

**TABLE 4. Distance traveled to farmers' markets**

Market	Number	Avg.	Maxi-
		distance*	mum
		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.

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# Sprinkler spacing affects almond frost protection

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***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 spac-

ing 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 opera-

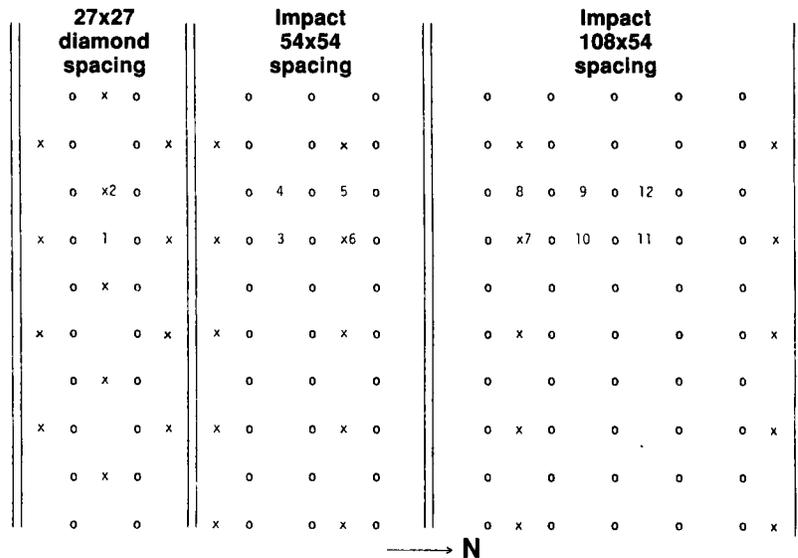


Fig. 1. Sprinkler head locations (x), trees (o), and temperature measuring sites (numbers) in 1987 almond frost experiment. Control stations 13 and 14 (not shown) were north of sprinkler plots. Several border rows were maintained between treatments.

tion 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.

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 °F	3:30 °F	7:30 °F
<b>27' x 27' diamond, non-impact:</b>				
1	Wet	32*	26.8	28.9
2	Int.*	28	28.2	29.5
Average		30.0		
<b>54' x 54' impact:</b>				
3	Int.	28	28.8	29.3
4	Dry	28	29.1	29.3
5	Wet	28	30.4 <sup>§</sup>	30.6 <sup>§</sup>
6	Wet	29	29.8	29.8
Average		28.3		
<b>108' x 54' impact:</b>				
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		
<b>Control:</b>				
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.

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*The authors thank Robert N. Hennigan of Hennigan Farms, Chico, California, for the interest and cooperation that made this work possible. This work was supported in part by a grant from the Almond Board of California.*