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# PRELIMINARY COMPARISON OF THREE FULL CIRCLE IMPACT SPRINKLERS FOR COLD PROTECTION IN SHADEHOUSES

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*Abstract.* **Five combinations of sprinkler types and orifice sizes supplying water at rates from 4.4 to 6.2 mm·hr$^{-1}$ [0.17 to 0.24 inches·hr$^{-1}$] were compared in shadehouses for effects on sprinkler rotation rates, temperatures at the crop canopy and leatherleaf fern [*Rumohra adiantiformis* (Forst.) Ching] yield. The post and cable shadehouses, located in Pierson, FL, were 29.3 m (96 ft) long, 29.3 m wide, 2.5 m (8 $^1/_2$ ft) high and covered with polypropylene shade fabric designed to exclude 73% of incoming radiation. Nine 0.9-m (3-ft) tall sprinkler risers were spaced 9.8 m (32 ft) apart in each shadehouse. Sprinkler rotation rates varied from 7.7 (Rain Bird L20VH with 0.32 cm [$^1/_8$-inch] orifice) to 0.9 rpm (Rain Bird SW2000 with 0.28 cm [$^7/_{64}$-inch] orifice), and were positively correlated (*r* = 0.79) with postfreeze yield. During the coldest part of the freeze, canopy temperatures were higher and fluctuated less in the shadehouses equipped with sprinklers with higher (>6 rpm) rotation rates than those with lower rates (≤1.5 rpm). Postharvest yield was also positively correlated (*r* = 0.91) with water application rate.**

Water, applied using overhead (over-the-crop) irrigation systems, has been used since the 1960s to protect crops in Florida from cold damage (Harrison et al., 1974). This cold protection technique has been a critical factor in enabling several of Florida's agricultural commodities to be produced during the winter. Research on reducing water application rates needed to cold protect crops in plastic fabric covered shadehouses was started in the early 1980s (Stamps and Chase, 1981; Stamps and Mathur, 1982). As new sprinkler designs become available, there is a need to test them to determine if they will perform adequately during freezes. Additionally, there is the possibility that new sprinkler designs will apply water more uniformly and/or efficiently than older designs and, thereby, allow the amount of water needed to be applied for cold protection to be reduced.

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Published recommendations for *minimum* water application rates to use for cold protection of leatherleaf fern, the most valuable crop produced in shadehouses in Florida, range from 0.8-0.9 $cm \cdot hr^{-1}$ [0.3-0.35 $inches \cdot hr^{-1}$] (Harrison and Conover, 1970; Henley et al., 1980), equivalent to 1,300-1,478 $liters \cdot min^{-1} \cdot ha^{-1}$ [139-158 gal/min/acre]. Since 1985 the St. Johns River Water Management District (SJRWMD) has listed a maximum over-the-crop sprinkler system water application rate of 0.6 $cm \cdot hr^{-1}$ [0.22 $inches \cdot hr^{-1}$], equal to 935 $liter \cdot min^{-1} \cdot ha^{-1}$ [100 gal/min/acre], as one of the approved water conservation methods for use when growing leatherleaf fern under artificial shade (SJRWMD, 1985). About two-thirds of leatherleaf fern production in Florida occurs in shadehouses (Stamps et al., 1991). The critical temperature below which damage occurs to immature leatherleaf fern fronds is reported to be -1.1C [30F] (Henley et al., 1980).

The purpose of this experiment was to evaluate the effectiveness of two newer sprinkler designs in comparison to an established standard for use in cold protecting crops in shadehouses.

## Materials and Methods

This evaluation was conducted in Pierson, FL in five 29.3 m × 29.3 m [96 ft × 96 ft] post and cable shadehouses spaced 9.8 m [32 ft] apart and filled with established plantings of leatherleaf fern. The structures were 2.5 m [8 ½ ft] tall and covered on the roof and side walls with woven polypropylene shade fabric designed to provide 73 percent shade when the radiation source is perpendicular to the plane of the fabric. In each shadehouse, nine sprinklers were mounted on risers that extended about 1 m [3 ft] above the soil and were spaced 9.8 m [32 ft] apart. For cold protection, the water pressure at the pump was maintained at 275 kPa [40 psi] resulting in a pressure of about 200 kPa [30 psi] at each shadehouse.

Table 1 lists sprinkler model, nozzle types, sprinkler trajectories, orifice sizes, rotation rates and approximate water application rates tested. Three types of full circle impact sprinklers were tested—L20VH (Rain Bird Sprinkler Mfg., Glendora, CA), S20VH (SSteelHead Strong Drive, Rain Bird) and SW2000LF (SideWinder™ 2000, Rain Bird). L20VH sprinklers with either 0.28-cm [ 7/64 -inch] or 0.32-cm [ 1/8 -inch] orifices are commonly used for cold protection of cut foliage crops grown in shadehouses in central Florida because of their relatively good distribution patterns and rapid rotation rates even at low water pressures. Both 7°- and 12°- trajectory S20VH sprinklers and 8°- and 13°- trajectory settings on the SW2000 sprinklers were used to get maximum throw without having the water hit the overhead shade fabric. LPN-1 nozzles used in the L20VH sprinklers were installed with the 3° nozzle trajectory up to obtain an overall trajectory of 13° and a stream height similar to that of the other two sprinklers. Sprinkler rotation rates were determined for the three sprinklers in each shadehouse in the middle east to west row by timing sprinkler revolutions using a stopwatch. Although the ferneries were equipped with dual (over-the-shadehouse and over-the-crop) irrigation systems, only the over-the-crop irrigation systems were used.

Before and after the test, all risers were equipped with the same sprinkler (L20VH), nozzle type (LPN-1) and orifice size (3.2 mm [ 1/8 -inch]). This use of uniform sprinklers and nozzles in all houses, except when actually cold protecting the crop, assured that there would be no bias in the yield results due to non-uniform chemigation, fertigation or irrigation application among shadehouses.

Temperatures in each shadehouse were monitored with thermocouples (AWG 24, Omega Engineering, Stamford, CT 06907) attached to a datalogger (CR10, Campbell Scientific, Logan, UT 85321) via a multiplexer (AM32, Campbell Scientific) housed in an insulated enclosure. Two thermocouples were located near the top of the fern canopy in two central locations in each shadehouse. Thermocouples were checked prior to use using slurries of deionized water and ice made from deionized water. An anemometer (03101, Met One, Grants Pass, OR) and two additional thermocouples for monitoring ambient temperatures were attached to a second datalogger located 15 m [49 ft] north of the northernmost shadehouses.

Cold damage to leatherleaf fern fronds was determined by monitoring yields of fern harvested the week of 18-22 Mar. 1996, six weeks following the freeze.

Data were analyzed using analysis of variance and means separated using Duncan's multiple range test at $P = 0.05$.

## Results and Discussion

On the night of 4-5 Feb. 1996, a freeze occurred with a minimum temperature of -6.2C [21F] and wind speeds up to 2.2 $m \cdot s^{-1}$ [4.9 miles/hr] (Fig. 1). The over-the-crop irrigation systems were started when ambient air temperatures reached 0C [32F]. All irrigation systems maintained temperatures at the crop canopy above the critical temperature for cold damage.

Sprinkler rotation rates varied from 7.7 (L20VH with 0.32 cm orifice) to 0.9 rpm (SW2000 with 0.28 cm orifice) (Table 1). Although rotation rates increased with increased water application rates for a given sprinkler model, the main factor affecting the relative sprinkler rotation rate was sprinkler design. L20VH sprinklers, which are designed for use in frost

Table 1. Sprinkler types, nozzle type, orifice sizes, sprinkler trajectories, rotation rates and approximate water application rates evaluated.

| Sprinkler Model[z] | Nozzle type | Trajectory (°) | Orifice size | Rotation rates (rpm) | Approximate water application rate[y] | Yield (number of bunches) |
|---|---|---|---|---|---|---|
| L20VH | LPN-1 | 13[x] | 0.28 cm [ 7/64 inch] | 6.3 | 0.47 $cm \cdot hr^{-1}$ [0.19 inch/hr] | 2415 |
| | | | 0.32 cm [ 1/8 inch] | 7.7 | 0.62 $cm \cdot hr^{-1}$ [0.24 inch/hr] | 2832 |
| S20VH | QF | 7 & 12[w] | 0.28 cm [ 7/64 inch] | 1.5 | 0.45 $cm \cdot hr^{-1}$ [0.18 inch/hr] | 2271 |
| SW2000 | Sidewinder | 8 & 13[w] | 0.28 cm [ 7/64 inch] | 0.9 | 0.44 $cm \cdot hr^{-1}$ [0.17 inch/hr] | 1974 |
| | | | 0.30 cm [ 15/128 inch] | 1.0 | 0.52 $cm \cdot hr^{-1}$ [0.20 inch/hr] | 2410 |

[z]All sprinklers made by Rainbird Sprinkler Mfg., Glendora, CA.
[y]At 200 kPa [30 psi] and 9.8 m [32 ft] riser spacing.
[x]Combination of 10° sprinkler and 3° nozzle trajectories.
[w]Trajectories varied depending on shade fabric height so that water stream did not hit fabric.

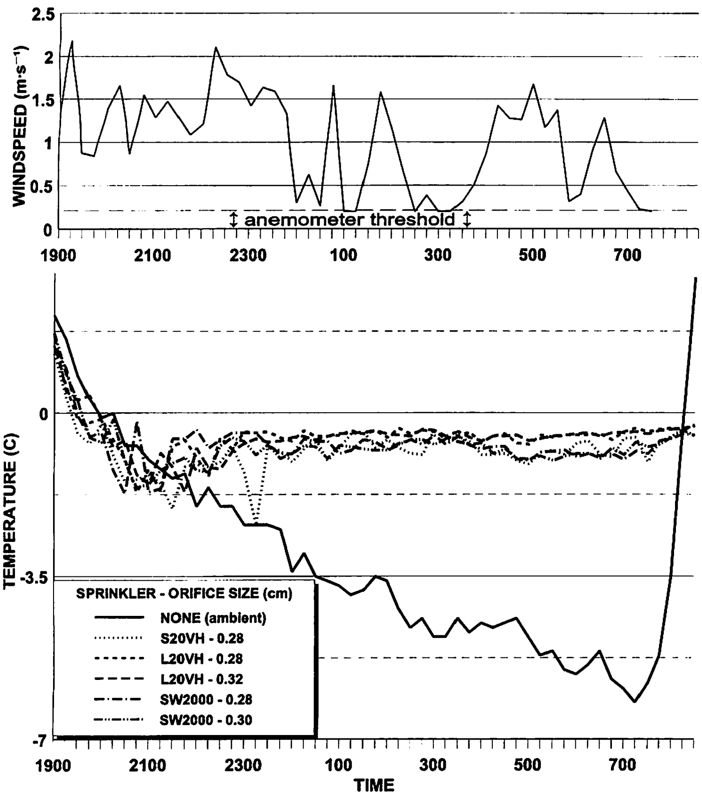


Figure 1. Windspeeds and ambient temperatures outside ferneries and temperatures at the crop canopy in five shadehouses irrigated using various combinations of sprinklers and orifice sizes. 4-5 Feb. 1996.

protection, had the highest rotation rates. During the period when ambient temperatures were coldest (0300-0745 HR), canopy temperatures were higher in the shadehouses equipped with these sprinklers with the high rotation rates (>6 rpm) than those with the lower rotation rates (≤1.5 rpm) even though the water application rates were similar (Fig. 2). The wedge drive frost protection sprinklers (L20VH) rotated significantly faster than the other sprinklers. Research has shown that faster rotation rates can improve cold protection using impact sprinklers (Stamps and Mathur, 1982; Wheaton and Kidder, 1965). Despite the absence of any significant visible cold damage in any of the shadehouses, postharvest yields were positively correlated ($r = 0.79$) with sprinkler rotation rates. In addition to the sprinkler rotation rate effects, yield was also positively correlated ($r = 0.91$) with water application rate. The highest yield, 2,832 bunches, from the shadehouse with the L20VH sprinklers with 0.32 cm orifice was

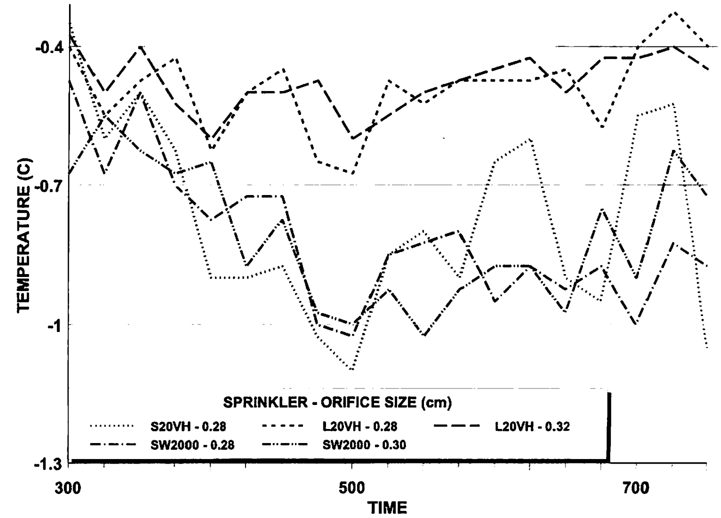


Figure 2. Comparison of temperatures at the top of the crop canopy during cold protection using irrigation water provided by five combinations of sprinklers and orifice sizes.

22% higher than that from the shadehouse with the SW2000 sprinklers with 0.28 cm orifice. Further testing using replication is needed to confirm this effect.

The two newer sprinklers (S20VH, SW2000) tested proved adequate for use in cold protecting crops in shadehouses under the conditions occurring during this preliminary evaluation. However, these results indicate that efforts to increase the rotation rates of these designs would probably be beneficial in providing better cold protection.

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