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Cold Protection of Kiwifruit Plants with Trunk Wraps and Microsprinkler Irrigation

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Abstract. **Own-rooted, 4-year-old kiwifruit plants *[Actinidia deliciosa* (A. Chev.) C.F. Liang et R. Ferguson var. *deliciosa]* protected by a Styrofoam insulation wrap with a water-filled pouch (Reese clip-on trunk wrap) or by microsprinkler irrigation sustained less freeze injury than unprotected plants under field conditions at temperatures as low as -17.8C. Trunk splitting occurred on the plants, but no injury was detected on canes, buds, or shoots in the canopy of the plants. Unprotected plants had more trunk splitting and at greater heights than protected plants. New canes developed from suckers of cold-injured plants and developed a trellised canopy the following season.**

Kiwifruit plants require exacting climatic conditions for optimum production that generally do not occur in most temperate climates (Warrington and Weston, 1990). Standard cultivars, such as 'Hayward', require a particularly long frost-free growing season of ≈ 220 days and 750 to 800 chilling units for satisfactory flower production (Ferguson, 1990). Studies by Caldwell (1989) in South Carolina showed that 'Hayward' required at least 900 h of chilling for sufficient vegetative budbreak and flower development and that 1150 h chilling were needed for maximum flowering.

Sites that receive sufficient chilling to allow for both a high percentage and uniformity of budbreak often experience minimum winter temperatures that can cause vine injury or death. The minimum temperature tolerated by kiwifruit vines depends on vine age, preconditioning, time of year, and the stage of crop development. Serious winter injury has been reported on vines in all major kiwifruit production regions, including New Zealand (Hewett and Young, 1981; Pyke et al., 1988), Switzerland (Gremminger et al., 1982), France (Blanchet, 1985), California (Weet, 1979), and Georgia (Krewer et al., 1986). Damaging temperatures for dormant vines have been reported by various authors to be in the following ranges: -10C (Hewett and Young, 1981); -5 to -7C (Pyke et al., 1988); -9 to -12C (Johnson et al., 1988); -2 to -4C (Blight, 1981); and -6C (Blanchet, 1985; Weet, 1979). Many methods of freeze protection, including insulating trunk wraps (Krewer et al., 1988; Pyke et al., 1988; Rieger et al., 1988) and microsprinklers (Rieger, 1989), have been used for kiwifruit and other horticultural crops. The climatic conditions experienced at locations in Alabama where kiwifruit plants receive sufficient chilling can result in trunk injury from damaging winter temperatures. Our experiment was conducted to determine the feasibility of using commercially available trunk wraps and microsprinklers to protect plants from damaging low temperatures.

Kiwifruit cuttings grown for 1 year in 3.8-liter pots were planted at 2.4 m between plants in the row and 4.9 m between rows at the Chilton Area Horticulture Substation, Thorsby, Ala., in Mar. 1986. A T-bar trellis system (Sale, 1985) was used to support the plants, with crossarms 1.8 m above the soil and five wires spaced 46 cm apart. Cultivars included in the study were the male selections 'AU lM', 'Matua', and 'Tomuri' and female selections 'Hayward' and 'AU 1F'. 'AU 1F' and 'AU 1M' are seedling selections developed from fruit of unknown origin that have performed well under Alabama climatic conditions. The research location receives 1330 chilling hours annually, has an average frost-free growing season of 220 days and an expected annual minimum winter low of -13.7C; the mean date of the first freeze (0C) in the fall is 5 Nov. The lowest annual temperatures that occurred since this planting was established were -9.4, -9.4, -8.3, and -17.8C for the dormant seasons of 1986 87, 1987-88, 1988-89, and 1989-90, respectively. All weather data reported are from the National Weather Service, Southeast Agr. Weather Service Center, Auburn, Ala., and were collected at their official data collection station at Thorsby, 0.1 km from the planting. Plants in this experiment had not received any visible low-temperature damage before injury received during the 22-26 Dec. 1989 cold period we have described.

Freeze protection treatments included Reese clip-on trunk wraps (Reese Citrus Insulators, Lakeland, Fla.), micropsrinkler irrigation with Maxi-Jet mist nozzles (Maxi-Jet, Dundee, Fla.), and unprotected. Five 33.7.cm-long Reese trunk wraps were stacked around the trunk of each protected plant and the joints were sealed with duct tape to provide protection from the soil line to the crossarm. Microsprinkler irrigation treatments consisted of two Maxi-Jet mist nozzles with a 360° sprinkler pattern per plant. The first nozzle was placed 1 m above the soil line to wet the trunk, and the second nozzle was placed 54 cm above the plant to wet the canopy. The mist nozzles had an orifice size of 0.10 cm and delivered 39.7 liters of water per hour at 140 kPa. The microsprinkler protection system was regulated by a thermostat that began water application when the air temperature dropped to 2.2C and ran continuously until the air temperature rose above 2.2C.

The treatments were arranged as a split plot with six replications in randomized complete blocks. Cultivars were the main plot treatment and freeze protection methods the subplot. The data were examined by analysis of variance with mean separation according to the split-model. Means of treatments overall and within each cultivar were examined using Duncan's multiple range test at $P = 0.05$ where appropriate. Standard errors were computed from the appropriate means square error from the analysis of variance (Table 1).

In 1989 temperatures were typically 18.7C and 11.2C for daily maximums and 3.8C and -1.6C for minimums in Nov. and the first half of Dec., respectively. Before the first severe cold period in Fall 1989, the site had experienced 20 days in which temperatures had dropped below 0C. Temperatures in Dec. 1989 were unusually low in Alabama, averaging 5C below normal for the month at Thorsby. The first severe cold period occurred on 16 and 17 Dec., with a low each night of -11.7C. This period was followed by a severe freeze on 22-26 Dec., with lows of -15.6, -17.8, -16.7, -12.8, and -4.4C, respectively. The temperature remained below 0C throughout this 5-day period.

The trunk wraps were removed on 2 Apr. 1990, and trunk diameter at 15 cm above the soil was measured. The number of vines with freeze damage (as evidenced by bark splitting) and the height of injury on the plants were determined. On 10 Apr. 1990, all plants with detectable freeze injury were cut back to the soil line. On 13 Oct. 1990, the di-

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Table 1. Effect of freeze protection methods on cold injury of kiwifruit plants.

Cultivar/criterion	Cold protection treatment[z]			
	Control	Trunk wrap	Microsprinkler	SE[y]
AU 1M				
Height of injury (cm)	164 a[x]	80.8 b	16.5 c	27.99
Injured plants (%)	100 a	66.0 ab	33.0 b	0.18
Matua				
Height of injury (cm)	87.6 a	6.4 b	11.9 b	10.89
Injured plants (%)	83.0 a	17.0 b	17.0 b	0.12
Tomuri				
Height of injury (cm)	91.9 a	0.0 b	11.9 b	11.11
Injured plants (%)	83.0 a	0.0 c	33.0 b	0.14
AU 1F				
Height of injury (cm)	55.9 a	0.0 b	0.0 b	2.46
Injured plants (%)	100 a	0.0 b	0.0 b	0.00
Hayward				
Height of injury (cm)	90.2 a	0.0 c	20.5 b	21.16
Injured plants (%)	100a	0.0 b	17.0 b	0.09
Mean				
Height of injury (cm)	95.0 a	15.2 b	14.1 b	7.24
Injured plants (%)	92.0 a	16.0 b	20.0 b	0.05

[z]Treatments: control = no freeze protection provided; trunk wrap = Reese trunk wraps placed around trunk of plants from ground line to trellis wire; and microsprinkler = one Maxi-Jet placed 1.1 m above soil line next to plant trunk and one Maxi-Jet placed 0.57 m directly over the plant trunk above the trellis.
[y]Standard errors computed from the appropriate mean square errors from the analyses of variance.
[x]Mean separation within rows by Duncan's multiple range test, $P = 0.05$.

ameter of new regrowth trunks was measured 15 cm above the soil line, along with the total cane length of the two future cordons from their juncture with the trunk. The number of lateral shoots arising from these canes (cordons) was counted.

Both trunk wraps and microsprinkler irrigation proved effective in protecting kiwifruit plants from winter freeze damage. Winter injury sustained by the 4-year-old kiwifruit plants in this study was characterized by extensive bark splitting on the trunks that occurred as a result of the 22-26 Dec. freeze. The injury began near the soil line and extended up the trunk to a mean height of 9.5 cm on unprotected plants and of 14 to 15 cm on protected plants (Table 1). The mean height of injury sustained on protected plants was similar for trunk wraps and microsprinkler treatments. However, when considering individual cultivars, the height of injury on protected plants was higher on 'AU-1M' plants protected with trunk wraps than with microsprinklers and on 'Hayward' plants protected with microsprinklers than with trunk wraps.

There was no detectable freeze injury observed on cordons, buds, or shoots in the canopy of plants that survived the winter freeze without trunk injury. There were no differences among treatments in the number of buds developing the following spring on noninjured plants (data not shown). Mean number of injured plants across all cultivars was significantly less with the trunk wrap and microsprinkler treatments than on the unprotected plants. Differences between trunk wrap and microsprinkler treatments occurred when individual cultivars were considered. There were no interactions between cultivar and cold protection treatments. Fewer plants of 'Tomuri' protected with the trunk wrap were injured than plants protected with the microsprinkler. The number of injured 'AU 1M' plants protected by the trunk wrap was similar to the unprotected control. None of the 'AU 1F' plants protected by either treatment, nor the 'Hayward' plants protected by the trunk wrap treatment, were injured. However, all unprotected plants of 'AU 1F' and 'Hayward' cultivars were injured.

Most of the injured plants developed sprouts from their root systems, and by Oct., the vines had grown the length of the allotted spaces on the trellis (2.4 m) and developed lateral branches along the main trellis cane. There were no treatment effects on cane length or number of lateral branches that developed from the main cane. The cane length of the developing cordons ranged from 207 cm for 'Matua' to 228 cm for 'Hayward'. The number of shoots arising per cane ranged from five for 'Hayward' to 11 for 'Matua'. The trunk diameters of the microsprinkler-protected plants were larger than those of plants that had been protected by trunk wraps and those of the unprotected plants. The trunk diameter of 'Hayward' (19 mm), which is a slow-growing cultivar, was less than that of 'Matua' (29 mm) or 'Tomuri' (29.5 mm) but did not differ from that of 'AU 1M' (24 mm) or 'AU 1F' (20 mm). The treatments had no effect on the percentage of injured plants that died. However, 22% of the 'AU 1M' and 11% of the 'Matua' plants died, whereas none of the 'Tomuri', 'AU lF', and 'Hayward' plants died. As a group, 11% of control plants, 6% of microsprinkler-protected, and 3% of trunk-wrapped plants died.

No cold injury occurred during the first 3 years of this experiment even though the lowest annual temperatures during these winters were within the range reported to be damaging and lethal to kiwifruit tissue (Blight, 1981; Hewett and Young, 1981; Johnson et al., 1988; Pyke et al., 1986). Extensive injury occurred following the severe freeze on 22-26 Dec. 1989, when a minimum of -17.8C was reached on one occasion. All unprotected female 'Hayward' and 'AU 1F' and male 'AU 1M' plants were killed to ground level. However, 17% of the unprotected male 'Matua' and 'Tomuri' plants survived and grew well. This trend in male plant survival is contrary to previous reports (Gremminger et al., 1982; Johnson et al., 1988; Pyke et al., 1986; Weet, 1979). Differences in cultivar hardiness, as measured by plant death, were not statistically significant in our study. The variations reported in cold hardiness among cultivars, temperatures at which injury occurs, and the duration of low temperatures necessary for injury to occur under field conditions are influenced by degree of cold acclimation and the level of hardiness the vines have attained before freezing (Lu and Rieger, 1990; Pyke et al., 1986; Sale, 1985).

The prevention of freeze damage to kiwifruit plants by the use of trunk wraps and microsprinkler irrigation observed in this investigation substantiates the findings of Krewer et al. (1988). It is important to note that the temperatures that occurred during our study were much lower and were sustained over a longer period than in the previous report; however, the plants in our study may have been better acclimated.

Results of our study indicated that freeze damage can be significantly reduced by either trunk wraps or microsprinkler irrigation. If plants on their own roots are used to establish the planting, sprouts from the root system of freeze-injured plants can quickly reestablish the fruiting potential of the planting. However, the potential for annual losses in production from winter injury is so great that the development of a viable commercial industry is not likely without reliable freeze protection methods. The height of trunk injury sustained in our research and other reported research indicates that the trunk needs to be protected from the soil to the crossarm wire.

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