

# Temperature Modification in Citrus Trees Through the Use of Low-volume Irrigation

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**Abstract.** Low-volume sprinkler irrigation increased the mean trunk, mean scaffold limb, and mean canopy temperature 4.6°, 0.6°, and 0.8°C, respectively, higher than the nonirrigated trees of 'Washington Navel' orange (*Citrus sinensis*). Similar results were obtained with 'Owari' satsuma (*Citrus unshiu*) trees in that the mean trunk, mean scaffold limb, and mean canopy temperature was increased 3.9°, 1.7°, and 0.9°, respectively, higher than the nonirrigated trees. These results lend support that scaffold branch irrigation is effective as a method of freeze protection.

Recently, a great deal of emphasis has been placed on the use of microsprinklers for citrus freeze protection (1-4, 6-16). Scaffold branch irrigation can be used to enhance tree survival and reduce the severity of tree damage when exposed to a severe freeze (1).

Wilcox and Davies (16) reported that leaf temperatures in the lower canopy of high-volume irrigated trees were as much as 7.3°C greater than those in nonirrigated trees. Buchanan et al. (3) showed that high-volume sprinklers increased leaf temperature as much as 3.8°, while low-volume irrigation increased leaf temperature 1.5° to 3°. Leaf temperature for sprinkler-irrigated trees averaged 1.1° to 2.2° higher than for nonirrigated trees (4, 5). Davies (4) stated that high-volume sprinklers provided a 0.5° to 1.1° increase in leaf temperature even during a severe advective freeze. Microsprinkler irrigation maintained leaf temperature 1.1° higher than nonirrigated trees at a height of about 1 m above the ground surface (13). Parsons et al. (14) reported that leaf and trunk temperatures in the direct water spray frequently were 6.1° to 7.8° warmer than those in the nonirrigated area. Davies et al. (6) stated that low-volume undertree irrigation maintained trunk temperature above or near -1.1° when air temperature reached a minimum of -9.4°.

Parsons et al. (15) showed that air tem-

perature was generally 0.5° to 1.5°C warmer (range = 0° to 2.8°) in an irrigated area above the spray zone than in the nonirrigated area. Harrison and Smajstrla (7) also showed that undertree irrigation of an entire grove resulted in a temperature rise of up to 3.3° to 3.9°, compared with adjacent nonirrigated areas.

The objective of this study was to determine the effectiveness of microsprinkler irrigation in elevating temperature at key locations on the tree and to determine to what extent the temperature would be increased.

Temperature measurements were made during freeze conditions on 25 Dec. 1985 on young 'Washington Navel' orange and 'Owari' satsuma trees on *Poncirus trifoliata* 'Rubidoux' rootstock located at the LSU Citrus Research Station. The test trees were 1

to 1.5 m tall and 1 to 2 years of age and spaced 6.1 × 7.6 m apart. Remote temperature sensing was accomplished through the use of a Campbell Scientific 21X micrologger located 13 m from test trees. Copper-constantan (24-gauge) thermocouples were used to monitor the temperature at three locations on each tree: i.e., a) bud union or trunk (15-20 cm above soil surface), b) scaffold limb (0.5 m above soil surface), c) canopy or leaf (0.75 m above soil surface) and an ambient air temperature (1.2 m above soil surface) at the micrologger station. The irrigated trees did receive water spray at each location of the thermocoupler. Temperature measurements were made every 15 min and stored on tape throughout the duration of the test.

Two micrologger sites ≈40 m apart were installed, one for 'Washington Navel' orange, the other for 'Owari' satsuma trees. Freeze-protected or irrigated trees were equipped with a Senninger 360° Super Spray sprinkler with a #5 tip, [1.99 mm (5/64") diameter opening] and a smooth, flat deflector, which is capable of applying 1.9 liters·min<sup>-1</sup> (30.1 gal/hr) at 69 kPa (10 psi) and delivering a spray pattern of 2.1 m around each tree. Two 'Washington Navel' orange and two 'Owari' satsuma trees adjacent to other freeze-protected trees were protected (irrigated) and two of each cultivar adjacent to an area of no freeze protection were non-protected (nonirrigated).

Irrigation on the protected trees was begun when the air temperature on the evening of 25 Dec. 1985 reached about ≈ -1.4°C, or 10:30 PM, and the system remained on until the ambient air temperature was well above freezing.

The effect of scaffold branch irrigation on trunk temperature of 'Washington Navel' orange trees is shown in Fig. 1. Sprinkler irrigation for freeze protection significantly increased the trunk temperature of 'Washington Navel' orange and 'Owari' satsuma trees when compared with the trunk temper-

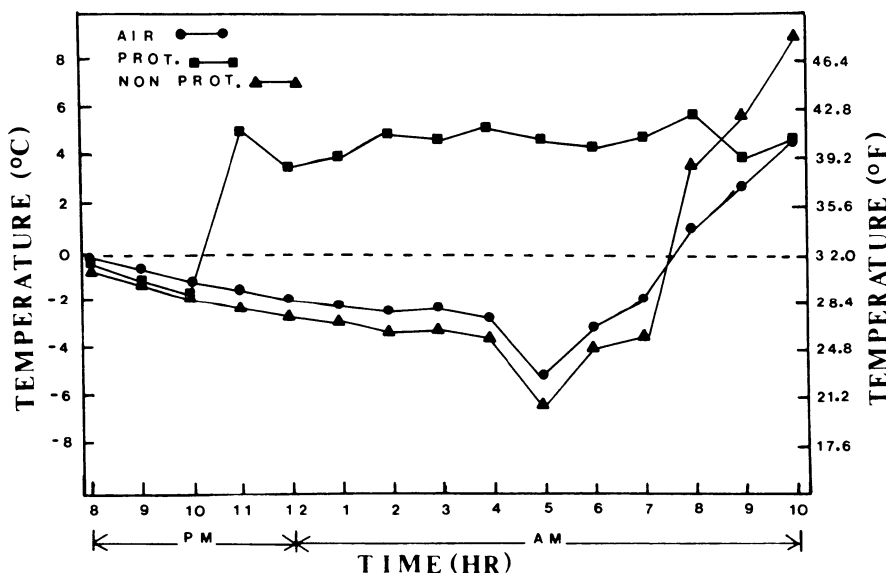


Fig. 1. The effect of irrigation on trunk temperature of young 'Washington Navel' orange trees during exposure to -5.1°C. Data represent measurements made on two protected and two nonprotected trees the night of 25 Dec. 1985. (LSD, 0.05 = 0.38)

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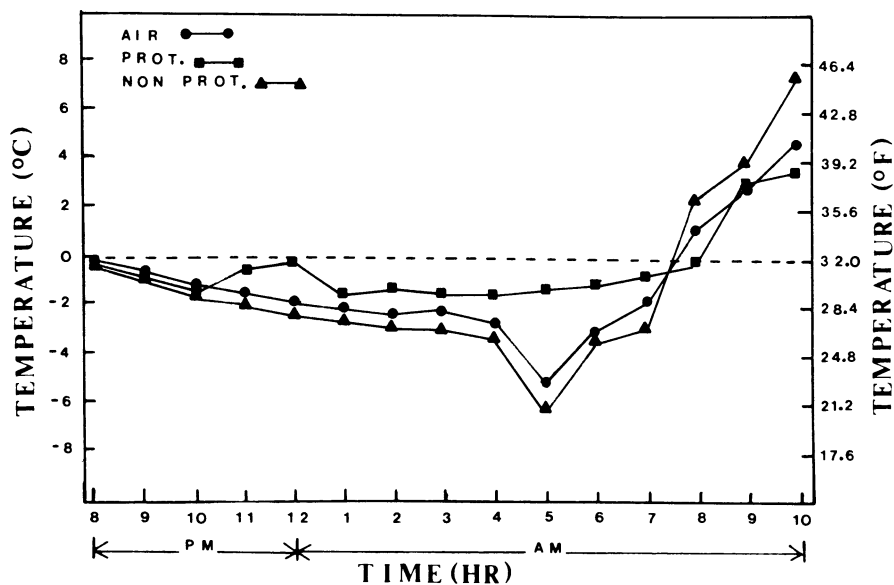


Fig. 2. The effect of irrigation on scaffold limb temperature of young 'Washington Navel' orange trees during exposure to  $-5.1^{\circ}\text{C}$ . Data represent measurements made on two protected and two nonprotected trees the night of 25 Dec. 1985. (LSD, 0.05 = 0.67)

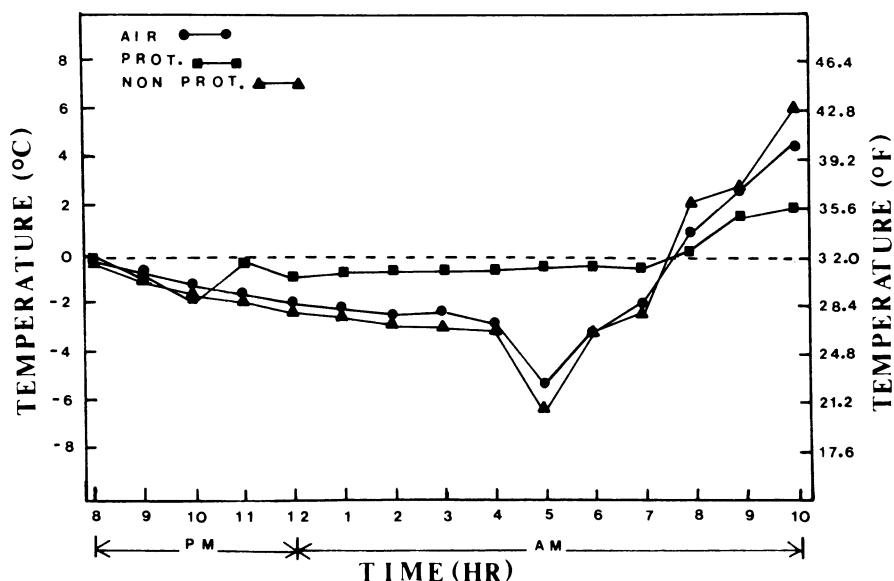


Fig. 3. The effect of irrigation on canopy temperature of young 'Washington Navel' orange trees during exposure to  $-5.1^{\circ}\text{C}$ . Data represent measurements made on two protected and two nonprotected trees the night of 25 Dec. 1985. (LSD, 0.05 = 0.27)

ature of nonirrigated trees and the ambient air temperature. Sprinkler irrigation increased the mean trunk temperature (consist of 34 repeated observations) of 'Washington Navel' oranges  $4.6^{\circ}\text{C}$  higher than the mean trunk temperature of the nonirrigated or nonprotected treatment, which was  $4.3^{\circ}$  higher than the mean ambient air temperature. The mean trunk temperature of 'Owari' satsuma was  $3.9^{\circ}$  higher than the mean trunk temperature of the nonirrigated treatment and was  $3.3^{\circ}$  higher than the mean ambient air temperature. There was no significant differences between the trunk temperature of the nonirrigated trees of either cultivar and the ambient air temperature. The trunk temperature of the nonirrigated 'Washington Navel' and 'Owari' satsuma trees was consistently lower than the ambient air temperature during the freeze.

Sprinkler irrigation significantly increased the scaffold limb temperature of 'Washing-

ton Navel' orange trees when compared with the nonirrigated treatment and the ambient air temperature (Fig. 2). The mean scaffold limb temperature of 'Washington Navel' orange was  $0.6^{\circ}\text{C}$  higher than the mean scaffold limb temperature of the nonirrigated treatment and was  $0.3^{\circ}$  higher than the mean ambient air temperature. The mean scaffold limb temperature of 'Owari' satsuma was  $1.7^{\circ}$  higher than the mean scaffold limb temperature of the nonirrigated treatment, and was  $1.3^{\circ}$  higher than the mean ambient air temperature. There were no significant differences between the scaffold limb temperature of the nonirrigated trees of 'Washington Navel' and 'Owari' satsuma and the ambient air temperature. The scaffold limb temperature of the nonirrigated trees of 'Washington Navel' and 'Owari' satsuma again showed a pattern equal to or lower than the ambient air temperature. No limb breakage was observed during the test period on either the

'Washington Navel' or 'Owari' satsuma trees.

Fig. 3 represents the effect of scaffold branch irrigation on canopy temperature of 'Washington Navel' orange trees. Sprinkler irrigation significantly increased the canopy temperature in the sprayed area of 'Washington Navel' and 'Owari' satsuma when compared with the nonirrigated treatment and the ambient air temperature. The mean canopy temperature of 'Washington Navel' was  $0.8^{\circ}\text{C}$  higher than the mean canopy temperature of the nonirrigated treatment and the mean ambient air temperature. The mean canopy temperature of 'Owari' satsuma was  $0.9^{\circ}$  higher than the mean canopy temperature of the nonirrigated treatment, and was  $0.8^{\circ}$  higher than the mean ambient temperature. There were no significant differences between the canopy temperature of the nonirrigated trees of either 'Washington Navel' or 'Owari' satsuma and the ambient air temperature. The nonirrigated trees again showed a pattern of equal or lower canopy temperature when compared with the ambient air temperature.

The results obtained indicate that the use of scaffold branch irrigation did modify the temperature at various locations in the citrus tree. The increase was of such a level as to offer protection to citrus trees during the advent of a freeze. Even though the 25 Dec. 1985 freeze was not as severe as several past freezes, the use of scaffold branch irrigation did maintain temperatures well above or just below freezing at the trunk, scaffold, and canopy in both 'Washington Navel' orange and 'Owari' satsuma trees.

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## Mechanical Harvest of Red Raspberry as Affected by Training Systems

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**Abstract.** Red raspberry (*Rubus idaeus* L, cv. Meeker) was grown with either 3-m or alternate 3-m and 1.5-m between-row spacing. Canes were trained as: a) pruned upright bundles, b) pruned and individually woven canes, or c) unpruned looped bundles, all secured to wires 1.5 m high. Training did not consistently affect yield as obtained with a Littau mechanical harvester. Fruit size was smallest in the unpruned bundles. The amount of fruit that dropped between or during harvests was substantial, but was similar for row spacings and training systems.

The 4.5 to 5.5 t·ha<sup>-1</sup> average annual yield of red raspberries in Oregon is below the crop potential (3) for the Meeker cultivar. Researchers and growers have experimented with training systems (4, 13), pruning techniques (1, 9, 12), and soil fertility (5, 10), and studied the effects of such treatments on plant population density, cane diameter, bud number, budbreak, berries per cluster, and their relationship to yield (8, 14). Many factors (cane population, fruits/lateral, fruit size) contribute to variations in yield, often compensating for each other (6, 7, 11). Characteristics that consistently and predictably relate to yield from mechanical harvesting and cultural practices that minimize fruit loss have not been identified.

High-density planting is one practice that may increase red raspberry yield. The harvesting machine will operate successfully in closed-space rows; thus, higher than normal cane density may be established and harvested. There is little information on plant response to high density. These studies determined the effect of cane population and training system on plant and fruit characteristics and efficiency of mechanical harvesting.

The red raspberry, ('Meeker') was established in two adjacent plantings at North

Willamette Experiment Station (Aurora, Ore.) in 1980, one with 3 m between rows (standard) and the second with alternate 1.5 m and 3 m between rows (modified). Each plot consisted of one hedgerow 30 m long. Within a given area, the modified planting contained 33% more individual rows than the standard. A Littau mechanical harvester was operated in the 3-m between-row spaces.

The Littau harvester is a self-propelled over-the-row machine. Fruits are dislodged by flailing rods that pass along both sides of the row and transmit the shaking action throughout the plant. Detached fruits drop to spring-loaded overlapping catch plates, then roll onto pocket belt conveyors that move the fruit through a pneumatic cleaner onto an inspection belt and into containers.

Three training systems were compared: a) upright bundles pruned to 1.8 m, b) individually woven canes pruned to 1.8 m, and c) looped bundles of unpruned canes 1.8-2.4 m. All canes, individual or bundled, were secured to a wire 1.5 m from the ground. Plots were replicated three times in each planting.

Fruit yield and size and cane number/plot were recorded for all treatment combinations. A random sample of 10 canes/plot was used to estimate cane diameter, bud number/60-cm cane midsection, fruiting laterals/60-cm section, and fruits/lateral (one lateral 45 cm from base) for the woven system in 1982 and 1983. In 1984 and 1985, data were taken on all three training systems. In 1984, 5-m sections of each plot were gleaned for dropped fruit after each harvest. In 1985, dropped fruit was gleaned immediately before harvest

and immediately after harvest to identify loss occurring in the interval between harvests and loss during harvest.

Harvest data and cane measurements were subjected to two-way analysis of variance in comparisons of training methods. Correlation coefficients (*r* values) were calculated for identifying relationships between harvest data and cane characteristics. Because the two-row spacings actually constituted independent experiments, the yields and cane numbers from the standard and modified plantings were compared using paired *t* tests each year.

Training method did not affect mechanically harvested yield in the modified planting (Table 1). In the standard planting, differences in yield were attributable to training method only in 1983 and 1984. Differences in fruit size, when present, showed that canes in looped bundles produced the smallest fruit (Table 1). The small fruits in terminal clusters of the unpruned canes apparently reduced the average berry size in this treatment, a practical consideration in hand picking but of little importance when machine picking.

The inconsistent production of woven plots with evenly spaced canes with the buds well-exposed to light is explained in that woven plots generally had significantly fewer trainable canes/m<sup>2</sup> than upright or looped plots (Table 1). All canes too short to reach the training wire or too delicate to support an adjacent cane were removed at training. The upright bundle training system allowed for the retention of marginally acceptable canes, since even the smallest canes not long enough for looping could be secured in a bundle with other canes.

The population of trained canes is the factor most consistently associated with yield. Yield/m<sup>2</sup> was correlated with canes/m<sup>2</sup> in 1982, 1983, and 1984 (*r* = 0.649, 0.501, and 0.706, respectively). Yield/m<sup>2</sup> was correlated with cane diameter (*r* = 0.716) only in 1983. In 1982 and 1983, number of buds/60-cm cane section was negatively correlated with yield (*r* = -0.623 and -0.584). Other plant characteristics measured had no significant relationship to yield.

Plant competition for light, water, and nutrients may, in part, explain the failure of the modified row spacing to increase yield in proportion to the increase in cane population (Table 2). Despite significantly greater number of canes in the modified planting (Table 2) and the correlation of cane population and yield (prior), yield in the modified planting was greater only in 1984 (Table 2).

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