Microsprayer Frost Protection in Vineyards


I. OVERVIEW OF VINEYARD FROST PROTECTION

Low temperature damage is a significant problem in many grape-growing regions. Cold injury to grapevines may result from the winter minimum temperature; spring temperatures below -0.6°C (31°F), which may damage developing buds; or fall temperatures below -0.6°C (31°F), which may injure maturing canes and berries. This section will focus on factors influencing the incidence and severity of spring frost damage in California vineyards.

Efforts to minimize damage from spring freeze events can be divided into passive and active methods. Passive methods involve site selection, variety selection, and cultural practices, while active methods involve modification of the vineyard climate. The effectiveness of frost protection methods is dependant on the characteristics of the freezing event.

Types of Freeze Events

The types of freezing events encountered in California vineyards are radiation and advection freezes. These types of freezing events differ greatly in their frequency of occurrence and the meteorological conditions associated with them. Widespread cooling occurs as a result of the advection (horizontal movement of an air mass over land) of cold air into a region or from loss of heat due to radiation. An advection freeze occurs when cooling by advection predominates, and a radiation freeze occurs when radiational heat loss is the predominant form of cooling.

Radiation freezes occur mostly on clear, calm nights after cold air has moved into the region. The primary mechanism is loss of heat into space during the night.

The rate of heat loss by radiation into space is partially determined by the amount of moisture present in the atmosphere. If the air is dry (low dew point) heat loss will be greater than when the air is moist. During radiation freezes, layers of cold air are formed with the coldest air usually found near the radiating surface. Normally, temperature decreases as height in the atmosphere increases. Thus, this meteorological condition is known as a temperature inversion (warm air layers over cool air layers).

An advection freeze occurs when a large mass of Arctic air invades and covers the region resulting in low day and night temperatures. Conditions can be clear or cloudy with strong winds which continue into the night. Due to the wind there is considerable mixing of the lower layers of the atmosphere.

Almost all spring freeze events in California vineyards are radiation freezes. Fortunately, a wide range of frost protection methods can be employed against radiation freezes. Advection freezes are relatively rare and normally occur only during the dormant season. The December 1990 freeze is an example of an advection freeze. There is little that can be done to protect vine-
yields from damage during a severe advection freeze. Therefore, the remainder of the article will deal with the protection methods for radiation freezes.

Passive Protection Methods

Passive protection methods are used to avoid or minimize spring frost damage. Site selection, variety selection, and crop rotation are basic passive protection methods. These methods can provide a certain degree of protection, but generally do not offer as much protection as active methods. However, 0.6-1.2°C (3.3-2.2°F) of protection can often mean the difference between having a crop and crop loss. Also, passive protection methods do not cause significant increases in establishment costs for most vineyards.

Passive protection practices can be divided into those which are done prior to vineyard establishment and those which are done after vineyard establishment. Preplanting practices are site and variety selection while postplanting frost protection efforts involve cultural practices such as soil management, row middle management, and pruning.

Site and variety selection are of great importance in reducing spring frost damage in vineyards. Site characteristics which influence air temperature are slope, exposure to the sun or aspect, and elevation. Slope, ground and elevation are important because they provide good air drainage. Cold air is more dense than warm air and flows downhill in a similar manner as water. Vines growing in low areas where cold air accumulates are more likely to be damaged by frost. However, sites which have impediments to cold air drainage such as raised road beds, buildings or vegetation (fences, overgrown fence rows, etc.) should be avoided. Sites of hills facing south (SE or SW slope) will be warmer than hillsides facing away from the sun. In the spring, warm temperatures can result in early bud development. Planting on a north slope instead of a south slope may delay bud burst and reduce the possibility of frost damage.

Another site characteristic which is important is certain vineyard districts outside California is distance from large bodies of water. Large bodies of water, such as the Great Lakes, substantially moderate the climate of land areas on the leeward side of these bodies of water. The modifying effect is sometimes one of cooling the air while at other times it is one of warming the air, depending on the season and the prevailing weather conditions. In early spring warm air moving over the lakes is cooled, which can delay bud burst beyond the period of time when frost damage is most likely. Later, after bud development has begun, cold air moving into the area are warmed by the lakes and late spring freeze damage is avoided. The beneficial effects of large bodies of water are greater for sites which are as close to the leeward side of the body of water as possible. As distance increases, temperature modification due to large bodies of water decreases.

Variety selection can influence the incidence and severity of spring frost damage in a vineyard. susceptibility among varieties is often related to bud phenology. In general, as bud development proceeds in the spring, the critical temperature (temperature at which buds will endure for 30 minutes or less without injury) increases or becomes warmer. Therefore, varieties which have early bud burst and development are usually more susceptible to spring frost damage than varieties with late bud burst and development. For example, bud burst of Chardonnay vines is earlier than bud burst of Cabernet Sauvignon vines when grown in adjacent blocks. Planting Chardonnay in frost prone sites without some active method of frost protection is inviting disaster. On the other hand, Cabernet Sauvignon might be planted on this site and grown successfully.

Varietal differences in frost tolerance may also be related to factors other than bud phenology. Johnson and Howell (1981) detected small but consistent differences in cold resistance of buds from three varieties at the same stage of development. After the vineyard has been established, other active protection methods can be used to reduce the chance of frost damage. Some examples are soil management, row middle management, and pruning.

Soil and row management can influence the minimum temperature in vineyards. The minimum temperature is affected by soil texture and soil water content. In general, paunch soils do not store or conduct heat as well as loam or clay soils. Also, darker colored soils may absorb more solar radiation and store more heat than lighter colored soils. Consequently, if all other factors are the same, sandy soil would pose a greater hazard of frost damage than clay or loam soil. However, soil texture effects are probably not as important during most freeze events. Other factors usually have a greater impact on soil texture:

Soil conductivity and heat storage are also affected by the soil texture and soil-water content. This is due to the unique properties of water which allow it to store considerable heat energy which soil water and dry soil will conduct heat better than dry soil. Frost hazard is lower for moist soil as compared to dry soil. Growers with furrow irrigation can provide some protection for their vines by applying water before predicted freeze events. There would be no benefit from this action if the soil is already moist. Furrowing the vineyard bare to berm is better than using furrows and the irrigation does not have to be deep. The additional foot of soil needs to be moist.

Row middle management can have an important impact on the susceptibility of vines to spring freeze damage. Until recently, recommendations for row middle management to avoid frost damage were to have moist, firm, bare soil in the row middles. The basic recommendation was that the condition described favored absorption of solar radiation and subsequent transfer of the absorbed heat to vines during a freeze. These recommendations were still valid and should be followed in most situations. However, recent research results and grower observations indicate that in some situations these recommendations need to be revised. Haun and others (1993) found that vines where early season vegetation between rows was killed by spraying with herbicide had slightly warmer minimum temperatures than vines where row middle vegetation was killed by spraying or discing. This occurred on most nights during the spring freeze season and was not influenced by vineyard canopy development. Also, some growers have observed that the presence of a cover crop (mowed close to the soil surface) has not caused increased risk of frost damage. Furthermore, the risk of frost damage with higher cover crops needs to be re-evaluated in different viticultural districts due to the positive benefits that have been documented from cover crop use.

Pruning practices can be effective in reducing frost hazard, particularly on sites which are frost prone. The most obvious pruning practice to avoid frost damage is delayed pruning or late pruning, or effective pruning strategy for small acreages, varieties with early bud burst, or as mentioned above, sites which already have frost. Delayed pruning is not the answer when the grower has a large acreage which must be pruned, unless mechanical pruning is used. Another practice which can be implemented is long-cane pruning. Bush vine system can be used at the apex of the cane. This can be used to provide protection from late frost events. Long canes are retained for fruiting during standard pruning. Vines are pruned to retain long canes and then, after the frost period has passed, canes are cut back to the proper length. Long cane pruning is effective for frost protection, but would not be cost effective for most vineyards in California due to the trellis systems used and additional labor requirements.

Active Protection Methods

Active frost protection methods involve modification of the vineyard climate. The climate of the vineyard can be altered by 1) utilization of atmospheric heat (wind machines, helicopters); 2) addition of heat (heaters, sprinklers); and 3) a combination of atmospheric and heat (wind machine/heater combinations). Atmospheric heat can be used for frost protection if temperature inversion exists. Wind machines or helicopters are used to mix the warm air aloft with the layer of cold air next to the ground. Depending on the strength of the inversion (difference in temperature between the 1.5m (5 ft) and 18m (60 ft) level) and other characteristics of the freeze event, protection down to approximately -1.7°C (29°F) can be attained in this manner. Use of heaters in combination with wind machines allows for protection down to approximately -3.3°C (27°F).

The application of heat to a vineyard may be accomplished by using heaters or by the freezing of water applied by sprinklers. Twenty to forty heaters per acre are required depending on whether heaters are alone or in combination with wind machines. The lower number of heaters per acre is generally suitable when heaters are combined with wind machines for frost protection. Use of heaters alone can provide up to 2.5°C (5°F) of protection. However, the use of heaters can be
Vine Recovery from Frost Damage

If protective measures fail and the critical temperature is reached, injury will occur. The grower faced with this situation must manage his vineyard to maximize yield for the current season and vegetative growth so that yield is unaffected in the following season. Freeze injury usually does not result in complete crop loss. The grapevine node has three growth points or buds (the primary, secondary, and tertiary buds). Primary buds usually develop first and have the greatest crop potential. Due to their early development, primary buds are also more susceptible to frost damage than are secondary and tertiary buds. Certain varieties, such as Thompson Seedless or Concord, bear almost all their crop from primary buds. Other varieties will bear a partial crop from secondary, tertiary, and latent buds. For some wine grape varieties, the amount of crop from growing points other than the primary bud can be significant.

Probsting and Brummond (1978) evaluated the response of Concord grapevines to spring freezing injury. All shoots were lost on frozen vines (complete primary bud kill), while control vines (protected by sprinklers) displayed no shoot injury. Freeze injury delayed bloom which appeared to be beneficial since conditions were generally unfavorable during the normal bloom period. As a result, vines which were injured had more berries/cluster than non-injured vines.

Frost damage reduced yields significantly, and the reduction was due to a reduction in the number of clusters per vine. Berries from injured vines were less mature than berries from non-injured vines.

Removal of injured shoots was investigated by Kasimatis and Kessler (1974) to find a method of increasing the yield of vines exposed to frost. Treatments consisted of removal of all primary shoots, removal of frost-damaged shoots only, and control. None of the shoot removal treatments significantly improved yield. Shoot removal had little effect on fruit maturation. For most situations, it appears that removal of frozen shoots would not be beneficial.

Growers should also evaluate their cultural practices following spring freeze events which injure vines. If crop loss is severe, pest and disease control measures may be reduced somewhat without influencing the crop potential for the following season. Other cultural practices, such as uniform irrigation, etc., should be done in a normal manner to allow for good vegetative growth.

Summary

Frost protection is an important element of commercial viticulture. Nearly all vineyard regions of the world are subject to spring frost damage. Avoidance of frost...
damage can be achieved through use of passive or active methods. Passive methods, such as site selection, variety selection, and cultural practices are less costly than active methods and provide a few degrees of protection. On the other hand, active methods (wind machines, heaters, wind machine/heater combinations or sprinklers) are more expensive but can provide 2.4-3.3°C (5-6°F) of protection under ideal conditions. A combination of passive and active methods will likely produce the most effective frost protection program.

II. EVALUATION OF MICROSPRAYS FOR FROST PROTECTION

Reduction in water use or increased water use efficiency are important concerns for wine grape growers. However, conservation of water must not reduce productivity, wine quality, or increase production costs. The application of water directly to the crop, eliminating unnecessary watering between the crop rows is known as targeted frost protection. Targeted systems have been used in tree fruit and citrus orchards to provide frost protection while reducing the amount of water used. Potential benefits of a targeted system, such as microsprayers or microsprinklers, for frost protection in vineyards include reduced water use; reduced need for reservoir capacity; lower equipment costs for installation (smaller pumps and piping); and less energy use.

A. EQUIPMENT DEVELOPMENT AND SELECTION

Targeted frost protection for orchards was pioneered in part by the New Zealand Agricultural Engineering Institute (1986). Tests were carried out in Central Otago, New Zealand to evaluate the effectiveness of targeted frost protection on peach and nectarine trees.

The microsprinklers used in the New Zealand study were installed 5 m (16 ft.) apart, producing a wetted diameter of 3.5 m (11.5 ft.) and an application rate of 4 mm/hr. The wetted pattern from these microsprinklers is circular. In order to best use targeted frost protection on a vineyard, the Center for Irrigation Technology (CIT) determined an emission device that would have to produce a wetted strip. This eliminated microsprinklers because of their inherent circular pattern. The search was begun for a microsprayer (nixed pattern) that produced a rectangular pattern.

A preliminary investigation suggested the microsprayer needed to protect vines should produce a pattern approximately 1 m by 3.7 m (3.3 ft by 12 ft). This is based partially on the typical vine spacing of approximately 2 m (7 ft). Thus a microsprayer could be placed on every other vine to provide a continuous wetted strip 1 m (3.3 ft) by the length of the vine row.

Since typical vine row spacing is around 3.7 m (12 ft), frost protection would be provided on 25 to 30 percent of the vineyard area. This has the net effect of reducing the total water requirement for the frost protection system by the same rate. Thus, if this approach provided the same level of frost protection, water application rates per hectare could be reduced from 470 /min (50 gpm) to 150 l/min (16 gpm). This holds the potential for significant water and energy savings.

A hydraulic review suggested a targeted flow rate of around 11.5 l/hr (0.3 gph). Initial laboratory testing at these flow rates and a pressure of 207 KPa (30 psi) produced a droplet spectrum with a high incidence of fine drops. Since the destination of those drops cannot be predicted in high winds, it was determined that conventional product design would not work under field conditions. An alternative product design was sought.

The ideal product would produce large droplet sizes, while operating at extremely low flow rates. A new product that met these criteria was identified. It was the Pulsator® microsprayer, which is manufactured by NIBCO Irrigation Systems. As given in its name, this product delivers water in pulses. The design has a small accumulator which delivers water in short bursts or pulses. This allows for a microsprayer to deliver water at an instantaneous rate of 21 l/hr (5.5 gph) or so. The net delivery rate, though, is around 11.5 l/hr (3 gph) due to the pulsing feature. The advantages of this technique are its large average droplet size and increased wetted radius at comparable flow rates of conventional microsprayers.

Technicians with CIT worked with product engineers at NIBCO to evaluate and recommend changes in the wetted pattern. Computer modeling using CIT's Sprinkler Placement and Coverage Evaluation (SPACE) program was utilized to select the design which proved most advantageous. A prototype was recommended for field testing.

B. FIELD STUDY

The purpose of this trial was to investigate the use of microsprayers for frost protection in a commercial vineyard. The objectives were as follows:

1) To determine if an alternative method of frost protection (targeted microsprayer system) in vineyards was feasible, and;
2) To determine if this method was less water consumptive than current practices.

Continuing studies will include a series of tests under controlled freezing conditions in a cold chamber.

III. SUMMARY

Sprinklers have been used successfully for many years as an active frost protection method in vineyards. With increasing population and environmental pressures, along with unfavorable climatic conditions, water supplies for frost protection are becoming more costly to use. Previous studies have evaluated the use of microsprayers and/or microsprinklers for frost protection in other crops, such as trees (Davis, et al., 1988; Evans, 1991; Parsons, 1991; Rieger and Myers, 1990; von Bernuth and Dunn, 1991).

The purpose of this study was to determine if microsprayer technology could be improved upon and proven for use as a frost protection alternative in vineyards. As a result, researchers and a microsprayer manufacturer cooperated to develop a targeted microsprayer technology that was used as an active spring frost protection method in a commercial vineyard. The targeted microsprayers were designed specifically for vineyard applications and were evaluated under laboratory and field conditions.

Targeted microsprayers were compared to conventional sprinklers in a commercial vineyard during the springs of 1993 and 1994. Data collected and presented here indicate that targeted microsprayers provided frost protection similarly to conventional sprinklers, but with 80 percent less water used.
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REFERENCES


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