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MODIFICATION OF AIR TEMPERATURE AND CITRUS LEAF TEMPERATURE WITH HIGH VOLUME UNDER-TREE SPRINKLERS

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Abstract. **Irrigation with high volume under-tree sprinklers, 0.4-0.5 acre-inches/hr (0.41-0.51 cm-ha/hr), increased leaf and air temperatures for 15-year-old 'Orlando' tangelos (Citrus paradisi Macf. x Citrus reticulata Blanco) and 'Pell' navel orange (Citrus sinensis (L.) Osbeck) trees during 2 radiation-type freezes in 1981. Leaf temperatures decreased from the canopy base to the top under all experimental conditions. This pattern was similar in both 8 ft (2.4 m) and 20 ft (6.1 m) trees, although temperature gradients were more pronounced in the larger trees. The temperature of upper canopy leaves was similar in irrigated and non-irrigated blocks. However, leaf temperatures in the lower canopy of irrigated trees were as much as 13°F (7.3°C) greater than those in non-irrigated trees. Furthermore, leaf survival was greatest and fruit pack-out best in the lower third of the canopy of irrigated trees.**

High volume under-tree sprinklers have been used successfully for citrus cold protection in California (1, 7, 8) and Florida (3, 4). Air temperatures were increased and freeze damage decreased by use of Senninger® pop-up systems during the 1979 Florida winter (3, 4). Irrigated trees sustained a smaller % leaf drop and less fruit damage than non-irrigated trees (4). Additionally, leaf temperatures were higher in irrigated trees under both advective and radiation-type freeze conditions in Florida (3).

Leaf temperature during a freeze can also be affected by leaf position in the tree canopy (5, 11). Temperature gradients between leaves and air under freeze conditions were greater in the upper than in the lower canopies of apple trees (11). Leaf temperatures in the exterior canopy of citrus trees were 2.5°F (1.7°C) lower than those of interior canopy leaves (5).

Another factor affecting leaf temperature as air temperature decreases is tree size (6). The temperature of large trees, because of their greater mass and insulating qualities, may be higher than that of small trees at the same air temperature (6). Similarly, twig temperatures decrease more slowly with decreasing air temperature than do leaf temperatures, and tree trunks cool more slowly than small wood. Leaf, twig and trunk temperatures were 9.5°F (−12.4°C), 11.5°F (−11.4°C), and 21.1°F (−6.11°C) respectively, at an air temperature of 12°F (−11.1°C) during the 1962 freeze in Florida (5).

Post-freeze injury to citrus is often observed to be more severe in small than in large trees (6). Leaf and twig injury generally occur before injury to scaffold branches and trunks (5). The specific pattern of freeze injury may be related to differences in critical temperatures between various tree tissues, and differences in minimum temperatures to which tissues were exposed. High volume under-tree sprinkling can increase the minimum temperatures to which different tissues are exposed during a freeze (3) and decrease tree injury (4).

The objectives of this study were twofold: 1) to determine the effects of high volume under-tree sprinkling on leaf temperatures throughout the canopies of small and large citrus trees and 2) to relate thermal patterns throughout the canopy to tree damage and fruit pack-out.

Materials and Methods

Temperature measurements were made during freeze conditions on 15-year-old 'Orlando' tangelo trees on Cleopatra mandarin (*Citrus reticulata* Blanco) rootstock and 13-year-old 'Pell' navel orange trees on sour orange (*Citrus aurantium* L.) rootstock located at the University of Florida Horticultural Research Unit approximately 8 km (4.3 miles) northwest of Gainesville, FL. The tangelos were approximately 20 ft (6.1 m) tall and were located in a block of 100 trees on the northern border of a 2.8 acre (1.1 ha) planting. The navel trees were approximately 8 ft (2.4 m) tall and were located in a 1.4 acre (0.6 ha) block directly south of the tangelos. The eastern halves of both blocks were irrigated for cold protection with Senninger® pop-up sprinklers at a rate of 0.40-0.50 acre-inches/hr (0.41-0.51 cm-ha/hr). The western halves of both blocks were not irrigated and received no cold protection.

Temperatures were sensed on exterior leaves of irrigated and non-irrigated trees. Canopies were divided into upper, middle, and lower thirds. Leaf temperature data represent the average of measurements made on 3 trees in each block. Tree temperatures were sensed with a Barnes Instatherm infrared thermometer (series 14-220D). Air temperatures were measured at a 4.5 ft (1.4 m) height with a sheltered Taylor minimum temperature orchard thermometer located in each experimental block.

January 3, 1981. Irrigation was started at midnight when the air temperature was 27°F (−2.8°C) and terminated at 8 AM the following morning. Canopy and air temperatures

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were recorded at 2 hr. intervals throughout the night in irrigated and non-irrigated tangelo blocks.

January 13, 1981. Irrigation was started at 8 PM when air temperature was 22°F (—5.6°C) and continued until mid-morning the following day. Canopy and air temperatures were measured at 2 hr. intervals through the freeze, in irrigated and non-irrigated blocks of both cultivars; however, only 10 PM data are presented here.

Leaf and Twig Damage Determination

Prior to the freezes of 1981, leaves were counted and tagged on 10 irrigated and 10 non-irrigated 'Orlando' trees. A total of 300 leaves were tagged on each tree. Twenty-five leaves were counted on 4 different branches in the upper, middle and lower third of each canopy. Leaves were counted from the tip of a branch toward the trunk in all 12 locations. Damage was assessed as the percent leaf and twig survival in each third of the canopy. Evaluation of damage was made in late March when buds were breaking and the extent of twig dieback was obvious.

Fruit Pack-Out

Fifty fruit were harvested from the upper and lower section of the canopies of a random sample of irrigated and non-irrigated 'Orlando' tangelo trees on January 23, 1981. Fruit damage was determined immediately after harvest as described previously (11).

Results and Discussion

January 3. The effect of irrigation on 'Orlando' tangelo leaf temperature was mainly in temperature modification in the lower third of the canopy. In both irrigated and non-irrigated tangelo trees, the temperature decreased in the lower third of the canopy throughout the night and rose at dawn (Fig. 1). However, the minimum leaf temperature in the lower canopy of irrigated trees was 33.5°F (0.8°C); whereas, non-irrigated trees reached a minimum temperature of 28.7 (—1.6°C). Air temperatures were increased 4-5°F (2.2-2.8°C) by irrigation as previously observed (3).

Leaf temperatures in the middle and upper portions of the canopy were not greatly affected by irrigation and were comparable in irrigated and non-irrigated trees (Fig. 1). Decreasing temperature in the upper and middle canopy paralleled decreasing air temperature in non-irrigated trees. Upper and middle canopy temperatures of irrigated trees were below the air temperature recorded at a height of 4.5 ft (1.4 m) due to the increase in the latter from undertree sprinkling.

January 12. Leaf temperatures in the lower canopy of navel trees and 'Orlando' tangelo trees were higher in

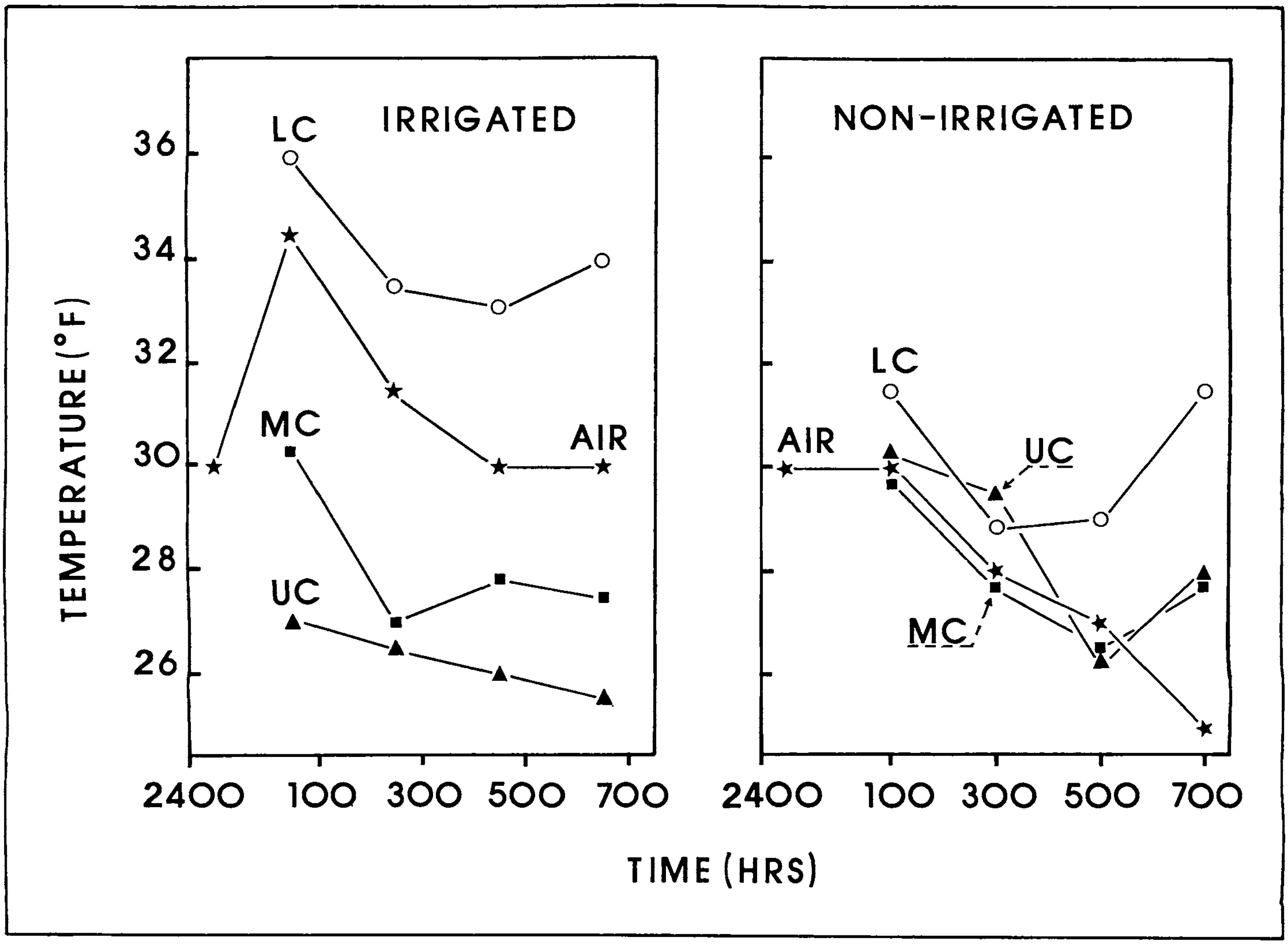

Fig. 1. Grove air temperature and leaf temperatures in 'Orlando' tangelo canopies during freeze of January 3, 1981. Data represent measurements made on 3 irrigated and 3 non-irrigated trees. LC = lower canopy, MC = middle canopy, UC = upper canopy.

the irrigated than non-irrigated blocks and remained above freezing (Figs. 2 & 3). Leaf temperatures generally decreased from the canopy base to the top. The temperature differences between the base and the top of irrigated small trees was 10°F (5.6°C). However, in large trees the difference was 15°F (8.4°C). Thus, under-tree sprinkling had its greatest effect on temperature in the lower canopy of both small and large trees, but increased leaf temperature over a greater percentage of the canopy surface in small trees.

Leaf, Twig, and Fruit Damage

Sixty-seven percent of the leaves survived the winter on irrigated trees, 47% of them in the lower canopies where leaf temperatures remained above freezing. Irrigation offered little protection to the middle third of the canopy and had no effect at the top of the canopy where leaf temperatures in non-irrigated and irrigated blocks were similar. Previous work has also shown that total leaf drop in citrus due to freeze injury was reduced from 20.2% to 11.5% with under-tree sprinkling, although the percentage leaf drop in specific canopy locations was not determined (4).

Eighty-five percent of twigs in the upper third of irrigated canopies survived while only 33% of the twigs in non-irrigated upper canopies survived (Table 1). There was little protection afforded twigs in the middle third of the canopy and freeze injury to wood in the lower canopy was the same in irrigated and non-irrigated trees.

Leaf counts were only of academic importance for the navel orange block. Very few trees survived in the non-irrigated block as air temperature reached 9°F (—12.8°C). There was considerable leaf mortality in the upper third of the irrigated block with a minimum air temperature of 16°F (—8.9°C), but all of the trees showed evidence of new growth by late March and many trees produced a crop in 1981. Air temperature for the irrigated block averaged 16°F (—8.9°C).

Fruit pack-out was marginally better in the irrigated block but damage to fruit was, however, strongly related to position on the tree (Table 2). In both irrigated and non-irrigated trees, more fruit with no damage, and fewer fruit eliminations were harvested from the bottom half of the canopy of both irrigated and non-irrigated trees. Davies *et al.* (4) also found under-tree sprinkling improved fruit pack-out. However, they (4) did not evaluate fruit damage in relation to canopy position. Thus, the relative importance of canopy position, fruit temperature, and irrigation to fruit damage may be difficult to separate in the 2 studies.

High volume under-tree sprinkling provides effective cold protection for 'Orlando' tangelo and navel orange trees. The increase in air temperature resulting from under-tree sprinkling resulted in less radiation heat loss from irrigated than non-irrigated trees during the winter of 1981. Leaf temperatures were increased in the canopies of irrigated trees resulting in less freeze damage to irrigated trees especially in the lower canopies where leaf temperatures were maintained above freezing. There was a 13°F (7.3°C) increase in leaf temperature in the lower canopy of irrigated trees as compared to the lower canopy of non-irrigated trees. Leaf temperatures in the upper portions of tangelo trees were not increased by under-tree sprinkling. There was a slight increase in leaf temperature in the upper portions of irrigated navel orange trees. Leaf survival was highest in the lower third of irrigated canopies where leaf temperatures were highest.

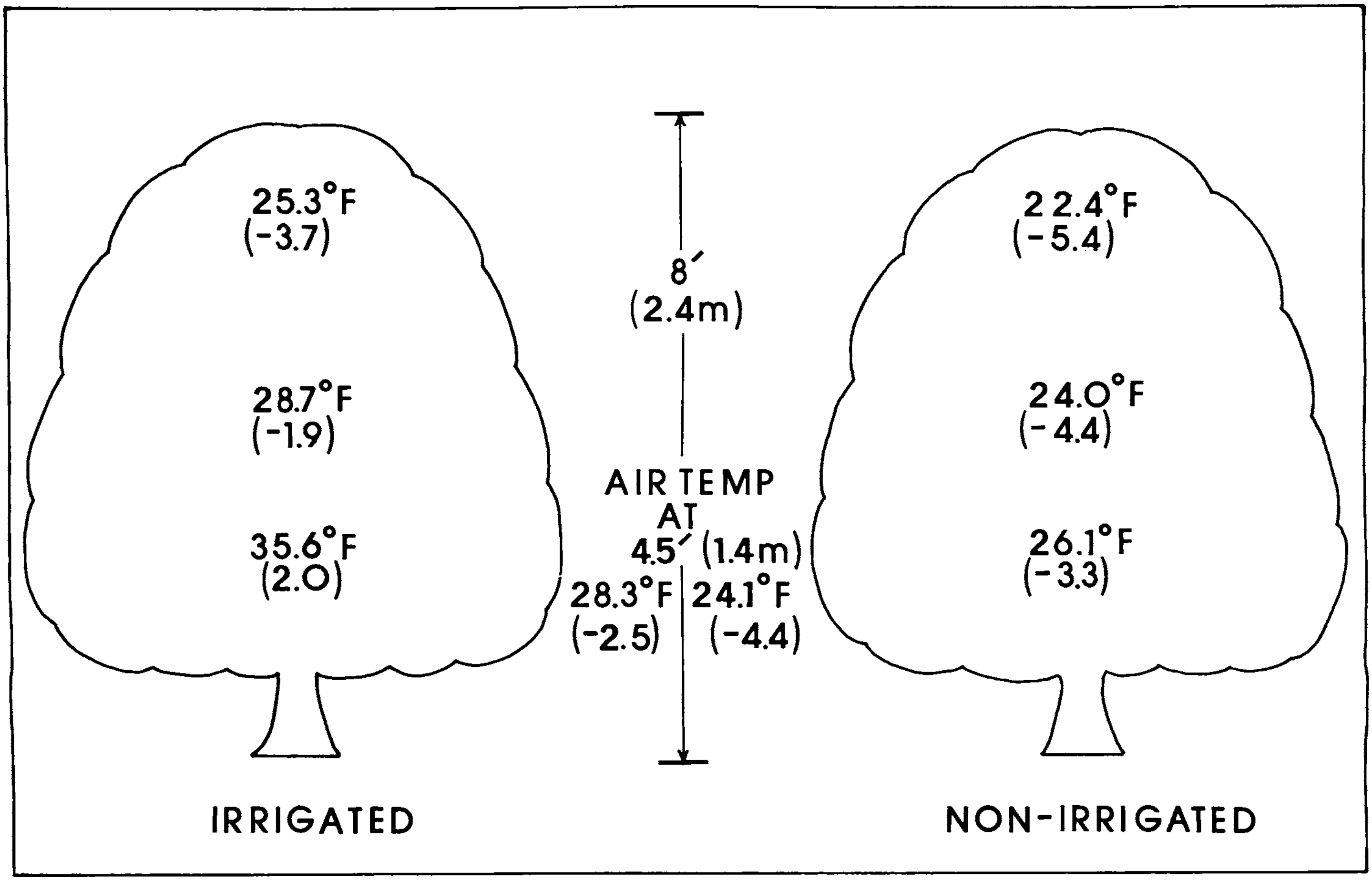

Fig. 2. The effect of irrigation on canopy temperatures in 8 ft (2.4 m) 'Pell' navel orange trees. Data represent measurements made on 3 irrigated and 3 non-irrigated trees during the night of January 12, 1981.

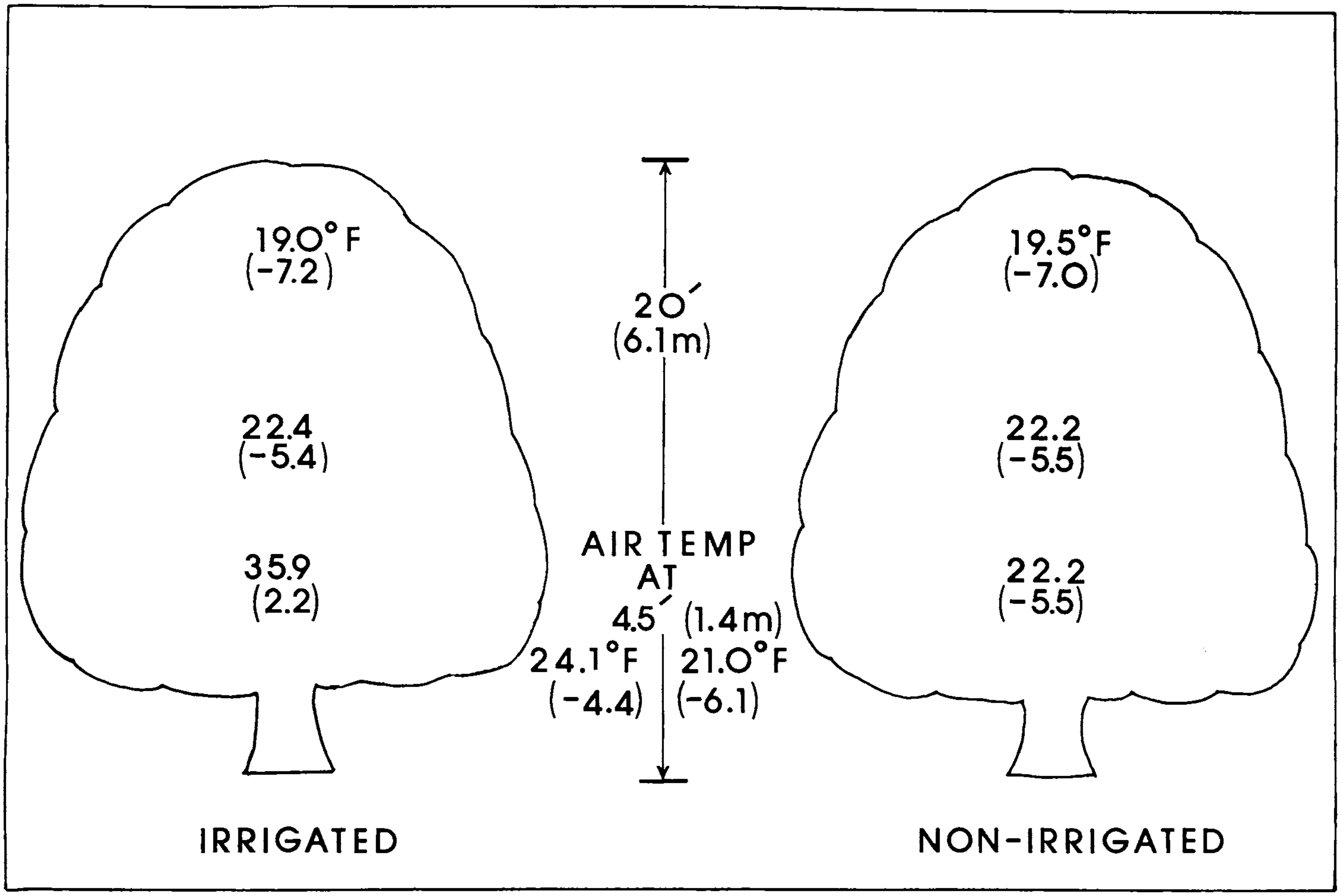

Fig. 3. The effect of irrigation on canopy temperatures in 20 ft (6.1 m) 'Orlando' tangelo trees. Data represent measurements made on 3 irrigated and 3 non-irrigated trees during the night of January 12, 1981.

Table 1. Leaf and twig survival in irrigated and non-irrigated 'Orlando' trees following the 1981 freezes.

	Leaf Survival[z] (%) Lower Canopy	Middle Canopy	Upper Canopy
Non-irrigated	0	0	0
Irrigated	47	19	1
	Twig Survival[x] (%) Lower Canopy	Middle Canopy	Upper Canopy
Non-irrigated	73	50	85
Irrigated	73	68	33

[z]Based on 100 leaves tagged in the lower, middle and upper thirds of the canopy. Initial leaf count was made prior to freezing temperatures. Percent survival determined in late March, 1981.
[x]Based on 4 twigs tagged in the lower, middle and upper thirds of the canopy. Initial twig count made prior to freezing temperatures. Percent survival determined in late March, 1981.

Although leaves in the upper canopy were not protected by irrigation, twig survival in this area of irrigated trees was greater than in non-irrigated trees. Twigs generally remain warmer than leaves under freeze conditions and upper *canopy twigs* were probably warmer than recorded leaf temperatures due to their greater mass and the insulating properties of the surrounding leaves. Thus, leaves in the upper canopy probably reached a critical minimum temperature but twigs remained above their critical level. Similarly, the equal percent of twig survival in lower canopies of irrigated and non-irrigated canopies is probably attributable to the fact that non-irrigated lower twigs were warmer than non-irrigated leaves and were insulated from radiation heat loss by surrounding leaves. Irrigation provided slight protection to twigs in the middle portion of the canopy.

Table 2. Effect of irrigation on pack-out of 'Orlando' tangelo fruit following the January freezes of 1981.[z]

	No damage (%)	US #1 (%)	US #2 (%)	Eliminations (%)
Non-irrigated				
Canopy top	0	52	28	20
Canopy bottom	22	58	16	4
Irrigated				
Canopy top	4	56	26	14
Canopy bottom	32	40	24	4

[z]Based on a random sample of 50 fruit from the irrigated and non-irrigated block.

Temperature patterns are similar in the canopies of large and small trees. However, high volume under-tree sprinkling results in increased leaf temperature in a larger proportion of the canopy of small trees and consequently appears more effective when used under small trees.

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EVALUATION OF SEVERAL TREE WRAPS ON CITRUS[1]

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Abstract. **Growers have been using a number of different wraps to protect young citrus trees from cold damage. Field observations indicate differences in effectiveness of the various wraps on the market. A field study of seven wraps was conducted over two seasons to determine their effectiveness in protecting young citrus trees during freezing conditions. Also observed was wrap resistance to weathering, ease of installation, effect on the tree during hot weather, and their ability to control sprouts. During the first year of the test, temperatures under the wraps were measured and recorded hourly for 30 days. During the 1980-81 winter ambient air temperatures of 12°F to 14°F were experienced. As a result extensive damage occurred and the wraps were evaluated on the basis of tree damage. Five of the wraps did a satisfactory job of protecting the trees while two did not.**

Widespread use of various tree wraps has stimulated a number of questions regarding the effectiveness, durability and desirability of this method of protecting young trees. This test was conducted to evaluate several new wraps, comparing them to soil banks and previously tested wraps (1, 2, 3, 4), for effectiveness in cold protection. In addition to this primary objective the wraps were evaluated for durability, sprout inhibition, ease of installation and possible adverse tree effects such as bark sloughing, foot rot, sun scaling, and ant activity.

Materials and Methods

The field study was begun during the fall of 1979. Wraps were placed on the trees prior to the winter season. One year old Dancy tangerines (*Citrus, reticulata,* Blanco) on Cleopatra mandarin (*C. reticulata,* Blanco) and Nova tangelos (*C. reticulata* X *C. paradisi*) X *C. reticulata* on sour orange (*C. aurantium* L.) were selected in an area just north of Astatula, Florida. The entire area had a past history of low minimum temperatures with only the hardiest of citrus varieties surviving.

Various wraps were tested the first season with the soil bank as the standard used for comparison (Table 1). Care was taken to have the bank the same height as the wraps. An unprotected check was also included. Each of the 9 treatments was replicated 9 times giving a total of 81 trees in the study.

Table 1. Tree wrap treatments.

1.	Soil bank
2.	Fiberglass — 3 inch foil-backed held in place with 1 inch mesh wire
3.	Polyurethane foam—1 inch foam without skin, wrapped approximately 3 times around tree
4.	Polyurethane foam—1 inch foam with a protective skin, wrapped 3 times around tree
5.	Reese Clip-On®—a rigid two section styrofoam structure with water bags attached to each half and clipped onto trees
6.	Reese Clip-On®—as above without water bags
7.	Micro-foam—1/8 inch thick flexible sheet of insulating material wrapped approximately 8 times around trees
8.	Polyethylene—translucent sheets approximately 1/4 inch thick wrapped 4 times around trees
9.	Check—no protection

From January 24, 1980 until February 27, 1980 trunk temperatures were recorded for two replications at hourly intervals 24 hours per day. Thermistors, connected to a Grant recorder, were taped to the trunk 4 inches above the union and temperatures were recorded on tape for computer analysis. The summer of 1980 could best be described as hot and dry, while the winter was colder than normal with minimum temperatures reaching record lows. In 1980-81 temperatures were monitored on grove thermometers in the area. Since extensive damage occurred, three measurements were taken to determine tree condition. The trunk circumference just above the bud-union, the circumference of the smallest live limb, and the height of the tree after pruning were measured. The results of all three are shown in Tables 2, 3, 4.

Results and Discussion

During the winter of 1979-80 minimum temperatures dropped to the mid-twenties on several occasions, with a

[1]Appreciation is extended to Dr. George Yelenosky, USDA, Orlando, FL for help in measuring temperatures.