

EVAPORATION COOLING



VIN

D. E. GILBERT

EXCESSIVELY HIGH TEMPERATURES from June through September are a major concern to agriculturists in the San Joaquin Valley of California. This "semidesert" area receives high levels of incoming radiation resulting in daily maximum temperatures consistently exceeding 90°F with daytime relative humidities dropping below 25 per cent. Experienced growers believe that 90°F is the critical temperature for most temperate zone crops and slightly above this for subtropical species. Producers of citrus, avocados, grapes, and other crops attribute large losses to the excessively warm and dry temperatures. For example, Tokay grape yields are frequently reduced 10 to 20 per cent because of sunburn damage. Growers are constantly seeking means of avoiding these high-temperature losses. The use of permanent over-vine or over-tree sprinklers is one possibility reported in this study.

Studies were conducted in San Joaquin Valley vineyards from 1967 through 1969 directed toward evaluation of atmospheric stress reduction at different sprinkler application rates. Temperature measurements of plant parts and quality measurements of fruit were attempted. In this

geographical area, water supplies are adequate but seldom abundant.

Two commercially available, permanent, over-vine systems were used during the investigations. A conventional sprinkler system, e.g., impact sprinklers operated at 55 psi, was operated in a 20-acre vineyard containing five wine grape varieties. Sprinklers were spaced 40 ft by 48 ft, equipped with 7/64-inch nozzles. Heads rotated one to one and two-thirds times per minute.

The system used in a 4-acre Tokay vineyard was a fully-automated, high-pressure system. Sprinkler heads, equipped with 1/8-inch nozzles, were spaced 40 ft by 44 ft in a triangular pattern. Twenty-seven plastic heads per acre, operating at 82 psi at the nozzle, normally functioned sequentially at 6 seconds on and 18 seconds off. During the "on" time the heads rotated one to one and one-quarter times.

Duration of operation

Because of limited water quantities, initial investigations were aimed toward establishing the optimum time sequence for intermittent water application. During the 1967 season, a thermistor bead 1/8-inch in diameter was placed against the upper surface of a grape leaf. The leaf selected was perpendicular to the sun's rays. The sprinklers were started and the temperature decline recorded. The temperature of the probe decreased from 105°F at the onset of the trial to the approximate lower limit of 78°F at the end of 5.5 minutes. At that time the temperature stabilized with no further significant change. During the 55 minute operation, the air temperature outside the sprinkled area decreased two degrees. This is normally observed when air temperature is measured with sensitive equip-

Effective crop cooling of vineyards was obtained with the use of small amounts of water, intermittently applied through overhead sprinklers. The light sprinkling cooled the air, raised the humidity, and cooled the plants. Sprinklers functioning on 3-minute on and 15-minute off periods cooled the air by 7 to 10 degrees and raised the humidity 10 to 20 per cent. Plant temperatures were reduced 15 to 25 degrees. The cost of this operation was minimal. The true potential is still to be explored.

ment during short time intervals. Thus a net decrease of 25°F, due to sprinkling, was observed.

A similar trial was conducted with the probe taped to the underside of the leaf. The temperature decreased from 91°F to 83°F while the sprinklers were functioning. During this same time period the unsprinkled air temperature declined 1°F. Thus a net cooling of 7°F was obtained. The cooling was achieved during the first 3 minutes of operation while an additional 3-minute period made no significant contribution. In fact, the probe temperature started to increase. In addition, 15 minutes elapsed after sprinkling ceased before the temperature reached the level prior to the water application.

Leaf temperatures were measured in 1968 and 1969. During the 1968 trials, thermocouple sensors were used, and during the 1969 season, 28 gauge hypodermic thermistors were employed. During both seasons the sensors were inserted into leaf tissue at the junction of the leaf blade and petiole. A temperature decrease of nearly 12 degrees was obtained during

SUMMARY OF TEMPERATURES AND HUMIDITY CHANGES DURING 35 CONSECUTIVE DAYS OF SPRINKLER OPERATION FOR VINEYARD COOLING IN SAN JOAQUIN VALLEY, 1969

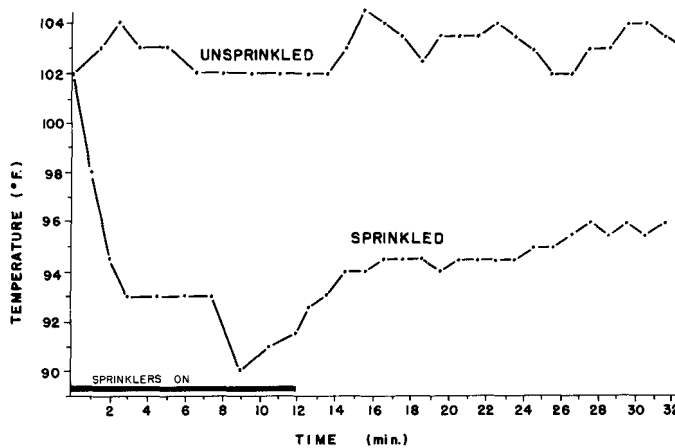
Range of temperature decrease	Number of days	Range of humidity increase	Number of days
6°-10°	25	9%-10%	4
11°-15°	4	11%-20%	15
16°-20°	5	21%-30%	6
21°-25°	1	31%-40%	1
		41%-50%	1
		51%-60%	0
		61%-70%	2
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Total	35	Total	34*

* One day of missing data.

OF VEGETABLE GARDENS

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GRAPH 1. AIR TEMPERATURE CHANGE DUE TO SPRINKLER OPERATION



the 3 minutes of sprinkling. The temperature had stabilized during the last 30 to 45 seconds of operation, hence the sprinkling was terminated at the end of 3 minutes. An additional cooling of 4 degrees, after the sprinklers were turned off, can be attributed to the evaporation of the water which had adhered to the leaf surface. Forty-five minutes after sprinkling stopped, the temperature had not yet reached the level it had been at prior to the sprinkling.

These observations and others showing similar trends make it apparent that 3 minutes of sprinkler operation is sufficient to cool the crop, and that 15 minutes between cooling periods is adequate. Following this sequence of operations, the conventional irrigation system would apply 0.03 inches of water per hour and the automated system would apply 0.06 inches per hour. Neither of these quantities adds an appreciable amount of water to the soil, or affects irrigation. It is not uncommon, for example, for vigorous vineyards to lose 0.25 inches of water per day, or more, through evapotranspiration.

During the 1969 season, the automated system was redesigned to apply 0.01 inches per hour, with the results being nearly comparable to the conventional system which provided 0.03 inches per hour.

Air temperature changes

During the years of investigation, hygrothermographs, at standard instrument height, were placed in the sprinkled and unsprinkled areas. The unsprinkled site was adjacent to the treated area but upwind. Wind speeds averaged 3 to 5 miles per hour all three seasons. Records obtained on a warm day during the 1967 season, see graph 1, showed the sprinkled air temperature decreased 12 degrees during the period of operation. The sprinklers were operated past the previously established 3-minute duration to reevaluate the temperature-time relationship. It was obvious, even in this case, that the 3-minute sprinkling duration is satisfactory. Nine degrees of cooling had occurred within that time interval while an additional 3 degrees required an added nine minutes of operation. Similarly, the air

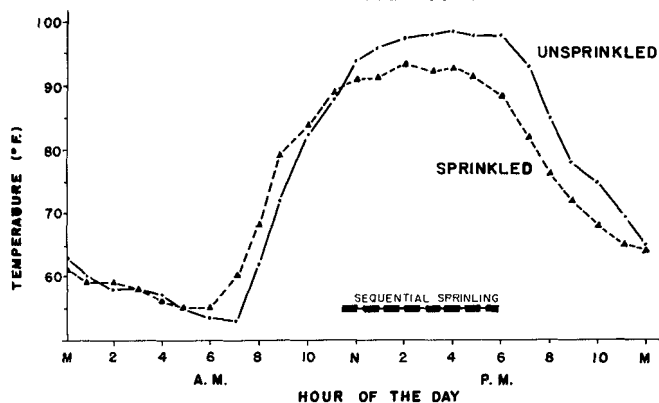
temperature failed to reach its initial point during the succeeding 20 minutes following cessation of sprinkling.

A complete day recorded in 1969 (graph 2) involved sprinkler operation intermittently (3 minutes on and 15 minutes off, from 11:00 am to 6:00 pm). During this time, air temperature decreased from 7° to 10°F. The greatest influence occurred at the time of unsprinkled air maximum temperature. It was further observed that the sprinkled area maintained cooler air temperatures throughout the rest of the 24-hour day. Coincidence of temperature between the sprinkled and unsprinkled areas was not achieved until midnight.

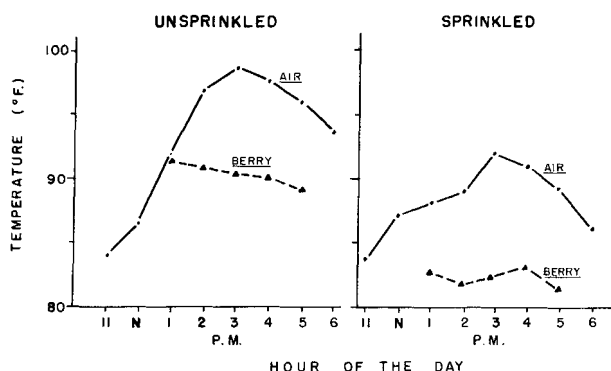
Humidity changes

An expected humidity increase accompanied the temperature decrease. This is due to two factors—one being the cooling process itself, the other being the incorporation of moisture into the atmosphere. The usual relationship occurring during days of the field trials was that relative humidity was increased at least 9 per cent, due to intermittent sprinkling, dur-

GRAPH 2. INFLUENCE OF SPRINKLER OPERATION ON THE DAILY AIR TEMPERATURE



GRAPH 3. INFLUENCE OF SPRINKLER OPERATION ON AIR AND GRAPE BERRY TEMPERATURES (SPRINKLERS OPERATED SEQUENTIALLY FROM 1:00 PM TO 6:00 PM)



ing the period of highest temperature. The greatest increases achieved, throughout the season, while the air temperature was above 90°F, were two rises to more than 60 per cent. These occurred during the late afternoon just prior to termination of sprinkling and were exceptions to the general situation.

A summary of results for the 1969 season is shown in the table. The temperatures indicated are air temperatures. These data suggest that air temperature due to sprinkling is usually depressed by 6 to 10 degrees and humidity increased by 10 to 20 per cent. This has been the experience over the past three seasons.

Plant temperature changes

Plant temperatures (leaf tissue and grape berry temperatures) are generally depressed by 15 to 25 degrees and 10 to 13 degrees respectively. Since the grape berry is the end product of vineyard operations, study has been concentrated on measuring the temperature of the berries (graph 3). Measurements of berry tissue in 1969 revealed that whenever sprinklers were in operation throughout the season, berry temperatures seldom exceeded 90°F; and in those three or four instances where 90°F was exceeded, the deviation was less than 0.5°F.

As previously stated, experienced growers believe that 90°F is the optimum temperature for the growth and development of both Tokay and wine variety grapes. Using this as base data, radio control equipment set at 90°F was used during the 1968 and 1969 seasons to start the sprinklers. Recording instruments were started at 88°F.

During the 1968 tests the sprinklers remained in operation until the air temperature outside the test areas dropped below 90°F. While the sprinklers started, as a general rule, between 10:00 and 11:00 a.m., they often continued until 8:00 p.m. or after. By the end of the season, two varieties of the wine variety block and the Tokay plot had developed serious *Botrytis cinerea* rot problems. During 1969, the tests started at the 90°F threshold but terminated at 6:00 p.m. Sprinkler shut-down was accomplished by an electric time clock. The two wine grape varieties, susceptible to rot during 1968, continued to show heavy *Botrytis* rot damage. The Tokay plot contained far less bunch rot than in 1968. It is now believed an earlier shut-off would be desirable, and that variety response to this technique may be a genetic factor not yet evaluated.

Before vineyard cooling will be widely

accepted, it must meet two specific criteria: *first*, the cost must be minimal; *second*, an increase in yield or an increase in the quality of product should result.

Using 1 to 1.5 cents per horsepower-hour as the cost of sprinkling, and keeping in mind that sprinklers operate only 10 minutes in an hour, the cost of this technique would seldom, if ever, exceed \$10.00 per acre per year.

In the 1967 and 1968 tests, the Tokay vineyard tended toward higher yields. However, these were not critically evaluated, hence remain a trend. Wine grapes, on the other hand, have not indicated a yield advantage. However, fruit quality, measured by pH, sugar/acid ratio, and total acidity, tends to be slightly better with some varieties when crop cooling is practiced. The true test for the wine varieties lies in the quality of wine produced.

Still another consideration lies in the application of this technique. In some areas of California it may be possible to change the environment into one more suitable to the production of specific crops—or to eliminate a predictable warm period limiting the quantity or quality of crops presently grown. For example, modifications possible in some areas of the San Joaquin Valley appear capable of producing growing conditions approximating those of the coastal valleys of California. In the desert areas, early crop production is limited by the rapid increase in daytime temperatures during the springtime. Adaptation of evaporation cooling may suppress the rate of rise sufficiently to permit satisfactory crop production.

Both of these examples point out alternatives which could be used when specific crop demands exceed availability because of limited growing sites, or maximum production in ideally suited areas.

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Instrumentation was made available through a grant to the University of California by the C.R. E. A. (California Committee on Relation of Electricity to Agriculture) for crop cooling and frost protection studies. Equipment for radio control was provided by RACO Manufacturing Company, Berkeley, California.

DON LUVISI · GEORGE NYLAND

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TOK FURUTA

ROSE PLANTS may be infected with virus even when symptoms are not visible. Various growth abnormalities and color patterns have been associated with virus infection. Despite their demonstrated presence, factual data have not been available to demonstrate the effects of virus on plant growth, survival or flowering.

Heat treatments were used to obtain rose plants free of Prunus ring spot virus. Sufficient quantities of heat treated Rosa "Dr. Huey" understock, and budwood of Chrysler Imperial were available in 1966-67 to begin studies on the influence of virus on performance of the plants in the nursery, and in the landscape.

Nursery performance

The plants were propagated by a nursery in their commercial rose fields during the 1967-68 growing seasons. Three combinations of scion and stock were made but only two were compared—(1) non-heat-treated scion and stock, vs. (2) heat-treated stock and virus free scions. Indexing for virus on "shiro-fugen" flowering cherry showed none of the plants in the latter combination to have virus while those of the first combination were 100 per cent infected.

The plants were harvested in December, 1968 and graded. Composite results were as follows:

Treatment	Per cent survival to harvest	Grade distribution per cent of original planting		
		#1	#1½	#2
Heat treated "virus free"	97	57.6	21.4	11.0
Non-heat-treated	89	50.2	22.4	11.0

The source of the budwood influenced the results. The non-heat-treated budwood came from six sources that were identified throughout the study, five of them from Davis. All these showed visual symptoms of virus. The variation in results is shown by these data:

Non-heat-treated budwood source	Per cent survival to harvest	Grade distribution per cent of original planting		
		#1	#1½	#2
Source 1 (Davis)	94.0	52.0	22.0	10.6
Source 3 (Davis)	81.4	39.4	23.4	14.0
Source 6 (Wasco)	92.6	64.6	15.4	10.6