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Factors Related to Spring Frost Damage: What Are the Options

G. Stanley Howell
Professor of Horticulture
Program of Viticulture and Enology
Michigan State University

Summary.

Spring frost is a significant production hazard in nearly all locations of temperate zone viticulture. While the technologies to achieve crop protection exist, both economic and practical considerations limit their application.

Prevention is the best weapon to keep frost concerns to a minimum. The most important time to consider frost concerns is in the vineyard establishment phase. Geiger, *et al.* (1995) notes, "It is incomprehensible that even today, the most fundamental laws of microclimatology are disregarded time and again when vineyards are being established at great cost in areas subjected to repeated frost." He wrote that in the first edition of "The Climate Near The Ground" which was published at the turn of the 20th Century.

Location/ Site is the most critical issue in vineyard development. Site selection is an on-going process, and regardless of the emotional tie one has to a site, the best choice may be to pull-out and discontinue rather than to continue to pour money into a venture incapable of success. That termination must be viewed as a positive process (Dethier and Shaulis, 1964).

The best vineyard practices in vineyards on frost vulnerable sites include the following:

a) Mow between row grass or cover crop; do not cultivate the soil. Both practices provide a surface insulation to the soil and reduce the heat accumulation by the soil during the day and enhance radiation heat loss at night.

b) Consider long cane pruning to delay bud burst of buds at basal nodes to be retained for production once the frost hazard has passed.
c) Retain ‘spare parts’ as extra canes with extra buds as insurance against a frost. If no frost occurs, this extra bud number must be eliminated.
d) Select a training system that raises the fruiting zone well above the soil level. A high cordon/hanging curtain system may be best at a site with frost concerns.
e) Monitor air temperatures as a means of determining whether a frost event is likely and whether available protections are justified.

An understanding of the frost event is important with regard to the value of protection efforts. There are 3-types: radiation, advection, and radiation-advection. Of these, only the radiation-freeze has the potential for climatic modification (Geiger, *et al.*).

The evaluation of a frost protection system for one’s vineyard conditions is a serious economic matter. Before such an investment information needed includes:

a) Will it provide the level of protection needed? Are typical frosts radiation or advective?
b) Is it reliable?
c) Risk and cost: benefit analyses are needed. The truth is, the most effective systems are commonly the most expensive

Finally, there is a need for information concerning the temperature for critical damage to occur (T_{50}) (Johnson and Howell, 1981). This varies with cultivar and with the status of bud development (bud phenology). There are some values that have been developed, primarily with Concord and the Resistant Hybrids. The data for *Vitis vinifera* cultivars is scarce.

<u>Factors Influencing Damage.</u>

Site-

No selection, including cultivar selection, has greater impact on potential for failure or success than the choice of site. The impacts are many, but here we will focus on the mesoclimatic response to slope. Cold air is heavier than warm air and it will settle and form lavers with the coldest air near the ground. If the site is flat, or worse, if it is in a low spot with high ground around it the cold air will settle or flow there. By contrast a sloping site allows the heavier, cold air to flow down slope and is replaced by warmer air from aloft.

Training System-
In a manner similar to site, the height of the fruiting and renewal zone provides a means to avoid cooler air near the ground.

Bud Phenology-
As buds begin to swell tin the spring we can observe the response to increasing water content of the buds. As the development progresses from scale crack to swell to burst, the developing bud progresses to become a shoot and at the same time progressively loses the capacity to withstand a freeze event (Johnson and Howell, 1981).

Phenological development cane is influenced by several factors, some of which are under producer control. First is genetic (Anderson, et al.). Individual cultivars possess differences in response to temperatures near the threshold for bud expansion and the result is a range of differences in onset of growth, and therefore frost hazard, of up to 14-days.
Cultivars can influence frost damage another way. There appears to be differences among cultivars that are not explained by phenology differences. At the same stage of phenology there are differences if T_{50} (Johnson and Howell, 1981). This means that both phenology and critical temperature differences can be considered with regard to cultivar choice.

Phenology is also influenced by the length of the cane on which the bud is borne (Howell and Wolpert, 1978). More precisely, a bud is delayed as a function of the number of buds that are apical to it. The delay here is also in the range of 14-days.

Production Habit-
Another cultivar related factor influencing the frost hazard is production habit. If we experience a spring freeze event that kills less that 10% of buds we are satisfied that within vine compensation will make that loss meaningless. If a spring frost occurs on a Concord vine and kills 60% of the primary buds we are concerned because we know that means economic crop loss. This is because the secondary bud at the nodes in question will have a capacity of approximately 35% of the lost primary and the loss will calculate (60 X .35= 21) at 21% of the original and when added to the 40% that survived we see we have 61% of the original crop potential. This is similar

for Niagara and for most *vinifera*. It is not true for many Resistant Hybrids. These vines possess the capacity to produce fruitful shoots from 'Non-count' base buds (Wolpert, *et al.*, 1983). Important cultivars having the capacity include Marechal Foch, Chancellor, Seyval and Vidal blanc, to name a few. This capacity is a very important characteristic for culture where frost occurrence is frequent.

Type of Freeze-

There are 3-types that can cause damage in vineyards in the Great Lakes Region. These include:

a) *radiation*- which is a freeze characterized by still air and clear skies. Under these conditions air stratifies near the ground and radiant heat loss occurs from the ground and vine tissues. Under such conditions vine tissues can be less than ambient air temperature;
b) *advection*- which is a freeze characterized by a mobile frontal system moving through and cloud cover. There is no air stratification and no radiant heat loss.
c) *Radiation-Advection*- which combines the characteristics of the 2-freezes and is most damaging.

Protection capability will depend on the type of freeze one is experiencing.

Ice Nucleation Active Bacteria-

Buds are primordial tissues and as such their basis for protection is via a process called supercooling. Simply put, the buds do not have sites within them that can serve as a spot where a few drops of water can change phase from liquid to solid. Liquid water in the tissues will thus 'supercool' to temperatures below the actual freezing point of the water. Ice nucleation active (INA) bacteria possess the capability to serve as such a site (Lindow, 1983). The 2-INA bacteria of concern are *Pseudomonas syringae* and *Erwinia herbicola*. On tissue surfaces bacterial populations can build-up and if sufficiently large (about 10,000/cm^2) they can serve as an ice nucleation site. Fortunately for viticulturists, this level is seldom reached in the window of grapevine frost susceptibility in the Great Lakes Region.

Dealing With the Hazard.

The material presented above provides a number of options for reducing the hazard of frost damage. The reality for grape producers in the northern temperate zone is managing a vineyard that has been frost damaged.

First-
Determine the level of the damage. Spring frost is an emotional experience. It means economic hardship for many producers. That is a sad reality of farming. However, before settling into despair, make an assessment of the level of the damage. In the example given above, the notion of 60% primary loss is tragic, but a careful assessment of the vineyard status revealed a 60%+ crop. Not great, but not a washout either. Further, vines have this ability to compensate. When such losses occur, reduced cluster number can result in 1-3 more berries per cluster being set.

Most terrible is the condition that resulted in no crop protective sprays because the crop was perceived as a disaster and the realization in July that an economic crop was there and it was too late to put on critical protective sprays.

The protocol we employ every spring at about 2-inches growth to assess vineyard status. It involves selecting a 3-vine panel of vines in important locations within the vineyard. Create a tally sheet and count and record all buds on vines in the panel. The same vines are counted again for blind nodes (no shoot pushed), record. Then the vines are counted for # dead primary buds, record. Then secondary buds dead, record. The crop potential for that area of the vineyard can then be estimated.

Calculating Crop Potential-
Blind nodes- 4%
Dead primaries- 42%
Dead secondaries- 14%

Based on 100% of initial crop potential

Loss of 4% blind = 96% potential
Loss of 14% of both primary and secondary buds = 96-14=82%
Remaining dead primary buds 42-14= 21%. Reduction of potential yield is then 82%- 21(.65)= 68% of original potential crop. If projected tonnage was 8 T/A then the crop, assuming no compensation would be 5.54 T/A. Not great, but not a disaster either.

In reality there are likely to be years when the numbers are so bad as to make the production a write-off. Vineyard maintenance under those conditions will be challenging. Great care will need to be taken to insure vine survival, adequate leaf area and culture to avoid excess vigor. There has been one such year for juice grapes in the last 35 I have seen in Michigan, but there have been several, including 2002 where the crop was much reduced, but one could make the determination for a given vineyard only by doing the kind of objective assessment suggested here.

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