Annual Report - 1988

Correct Project Number: 88-O8

Project No. 88.08 - Freeze Protection - Under Tree Sprinklers

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Objectives:

(1) Study the effects under-tree sprinkler operation on the microenvironment within an almond orchard under freezing weather conditions.

(2) Explore methods of improving the effectiveness of frost protection with under-tree sprinklers so recommendations on optimal use of the system can be made.

(3) Objectively evaluate frost susceptibility of different varieties and determine how time and duration of frost affects nut set.

Interpretive Summary:

Automatic weather stations were set up in an almond orchard north of Chico during the spring of 1988. Measurements of temperature, humidity, wind speed and direction, net radiation, and soil temperature were taken inside and on the prevailing upwind side of the orchard.

Only one frost event occurred during the 1988 experiment. Large differences in temperature between the sprinkled and unsprinkled areas were not observed mainly because the frost event was mild and temperatures in both treatments were near 32°F. There were no differences measured in nut set in sprinkled and unsprinkled plots near the north edge of the orchard. We hypothesize that there were no differences between treatments because cold air intrusion from the north overwhelmed the beneficial sprinkler effects. The south side of trees in both treatments had slightly higher nut set than the north side but no statistical inferences can be made.

An experiment to study the effects of ground cover on orchard temperatures was also conducted. We used an infrared thermometer to measure surface emitting temperatures of ground covers with differing heights. We did observe that temperatures were cooler for taller ground cover. However, there were no severe frost events so the experiment will be repeated in 1989.

Experimental Procedure:

The experimental procedure was the same in 1987-88 as in previous years. One automatic weather station is permanently installed in our experimental orchard to record the microenvironment in a sprinkled area. A second station was set upwind from the orchard as a control. A completely randomized block design was used to study the effects of ground cover on surface emitting temperatures.

Results:

Because there were no serious frost events during 1988, data are not reported here. Severe frost events from February 1987 were analyzed and figures showing observed microclimate parameters during the two nights are attached. On both nights, we feel that a microscale advection rather than a radiation frost occurred. This was concluded because the wind changed direction just before the large temperature drop which was observed on both nights during the morning hours. The large temperature drop occurred because of cold air drainage from the mountain foothills located east of the orchard. Before the temperature drop, the wind was from the northwest for several hours and then it stopped before the cold air drained in from the east.

Discussion:

There was no differences in nut set in sprinkled and unsprinkled plots along the edge of the orchard resulting from the mild frost event during February 1988. We believe that this is the result of an edge effect. Cold air intrusion negates the benefits of sprinkler operation along the edge for some distance into an orchard depending on weather conditions.

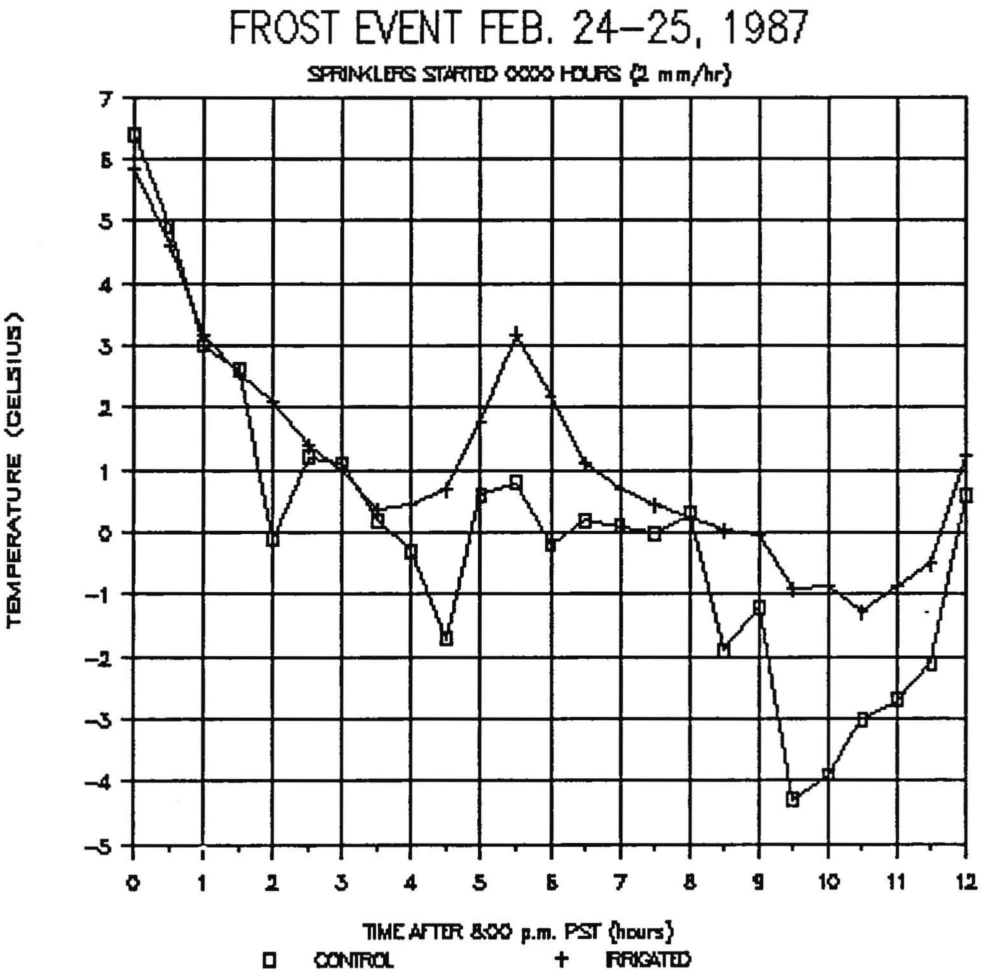
An infrared thermometer was used to measure surface emitting temperature rather than air temperature for the ground cover experiments. This was necessary because for air temperatures to be representative of a particular ground cover management, the cover must be extensive. However, natural microclimate differences are likely if the ground cover is extensive and thus measuring air temperatures to study ground cover effects may be misleading. Surface temperatures were measured in a small area so microclimate differences are unlikely. Our hypothesis is that differences in surface emitting temperatures are likely to lead to differences in air temperatures if the cover is extensive.

Our results from the February 1987 frost events showed that microscale advection may be the culprit behind much of the frost damage that occurs in California. Cold air can accumulate in depressed areas and later drain into an orchard causing considerable damage if the wind speed and direction change. These observed frost events partially explain the difficulty in forecasting freezing temperatures, and they show that a new approach to preventing severe frost damage might be to modify the cold air upslope where it forms upslope rather than in the orchard.

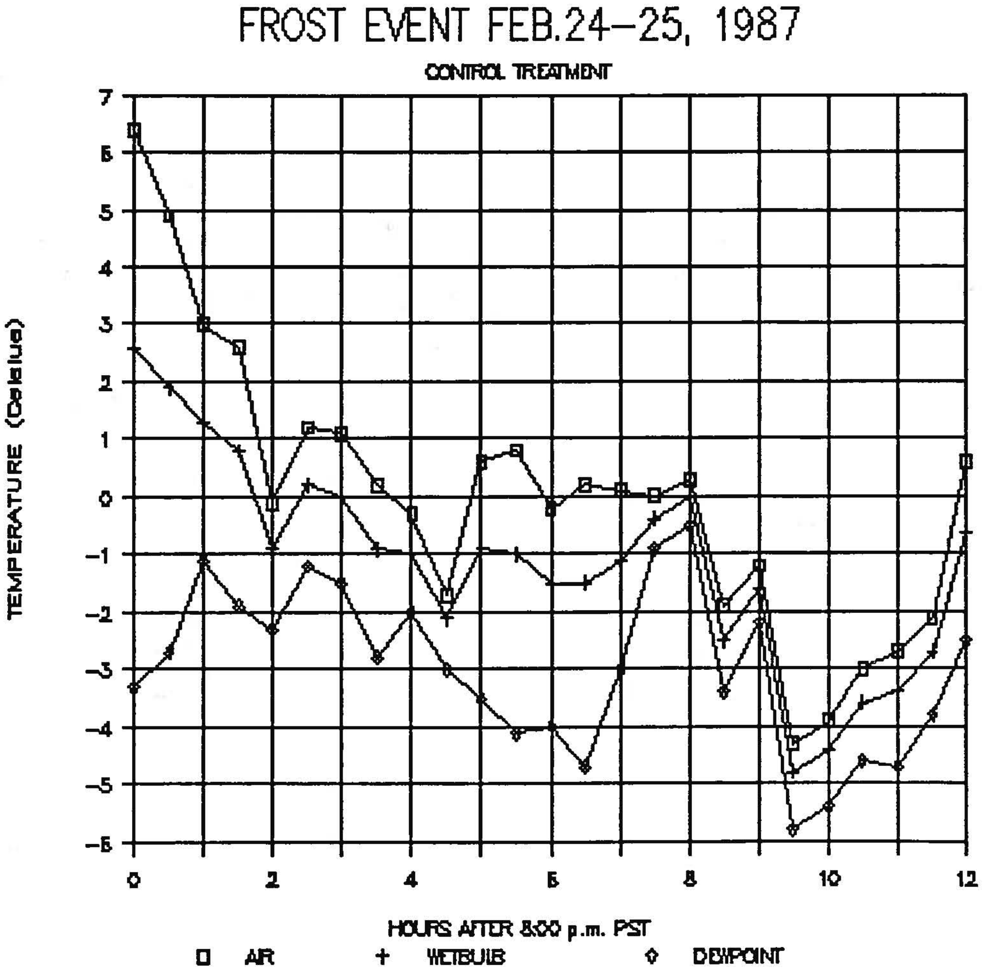
A freezing chamber using a commercial freezer and flow controlled nitrogen has been constructed. It will be used to test for a variety differences in sensitivity to frost damage during the 1988-89 season.

Publications:

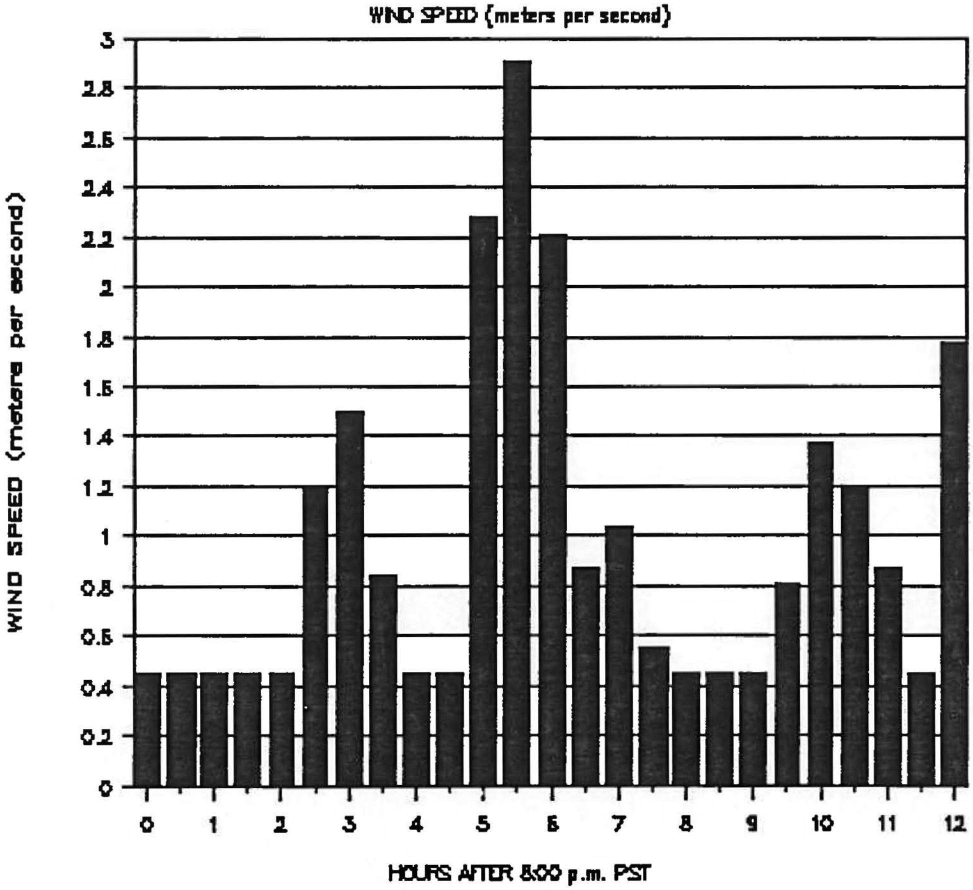
A new publication entitled "Sprinkler spacing effects almond frost protection" is in press and will probably be published in the January-February, 1989 issue of California Agriculture. The University of California One Page Answer Number 7165 entitled "Frost protection: When to turn sprinklers on and off" is currently available in local Cooperative Extension offices.

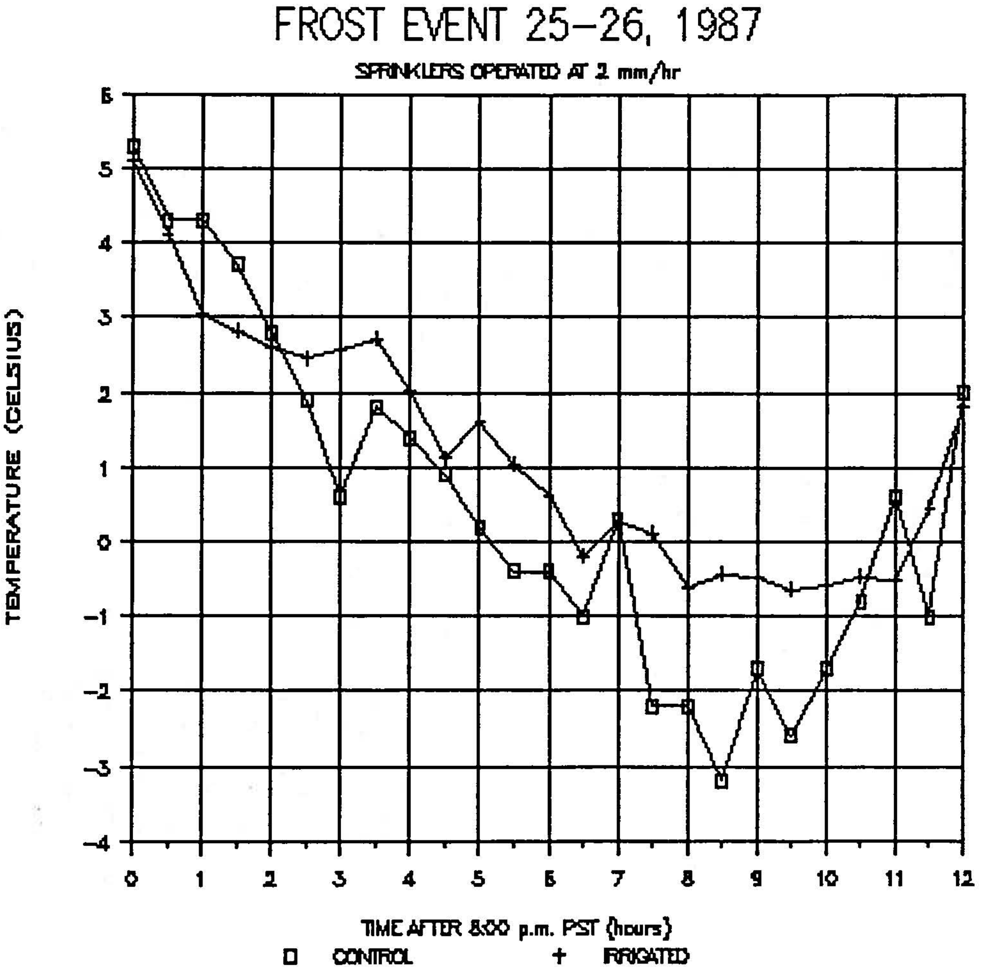

FROST EVENT FEB. 24–25, 1987

SPRINKLERS STARTED 0000 HOURS (2 mm/hr)

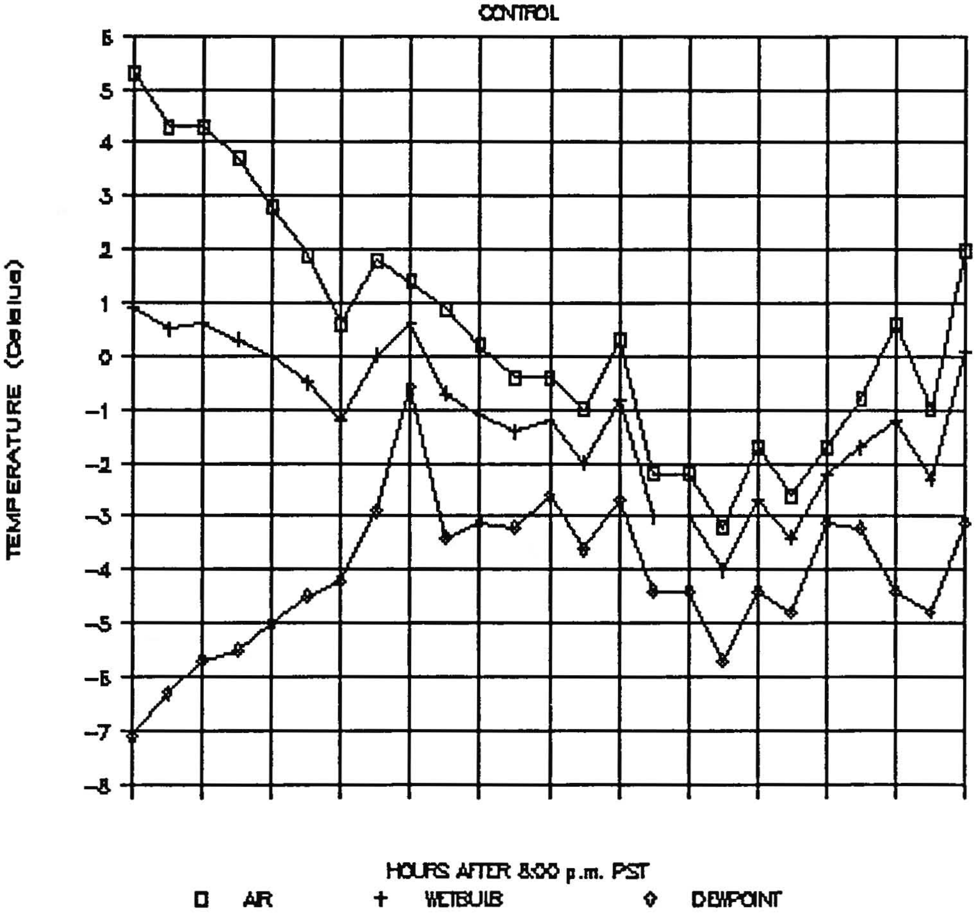

FROST EVENT FEB.24-25, 1987
CONTROL TREATMENT
TEMPERATURE (Celsius)
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
0
2
4
6
8
10
12
HOURS AFTER 8:00 p.m. PST
□ AIR
+ WETBULB
◇ DEWPOINT

FROST EVENT FEB.24–25, 1987




FROST EVENT 25-26, 1987
SPRINKLERS OPERATED AT 2 mm/hr
TEMPERATURE (CELSIUS)
6
5
4
3
2
1
0
−1
−2
−3
−4
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME AFTER 8:00 p.m. PST (hours)
□ CONTROL
+ IRRIGATED

FROST EVENT FEB. 25–26, 1987



FROST EVENT FEB. 25-26, 1987

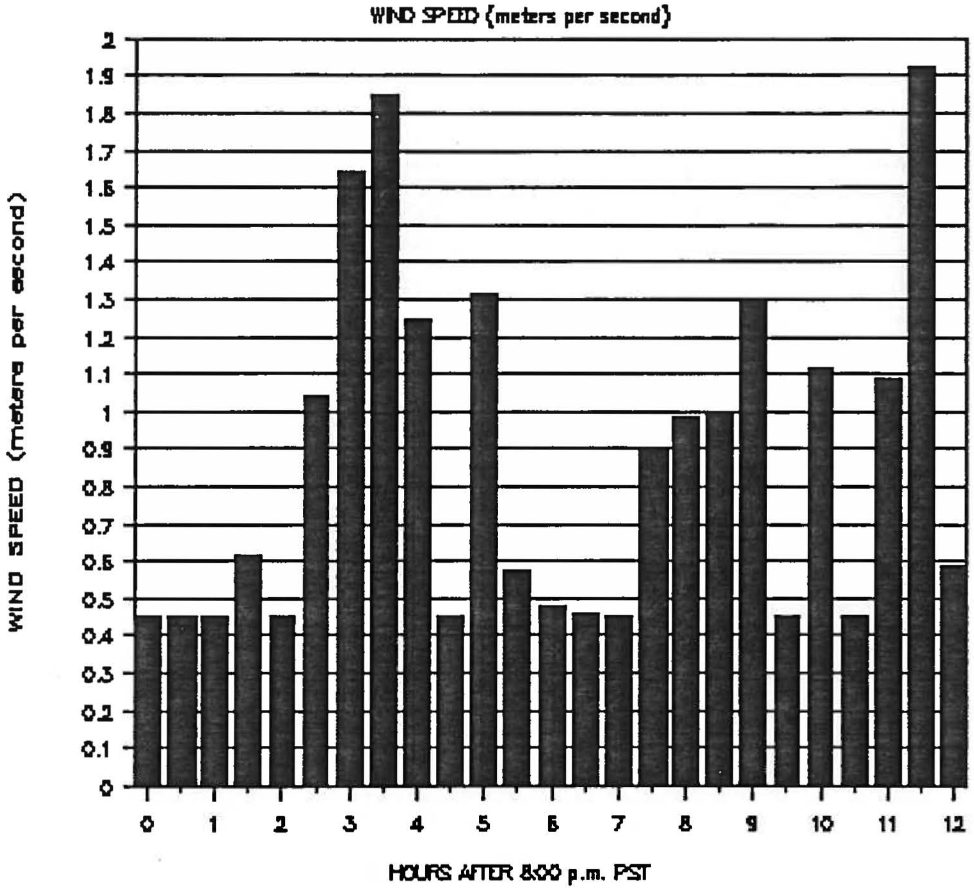


TABLE 4. Distance traveled to farmers' markets

Market	Number	Avg. distance*	Maximum
		mi	*mi*
San Francisco	58	142	250
San Rafael (Marin County)	35	107	494
Los Angeles	53	96	362
Morro Bay/San Luis Obispo	36	48	143
Sacramento	33	46	219
Stockton	62	6	74

TABLE 5. Main reasons for selling at farmers' markets

Reason	Total sample	Growers by category		
		Small	Medium	Large
	%	%	%	%
More profits	32	31	48	38
Enjoy selling there	14	14	14	13
Cash sales	10	10	10	31
Another outlet	8	8	5	13

Vegetables and melons were grown by 75% of the farmers, fruits and nuts by 52%.

Distances traveled

Most of the sellers at rural markets were local farmers, but many growers traveled great distances to sell at large urban farmers' markets. Growers traveled an average of 142 miles each way to the San Francisco Alemany Market (measuring between county centers), 107 miles to the San Rafael market, and 96 miles to Los Angeles markets (table 4).

Over 20% of the growers interviewed in Los Angeles markets traveled more than 200 miles each way, and many commuted these distances several days a week. In contrast, rural markets drew farmers from shorter distances, with an average distance traveled to the Stockton market of 6 miles.

Reasons for selling at markets

When asked their main reason for selling at farmers' markets, growers most often replied "profits." The second most frequent answer, however, had nothing to do with economics—it was that they enjoyed selling at farmers' markets. Other motivations included cash sales and finding an additional outlet for crops (table 5). Growers in all farm size groups ranked profits first, but large growers ranked cash sales as more important than enjoyment.

Other reasons mentioned for selling at these outlets were to find out what consumers want, to promote the farm or a particular product, and to educate consumers about different varieties of crops. Several mentioned the convenience of selling at markets close to their farms.

Conclusion

Growers who sell at these markets do not fit the common perception of backyard or part-time farmers whose only outlet is the local farmers' market. The gross annual sales of farms represented at farmers' markets is consistent with the distribution of all California farms, ranging from under $2,500 to over $500,000. Farm size of farmers' market producers ranges from a backyard plot to 960 acres. There are smaller proportions of noncommercial and part-time farmers selling at farmers' markets than there are in the state as a whole.

Figures are not available on the number of farmers selling at Certified Farmers' Markets or the sales volume. It is clear from the rising number of markets, however, that they are becoming important marketing channels to more farms of all sizes. These markets are a full-time business for some farmers and a supplementary outlet for others. Several growers credited farmers' markets with saving their farms from bankruptcy.

Suzanne Vaupel is a Research Agricultural Economist, Department of Agricultural Economics, University of California, Davis. This study was funded by the Cooperative Extension Rural Development Program, Department of Applied Behavioral Sciences, UC Davis. Support and cooperation were also given by the Direct Marketing Program of the California Department of Food and Agriculture, California Direct Marketing Association, Southland Farmers' Market Association, and Bay Area Marketing Group. Photos by the author.

Sprinkler spacing affects almond frost protection

Joseph H. Connell ❑ Richard L. Snyder

The use of under-tree sprinklers for frost protection is an established practice but the specific mechanisms of the practice aren't well understood. This study of sprinkler spacing showed that best protection depends on placement of lines and air movement within the orchard.

Almond growers who irrigate with hand-move aluminum sprinkler pipe are usually limited in the area they can cover at any one time, by either the amount of water or the amount of pipe available. When frost is a danger, placement of these limited resources may make a difference in the protection obtained. The choice has to be made between spreading sprinklers over an entire orchard, so that dry areas are left between sprinkler lines, and concentrating water application to provide more complete protection in one area. The purpose of this study was to learn how sprinkler operation at various spacings physically affects the orchard environment and which spacings provide the best management of limited frost-protection resources.

The experiment

An aluminum hand-move sprinkler system was simulated in a 12-year-old almond orchard near Chico, California, during the winter of 1986-87. Normally, a permanent set irrigation system is used in this orchard, but part of the system was blocked so that we could study the simulated hand-move arrangement. There were four treatments in the experiment including the control (fig. 1).

Treatment 1 was the grower's permanent set sprinkler system, which has a 27- by 27-foot diamond spacing. The system has Toro nonimpact sprinkler heads that apply water at a rate of approximately 0.08 inch per hour (36 gpm per acre).

Treatment 2 simulated hand-move sprinklers with 54 feet between heads and between the lines. Treatment 3 also simulated hand-move sprinklers but they were spaced 108 feet between the lines. The latter spacing is commonly used by California growers. Impact sprinklers with 5/32-inch orifices were used on the hand-move system in treatments 2 and 3. Line pressure was approximately 55 psi and the flow rate 5.3 gpm with 5/32-inch nozzles. The irrigation rates were 79 and 39 gpm per acre for treatments 2 and 3, respectively. Sprinkler patterns did not overlap in either treatment, leaving dry areas between the lines.

Treatment 4 was the control, where no sprinklers were operated.

Minimum temperatures were measured at 14 locations in the orchard. The measurements were taken with minimum glass thermometers in modified orchard minimum recording thermometer shelters. A short lip was placed over the front of the shelters to keep sprinkler water from hitting the thermometers.

Temperature sites were selected to represent expected extremes within each treatment (fig. 1): adjacent to sprinklers (sites 2, 6, and 7); as far as possible from sprinklers (sites 1, 4, and 12); and at intermediate distances (sites 3 and 5 in treatment 2 and 8, 9, 10, and 11 in treatment 3). Sites 13 and 14 were in the control treatment, which was north (upwind) of the other treatments. During the experiment, wind speeds of less than 2 miles per hour were recorded, predominantly from the north.

Soil surface temperatures were measured with an infrared thermometer on the north side of each thermometer shelter from about 1 meter height at an angle of approximately 15° from vertical.

Temperature observations

The sprinkler system was operated on the night of January 18-19, 1987, when the trees were dormant. The minimum air temperatures recorded in the control treatment were 26° and 27°F. Air and soil surface temperatures for the other sites are listed in table 1.

There was only a small difference in air temperatures at any of the sites within or across treatments. This was not totally unexpected, since the plots were small and local air movements tend to equalize differences due to treatments. The treatment averages show that closer spacing of sprinklers might result in higher temperatures. If the plots had been larger, the differences might have been greater, but natural microclimate differences between larger plots are probably greater than the treatment effects and misinterpretation could result. We have observed natural air temperature differences of 1° to 2°F due to microclimate alone in an orchard with uniform management and flat topography.

The effects of air movement on soil surface temperatures should be small. We therefore measured surface temperatures twice during the night of sprinkler operation to identify treatment differences. On a large scale, soil surface temperature is related to air temperature when an entire orchard receives the same sprinkler management. If the average soil surface temperature were lower, we would expect the minimum air temperature to be lower too.

Infrared thermometer readings taken at the orchard thermometer sites provided surface temperatures near and far from sprinklers in each treatment (table 1). Soil surface temperatures tended to be lower where sprinkler water wet the surface little or not at all (sites 3, 4, and 9-14). Thus, if the entire orchard were protected by sprinklers at a spacing of 108 by 54 feet, we would expect a larger area with colder surface temperatures and we would also expect the air temperature to be lower than that measured in this experiment.

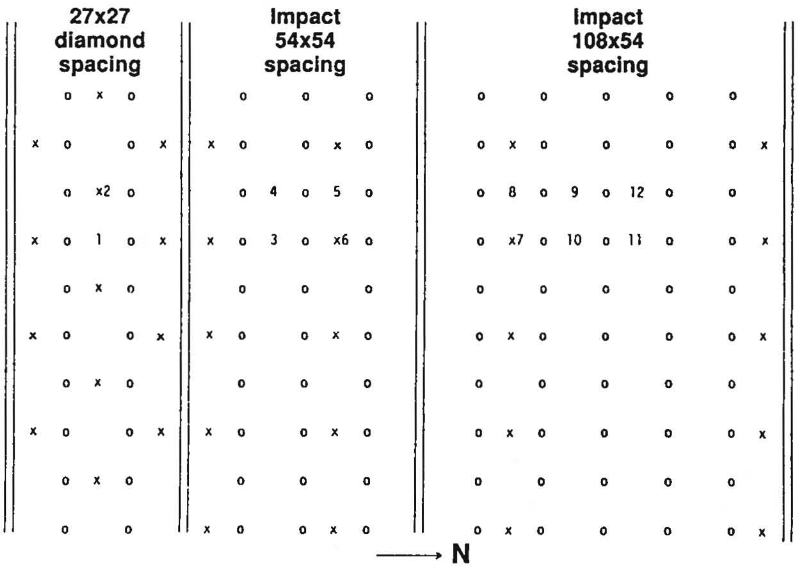


Fig. 1. Sprinkler head locations (x), trees (o), and temperature measuring sites (numbers) in 1987 almond frost experiment. Control stations 13 and 14 (not shown) were north of sprinkler plots. Several border rows were maintained between treatments.

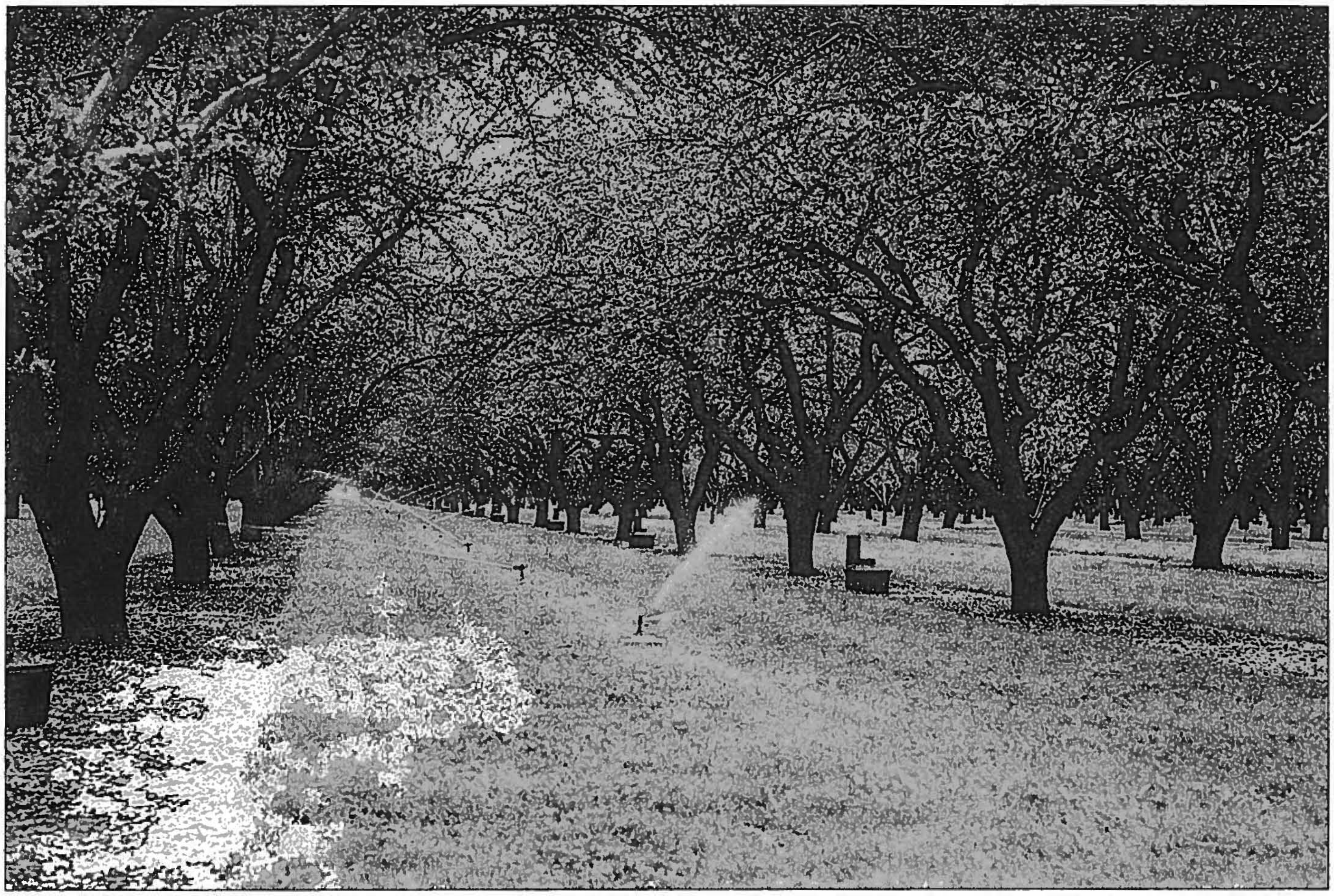
TABLE 1. Minimum air temperatures and soil surface temperatures at 3:30 and 7:30 a.m. Jan. 19, 1987

Sprinkler treatment, site No.	Surface wetness	Temperature: Minimum air	Soil surface: 3:30	7:30
		°F	°F	°F
27' x 27' diamond, non-impact:				
1	Wet	32[*]	26.8	28.9
2	Int.[†]	28	28.2	29.5
Average		30.0		
54' x 54' impact:				
3	Int.	28	28.8	29.3
4	Dry	28	29.1	29.3
5	Wet	28	30.4[§]	30.6[§]
6	Wet	29	29.8	29.8
Average		28.3		
108' x 54' impact:				
7	Wet	25	30.0	29.5
8	Wet	28	30.0	30.2
9	Dry	27	27.0	28.9
10	Int.	27	27.7	29.7
11	Dry	28	27.0	27.7
12	Dry	27	26.8	26.8
Average		27.0		
Control:				
13	Dry	26	26.6	26.6
14	Dry	27	27.1	27.5
Average		26.5		

[*] This thermometer was accidentally bumped during reading.

[†] Int. = intermediate

[§] Water was ponding on the soil where the surface temperature was measured.



Sprinklers between rows of trees in a nontilled almond orchard can hold temperatures 1° to 2°F above unsprinkled areas, effectively protecting trees from mild frost. Sprinklers between every fourth and fifth rows can protect an entire orchard.

Conclusions

In this study, air temperatures in the sprinkled treatments were 1°F to 2°F warmer than in the unsprinkled treatment. Under these mild frost conditions with light wind there were no appreciable differences in air temperature between the various sprinkler spacing treatments.

Soil surface temperatures showed a more direct relationship to sprinkler spacing and may be a better indicator of what might be expected under more severe frost conditions. In this trial the surface temperature was lower as the distance from the sprinklers increased. At the widest spacing, the surface temperature in the dry middle area between sprinkler lines was as cold as the surface temperature in the unsprinkled control plots.

The spacing between sprinkler lines does affect soil surface temperatures. Since the heat that provides frost protection from under-tree sprinkling is mainly that radiated from the soil surface, protection depends on the spacing between the sprinkler lines and on air movement. Therefore, the sprinkler spacing of 54 by 108 feet used by California growers is a practical limit. More than that would diminish protection.

Air movement evens out the benefits provided by under-tree sprinkler frost protection. Under severe frost conditions with little air movement, the protection provided in the dry middle between widely spaced sprinkler lines would be inadequate. In many orchards, sprinkler lines must be spaced out in every fourth middle due to water or pipe limitations. Under such conditions, placing the lines next to the most frost-sensitive almond varieties would be the best use of resources in moderate to severe frosts. Under mild to moderate conditions, with adequate air movement, sprinkler lines in every fourth middle have provided frost protection to the entire orchard.

Joseph H. Connell is Farm Advisor, University of California Cooperative Extension, Butte County; and Richard L. Snyder is Biometeorologist, Cooperative Extension, Department of Land, Air and Water Resources, UC Davis.

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Frost Protection:
When to Turn Sprinklers On and Off

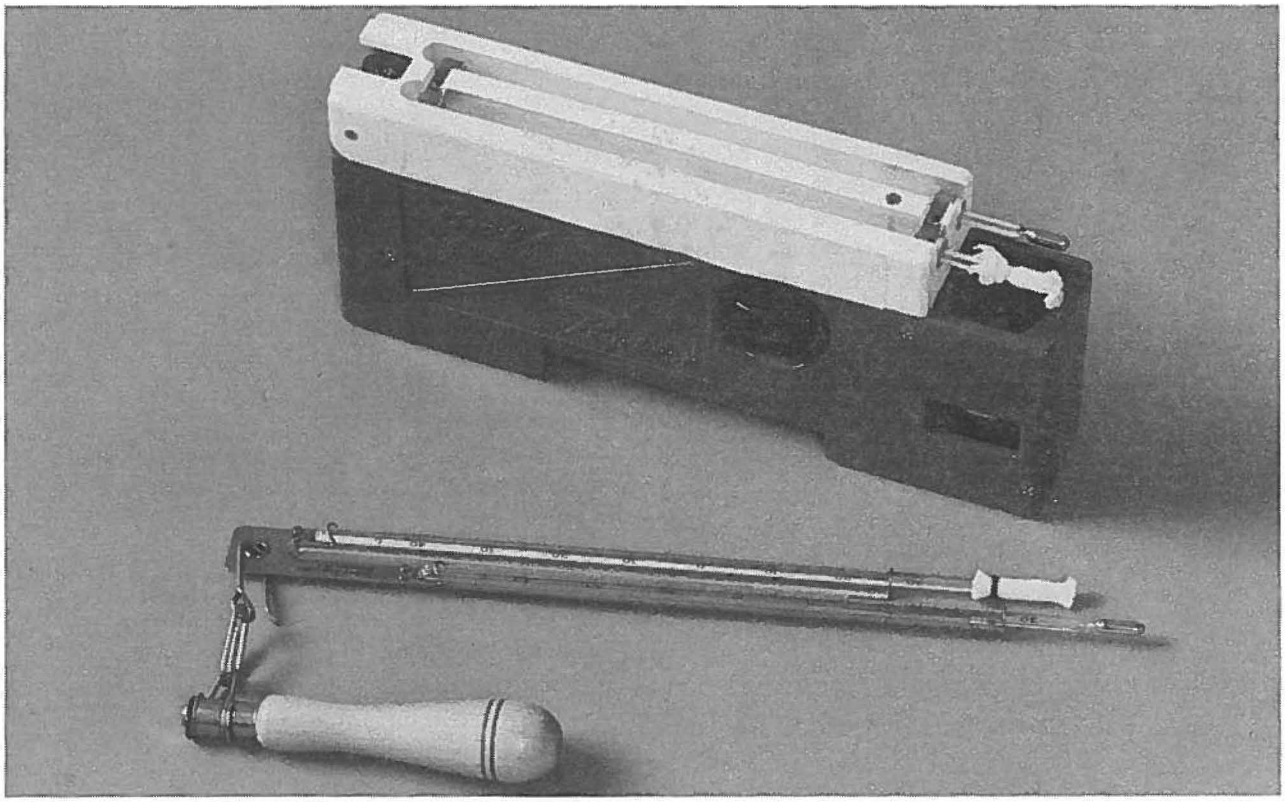
Sprinklers have been used extensively for frost protection in California, and proper management is required to obtain beneficial results. Two of the most critical decisions are when to turn the system on and when to turn it off. The decisions should be based on both temperature and humidity in the orchard.

Recommendations given here can be used for either over-plant or under-plant sprinklers. Sprinklers can be turned on or off at higher, but not lower, temperatures than those recommended. All sprinklers in a protection area should be on when the temperature drops to a specified air temperature that depends on humidity and the "critical temperature" for crop damage.

A wet plant's temperature will not fall below the wet-bulb temperature, if sprinklers stop or if an application rate is inadequate. Consequently, starting and stopping sprinklers should always occur when the wet-bulb temperature is above the critical temperature for damage to the crop. Even if the sun is shining on the plants and the air temperature is above the melting point (0°C or 32°F), sprinklers should not be turned off unless the wet-bulb temperature is above the critical temperature. Permitting the wet-bulb temperature to exceed the melting point before turning off the sprinklers can be done safely if soil waterlogging is not a problem.

The wet-bulb temperature can be measured directly with an instrument called a psychrometer (see photo) or it can be determined from the dew point and air temperature (table 1).

The wet-bulb temperature is determined with a psychrometer by wetting the cotton wick and swinging the psychrometer (or aspirating with the fan)



Aspirated (*upper*) and sling (*lower*) psychrometers are used to determine humidity by measuring dry-bulb and wet-bulb temperatures. The cotton wick on a wet-bulb thermometer is wetted with distilled or deionized water, and it is aspirated by a fan or by swinging the psychrometer until the temperature stabilizes at the wet-bulb temperature. This resulting wet-bulb temperature can be used to time the operation of sprinklers for frost protection.

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until the temperature of the wet-bulb thermometer stabilizes. If the temperature is below 0°C (32°F), the water on the cotton wick should be frozen and aspirated until the temperature stabilizes. Touching the wick with cold metal or ice will cause freezing.

Air temperatures for a range of wet-bulb and dew-point temperatures are given in Table 1. A wet-bulb temperature just above the critical temperature can be chosen and, if the dew-point temperature is known, the air temperature to turn the sprinklers on or off can be selected from table 1. If relative humidity and temperature figures are available instead of dew-point temperature, use table 2 to determine the dew-point temperature; then use table 1 to obtain the desired air temperature.

Critical temperatures are specific to the crop being protected and sensitivity to frost damage during the growth stage when the frost night occurs. Generally, sensitivity increases from first bloom to the small nut or fruit stages when a crop is most likely to be damaged. Sensitivity is also higher when warm weather has preceded a frost night.

The author is Richard L. Snyder, bioclimatologist, Department of Land, Air, and Water Resources, UC Davis.

TABLE 1. Minimum turn-on and turn-off air temperatures for sprinkler frost protection for a range of critical damage and dew-point temperatures*

Dew-point temperatures (°F)	Wet-bulb temperature (°F)										
	22	23	24	25	26	27	28	29	30	31	32
32											32
31										31	33
30									30	32	34
29								29	31	33	34
28							28	30	32	33	35
27						27	29	31	32	34	35
26					26	28	30	31	33	34	36
25				25	27	29	30	32	33	35	37
24			24	26	27	29	31	32	34	35	37
23		23	25	26	28	29	31	33	34	36	38
22	22	24	25	27	28	30	32	33	35	36	38
21	23	24	26	27	29	30	32	34	35	37	39
20	23	25	26	28	29	31	33	34	36	37	39
19	24	25	27	28	30	31	33	34	36	38	39
18	24	26	27	29	30	32	33	35	37	38	40
17	25	26	28	29	31	32	34	35	37	39	40
16	25	26	28	29	31	33	34	36	37	39	41
15	25	27	28	30	31	33	34	36	38	39	41

*Select a wet-bulb temperature that is above the critical damage temperature for your crop and locate the appropriate column. Then choose the row with the correct dew-point temperature and read the corresponding air temperature from the table to turn your sprinklers on or off. This table assumes a barometric pressure of 1000 millibars.

TABLE 2. Dew-point temperatures for a range of air temperatures and relative humidities

Relative humidity (%)	Temperature (°F)					
	20	25	30	35	40	45
100	20	25	30	35	40	45
90	18	23	27	32	37	42
80	15	20	25	30	34	39
70	12	17	21	26	31	36
60	8	13	18	23	27	32
50	4	9	14	18	23	28
40	0	4	9	13	18	22
30	− 7	− 2	2	7	11	15
20	−15	−10	− 6	− 2	2	6
10	−18	−24	−20	−16	−12	− 8

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