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MICROCLIMATE OF YOUNG CITRUS TREES PROTECTED BY MICROSPRINKLER IRRIGATION DURING FREEZE CONDITIONS

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Abstract. **Air temperature, dewpoint, net radiation and soil temperature were measured around 2-year-old 'Hamlin' orange (*Citrus sinensis* (L.) Osb.) trees on sour orange (*Citrus aurantium* L.) or trifoliate orange (*Poncirus trifoliata* (L.) Raf.) rootstock irrigated with microsprinklers during advective and radiative freezes. Microsprinkler irrigation did not affect air temperature or dewpoint in the tree canopy during severe advective or radiative freezes. Net radiation was 8 to 16 W per yd², more negative above irrigated than unirrigated trees under advective freeze conditions, but was not affected by irrigation under radiative freeze conditions. Irrigation rates > 10 gal per hr increased soil temperature, while lower irrigation rates decreased soil temperature with respect to the unirrigated condition. Apparently, the elevation in trunk temperature of wrapped young citrus trees resulted from direct heat transfer from the irrigation water, and not through microclimate modification.**

Methods of freeze protection that use water include flood irrigation, fog generation and sprinkler irrigation, each of which influence the microclimate of the orchard. Flooding an orchard during a freeze can increase soil and air temperatures and upward radiant heat flux from the orchard floor (1, 6), thereby increasing tree temperatures. Pre-freeze irrigation by either flooding or sprinkling can have similar effects, but does not present the problem of standing water in the orchard (6). Fog retards the loss of infrared radiation from an orchard and raises the dewpoint, which can prevent tree temperatures from decreasing to damaging levels (8). Therefore, flood irrigation and fog generation affect temperatures of trees primarily by modifying the microclimate of an orchard.

Sprinkler irrigation provides protection primarily through direct transfer of latent heat from the ice-water mixture that coats the tree (3, 7, 12), but also modifies microclimate of mature citrus trees (4, 11, 14). Leaf and air temperatures were 0 to 6 °F higher for irrigated than unirrigated 'Orlando' tangelo trees (4, 14) and protection varied with position in the canopy and freeze conditions. Similarly, Parsons et al. (10) reported 0 to 2 °F differences in air temperature between irrigated and unirrigated mature citrus canopies using low-volume microsprinkler irrigation. Fog or mist generation by microsprinklers occurs under high dewpoint conditions and is thought to decrease radiant heat loss from the trees and soil surface (11). However, canopy temperatures at the 6 and 9 ft height of irrigated citrus trees were similar to those of unirrigated trees, despite the presence of fog or mist around irrigated trees (14). Preliminary studies indicated that net radiation above young citrus trees was about 7 W per yd² more negative with high irrigation rates than low rates, but values for unirrigated trees were not reported (5).

The effect of microsprinklers on microclimate and subsequent freeze damage of young citrus trees has not been studied. The objective of this research was to determine the effect of microsprinkler irrigation on air temperature, dewpoint, net radiation and soil temperature around young citrus trees under various freeze conditions.

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Materials and Methods

Plant material, freezes and treatments. A 0.7-acre planting of 126 2-year-old 'Hamlin' orange trees on either trifoliate orange or sour orange rootstock was used for all experiments. Trees were spaced 15 x 20 ft, were 2 to 5 ft in height, and about 1 in in diameter at the bud union. The lower 16 in of all trees were wrapped with 3.5 in (R-11) foil-faced fiberglass insulation. Microsprinklers were placed 3 ft from the trees on the northwest side because winds are generally from this direction during advective freezes in Florida (9).

Microclimate measurements from 6 freezes exhibiting widely variable meteorological conditions were chosen for analysis of irrigation treatment effects. Freeze conditions measured outside the research plot are given in Table 1.

In Jan. 1985 microsprinkler irrigation treatments were applied in a factorial combination of 3 irrigation rates (10, 15, and 23 gal per hr) x 2 spray patterns (90° and 360°), plus an unirrigated control. Treatments in Dec. 1985-Jan. 1986 consisted of 4 irrigation rates (3, 6, 10, and 15 gal per hr) applied in a 90° spray pattern, plus an unirrigated control. In Jan. 1987, only a 10 gal per hr irrigation rate applied in a 90° spray pattern and an unirrigated control were used.

Microclimate measurements. Air temperature, relative humidity, and net radiation data were recorded hourly during the freezes in Jan. 1985, and soil temperature was measured during the Dec. 1985-Jan. 1986 freezes. Net radiation measurements were repeated on 11-12 Jan. 1987 to confirm results from 1985. Observations on fog and

Table 1. Freeze conditions on dates used for analysis of effects of microsprinkler irrigation on microclimate of 2-year-old 'Hamlin' orange trees.

Date	Minimum air temperature (°F)	Windspeed (mph)	Dewpoint (°F)
20-21 Jan. 1985	11	4-12	−15-17
26-27 Jan. 1985	23	< 2	16-22
25-26 Dec. 1985	19	2-6	12-16
26-27 Dec. 1985	25	0-4	18-21
27-28 Jan. 1986	19	2-8	5-9
11-12 Jan. 1987	27	2-6	25

mist generation from microsprinklers were made on all dates. Relative humidity and temperature measurements were made inside and outside the planting with a sling psychrometer on all dates to determine whether microsprinkler irrigation changed the microclimate of the entire plot or only in the vicinity of the trees.

Air temperature was measured with copper-constantan thermocouples in the canopy of one tree in each treatment at a height of 3 ft. Relative humidity was measured with humidity sensors (Viasala Instruments, Woburn, Mass.) in the same location as air temperature for one tree in each treatment, and dewpoint was calculated from simultaneous measurements of air temperature and relative humidity. Net radiation was measured with Fritschen-type net radiometers placed at a height of 32 in and centered directly over the water spray, between the tree and the microsprinkler. Preliminary experiments indicated that at a height of 32 in, net radiometers were sensitive enough to measure differences in upward radiant flux of about 4 to 8 W per yd^2 from an area of about 3 yd^2 (data not shown). One net radiometer per treatment was used in the 1984-85 and 1985-86 winters, and 4 net radiometers per treatment were used in the 1986-87 winter. Soil temperature was measured with thermocouples placed approximately 0.5 inches below the soil surface next to the trunk of one tree in each treatment. This location was chosen because it was suspected that soil temperature could influence trunk temperature above the soil surface by conduction of heat vertically along the trunk.

Results and Discussion

Microsprinkler irrigation rate did not affect air temperature, dewpoint or net radiation of the trees within either the 90° or 360° spray pattern during the Jan. 1985 freezes (data not shown). Hence, data were classified as either irrigated-90°, irrigated-360° or unirrigated to simplify discussion of these variables.

Air temperature. Air temperaure in the tree canopy was similar for irrigated-90°, irrigated-360° and unirrigated treatments during severe advective and radiative freezes (Fig. 1). Furthermore, air temperatures for all trees were typically within 1 °F of those outside the research plot under both types of freeze conditions (data not shown). Air temperature in the irrigated-90° treatment was 2 °F higher than in the unirrigated treatment °F under radiative conditions for a 3-hr period during the 26-27 Jan. 1985 freeze. Although this may be attributable to heat released by the irrigation water, the transient nature of the increase suggests random variation in air temperature which is frequently observed on radiative nights. Parsons et al. (11) observed consistent increases in air temperature of 1 to 3 °F for irrigated young trees, although their microsprinklers were more closely spaced and freeze conditions were less severe than in this study.

Dewpoint. Variations in dewpoint were typically less than 2 °F among irrigated-90°, irrigated-360°, and unirrigated treatments under advective and radiative freeze conditions (Fig. 2). As with air temperature, there was a 3-hr

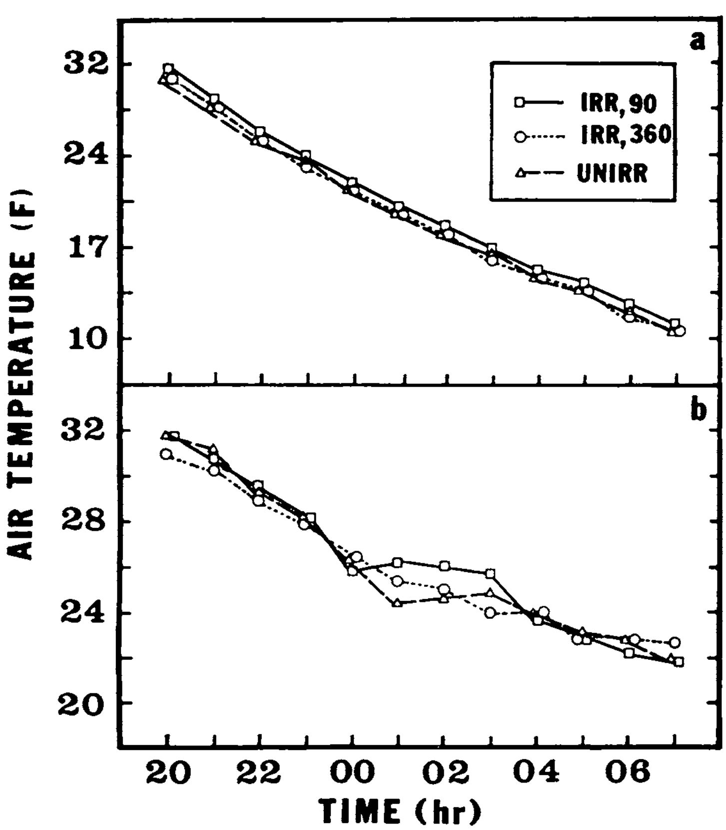

Fig. 1. Air temperature at a height of 3 ft in the canopy of 2-year-old 'Hamlin' orange trees during a severe advective freeze on 20-21 Jan. 1985 (a) and a radiative freeze on 26-27 Jan. 1985 (b). Points are means of 3 values for the irrigated-90° (IRR,90) and irrigated-360° (IRR,360) treatments, and single values for unirrigated (UNIRR) treatments.

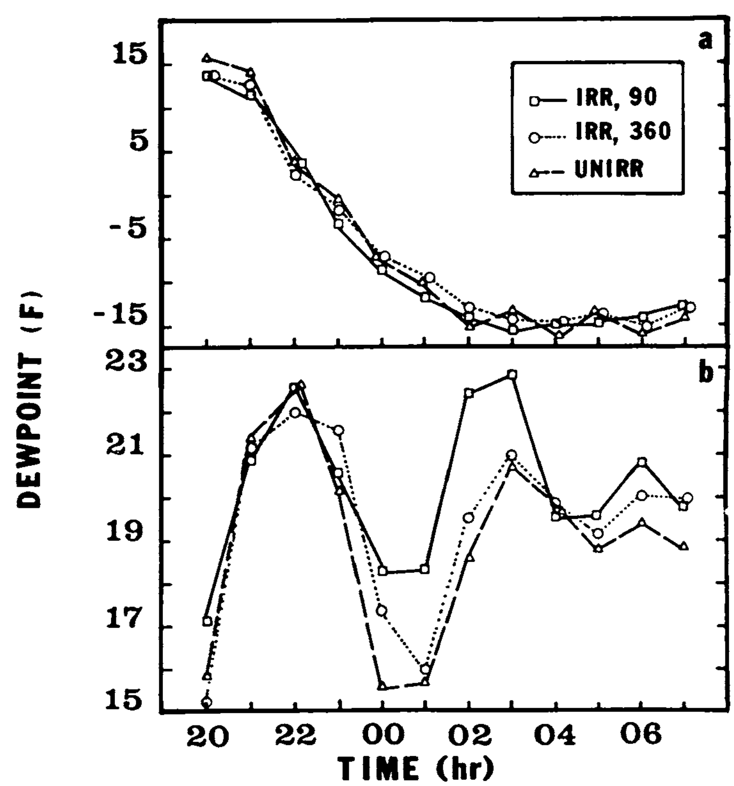

Fig. 2. Dewpoint temperature at a height of 3 ft in the canopy of 2-year-old 'Hamlin' orange trees during a severe advective freeze on 20-21 Jan. 1985 (a) and a radiative freeze on 26-27 Jan. 1985 (b). Points are means of 3 values for the irrigated-90° (IRR,90) and irrigated-360° (IRR,360) treatments, and single values for unirrigated (UNIRR) treatments. Dewpoint was calculated using simulataneous air temperature and relative humidity measurements.

period in the middle of the radiative freeze night where values were higher for the irrigated-90° than unirrigated trees (Fig. 2b). However, this may be a mathematical artifact because air temperature was used to calculate dewpoint.

Mist was often observed over irrigated trees during calm conditions when dewpoint was close to air temperature, similar to the observations of Parsons et al. (11). However, humidity measurements made with a sling psychrometer near unirrigated trees were similar to those outside the research plot (typically 60-100%), indicating that humidity around unirrigated trees within the plot was not influenced by mist from neighboring irrigated trees.

Net radiation. Net radiation was 8 to 16 W per yd² more negative over irrigated than unirrigated treatments under advective freeze conditions (Fig. 3a). Higher net radiation values over unirrigated than irrigated trees were observed again during a less severe freeze that occurred on 21-22 Jan. 1985 (data not shown). Net radiation values outside the planting were comparable to values for unirrigated trees inside the planting. Hence, the increase in outgoing radiation from the irrigated treatments was localized, and probably caused by the presence of the 50 to 60 °F irrigation water. If irrigation were favorably modifying the microclimate of the trees, then one would expect net radiation values to be less negative over irrigated trees, but the opposite situation is seen (Fig. 3a).

No differences in net radiation occurred between irrigated and unirrigated treatments or among irrigated treatments under radiative freeze conditions (Fig. 3b). Net radiation was measured above irrigated (10 gal per hr, 90° pattern) and unirrigated trees during a mild, radiative freeze on 11-12 Jan. 1987 to verify results from 1985. Again, net radiation was found to be similar for irrigated and unirrigated trees (Fig. 4) and consistent with data presented in Fig. 3b. The reasons for the lack of differences in net radiation between irrigated and unirrigated trees under radiative conditions are unclear. Variability in incoming radiation under calm conditions may have masked any slight differences in upward radiant flux on both occasions.

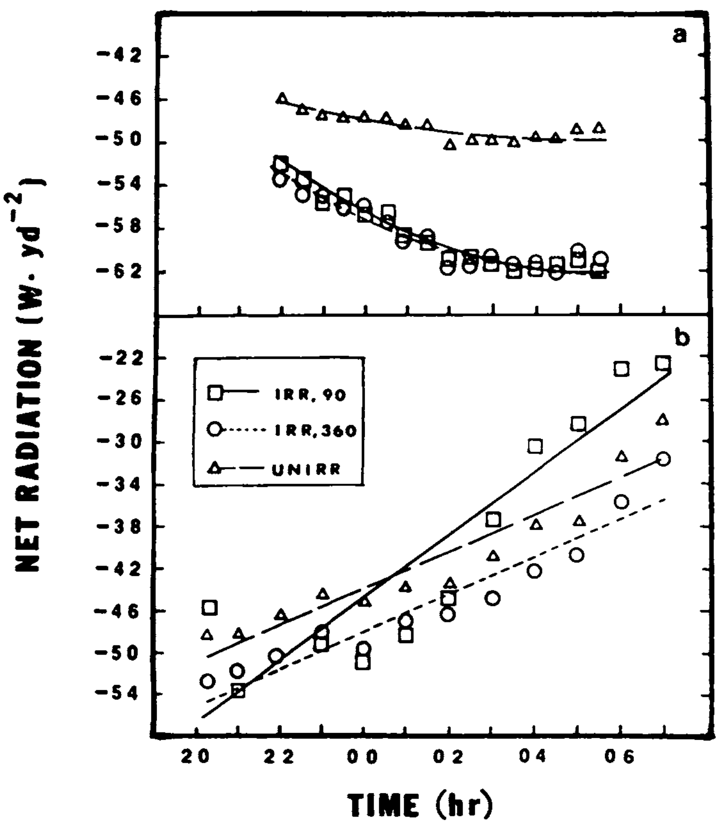

Fig. 3. Net radiation 32 in above the soil surface near 2-year-old 'Hamlin' orange trees during a severe advective freeze on 20-21 Jan. 1985 (a) and a radiative freeze on 26-27 Jan. 1985 (b). Points are means of 3 values for the irrigated-90° (IRR,90) and irrigated-360° (IRR,360) treatments, and single values for unirrigated (UNIRR) treatments.

Davies et al. (5) measured net radiation values of –51 and –44 W per yd² above trees irrigated with 90° 23 gal per hr and 360° 10 gal per hr microsprinklers, respectively, under radiative conditions. Their results could be explained by the presence of greater quantities of 50 to 60 °F water underneath net radiometers for the higher than the lower irrigation rate. However, it is unclear why differences between 90° and 360° spray patterns were not detected under radiative conditions in this study. Possibly, differences in net radiometer placement (5 ft for Davies et al. and 32 in in this study) were responsible for the conflicting results.

Soil temperature. Soil temperature generally was highest for the 10 gal per hr rate, intermediate for unirrigated trees, and lowest for the 3 gal per hr rate during 3 freezes in Dec. 1985-Jan. 1986 (Fig. 5). Soil temperatures for the 6 and 15 gal per hr treatments were very similar to those for the 3 and 10 gal per hr treatments, respectively (data not shown). The mist-sized droplets in the 3 gal per hr treatment probably cooled to a greater extent as they traveled through air than larger droplets in other treatments (7) which reduced soil temperatures below those for unirrigated trees. However, droplet size was comparable for 6 and 10 gal per hr microsprinklers. Thus, reduced soil temperatures for the 6 gal per hr treatment cannot be explained by droplet size alone.

Rieger (13) using computer simulation, found no influence of soil temperature on trunk temperature at the 20-cm height for 1-in diameter trunks. Thus, heat added to

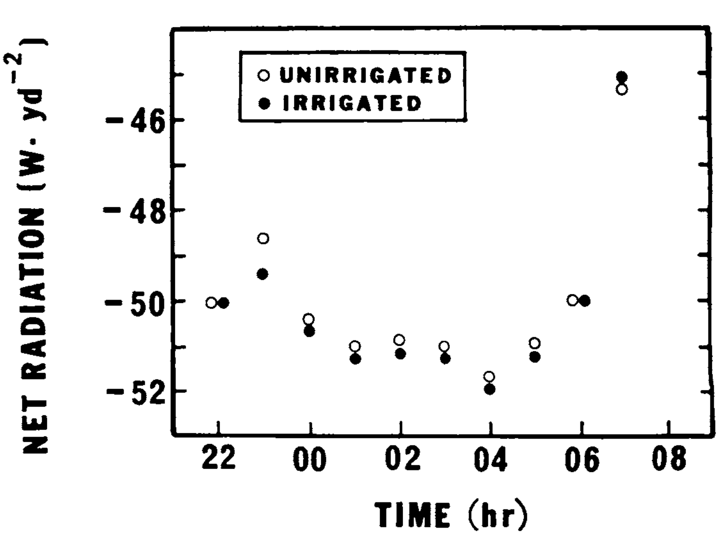

Fig. 4. Net radiation 32 in above the soil surface 2-year-old 'Hamlin' orange trees during a radiative freeze on 11-12 Jan. 1987. Points are means of 4 values for irrigated and unirrigated treatments.

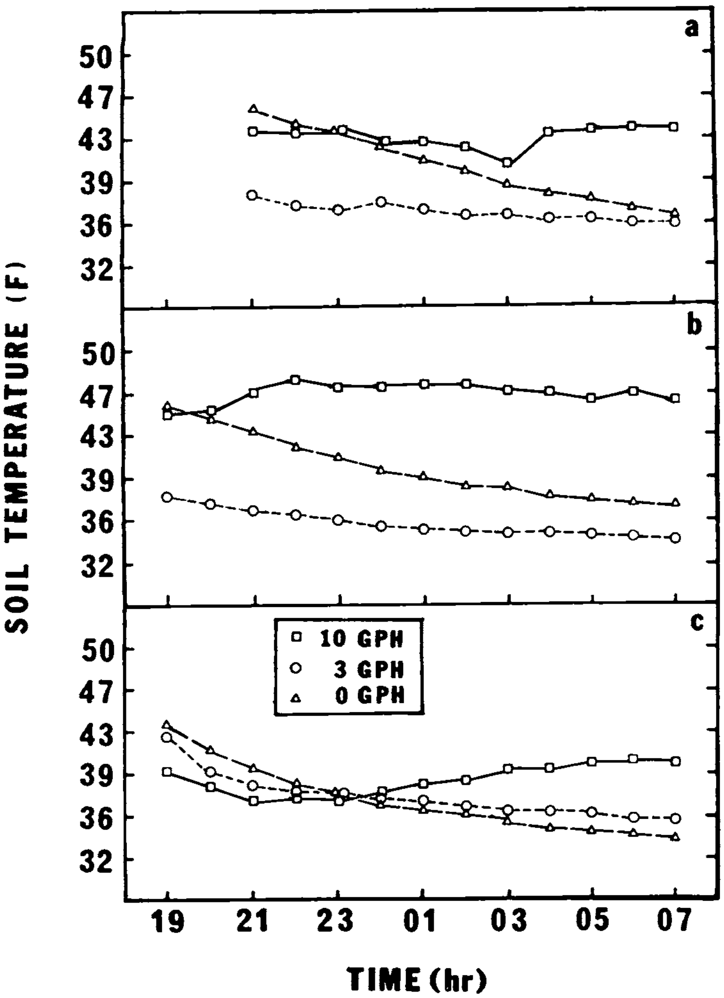

Fig. 5. Soil temperature measured 0.5 in below the surface and next to trunks of 2-year-old 'Hamlin' orange trees during freezes on 25-26 Dec. 1985 (a), 26-27 Dec. 1985 (b), and 27-28 Jan. 1986 (c). Points are single values for the unirrigated (0 GPH), 3 gal per hr (3 GPH) and 10 gal per hr (10 GPH) treatments.

the soil via irrigation water probably does not affect trunk temperatures at the 8-in height of wrapped young citrus trees when microsprinkler irrigation is used during freeze conditions.

Conclusions

Microsprinkler irrigation applied at standard rates and pressures and typical tree spacings does not appear to change the microclimate within a young tree planting in the same way as reported for mature trees (2, 10). Mature trees have much greater canopy volume than young trees, hence a greater capacity to decrease radiation losses, reduce windspeeds within the canopy, and retain heat released from the irrigation water. Irrigation may, under certain conditions, increase the long-wave radiant flux from the vicinity of a young tree, but these effects appear to be localized and do not affect air temperatures. Irrigation rates > 10 gal per hr elevate soil temperatures, while lower irrigation rates reduce soil temperatures with respect to the unirrigated condition. However, it is unlikely that soil temperature changes affect trunk temperatures at the 8-in or greater heights. Most, if not all of the elevation in trunk temperature of wrapped young citrus trees results from direct heat transfer from the irrigation water, and not through microclimate modification.

Literature Cited

1. Brewer, R. F. 1978. Soil-applied irrigation water as a source of frost protection. Calif. Citrog. 63:283-284, 304.
2. Buchanan, D. W., F. S. Davies, and D. S. Harrison. 1982. High and low volume under-tree irrigation for citrus cold protection. Proc. Fla. State Hort. Soc. 95:23-26.
3. Businger, J. A. 1965. Protection from the cold. Agr. Meterol. Soc. Monogr. 6(28):74-80.
4. Davies, F. S. 1980. High volume under-tree sprinkling for citrus cold protection. Proc. Fla. State Hort. Soc. 93:1-2.
5. Davies, F. S., L. K. Jackson, and L. W. Rippetoe. 1984. Low volume irrigation and tree wraps for cold protection of young Hamlin orange trees. Proc. Fla. State Hort. Soc. 97:25-27.
6. Georg, J. G. 1979. Frost protection by flood irrigation, p. 368-370. In: B. J. Barfield and J. F. Gerber (eds.). Modification of the aerial environment of crops. Amer. Soc. Agric. Eng., St. Joseph, Mich.
7. Gerber, J. F. and D. S. Harrison. 1964. Sprinkler irrigation for cold protection of citrus. Trans. Amer. Soc. Agr. Engr. 7:464-468.
8. Mee, T. R. 1977. Man-made fog for freeze protection and microclimate control. Proc. Int. Soc. Citriculture. 1:203-208.
9. Parsons, L. R. 1984. Microsprinkler irrigation for citrus cold protection. Univ. of Fla. IFAS Fruit Crops Fact Sheet 69, Gainesville, Fla.
10. Parsons, L. R., T. A. Wheaton, D. P. H. Tucker, and J. D. Whitney. 1982. Low volume microsprinkler irrigation for citrus cold protection. Proc. Fla. State Hort. Soc. 95:20-23.
11. Parsons, L. R., T. A. Wheaton, and J. D. Whitney. 1982. Undertree irrigation for cold protection with low-volume microsprinklers. HortScience 17:799-801.
12. Perry, K. B. 1979. Evaluation and refinement of sprinkler application rate models used in frost protection. PhD Diss., Penn. State Univ., University Park, Pa.
13. Rieger, M. 1987. Tree wraps and microsprinkler irrigation for freeze protection of young citrus trees. PhD Diss., Univ. of Fla., Gainesville, Fla.
14. Wilcox, D. A. and F. S. Davies. 1981. Modification of air temperature and citrus leaf temperature with high volume under-tree sprinklers. Proc. Fla. State Hort. Soc. 94:59-63.