of measurement					
	May 5	Apr. 30	Jul. 2	June 26	Oct. 27	Nov. 15
	Trunk circum. (inch)	Rating[y]	Trunk circum. (inch)	Rating[y]	Trunk circum. (inch)	Rating[y]
0	11.6	3.0	11.9	3.8	12.4	5.2
2.5	12.0	3.0	12.3	4.2	12.9	5.2
5.0	11.5	2.7	11.8	3.3	12.4	4.5
7.5	11.5	2.7	11.9	3.3	12.5	5.2

[z]Fertilizer was broadcast by hand in March, June and October, 1990. Fertilizer analysis was 8N (4.0% NH_4^-+, 4.0% NO_3^-)-0.86P-6.6K-0.4Mg. Trees also received a foliar application of Zn, Mn, B and Cu in April.
[y]Visual rating ranged from 1 (a poorly growing, unhealthy tree) to 8 (a healthy, vigorous tree). The rating represents a mean of trees with canopy damage ranging from 50-90%. There are no significant or meaningful differences among treatments.

again no visual differences were noted in tree vigor, appearance or trunk circumference related to fertilizer rate (Table 2). Moreover, there was no apparent carry-over effect from the previous year's treatment (data not shown).

As expected, fertilizer rate did affect leaf nutrient levels during both the June and October sampling dates in 1990 (Table 3). Leaf N levels were above optimum during June and increased with increasing fertilizer rates. Levels of all other nutrients were at the lower end of the optimum ranges. The relatively high levels of leaf N probably resulted from sampling spring flush leaves in June and may not be representative of the true nutrient status of the tree. Nutrient levels in leaves at this time are typically higher than those of leaves sampled in the fall.

Leaf nutrient levels were generally lower during October than June. Nitrogen levels were deficient for the 0 to 2.5 lb rates but increased to low levels at the 5.0 and 7.5 lb rates. Levels of P, K, Ca, Mg and Fe were within acceptable ranges, however, Zn and Mn levels were deficient.

These observations are in general agreement with those of Lawless (6) in 1940 for 'Pineapple' oranges in Florida. However, these data differ from those of Swietlik and LaDuke (7) in Texas who found that citrus trees receiving no fertilizer following the December 1983 freeze showed no signs of deficiency for the ensuing year with the exception of Mn. This observation is not surprising due to the more fertile nature of the soils in Texas as compared with north Florida.

The discrepancy between the visual observations and trunk circumference measurements and leaf nutrient levels is problematic. Based on the current recommendations these trees should have received 50-60% of the full rate (2.5 lb/tree/application) or less than 20% of full rate for severely damaged trees. The 2.5 lb rate was sufficient when assessing growth and vigor but produced low to deficient leaf N levels. The recommended rate, 5 lbs/tree/application, yielded leaf N levels at the lower end of acceptable ranges, while the 7.5 lb rate yielded leaf N levels at the upper end of the acceptable range.

Mature citrus trees that have been on a regular fertilizer program have the capacity to store considerable amounts of N and other nutrients (1). These nutrients are then mobilized to the new shoots and leaves. In this study shoot extension growth of 5-6 feet was common regardless of fertilizer rate provided that tree water status was maintained at optimum levels. Consequently, from a practical, visual standpoint, there is no reason to apply more than 50% of recommended levels of N to severely damaged citrus trees that will not produce a crop in the year following the freeze. Further, there is strong evidence that soil-

Table 3. Effects of fertilizer rate on leaf nutrient levels of 'Hamlin' orange trees, 1990.

Fertilizer applied (lbs/tree/appl)[z]	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
June									
0	2.75	0.22	1.9	4.1	0.31	69	18	29	6
2.5	2.95	0.20	1.8	4.0	0.30	76	20	22	8
5.0	3.10	0.20	1.8	3.7	0.30	77	21	19	6
7.5	3.20	0.21	1.9	3.9	0.30	88	25	22	7
October									
0	2.03	0.15	1.8	4.3	0.27	75	17	16	6
2.5	2.08	0.12	1.7	4.4	0.27	81	19	17	6
5.0	2.25	0.12	1.7	4.2	0.27	82	20	17	5
7.5	2.35	0.12	1.7	4.1	0.26	98	23	16	6

[z]Fertilizer was broadcast by hand in March, June and October, 1990. Fertilizer analysis was 8N(4.0% NH_4^+, 4.0% NO_3^-)-0.86P-6.6K-0.4Mg.

applied fertilization may not even be necessary for mature trees if they have received adequate fertilization in years prior to the freeze, or alternatively that only N should be applied to the soil with minor elements being applied as a foliar spray as currently recommended.

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YOUNG 'HAMLIN' ORANGE TREE FERTILIZER RESPONSE IN SOUTHWEST FLORIDA

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Abstract. **Southwest Florida has experienced a major expansion of citrus acreage, and fertilizer rates applied to young trees have generally been greater than present guidelines. Currently-recommended fertilizer rates were evaluated for young 'Hamlin' (*Citrus sinensis* (L.) Osb.) on Carrizo citrange (*C. sinensis (L.) Osb. x Poncirus trifoliata*) rootstock orange trees under this region typified by an extended growing season. Conventional water-soluble and controlled-release complete fertilizers were applied to newly-planted trees at N rates of 0, 0.06, 0.12, 0.24, and 0.48 lb/tree/yr. Water-soluble material was applied six times, while controlled-release materials [isobutylidene diurea (IBDU), methylene urea (MU), IBDU briquets, and Osmocote (OSM)] were applied one to three times. Twelve months after planting, trunk cross-sectional area increase and canopy volume were maximized at 0.12 lbs N/tree for Osmocote and 0.12-0.24 lbs N/tree for the other sources. Similar canopy volume was obtained for conventional, IBDU, and methylene urea sources at 0.24 lbs N/tree. Substantial growth measured on nonfertilized trees indicated that N may have been available from sources other than the fertilizer treatments.**

The expansion of citrus acreage in southwest Florida (Charlotte, Collier, Hendry, Glades, and Lee counties) has been substantial since the freezes of the early 1980s. Grove land within the region increased from 50,000 acres in 1980 to 126,000 acres by 1990 (3). Based on the amount of unplanted land which is currently permitted for citrus, southwest Florida could potentially have 150,000-200,000 acres of citrus by the year 2000.

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One concern associated with the expansion of citrus is the effect of agricultural practices on the environment. Because of the mobility of nitrogen fertilizer in sandy Florida soils, the potential for ground water contamination exists. Adoption of fertilizer management practices which increase fertilizer efficiency should minimize environmental effects and reduce costs. Two ways to increase nitrogen fertilizer efficiency are: using amounts close to the minimum amount required by the plant for maximum growth, and 2) using controlled-release N sources when multiple, small applications of water-soluble sources are not possible or practical.

Citrus growers in southwest Florida have recognized that the region's shorter winter (dormant) season relative to central Florida allows trees to grow for a longer time during the year. In an effort to accelerate fruit production of young trees, growers have attempted to "push" tree growth through the winter. Rates of fertilization in excess of current University of Florida/IFAS recommendations for young citrus trees are typically used. The current recommendations (6) do not differentiate between central and south Florida with respect to fertilizer rates.

Recent studies with young 'Hamlin' orange trees in central and east coast Florida have suggested that the current fertilizer recommendation for the first year of new plantings (0.40-0.60 lb N/tree) are above that which is required for maximum growth. Marler et al. (7) found no growth differences between N rates of 0.16, 0.32, and 0.48 lbs tree/yr for newly-planted trees grown at Gainesville. They also found no difference in growth between soluble and controlled-release fertilizers applied at 0.32 lb N/tree/yr. At Clermont and Fellsmere, Ferguson et al. (4) compared soluble fertilizer applied at 0.18 and 0.30 lb N/tree/yr to controlled-release materials applied at 0.04-0.13 lb N/tree/yr and found no differences in tree growth for the first year.

This study was designed in a similar manner as those mentioned to determine if there are any regional differences in fertilizer requirements for young, non-bearing citrus trees. The objectives were: 1) to determine the relationship between fertilizer rates and citrus tree growth in southwest Florida, and 2) to compare growth between trees fertilized frequently with a soluble N source and infrequently with controlled-release N sources.