ANNUAL REPORT - 1990

Project No. 90-010 - Freeze Protection - Under Tree Sprinklers
(continuation of Project No. 89-90)

Project Leaders:

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Objectives:

1. To study the effectiveness of microsprinkler and conventional sprinkler operation for frost protection.

2. To determine the critical temperatures for freeze damage to almond varieties at various growth stages.

Interpretive Summary:

During last winter and spring, three weather stations were set up in an almond orchard near Durham to test the use of microsprinklers, with three different application rates, for frost protection. We found that there was little or no air temperature or relative humidity differences between treatments. However, the exposed thermometer readings were higher for greater application rates. This indicates that radiation rather than convective heat transfer causes the differences in temperature between rates. Exposed thermometers more closely approximate the temperature of exposed buds, so protection is likely to be better with higher application rates.

After completion of the microsprinkler trials, the weather stations were moved to test the effectiveness of a conventional (0.08 inches per hour application rate) sprinkler system. The same measurements were taken as with the microsprinkler experiment. Freezing temperatures occurred on only one night, when the control temperature fell to 25°F. In the sprinkler area, temperature only fell to 27.5°F.

A third experiment on variety hardiness was conducted at the Chico State University Farm. The results of our experiment reconfirmed the critical damage temperatures for the varieties that previously had information available. In addition, frost sensitivity data on new varieties were obtained. Generally, we found that the earlier varieties tended to be more frost hardy than late varieties. All varieties became more sensitive to freezing with time after the initiation of bud and flower development. At the small nut stage, all varieties would have 100 percent loss when temperature falls to 26°F or below.

Experimental Procedure:

In the microsprinkler experiment, weather stations were set up in three treatments to measure soil surface temperature, shielded air temperature, relative humidity, exposed (unshielded) air temperature, wind speed, and wind direction. All of the measurements but the surface temperature were made at a height of 2 meters. An existing microsprinkler system was modified to provide application rates of 14.5, 24.9, and 39.8 gallons per minute per acre for the three treatments. Water from the sprinklers did not reach the ground surface under the weather station in the 14.5 gpm per acre treatment but the surface under the weather stations of the other two treatments was wetted.

A second field experiment to test conventional under-tree sprinklers was also conducted near the microsprinkler trials. A system with an application rate of 0.08 inches per hours was compared with a control site. In both sites, soil surface temperature, shielded air temperature, relative humidity, exposed temperature, wind speed, and wind direction were measured.

In the frost hardiness trials, we cut branches from several varieties during flower and nut formation. Samples were labelled and placed in a freezer. The temperature was slowly lowered and held at each degree Fahrenheit for 30 minutes. Samples were removed after each 30 minute exposure and they were checked for frost damage within a few days. The resulting percentage damage corresponding to 30 minutes at each temperature were recorded.

Results and Discussion:

The microsprinkler experiment clearly demonstrated that more protection is afforded when more water is applied. Also, we had a problem with loss of sprinkler heads for the low application rate treatment. We found that there was little or no air temperature or relative humidity differences between application rates. However, the exposed thermometer readings were higher for the for greater application rates. This indicates that radiation rather than convective heat transfer causes the differences in temperature between rates. Exposed thermometers more closely approximate the temperature of exposed buds, so protection is likely to be better with higher application rates.

Our experiment with conventional sprinklers reconfirmed that this method of frost protection can be effective under mild freezing conditions. We measured about 2.5°F higher temperatures in the sprinkler area than in the control. There was approximately 3.0°F difference in exposed temperatures. Wind speeds during the night were mostly around 2 mph.

The frost hardiness trials reconfirmed reported critical temperatures on older varieties and provided us with addition critical temperatures for new varieties. The results are given in Table 1.

Table 1. Percentage damage observed on several cultivars of almonds following artificial freezing of branches in the indicated stage of development. Percentages were rounded to the nearest 1, 5, or the closest 10%.

	Temperature (deg F)										
	30	29	28	27	26	25	24	23	22	21	20
NE PLUS ULTRA											
Pink Tip						1	10		20		20
Pink Bud					0	70	90	90	90	90	
Full Bloom			5	70	90	100					
Small Nut	1	5	20	50	100						
SONORA											
Green Bud						1			5		5
Pink Bud						20	10	30	10	5	10
Full Bloom					70	80	70	80	90		
Small Nut		1	5	60	100						
PEERLESS											
Green Bud						5			5		10
Pink Bud					1	50	100				
Full Bloom		0	5	90	100						
Small Nut		0	5	60	100						
NONPAREIL											
Pink Bud						20	40	40	30	50	40
Full Bloom				50	70	90	90	90			
Small Nut	1	1	40	90	100						
PRICE											
Pink Bud						30	30	30	40	40	20
Full Bloom				50	70	90	100	100			
Small Nut		0	30	80	100						
CARMEL											
Pink Bud						40	50	40	70	40	70
Full Bloom				60	90	100	100	100			
Small Nut	1	10	30	70	100						
BUTTE											
Pink Bud					40	80	70	80	90	90	
Full Bloom		0	0	60	90	100					
Small Nut		1	5	80	100						
PADRE											
Pink Bud					70	90	90	100	90		
Full Bloom		0	1	50	100	100					
Small Nut		1	5	30	100						
MISSION											
Pink Bud					90	70	90	80	100		
Full Bloom		0	1	80	100	100					
Small Nut		0	40	90	100						

Plans:

Frost experiments are not planned for next year. Instead, we will devote our time to publishing information we have gathered over several years.

Publications:

No new publications were completed this year.

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December 27, 1990

Susan McCloud
Research Director
Almond Board of California
P.O. Box 15920
Sacramento, California 95852

Dear Susan:

Enclosed is our annual report on project No. 90-010 - Freeze Protection - Under Tree Sprinklers. If you need additional information or have questions, please contact me.

Sincerely,

Richard L. Snyder

Richard L. Snyder
Biometeorologist

RLS:bkw
Enclosure

Annual Report - December 31, 1991

Project No. 90-010 Freeze Protection - Under-tree Sprinklers

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Objectives:

1. To determine the amount of freeze protection afforded by under-tree sprinklers

2. To determine sprinkler application requirements for a range of freezing conditions

Interpretive Summary:

The key to determining sprinkler precipitation requirements for under-tree freeze protection is to know the evaporation rate of the water under different environmental conditions. As sprinkler water cools and freezes, it releases heat to the environment providing additional heat to warm the air in an orchard. At the same time, evaporation of water removes heat from the environment. Cooling from 68°F to 32°F and freezing it releases approximately 100 calories per gram of water. However, evaporating water removes approximately 597 calories per gram. Therefore, more heat is lost than gained when more than 14.3% of the sprinkler water evaporates. Wind speed and humidity are the main factors affecting evaporation rates during a freeze night, so the sprinkler precipitation rate required to ensure that less than 14.3% of the water evaporates depends on wind and humidity conditions.

The freeze protection trials during the winter of 1990-91 were conducted at UC Davis using a weighing lysimeter to measure the evaporation rate. We found that the evaporation rate from ice on the lysimeter surface is too small to accurately measure with a weighing lysimeter when sprinkler operation has stopped. During sprinkler operation, the amount of water reaching the lysimeters was considerably less than would occur if there were no evaporation. This indicates that most of the evaporation is occurring as the water droplets fly through the air rather than from ice on the ground.

Experimental Procedure:

Plots were established during the winter of 1990-91 to study the evaporation rate of ice from the ground during freeze nights using the UC Davis weighing lysimeter. The lysimeter measures weight loss from the soil surface and provides a measure of the evaporation rate.

To quantify the environmental effects, temperature profiles were measured at 0, 2, 3, 4, 5, and 6 meters above the soil surface. Hand-move sprinklers were used to wet the surface. The sprinklers were spaced 30 feet between heads on the lines with 50 feet between lines. The sprinklers covered an area of three acres and the application rate was approximately 5.0 mm per hour (0.20 inches per hour). This precipitation rate is higher than normal for an almond orchard, but it was the only system available.

Results and Discussion:

During December 1990, one of the coldest weather events in recent California history occurred. Measurements were taken on several days during the advection freeze to determine the adequacy of the sprinkler precipitation rate. The lysimeter worked well on the first night, but ice formation along the lysimeter wall and problems with sprinkler line freezing affected readings on subsequent nights. Therefore, only results from the first night were usable.

On the night of December 20-21, 1990, the sprinklers were operated from 3:05 a.m. to 5:03 a.m. During the period from 4:00 to 5:00 a.m. in an unprotected area, the air temperature at 1.5 meters height averaged -4.0°C (24.8°F), the wind speed at 2.0 meters height averaged 8.35 meters per second (18.4 mph), and the dewpoint temperature at 1.5 meters height averaged -13.8°C (7.2°F).

From 4:00 to 5:00 a.m. the lysimeter recorded an increase in weight equivalent to 3.64 mm of water due to sprinkler operation. The application rate for the sprinkler system has been frequently measured at 5.00 mm per hour. Therefore, the difference 1.36 mm (27.2%) is water that evaporated during sprinkler operation. This evaporation rate is considerably greater than the 14.3% and there was a net loss of heat due to sprinkler operation during this advection freeze.

After the sprinklers were stopped, the evaporation rate from ice on the lysimeter surface was less than 0.3 mm per hour (within the error limits of the lysimeter). This indicates that evaporation rates from the surface ice are too small to measure accurately. Evidently, most of the evaporation losses occur during the sprinkler operation as droplets travel from the sprinkler heads to the ground.

While the sprinklers were operating, the measured surface temperature was maintained at approximately -0.25°C (31.5°F). At the same time, the temperature measured at 2.0, 4.0, and 6.0 meters height within the sprinkler area dropped from approximately -3.0°C (26.6°F) to -5.0°C (23.0°F). After stopping the sprinklers, the temperature at 2.0, 4.0, and 6.0 meters continued to drop but at a slower rate of approximately 0.5°C per hour. After stopping the sprinklers, the surface temperature dropped at a rate 0.1°C faster than the above ground temperatures. This indicates that some evaporation was occurring, but again the rate was too small to measure with the weighing lysimeter.

Conclusions:

Knowing the evaporation rate under different wind and humidity conditions is critical to establish the precipitation rate requirements for under-tree sprinkler freeze protection. Unfortunately, the evaporation rate is too small to measure with the UC Davis weighing lysimeter. At this time, we know of no method to make the evaporation rate measurements needed to determine precipitation rate requirements. The only approach to make evaporation estimates is to make theoretical calculations based on air and surface temperature responses and latent to sensible heat transfer.

Plans:

We have no plans to officially continue this research. However, we will continue to investigate possible methods to determine nighttime evaporation rates and estimate sprinkler precipitation requirements.

Publications:

Research results from previous years are in preparation for publication.