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Preventing Frost Damage in Vineyards

This leaflet reviews current cultural, management, and mechanical methods to prevent frost damage in California vineyards. One or all of the techniques described herein could be useful in the face of energy shortages and inevitably increasing costs. For more detailed economical considerations of frost prevention, consult *Frost Protection for North Coast Vineyards*, Leaflet 2743, University of California Division of Agricultural Sciences, or the U. C. Cooperative Extension Service in your county.

VALUE AND FEASIBILITY

Whenever air temperatures in grape vineyards drop to 31° F (the danger point for grapevines established by the National Weather Service), frost protection methods become necessary.

Prices of wine grapes have risen sharply in the past decade, and many growers have found it worthwhile and financially feasible to protect their vines against frost damage. In spite of recent drops in grape prices, it is more than likely that prices will become higher in the long run as the demand increases—especially for high-quality varieties. Frost protection can help to guarantee a continuous supply of these grapes.

Good cultural and management techniques alone may prevent frost damage. The cost of energy to operate various frost-reducing devices is rising, and, in view of a possible energy shortage, one or more of the following techniques may be needed: (1) late or double pruning to delay the time at which buds on the retained spurs leaf out; (2) growth regulators, such as gibberellin or alpha naphthaleneacetic acid, or sprinkling on sunny days in late winter and spring (both experimental) to delay leafing out of vine buds; (3) proper timing of cultural practices to enable soil to store heat during the day so that it is available at night; (4) removing obstacles to the natural air movement that prevents "frost holes."

Mechanical devices for frost control that are most reliable are overhead sprinklers, orchard heaters, and blowers or wind machines. Select the method according to the frost severity and climatic conditions in your vineyard location. Capital outlay or operational costs are greatly influenced by the availability and fluctuating prices of energy and of water (if sprinklers are used).

Overhead sprinklers are now designed for optimum efficiency and use less water than those used for irrigation. An installation can prove especially valuable during the days of early summer, when there is danger of shrivelling of berries during extreme dry and windy hot spells. However, they require a considerable amount of water if needed on successive days.

Heaters may cost less initially, but they require more energy and attention.

Blowers or wind machines need little attention, but in severe frosts they require the support of additional heaters, which do need to be ignited. Wind machines use pollution-free energy, but they are sometimes noisy. Manufacturers are working to improve them.

CULTURE AND MANAGEMENT

Pruning

Late or double pruning not only will delay leafing out and thereby protect against early spring frosts, but in some coastal vineyards it will also protect against abnormal leaf symptoms and shoot growth (wide

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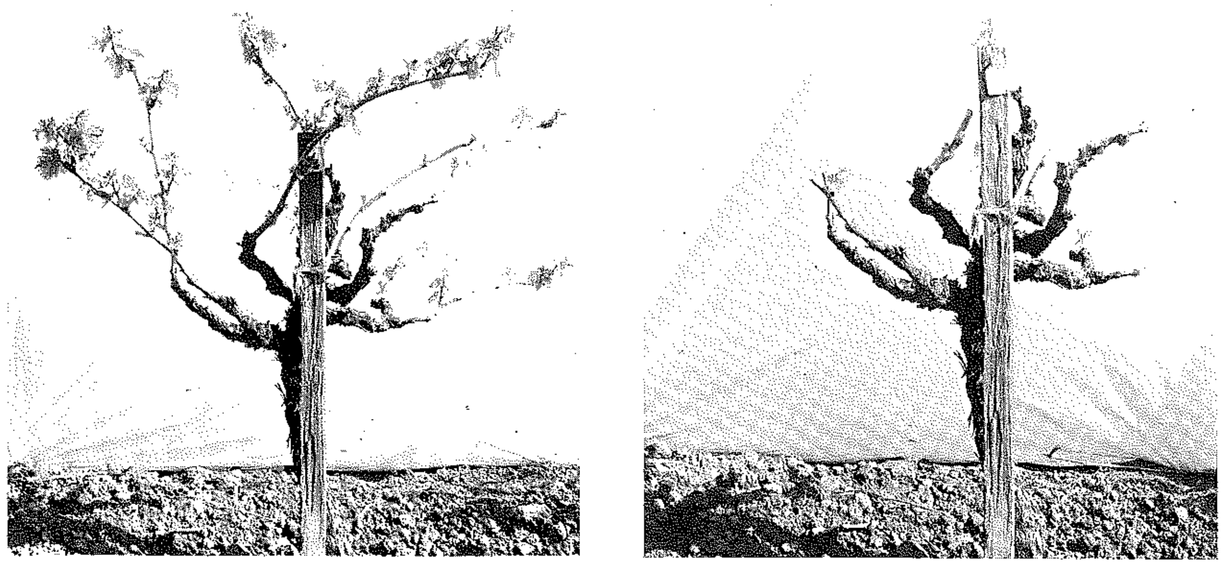


Double pruning of Carignane vines. Left: Vine pruned to half-long canes. Right: The same vine pruned back to normal spurs.

petiolar sinuses of the lower leaves and zig-zag and brushy shoot growth). While the cause of these symptoms has not been discovered, late or double pruning has been shown to restore normal growth and may even increase production by 15 to 35 percent—more than covering the costs of the pruning.

Late pruning. During the dormant season, the time of pruning generally has little or no effect on the time of leafing out, on the vigor of growth, or on the crop in the following years. Late pruning, however, after the buds on the apical parts of the canes have started to grow, delays the leafing out of the buds on the retained spurs and would protect vines from many early frosts. This delay may vary from 1 to 2 weeks, depending on the temperature. When it is very warm, the delay is short; when it is cold, the delay is longer. The shoots that grow mainly on the apical portions of the canes can be allowed to grow 3 or 4 inches without injuring the basal buds or the vine in general.

Delayed pruning in large vineyards until the apical shoots have grown 3 to 4 inches may present some labor problems—especially during seasons when vines burst into rapid growth. If shoots should grow considerably more than 3 or 4 inches before pruning, the vines may be weakened and the crop reduced.

Double pruning. Double pruning delays leafing out of the lower buds as effectively as late pruning and offers more advantages. During the dormant season, remove all canes except those to be used for spurs, and cut those back to 15 to 20 inches. In spring, after the apical buds on these half-long canes have produced shoots 2 to 4 inches long, cut back the canes to spurs of one to four buds according to their diameter. See photos above. Double pruning facilitates winter work, such as brush disposal and cultivation, and it doesn't require working under adverse weather conditions at a critical stage in growth, because the retained half-long canes can be cut back rapidly.

Double pruning should prevent frost damage up to about April 15. In most areas where grapes are now grown, frosts occur too seldom to justify such control measures. However, in areas similar to Ukiah and St. Helena where some frost damage often occurs every second or third year, protection offered by these measures would be very worthwhile. Although the most destructive frosts come later, records indicate that between 50 and 60 percent of the damaging frosts occur between April 1 and 15. The above measures will also offer some benefit beyond April 15, because vine growth will have been retarded, the depletion of reserve carbohydrates will be less, and the growth after a late frost will be more nearly normal, resulting in a higher recovery of crop.

Growth regulators

Leafing out may also be delayed by growth regulators. Various tests with gibberellin and naphthaleneacetic acid indicate the possibilities they afford; however, these materials have not been successful

enough for use in commercial trials in California. Other chemicals that may be useful are ethephon, benzothiazole-2-oxyacetic acid and morphactin.

Cultural operations and their timing

Proper timing of routine cultural practices also can diminish frost hazard. A firm soil with a bare, or almost bare, surface provides good storage of daytime heat. On clear nights the air will be kept warmer above such ground.

Also, soil should be kept moist; the large amount of air contained in a dry soil makes it a poor conductor of heat. In this case only the soil near the surface warms up during the day, and the small amount of heat stored is rapidly dissipated at night. Also, moist soil is usually darker than a dry soil and tends to absorb more heat in the daytime.

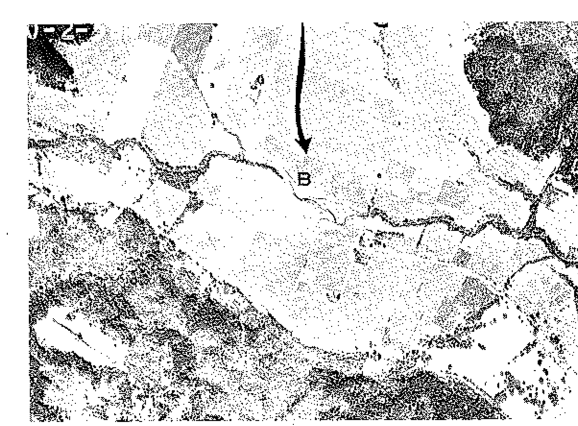
Absorption and release of heat is hindered by any vegetation or trash. Mow any ground cover as low as possible.

After the soil is turned, rainfall or irrigation can firm the soil. Firming of soil can also be accomplished by rolling or cultipacking. Daytime watering just before a frost night should be avoided, because evaporation from the surface will cause heat losses. But soils watered several weeks before the critical period and left undisturbed will assure a 1 to 2° F temperature advantage. Even a soil moisture content of only 5 to 10 percent provides a good conductivity, almost as good as the optimum of 20 to 25 percent.

Prevent "frost holes"

Cold air pockets should be eliminated. On clear and calm nights, the coldest air is found near the ground. The terrain brings this cold air into motion—down the slopes and out of the valleys—drawing down, as it flows, warm air from overhead. Wherever its movement is hindered by embankments, a brush row, low-branched trees, barns, or the like, so-called frost holes will form. An excellent example was found about 2 miles southeast of Calistoga, where a good air drainage is usually maintained by the Napa Valley wind and also from a tributary canyon to the north of the large grape area. See photos below. In the middle of this planted area tall trees and brush along a creek built a solid wall, on the north of which damaging frosts had occurred frequently. Removal of part of this wall permitted the previously stagnant cold air to flow out of the area more readily.

Elimination of air pocket prevents frost. Left: Cold air coming through the canyon (arrow) is stopped by the line of trees and brush, A, forming a pocket of stagnant air (1953). Right: The line of growth has been removed, allowing air to flow out through the gap at B (1958). Photo: USDA Commodity Stabilization.



RATES FOR APPLICATION OF WATER BY IMPACT SPRINKLER HEADS TO PREVENT FROST DAMAGE IN VINEYARDS

Wind speed and no. seconds/sprinkler rotation	Minimum water rates when air temperature is:		
	29° F	26° F	23° F
		inches per hour	
Calm to 1 mph:			
30 sec.	0.08	0.11	0.15
60 sec.	0.10	0.13	0.17
2 to 3 mph:			
30 sec.	0.10	0.13	0.18
60 sec.	0.12	0.15	0.20

SOURCE: From *Frost Protection with Overhead Sprinklers*, Univ. of Calif. Agric. Exp. Sta. Leaflet 201.

MECHANICAL DEVICES

Overhead sprinklers

Sprinklers will protect the vineyard practically under all conditions. Heat released by the freezing action of the droplets as they form an ice film around leaves and shoots provide the protection—not the ice film itself. This keeps the plant parts near the 32° F mark, although air temperatures may stay lower. One serious disadvantage that has not been reported in California, however, is apparent when frost is accompanied by wind of, say, 4 mph. Sprinkling then would require 50 percent higher than normal water rates. A second disadvantage is frost around the bud break time, which will be discussed later.

In earlier years, growers used equipment designed for irrigation purposes. This mostly was sufficient in light frosts. But protection was inadequate when severe frost threatens. The large sprinkler heads used then with their slow rotation speeds (2 to 3 minutes per revolution) applied water jets so infrequently that plant temperatures dropped critically during the wetting intervals. The water-ice mixture was not maintained. The large sprinklers also were installed more sparsely, only six to eight per acre—causing poor overlap, and irregular and spotty area coverage.

The special *impact sprinkler head* (3/32 inch nozzle orifice diameter) was developed by California manufacturers and eliminates all previous shortcomings. Rotation speed is about 30 seconds. Because they are small, usually 28 to 30 of them are needed per acre, mostly installed in a triangular pattern of 32 x 48 feet. These spacings can be modified to produce a different rainfall rate than the usual .10 or .12 inch per hour, which is satisfactory in the coastal districts. Varying the pump pressure can also modify the application rate, but hardly more than 10 percent.

Application rates should be high enough to provide protection against the strongest frost possible in the particular vineyard. The required rates are given in the table for two different rotation speeds and for two different wind conditions.

When to start sprinkling is somewhat difficult to determine under certain weather conditions. Growers tend to judge by a sheltered air thermometer, and they may consider 31° F to be the critical air temperature. However, when the plants are wetted, they will tend to sink and approach the lower wet-bulb temperature at the beginning of the operation for several minutes due to evaporative cooling, before the protecting freezing process sets in. The wet-bulb temperature (given by a usual thermometer covered by a wet wick) should, consequently, be observed, and 31° F (on wet bulb) would be the starting temperature. The grower can also determine the wet-bulb temperature by utilizing dry bulb readings and the dew point temperature. The latter is one of the many expressions for air moisture, and is announced by the National Weather Service in conjunction with the frost warning. The relation between these three magnitudes can be found in the standard psychrometric tables (except for column D) as follows: (A = dry bulb, B = wet bulb, C = dew point, D = starting temperature (dry bulb), all in deg. F).

A	B	C	D
32	31	30	32
33	31	28	33
34	31	26	34
35	31	25	34
36	31	23	35
37	31	21	35
38	31	18	36
39	31	16	36
40	31	13	37

In the psychrometric tables, it is assumed that the wick of the wet bulb is thoroughly wet and that it is ventilated by a draft of at least 10 mph. Neither of these conditions would exist in a vineyard, so that actually no such great differences between dry and wet bulb thermometers could develop. Therefore, the grower should consult columns C and D for his decision as a reasonable compromise, in which column D lists the recommended starting temperatures (dry bulb) for the different dew points.

Around bud break time, plant temperatures can be as low as 26° F on a clear night when air temperatures are about 29° F. Grapevines can probably endure temperatures lower than these without being killed. Frost sensitivity is believed to depend upon the moisture content of the plants—the drier they are, the greater the cold resistance. Therefore, sprinkling does not appear to be necessary when minimum *air* temperatures are not expected to drop below 29° F.

Two reports from Europe *discourage* sprinkling at bud break time because of failures to provide frost protection in early spring. We believe, however, that the reported failures should not be ascribed to the early stage of plant development but should be sought elsewhere: for instance, installations may be inadequate, and sprinkler rotations may be too slow. At bud break time when a plant provides only a very small catching surface, only a fast rotating speed can provide sufficient plant wetting. Furthermore, in one of the vineyards of the two reported cases, very low temperatures of 23° F were accompanied by strong wind.

Frost prevention with sprinklers at bud break time has not been studied in California, and little information is available. However, tests with potted vines in freezing chambers are presently underway at Davis.

When to terminate sprinkling. Air temperature outside the treated area should be at least 32° F before the water is turned off. If the dew point temperature is low (or the air is dry), wait until the air temperature has risen to 34° F. However, it is not necessary to wait until *all* ice has melted.

Heaters

Although 40 to 50 heaters per acre are recommended for the coastal grape vine districts, it is seldom that all of them need to burn at the same time. Protection of 5° F or more can be provided with heaters, depending on burning rate and inversion, and a large enough area. Twenty-five heaters, for example, would give 3° F protection or more, under the same conditions. Light only one-third of the heaters when air temperature is 31° F. Keep watching the temperature, however, especially at spots farthest from any burning heater, to determine whether additional heaters should be lit. These spots, so-called "dark spots," are the most vulnerable to frost damage. Under medium frost conditions, therefore, at least 25 heaters per acre should burn. Distribution of the heaters should always be even, except along edges where greater heat concentration is needed. This border heating is especially important for the nightly drainage flow or at those where vineyards are exposed to adjacent grassland, such as pastures and afalfa fields.

Unfortunately, while orchard heaters can provide complete protection against frost damage in all circumstances, even under the most adverse conditions, such as windy frost nights, their use is declining—for a number of reasons. Energy supply is decreasing, and its cost is going up. The high cost and shortage of manpower has forced many growers to modify their field equipment by installing pipelines for oil or gas or to abandon their heaters entirely. Furthermore, many types of heaters were outlawed for fear of air pollution, and growers often find purchasing of replacements too costly, especially in areas where heating may be needed perhaps only once every five years.

Many solid fuel heaters have been developed that use residues, such as petroleum coke or petroleum wax. Because they are small, more units per acre can be installed, providing more heat that is also better distributed. Few or no "dark spots" would occur under such conditions. However, state and county air pollution requirements may be difficult to pass.

Blowers

Blowers have become a substitute for heaters in several California areas. Two types are on the market—the tower mounted "wind machine," which is especially successful in citrus orchards, and the surface blower, which is often used instead of the wind machines in deciduous orchards and vineyards.

Blower action stirs the air, and the cold air near the ground moves away, while warmer air moves to the plants, which are 2° to 4° F colder even than the air near the ground. However, the warming effect with blowers is generally not so great or so evenly distributed as it is with heaters; they are fairly effective only within 150 feet from the blower. However, the greatest disadvantage is the variable degree of warm air (called inversion) available above the cold layer near the ground. Wind machines are sufficient in the coastal grape vine areas where many frosts are accompanied by inversions.

For stronger frosts, University of California tests have shown that adding a small number of heaters can provide more warming than might be expected. For instance, 8 to 12 heaters per acre to support a wind machine can provide an additional 1 1/2° or 2° F more than with the blower alone, because the blower distributes heat that otherwise would be partly lost by updraft from the heaters. The great advantage of the blower-plus-heater system is that only a few heaters have to burn, and that they can be lit gradually one or two hours after the blower is started. The blower itself can be started above 31° F, since operational cost is low. In severe frost situations, 25 heaters should be installed as a safeguard. They should be distributed as evenly as possible over the vineyard. Where there is wire-trellising or the like, the heaters could be arranged to border a square pattern—with some sacrifice of effectiveness, however. For instance, on a square of 600 x 600 feet, about 8 acres, 200 heaters could be spaced one every 20 feet for framing two squares of about 600 x 600 feet and 400 x 400 feet, one inside the other, with the wind machine in the middle. Grouping heaters more closely to the wind machine could result in too strong a concentration of heat. This concentrated heat would be lost by increased updraft, and the wind-machine effect could be reduced beyond the heater line.

Multiple installation of wind machines increases their effect. As the area response pattern usually is egg-shaped—elongated in the direction of the drainage flow—University of California studies found the following spacing to be advantageous: small blowers (about 25 HP)—600 feet along drift, 400 feet across the drift; large blowers (70 to 100 HP)—900 feet along drift, 700 feet across the drift.

Benefits from a "multiple installation" will be lost, however, with spacings larger than suggested. The closer settings are recommended, because adjacent wind machines help each other. The turbulence zone of one machine that reaches into the turbulence zone of another magnifies the total effect; for example, two neighboring blowers, working one at a time, will raise the temperature 1° F at a given spot. Working together, they will cause the temperature to rise 3° F.

Helicopters

Helicopters are used successfully where effects of wind machines are hampered by difficult terrain or infrequent frosts. They have the advantage of flexibility in area coverage. One helicopter can be used over a large area for light frosts; one pass in 5 to 10 minutes can provide protection. With more severe frost conditions, more frequent passes over individual spots are needed which would reduce the area coverage one helicopter can provide.

On the other hand, the area to be covered by one helicopter could be enlarged in very mild frosts. Many regions in California have marginal danger conditions. In such areas, damage appears to be inexplicable, because the air temperature remained hovering at the 31° F mark. However, field experience by forecasters of the National Weather Service indicates a tolerance of 31° F at maximum of 30 minutes duration. Under these conditions, therefore, one warm blast from one helicopter pass every 30 minutes might raise the temperature once every half hour. This assumes, of course, that an air-temperature drop below 31° F would not occur.

Successful operation of wind machines with or without heaters also requires constant thermometer reading. Two orchard miminum thermometers per 10 acres appear to be reasonable. When the thermometers are shielded, they show air temperature, and 31° F (air temperature) is considered the danger point. An unshielded thermometer, open to the sky (representing shoot temperature) would show about 27° F at the same time. Dangerous temperature drops were once experienced in the Napa Valley at sunrise when the drainage flow ceased before the first sunrays hit the ground. Especially careful watch, therefore, is recommended at dawn. For example, on April 22, 1960, between 5 and 6 A.M. (within one hour!) the air temperature in a University of California test vineyard near St. Helena dropped from 32° to 28° F, and an unshielded thermometer showed drops from a safe 28° to 24° F—3° below the danger point. Vines were 50 percent damaged.

Covers

In one part of this same 1960 U. C. test vineyard, 4-feet-wide black polyethylene strips were rolled over the rows, shielding the vines from the cold sky. Under these covers, no frost damage occurred and the unshielded thermometer did not drop below 27° F. A 3° F protection was obtained, but strip covering cannot provide enough protection in stronger frosts. Besides, covering is not economically feasible for larger plantings.

Opaque covers of plastic, burlap, or paper might be practical for one- or two-year-old vines, especially where they can be extended downward to the ground at night. Cap-type covers may be more useful than sprinklers, heaters, or wind machines—all of which are less rewarding when used for small and widely-spaced plants. Such covers, when double- or multi-layers, are highly frost-protective.

TREATMENT OF FROSTED VINES

Frost damage to grapevines becomes apparent within a few hours. However, one usually cannot ascertain accurately the degree of injury to clusters until after fruit set. In many frosted vineyards, it is best to do nothing, but in others shoot removal may be beneficial.

When vines are frozen, look to the secondary or tertiary buds or dormant latent buds. Some crop can be expected from varieties where these buds are fruitful, even if shoots that develop from the primary bud are frozen. The latter shoots must be broken out at the base, so that the two lateral buds may be released. Unfortunately, breaking out of primary shoots more often fails to enhance growth from secondary growing points. When growth does occur, secondary and tertiary buds usually start growth in about two weeks. Shoots should be removed immediately after a freeze; also best results occur when shoots are less than 6 inches long when frozen. When longer primary shoots are broken out, the secondary and tertiary growing points are also removed or dried. Following a frost, one should break out shoots on which clusters have frozen but not died back to the base.

Thompson Seedless has no fruitful secondary or tertiary buds, and therefore no treatment of frosted vines is recommended. If clusters are killed by freezing, canes may be cut back to spurs to promote shoot growth and better canes for the following year. No treatment is beneficial on spur-pruned vines with nonfruitful secondary or tertiary growing points such as in Emperor. However, with spur-pruned varieties with fruitful secondary and tertiary buds, such as Cardinal, Ribier, and most wine varieties, shoot removal may sometimes increase yield.

Dormant and latent bud growth present at the bases of spurs and canes is of little benefit in cane-pruned Thompson Seedless, but can sometimes increase yields in spur-pruned vineyards. Suckers or water sprouts except at bases of spurs and canes, can produce some fruit especially in wine varieties. If shoots are pruned off, only lateral buds near the base of the shoots develop, and these are not fruitful in Thompson Seedless.

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The authors:

H. B. Schultz is Professor of Agricultural Engineering, Davis, emeritus; R. J. Weaver is Professor of Viticulture and Viticulturist, Experiment Station, Davis.

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