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Air Temperatures within a Florida Citrus Grove Using Microsprinkler Irrigation for Cold Protection

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Microsprinkler irrigation is used extensively in Florida citrus groves as a method to protect mature and young trees from freezing temperatures. Historically studies have documented the effectiveness of this cold protection methodology to protect young citrus trees from freeze damage. However, limited information exists on the effectiveness of under-tree microsprinkler irrigation for freeze protection of mature citrus trees. This project documents the effect of under-tree microsprinkler irrigation for freeze protection during the freeze of 13 Dec. through 16 Dec. 2010 in a central Florida citrus grove. Under advective freeze conditions with microsprinkler irrigation, air temperatures were similar within the grove, within the citrus tree canopy, and outside the grove. During radiation freeze, conditions with microsprinkler irrigation air temperatures within the citrus tree canopy were up to 4 °F warmer than those outside the grove.

In Florida, microsprinkler irrigation is used extensively for citrus tree cold protection. Early studies looked at the effectiveness of this cold protection method to protect young citrus trees from freeze damage. Additional studies examined the effectiveness of microsprinkler and under-tree high volume irrigation on mature citrus trees and found that there was little modification of the mature citrus tree microclimate above the lower tree canopy using this methodology(Wilcox and Davies, 1981). However, growers' observations indicate that under certain conditions microsprinkler irrigation does provide a significant benefit in freeze protection when compared to adjacent trees without microsprinkler irrigation. Currently little information exists to document the positive effect of microsprinkler irrigation on the microclimate of mature citrus trees. This study was undertaken to document if there is a modification of the mature citrus tree microclimate using microsprinkler irrigation under specific freeze conditions.

Materials and Methods

The study was conducted in a research grove of 'Valencia' (*Citrus sinensis*) orange scion on Carrizo citrange (*Citrus sinensis* × *Poncirus trifoliata*) rootstock located at the Mid-Florida Citrus Foundation in Avalon, FL. The grove was planted in 2000 at a spacing of 25 × 12.5 ft for a total tree density of 139 trees per acre. Trees had formed a hedgerow with rows oriented in a north–south direction for a total of 25 grove acres. Irrigation was provided by one microsprinkler emitter per tree (Plastro Irrigation Systems Ltd., Gvat, Israel) delivering a flow rate of 17 gal per hour per emitter for a total per acre flow rate of 2,363 gal per hour per acre.

Two, 25-ft towers were erected to measure temperature, humidity, wind speed, and wind direction. These two towers were located outside the grove on the north and southeast sides in an open, exposed grassy field. Weather instrumentation on these towers consisted of temperature, wind speed, and wind direction at the 25-ft level, and temperature, humidity, and wind speed at the 5-ft level on each tower.

A total of four (H21-002), four-channel Hobo microstation data loggers (Onset Computer Corp.; http://www.onsetcomp.com/) were used to record outside tower weather data. Two Onset (S-WCA-M003) anemometer and direction sensors were used for measuring wind speed and direction at the 25-ft height, and two Onset (S-WSA-M003) anemometer sensors were used to measure wind speed at the 5-ft height. Two Onset (S-THB-M002) 12-bit temperature/relative humidity smart sensors were also used to measure air temperature and humidity outside the grove at the 5-ft height. Air temperature at the 25-ft height was measured using two Onset (S-TMB-M002) 12-bit temperature smart sensors.

Two additional 20-ft towers were erected in the interior of the block, in-row, at an existing missing tree space. One interior tower was in the geographical center of the grove with the second tower located in the center of the southeast quadrant of the grove. Weather instrumentation on these 20-ft towers consisted of wind speed at the 5-ft and 20-ft levels.

A total of two (H21-002) four-channel Hobo micro station data loggers (Onset Computer Corp.) were used to record inside tower wind data. Wind speed was measured using four Onset (S-WSA-M003) anemometer sensors at 5-ft and 20-ft heights.

Citrus tree canopy air temperature measurements were made at a tree adjacent to one interior tower at heights of 4 and 8 ft within the citrus tree canopy and at the outside edge of the tree

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Table 1. Average and minimum nightly air temperatures within the citrus tree canopy from 1745 to 0830 HR.

	Inside tree canopy (°F)						Edge of tree canopy (°F)			
Date	4 ft avg	4 ft min	8 ft avg	8 ft min	4 ft avg	4 ft min	4 ft avg	4 ft min	6 ft avg	6 ft min
13 Dec.	31	25	31	25	31	26	31	25	31	26
14 Dec.	30	26	30	27	31	27	30	26	30	27
15 Dec.	36	33	37	33	36	32	36	33	37	33

canopy underneath a skyward exposed citrus leaf at 4- and 6-ft levels. A second set of canopy air temperatures were measured at the other interior tower at a 4-foot level within the tree canopy.

Canopy air temperatures were measured using five (U10-001) Hobo single-channel temperature data loggers. The weather data were recorded at 15-min intervals from 13 to 16 Dec. 2010.

Results and Discussion

Air temperature measurements within the canopies of mature citrus trees were consistently similar for all three nights of the study (Table 1). The average nightly air temperature within the citrus tree canopy was within the accuracy range of the data loggers used in this study. On 13 Dec. 2010 with microsprinkler irrigation the nightly average air temperature was 31 °F at 4 and 8 ft above the microsprinkler and at the 4- and 6-ft levels at the canopy edge. The minimum temperatures at all levels within the canopy were similar at all locations ranging from 25 to 26 °F. This is consistent with the expectation that during advective freeze conditions wind velocities are elevated for the duration of the night. This persistent wind resulted in a mixing of the air throughout the citrus tree canopy resulting in similar canopy temperatures. On 14 Dec. 2010 the wind velocities were significantly lower resulting in radiational freeze conditions. With microsprinkler irrigation nightly average air temperatures within the citrus tree canopy, regardless of location, ranged from 30 to 31 °F. The minimum temperature at all levels within the citrus tree canopy ranged from 26 to 27 °F. On 15 Dec. 2010 radiational freeze conditions existed where wind velocities were lower than the previous night (14 Dec.) although the minimum temperatures were not as low. That nightly average air temperature ranged from 36 to 37 °F regardless of position within the citrus tree canopy and the minimum temperature ranged from 32 to 33 °F. Based on this information it appeared that air temperatures at those levels within a citrus tree canopy under microsprinkler irrigation were similar over all three nights.

Table 2. Average nightly wind velocity inside and outside a citrus grove from 1745 to 0830 HR.

	Inside towers (mph)		Outside towers (mph)	
Date	5 ft level	20 ft level	5 ft level	25 ft level
13 Dec.	0	8.2	4.9	10.3
14 Dec.	0	1.3	0.1	3.5
15 Dec.	0	0.4	0.1	1.9

Wind velocities were also measured for the three nights of the study. Wind velocity measurements were taken at the 5-ft and 25-ft level outside the grove in an open field and at the 5- and 20-ft levels inside the grove. The 20-ft level anemometer inside the grove extended approximately 5 ft above the top of the citrus tree canopy. On the night of 13 Dec., under advective freeze conditions, the average wind velocities were between 0 and 10.3 mph depending on the location of the anemometer. The lowest average wind velocity was measured at the 5-ft level inside the grove followed by the 5-ft level outside the grove. The highest wind velocities were recorded at the 20- and 25-ft levels regardless of location (Table 2). This trend was consistent during all three nights of the study. On the nights of 14 Dec. and 15 Dec. wind velocities, under radiational freeze conditions, were lower at the 5- and 25-ft level outside the grove and at the 20-ft level within the grove. At the 5-ft level inside the grove the average wind velocity remained at 0 mph for all three nights.

On the night of 13 Dec. a comparison of the average canopy air temperature was made with the average outside air temperature at the 5-ft level, which is the standard height of a National Weather Service air temperature measurement. The average nightly air temperature was similar to the temperature within the citrus tree canopy (Table 3). The average nightly air temperature was 31.3 °F compared to 31.1 °F within the citrus tree canopy. The temperature trace for 13 Dec. for within the citrus tree canopy and air temperature indicates that these temperatures were similar throughout the night (Fig. 1a). The wind velocity profile for that night indicates that the winds at all but the inside grove 5-ft level

Table 3. Average nightly air temperatures from 17:45 to 08:30 HR.

	Date					
Avg nightly air temp (°F)	13 Dec.		14 Dec.		15 Dec.	
Canopy temp	Inside	Edge	Inside	Edge	Inside	Edge
	31.0	31.2	30.4	30.0	36.3	36.5
Outside temp	5 (ft)	25 (ft)	5 (ft)	25 (ft)	5 (ft)	25 (ft)
	31.3	32.3	28.5	33.2	34.4	40.9
Inside and outside the grove	Inside	Outside	Inside	Outside	Inside	Outside
	31.1	31.3	30.2	28.5	36.3	34.4
Difference between inside canopy and outside at 5 ft	Inside		Inside		Inside	
	–0.2		+1.7		+2.0	

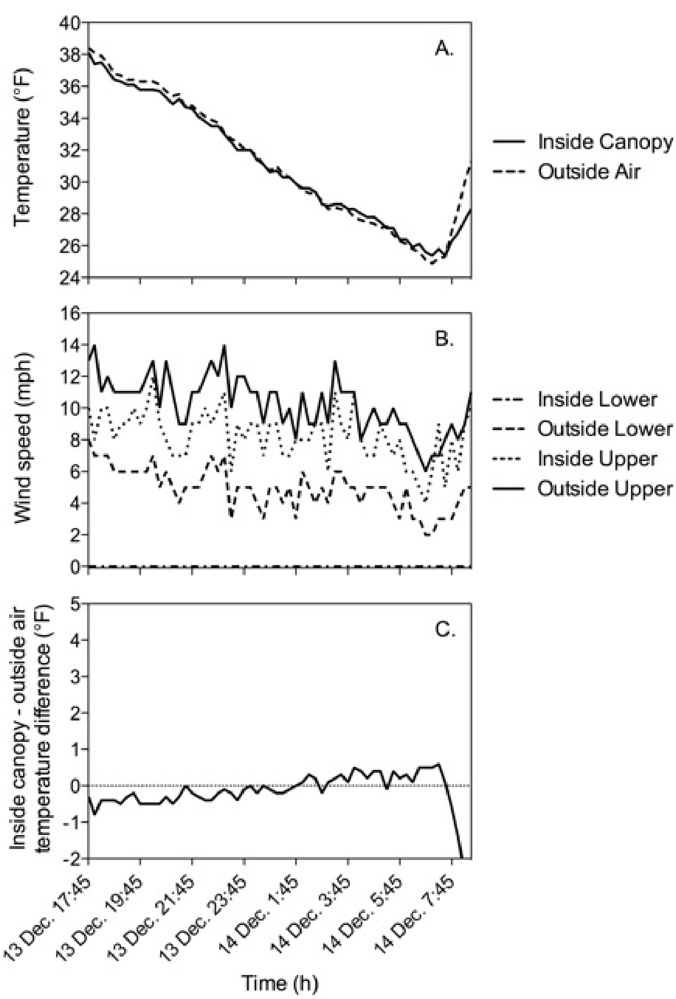

Fig 1. (**A**) Inside canopy and outside air temperatures, (**B**) wind velocities inside and outside grove, and (**C**) temperature difference between inside citrus tree canopy and outside grove air temperature from 13 Dec. 17:45 to 14 Dec. 08:30 HR.

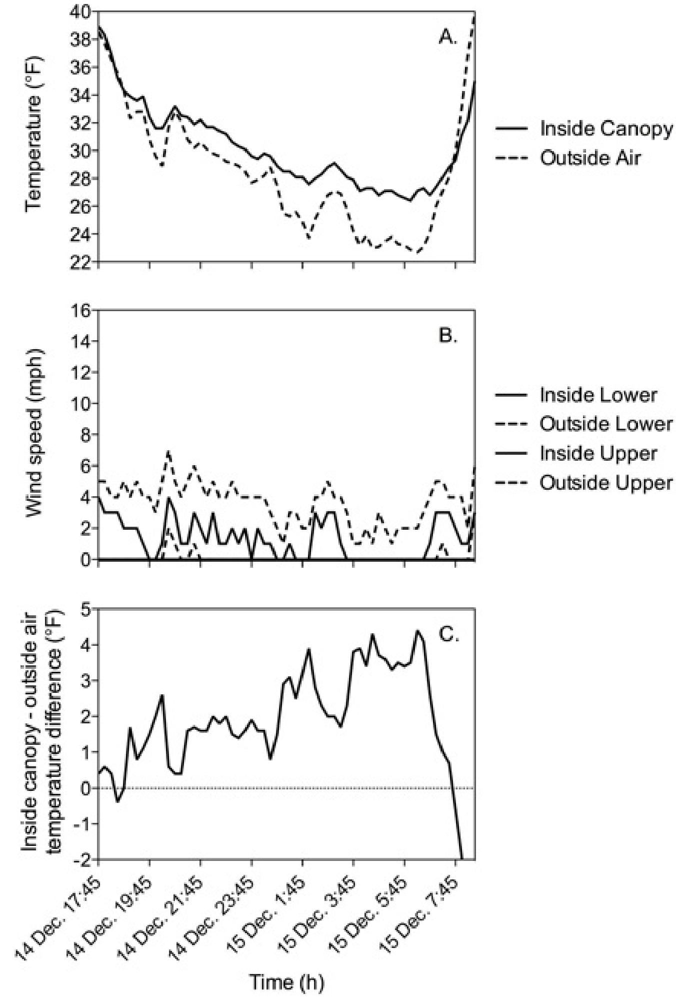

Fig 2. (**A**) Inside canopy and outside air temperatures, (**B**) wind velocities inside and outside grove, and (**C**) temperature difference between inside citrus tree canopy and outside grove air temperature from 14 Dec. 17:45 to 15 Dec. 08:30 HR.

measurement were elevated throughout the night (Fig. 1b). This mixing of air held air temperatures within the citrus tree canopy at similar values to the air temperature. The difference between the inside canopy temperature and air temperature ranged from 0.6 to –0.8 °F during most of the night with the largest differences occurring prior to sunrise (07:45 HR) and corresponding with lower wind velocities (Fig. 1c).

On the night of 14 Dec. a comparison of the average nightly canopy temperature and air temperature indicated that average canopy air temperature was 30.2 °F compared to 28.5 °F average nightly air temperature. The average nightly temperature difference was 1.7 °F warmer inside the citrus tree canopy compared to the air temperature (Table 3). The temperature trace for 14 Dec. (Fig. 2a) shows some variation in the temperature difference between inside the citrus tree canopy and the outside air temperature. Closer examination of this variability taking into account the wind velocity profile (Fig. 2b) for that night indicates that with increased wind velocities the difference between inside canopy and outside air temperature was reduced. The difference between the inside canopy temperature and outside air temperature (Fig. 2c) ranged from –0.6 to 4.4 °F during most of the night with the largest difference occurring during periods of near calm winds and near sunrise (07:45 HR).

On the night of 16 Dec. inside canopy temperatures averaged 36.3 °F compared to the outside air temperature of 34.4 °F an average difference of 2.0 °F warmer inside the citrus tree canopy (Table 3). The nightly temperature trace for 16 Dec. again exhibited some variation in the difference between the inside canopy and outside air temperature (Fig. 3a). This variation can be attributed to a corresponding increase in wind velocity (Fig. 3b) during the night. The increases in wind velocity resulted in minimizing the difference between inside canopy and outside air temperatures. During periods of calm winds this difference increased as seen previously during the night of 15 Dec. The difference in inside canopy and outside air temperature ranged from 0.0 to 4.0 °F during the night with the largest differences occurring during periods of calm winds.

In conclusion, with microsprinkler irrigation there was little variation in the inside citrus tree canopy air temperatures during the three nights of this study. The use of microsprinkler irrigation for cold protection in this study during windy or advective freeze conditions (13 Dec.) resulted in the inside canopy air temperatures

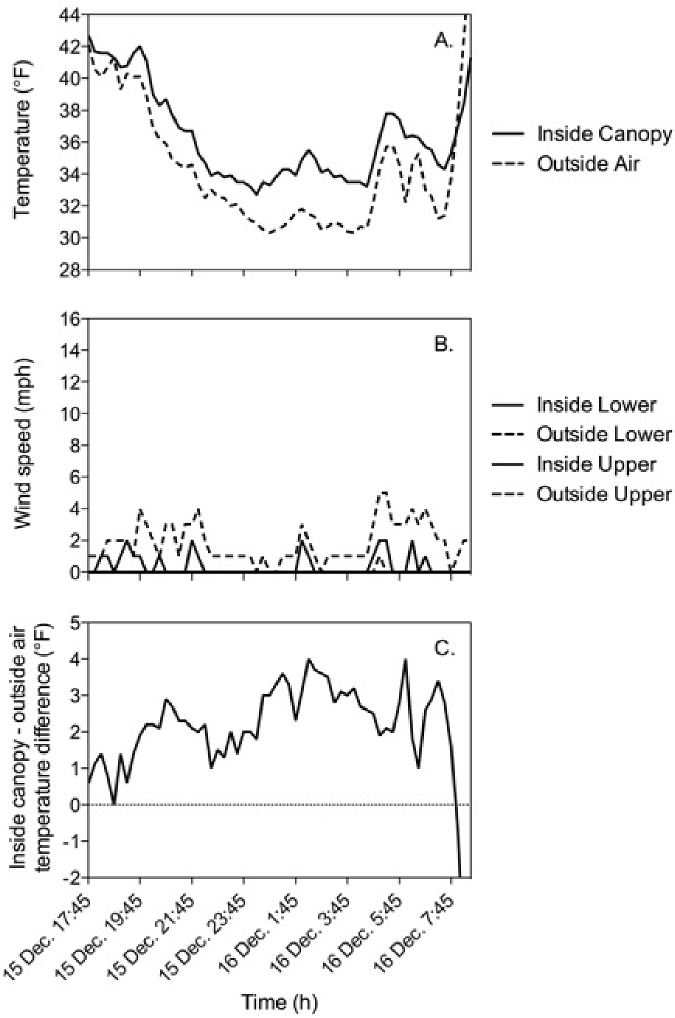

Fig 3. (**A**) Inside canopy and outside air temperatures, (**B**) wind velocities inside and outside grove, and (**C**) temperature difference between inside citrus tree canopy and outside grove air temperature from 15 Dec. 17:45 to 16 Dec. 08:30 HR.

being similar to the air temperature measured outside the grove. During this advective freeze wind velocities within the hedgerowed grove at the 5-ft level were 0.0 mph. Under these conditions there appeared to be enough air mixing above and around the tree canopies to maintain a consistent air temperature inside the tree canopy and outside the block. In this study during the radiation freeze events (15 and 16 Dec.) inside canopy air temperatures were consistently warmer during periods of calm or near calm winds than the air temperature measured outside the grove.

Literature Cited

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