grows extremely well on its own root from cuttings, produces fruit immediately, and will tolerate far more cold than budded trees. A $2,000 per acre savings for the grove owner solely on pound solids.

7. As a scion it may also be marketed for the fresh fruit market because of the large size and high quality sweet fruit (2 1/2" × 3"). One of the best candidates for nutritional supplements and cancer research because of its anti-virus qualities and high quality of juice and pectin.
8. It produces very high yields, up to 17-20 boxes at maturity. This could add enormous profits to the grove owner.
9. Is drought resistant because of its very deep root system.
10. Is tolerant to Citrus scab fungus (*Elsinoe fawcetti*) which is characterized on all citrus leaves except Sweet Oranges.
11. Will regenerate and send up sweet orange suckers and fruits immediately if a disastrous killer freeze or anything kills the scion union, unlike the millions of "sour type" unedible fruiting rootstock suckers in abandoned groves throughout the citrus belt today. This cost millions to the industry and is a complete avoidable major waste with new rootstocks.
12. Is genetically resistant to Foot Rot and Root Rot (*Phytophora parasitica*). Most sweet oranges heretofore have been reported to be the most susceptible. It has been tested. More field testing is desirable.
13. The first sweet orange rootstock to be successfully developed without major flaws. Ridge pineapple which has heretofore been tested by others is very susceptible to Phytophora and Tristeza.
14. Will tolerate a wide variety of different type soil conditions including high calcareous soils of South Florida.

Conclusion

These new citrus rootstock/scion cultivars were developed from Zygotic seedlings selected from thousands because they had all of the desirable morphological and genetic characteristics within single cultivars. Successive generations of sexual and asexual reproductions have been tested during the past decade by budding, tissue culture, and growing from seed. They have never been described or commercially distributed before.

The citrus industry can ill afford another major catastrophe like the 1983 billion dollar freeze. When it comes and ultimately it will because the history patterns of Florida freezes clearly predict it—just a matter of time. When it comes the catastrophic results will be appreciably the same because there's been very little done to rectify the problem, the genes are the same as before. If the new genetic cultivars and methodology are used as previously described, then Charles Darwin and Gregory Mendle's genetic laws of the universe would prevail. These scientific laws clearly predict with absolute certainty that the 100-year old survivors would perform precisely the same way *another* 100 years; if we simply replicate the parent tree by cuttings or tissue culture.

Cutting grown trees have been grown and tested in Lake County since the 1983 freeze with better results than any other method. Bill Baker has been the leading pioneer with over 100 acres to prove it.

The new citrus cultivars and methodology, a combination of cuttings and budding could save the citrus industry the same as the previous losses of **ONE BILLION DOLLARS**.

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DOES MOVING UNDERTREE SPRINKLERS INTO THE CANOPY ADD PROTECTION FROM COLD DAMAGE?[1]

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Abstract. **Little difference in the level of protection offered by various microsprinkler placements was observed following the Feb. 5, 1996 freeze in a 5 acre grove on the Main Campus of the University of Florida, Gainesville, during which the temperature in the grove dropped to 20.5F within the irrigated grove and to 15F at the Agronomy Farm 8 miles WNW of the grove. Damage to the trees was ranked from 1 (extensively damaged) through 9 (least damaged) on Mar. 14, 1996. The 455 trees were protected by 11 methods of sprinkler placement but with the rate to each tree held constant. The methods varied in both sprinkler number and in their locations on the ground beneath the tree and locations within the canopy. The means and SD for these treatments were 6.48 ± 1.55, 6.45 ± 1.69, 6.39 ± 1.55, 6.37 ± 1.69, 6.29 ± 1.62, 6.29 ± 1.79, 6.10 ± 1.91, 6.07 ± 1.62, 5.76 ± 1.41, 5.71 ± 1.66. No significant difference in the protection provided between any of the treatments was shown. No significant differences were observed between the undertree and intree treatments; 166 trees with sprinklers under them**

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were 5.99 ± 1.56 whereas the 289 trees with sprinklers within the canopy were 6.28 ± 1.65. Buoyancy of water vapor relative to dry air may explain these results.

The purpose of this paper is to report observations of freeze damage to a citrus grove on the main campus of the University of Florida in Gainesville following a freeze on February 5, 1996.

Following the advective freeze of 1962, most observers were convinced that overhead sprinkling systems, and especially those with precipitation rates of less than 0.1 inch per hour, caused more harm than good in severe advective freezes (Gerber & Martsolf, 1965; Gerber & Harrison, 1964). During the freezes of the 1980's observers began to recognize that undertree and intree microsprinklers were providing more protection than expected (Oswalt & Parsons, 1981; Buchanan, et al., 1982) even under advective conditions with a suggestion that the higher the sprinkler in the tree the more the protection (Davies, et al., 1984; Bourgeois & Adams, 1987). Following the Christmas 1989 freeze very convincing evidence was reported that the elevation of microsprinklers into the canopy added to the protection (Parsons, 1991; Parsons et al., 1991a, 1991b). But some indications that the buoyancy of water vapor created vertical mixing within the canopy would seem to have swept out some of the advantages that would otherwise accrue to the elevation of microsprinklers into the tree (Martsolf & Hannah, 1991; Martsolf, 1989, 1992, 1993). Some additional weight is added to the argument that water vapor fuels mixing within the canopy and the grove under stable atmospheric conditions (Cooper, et al., 1997).

Materials and Methods

Freeze: Perhaps the key mechanism in this study was the freeze of Feb. 4-5, 1996, described in Figures 1 and 2, by its temperature and windspeed traces. The data used to make up the two figures came from an automated weather station on the Agronomy Farm (Mishoe, et al., 1992) which is 8 miles WNW of the grove in which the cold damage observations were made. The minimum temperature reported in the climatological data record for the Agronomy farm was 15°F. Minimum temperature recorded with an alcohol-in-glass orchard thermometer on a standard orchard shelter at the North boundary of Block 5 (Fig. 3) in the grove in which the observations were made was 18°F, which is quite close to the minimum indicated in Figure 1.

Grove: Figure 3 provides a diagram of the grove in which the observations were made and its location relative to Fifield Hall on the Main Campus of the University of Florida in Gainesville, Florida. The Orlando Tangelo and the Robinson tangerine, both on Carrizo Citrange rootstock, were planted on April 2, 1990. The Ambersweet on Sour Orange were planted on April 17, 1990. Thus the trees were a bit over 6 years of age at the time of the freeze.

Irrigation System: The treatments, i.e., sprinkling methods, were allocated to specific rows. The sprinkling rate per tree was kept constant at approximately 16 gallons per hour per tree, i.e., equivalent to a green nozzle at 20 psi. When there were two nozzles per tree they were orange and when 3 were used they were black. Table 1 provides a guide to which irrigation treatment was installed in particular rows. Row 10 was designated "a" and Row 11 as "b" to keep the row numbers as single characters in the names supplied to each tree. For example the tree on the SE corner of the grove is 67b, as is indicated in Fig. 3. There were 11 treatments with the undertree treatment of Row b often considered to be the check. Although the experimental design permitted blocks to be left untreated entirely, there was no need to prove again that sprinkling provided protection, and there was a lot of incentive to preserve the whole grove and retain its uniformity in size and shape.

Figure 1. Temperature fall during the coldest night of the freeze in which the lower trace indicates the minimum temperature for the previous hour and the upper trace the maximum. This pattern is rather typical of an advective freeze, i.e., a relatively constant temperature fall with time. These data were acquired via ICON through AWARDS from an automated weather station on the UF/ IFAS Agronomy Farm in NW Gainesville, Florida.

Observational technique: Dr. Paul Lyrene (Horticultural Sciences Department, Gainesville) suggested a two step process from years of experience in evaluating plant condition. First, the freeze damage was divided into 3 categories: severe, normal, and light. Second, each one of those categories was divided into three divisions. The top and bottom of each category received a plus and a minus, with no symbol indicating mid-range. The original data were taken by walking N-S through each block and recording an observation for each tree's cold damage. The observations reported in this report were made on Mar. 14, 1996. When they were recorded in a spreadsheet on a microcomputer the codes were translated to a single digit between 1 and 9. These are the 9 levels of cold protection displayed in the charts, with 1 denoting very little protection and 9 indicating the most or nearly complete protection.

Results

The primary result is depicted by comparing all undertree methods with all intree methods (Fig. 4). There was very little difference in the means, with the intree showing only a slight edge over the undertree in terms of protection provided. This difference is insignificant when the size of the standard deviation from the mean is viewed for each of the means.

Figure 5 charts the means and standard deviations of the mean for each of the 11 methods in descending order of protection. There

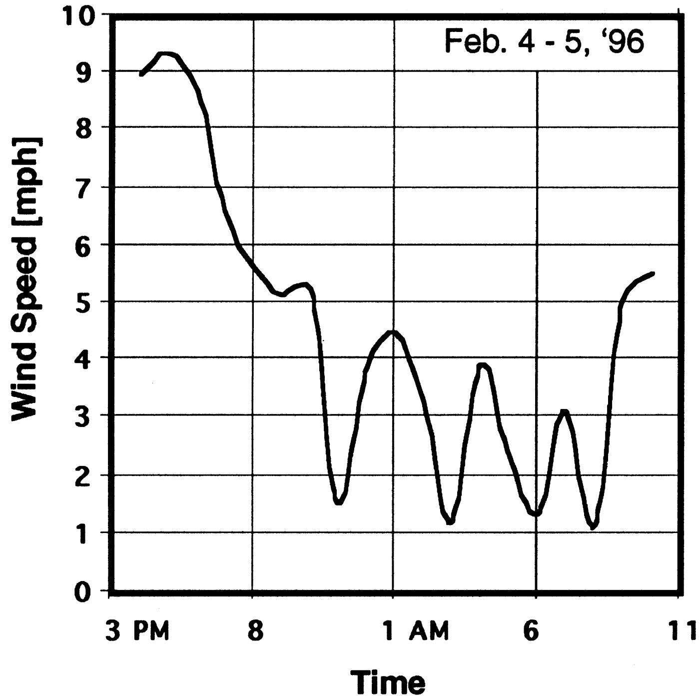

Figure 2. A plot of the windspeed on the coldest night of the freeze shows an oscillation between the 5 periods of advection separated by 4 relatively short calmer periods, at two hour intervals. These oscillations are rather typical of a very clear night in which the radiant cooling of the surface builds up an inversion layer forcing the advected flow upward until the temperature gradients build turbulence that in turn disrupts the inversion and the air near the surface is mixed. These data are from the same location and were acquired in the same manner as those in Figure 1. The calm periods were apparently of insufficient length to show up clearly in the minimum temperature trace in Figure 1, adding to the suggestion that the night be considered an advective freeze night in the Gainesville region.

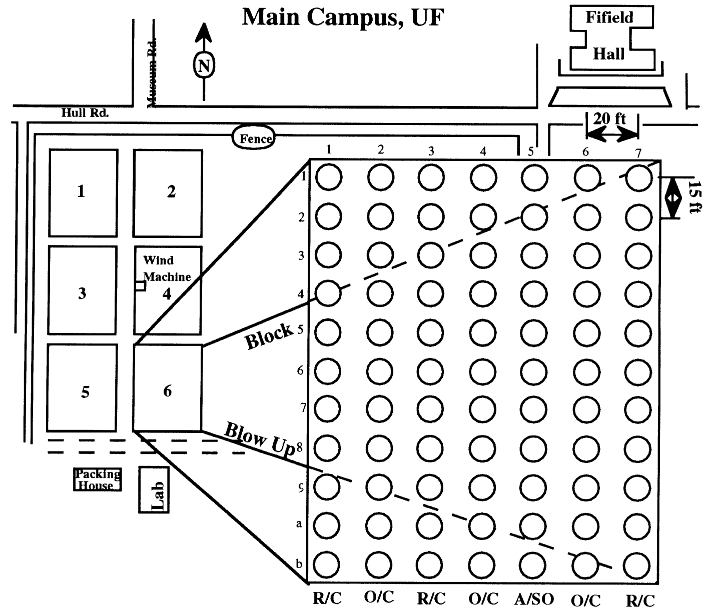

Figure 3. Diagram of the location of the 6 identical blocks of trees that make up the 5 acre research and teaching grove in which the observations reported were made. The treatments were laid out symmetrically so that the differences among the treatments and the variety/rootstock combinations could be more easily contrasted by students and visitors where the 11 treatments run E-W and are numbered 1 through b. The variety/rootstock run N-S where R/C=Robinson/Carrizo, O/C=Orlando/Carrizo, and A/SO=Ambersweet/Sour Orange.

is no significant difference among these means, but trees on the boundaries of the block, i.e., on the N and S, tended to be slightly more damaged than those within the block.

Figure 6 charts means for the protection methods observed for particular varieties on particular NS rows. In other words, the two outside rows, on the E and on the W of each block, were Robinsons (R) and had the most damage. Orlandos (O) displayed significantly less damage than that observed on the Robinsons (R) and Ambersweets (S) as expected. There were insufficient data (or insufficient differences and likely both) to reveal a significant difference between the Robinsons and the Ambersweets.

Discussion

These observations fail to support a commonly held notion that the further up in the canopy the microsprinkler is placed the more protection will be provided. But it should be stipulated that this exception to the rule occurred under particular conditions. The trees were adult in size, many reaching 12 feet in height and in the Orlando rows the canopies touched in the NS rows where the trees were planted 15 ft apart. The freeze was less severe than the 1989 freeze.

Convincing evidence that sprinklers within the canopy provide additional protection over those near the ground was gathered following the severe freeze of 1989 (Parsons, 1991; Parsons, et al., 1991a, 1991b). The grove indicated in Figure 3 was planted with an intent to demonstrate the effect of various sprinkling methods on cold damage.

Early in the life of the grove, it was reported that moving sprinklers into the trees resulted in more limb breakage (Martsolf & Hannah, 1991). Large differences in the amount of protection did not show up in those observations. During the investigation of heated irrigation, it was suggested that buoyancy of the moist plumes around sprinkler heads (see Fig. 7, Martsolf, 1989) may play a role in mixing the layers of air within a tree if not within the orchard microclimate. Later the mechanism was featured in a list of mechanisms which can be expected to provide protection from cold damage (see Fig. 1, Martsolf, 1992). The combination of the wind resistance of the canopy and the buoyancy of water vapor rich plumes was described as the likely cause of the patterns of cold damage observed after the advective freeze of March, 1993 (Martsolf, 1993).

Observations in this report support a theory as to why low level sprinkling is providing more protection than sprinkling models have suggested is to be expected. Cooper, et al. (1997) discuss the possibilities that this mechanism is much stronger than has been previously thought and support those contentions with data from the same orchard used in this study. Evaporation takes place where there is energy to support it and a gradient in vapor pressure driving the process. A relatively large amount of energy is required to

Table 1. List of sprinkler irrigation methods.

Row		Treatment (method) where U indicates undertree and I, intree
1	U	Two orange Maxijet 90° Swap top high angle, one about 3 feet from tree N and the other about 3 feet from the trunk to the NW. Both were pointed up into the center of the tree.

Table 1. List of sprinkler irrigation methods.

Row		Treatment (method) where U indicates undertree and I, intree
2	U	A single green Olsen 120° flat spray angled up into the canopy and about 3 feet to the NW of the tree trunk.
3	I	A single green Maxijet Max One 340° fan attached to a tree clip with which it was attached to a limb in the tree canopy at a height of approximately 30 inches.
4	I	A single green Maxijet 280° nozzle on a long stake in the center of the canopy at a height of approximately 30 inches.
5	I	A single green Maxijet spoke nozzle on a tree clip attached to a limb at a height of approximately 30 inches in the center of the canopy.
6	U	Three black high angle 90° Maxijet nozzles on short stakes beneath the tree at about 3 ft from the trunk on the N, NW, and W sides of the tree all pointed into the center of the canopy.
7	I	A single green Maxijet 280° nozzle with a deflector cap, on a long stake in the center of the canopy at a height of approximately 30 inches.
8	I	A single green Maxijet 340° Max One fan nozzle on a long stake in the center of the canopy at a height of approximately 30 inches.
9	I	Two orange Maxijet Max One 340° fan attached to tree clips with which they were attached to limbs in the tree canopy at a height of approximately 30 inches.
a	I	Two orange Maxijet Max One 340° fans held in a vertical configuration by two stakes, one at 30 inches and the second at 60 inches. The top nozzle was one called the Arnold; its pattern was angled downward and modified by a row of knobs at the periphery of the defector surface.
b	U	A single green Maxijet high angle 90° nozzle on a short stake about 3 feet from the trunk on the NW of the trunk aimed into the center of canopy.

evaporate water. Evidence of the large amount of heat required to fuel evaporation is felt as evaporative cooling on the surface of our bodies when we exit a shower in a relatively dry room. In that case the body must supply the heat and one feels the absence as cold. In the irrigation case the energy that fuels the evaporation comes from the heat within the water and surrounding air.

Energy is returned when the invisible water vapor comes in contact with a surface that is beneath the dew point in temperature, i.e., condensation takes place. This transfer of energy is termed latent heat transfer in contrast to the transfers that are more easily sensed and consequently termed sensible heat transfer. Latent heat transfer is invisible unless the observer pays particular attention to the products of condensation which in this case are the formation of dew and then perhaps frost up in the canopy well above the reach of the sprinkler pattern, or the formation of fog.

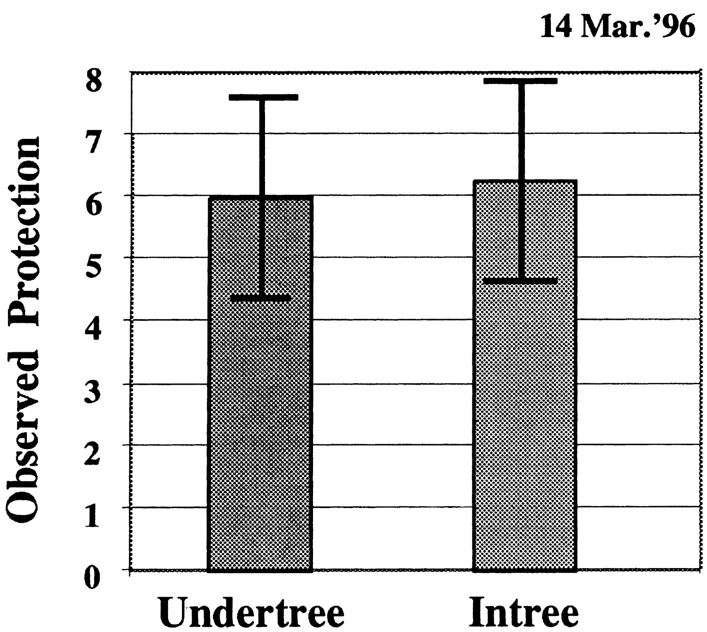

Figure 4. A chart of the protection provided 166 trees equipped with undertree sprinklers versus those (289 trees) protected within tree sprinklers. The bars indicate two standard deviations of the data, one above and one below the mean. The failure of either of the two means to extend above or below the bars plotted on the other mean suggests that there is no significant difference in protection provided.

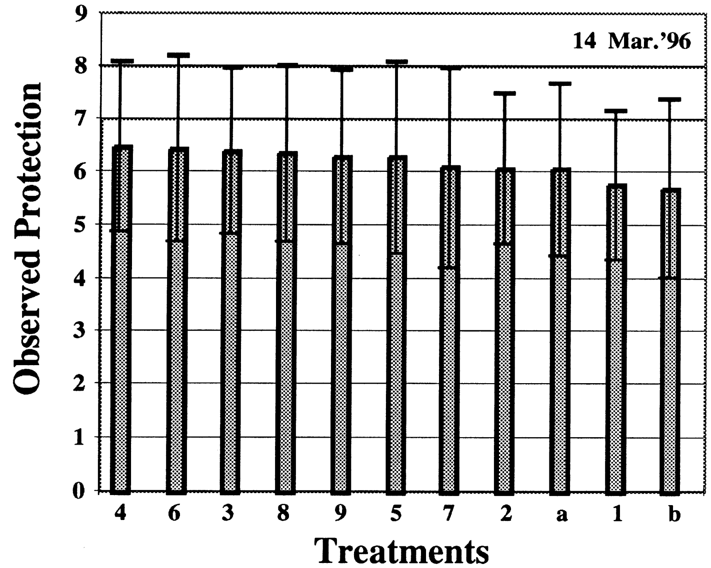

Figure 5. The treatment means are shown in descending order of protection. The standard deviations are indicated as in previous figures and they show that no significant differences exist among any of the treatments. A slight indication that the rows on the N and S borders of each block, i.e., treatment 1 and b, were damaged somewhat more than the interior treatments is indicated and this is consistent with expectations. The treatment numbers are the row numbers (see Table 1).

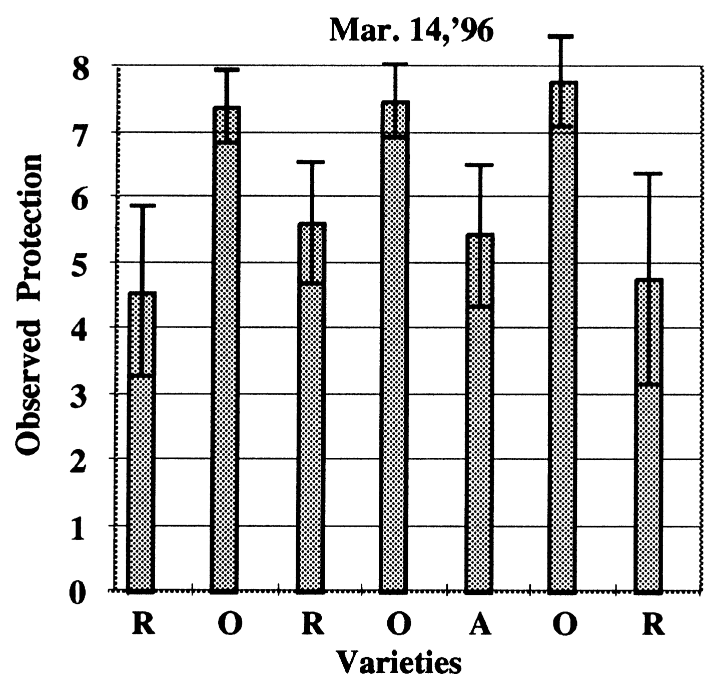

Figure 6. The bars show the protection values for each NS row as they were located (See Fig. 3), so that the two Robinson rows (R) are on the outside of the block. The Orlandos (O) displayed significantly less damage than the Robinsons and Ambersweets as was expected. While the damage to outside rows of Robinsons shows in the means, the differences are not sufficiently large to be significant.

Under special conditions trees with undertree sprinklers will appear to be "boiling" at the outer edges of their canopy. These are the outer limits of vapor plumes which are up to this point invisible but seen when water droplets begin to coalesce and form a fog which is still moving upward and outward. A diagram of the suspected circulation within and around an adult citrus tree was published over a decade ago (Krezdorn & Martsolf, 1984) but admittedly the radiational cooling of the outside of the canopy was seen as driving that circulation, for the role of the relative buoyancy of water vapor had not yet come to the forefront. The presence of a source of water for evaporation beneath that tree would only serve to intensify the circulation that was believed at that time to provide protection for adult groves simply by the extent of their canopies.

It seems much easier to install and maintain the sprinklers beneath the tree. There is incentive to leave the sprinklers beneath the trees during most if not all freezes if there are no convincing reasons to move them into the canopy. This work seems to chip away at what most felt were good reasons to move the sprinklers into the canopy.

Summary

The observations reported here fail to support a commonly held theory that sprinklers placed within the canopy provide more cold protection than when placed beneath the tree. On the other hand, they support a growing contention that the combination of the physical presence of the canopy of citrus trees and the buoyancy of the evaporated water, i.e., vapor, near the sprinklers, drives a circulation that is sufficiently powerful under some, if not most, freeze conditions to nullify much, if not most, of the value of moving sprinklers upward in the canopy. There is a suggestion that sprinklers may be left under the tree in all except the most severe advective freezes.

Literature Cited

Bourgeois, W. J. and A. J. Adams. 1987. Low volume scaffold branch irrigation for citrus freeze protection. HortScience 22:48-50.

Buchanan, D. W., F. S. Davies and D. S. Harrison. 1982. High and low volume undertree irrigation for citrus cold protection. Proc. Fla. State Hort. Soc. 95:23-26.

Cooper, H. J., E. A. Smith and J. D. Martsolf. 1997. Spray irrigation effects on surface-layer stability in an experimental citrus orchard during winter freezes. J. Appl. Meteorol. 36, 155-166.

Evans, R. G., M. O. Mahan and M. W. Kroeger. 1996. Utilization of heated water for orchard frost protection. Paper No. 96-2041, ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659. 16 pp.

Gerber, J. F. and D. S. Harrison. 1964. Sprinkler irrigation for cold protection of citrus. Trans. ASAE 7:464-468.

Gerber, J. F. and J. D. Martsolf. 1965. Protecting citrus from cold damage. Univ. Fla. Agric. Ext. Serv. Circ. 287, 29 pp.

Krezdorn, A. K. and J. D. Martsolf. 1984. Review of effects of cultural practices on frost hazard. Proc. Fla. State Hort. Soc. 97:21-24.

Martsolf, J. D. 1989. Heated irrigation cold protection. Proc. Fla. State Hort. Soc. 102:64-69.

Martsolf, J. D. 1992. Cold protection mechanisms. Proc. Fla. State Hort. Soc. 105:91-94.

Martsolf, J. D. 1993. Evaporation and wind: friend or foe in cold protection. Proc. Fla. State Hort. Soc. 106:65-70.

Martsolf, J. D. and H. E. Hannah. 1991. In-tree versus under-tree sprinkling for protection of young citrus trees from cold damage. Proc. Fla. State Hort. Soc. 104:139-142.

Mishoe, J. W., J. W. Jones, W. Williams and H. Niblack. 1992. AWARDS: Florida's weather data collection network. Paper 922146, Amer. Soc. Agr. Engrs, 2950 Niles Rd., St. Joeseph, MI 49085-9659. 8 pages.

Oswalt, T. W. and L. R. Parsons. 1981. Observations on microsprinkler used for cold protection during the 1981 freeze. Proc. Fla. State Hort. Soc. 904:52-54.

Parsons, L. R. 1991. Elevated microsprinklers for citrus frost protection. Citrus Industry 72(10):9.

Parsons, L. R., T. A. Wheaton, N. D. Faryna and J. L. Jackson. 1991a. Improved citrus freeze protection with elevated microsprinklers. Proc. Fla. State Hort. Soc. 104:144-147.

Parsons, L. R., T. A. Wheaton, N. D. Faryna and J. L. Jackson. 1991b. Elevated microsprinklers improve protection of citrus trees in an advective freeze. HortScience 26(9):1149-1151.