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Resources for vineyard frost protection

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With many vineyards at or just past budbreak throughout the state, many growers are concerned with spring frosts and protecting buds and emerging shoots. There are resources available to growers and vineyard managers to support decision-making during what may be a long spring frost season. This article summarizes the main factors related to frost risk and protection. For further reading, see the open access resources at the end of the article.

Type of frost matters. Two types of frost events may occur: radiation and advection frosts. Radiation frosts are the type most seen in Oregon vineyards. They occur under clear nighttime skies, and calm winds when heat previously absorbed by the vineyard is lost as radiant energy into the atmosphere. As a result, temperatures drop faster near the radiating surface, ultimately causing an inversion in which the ambient air temperature increases with height above the vineyard. The strength of the inversion determines the efficacy of frost protection methods. Advection frosts occur when a cold air mass comes in and replaces warm air. These events are associated with strong winds, no inversion, and low humidity. Temperatures typically drop below freezing (32˚F) and hold; thus, it is challenging to use standard frost protection methods. Fortunately, these are rare in Oregon during the growing season.

Sensitivity of buds and shoots. It is important to understand the critical kill temperatures for grapevine buds. As overwintering buds come out of dormancy and begin to grow, they rapidly become less tolerant of freezing temperatures (less cold hardy) as their internal water content increases. Researchers at Oregon State University determined lethal temperatures for Pinot noir buds in the late 1980s (Table 1).

Table 1. Critical temperatures for Pinot noir buds and young shoots. Adapted from Sugar et al. (2003). Bud development stages are classified according to the original MS thesis work by A. A. Gardea (1987) and the more commonly used modified E-L stages.

Modified E-L stage	Development stage	None killed (°F)	50% killed (°F)
2 – bud scales opening	Dormant bud enlarged	--	6.8
3 – wooly bud ± green showing	Green swollen bud	--	25.9
4 – budbreak; leaf tips separated	Budbreak	30.2	28.0
7 – first leaf separated from shoot tip	First flat leaf	30.2	28.4
9 – 2 to 3 leaves; shoots 1-2 in. long	Second flat leaf	30.2	28.9
11 – 4 leaves separated	Fourth flat leaf	31.0	29.8

Later, data from the UK supported the OSU findings using a slightly different approach. Buds of two obscure cool climate *Vitis vinifera* cultivars, Madeleine Angevine and Siegrebbe, were frozen, and temperatures were recorded at their freezing point. Then, buds were dissected and rated for damage. Though the freezing temperatures of buds did not vary much depending on the developmental stage

(25-26 °F), bud damage at the freezing temperature increased sharply as buds developed (Table 2). By the time the buds were at the wooly stage (whether green was visible or not), all were completely killed at temperatures < 26 °F (Fuller and Telli 1999).

Table 2. Mean freezing temperatures and associated damage ratings of buds as a function of developmental stage (DS0-DS5) for *Vitis vinifera* varieties Madeleine Angevine and Siegrebbe. Damage rating 0 = undamaged, 5 = completely killed. Bud development stages are classified according to the original work by Fuller and Telli (1999) and the more commonly used modified E-L stages.

Modified E-L stage	**Development stage**	**Freezing temperature (°F)**	**Damage rating (0-5)**
1 – Winter bud	DS0 – Dormant overwintered bud	25.8	1.3
2 – Bud scales opening	DS1 – Perceptible bud swelling	25.8	3.2
	DS2 – larger than DS1, but not wooly	25.7	2.8
3 – Wooly bud ± green showing	DS3 – wooly bud, but not green	25.1	5.0
	DS4 – wooly bud, green showing	25.5	4.9
4 – Budbreak; leaf tips separated	DS5 – leaf tips separated	25.2	4.9

Finally, Washington State University research further corroborated OSU findings, showing that post budbreak frost tolerance for 21 *V. vinifera* cultivars was 29.8 °F, with no cultivar differences (Ferguson et al. 2013). However, it is important to note that cultivars differ in budbreak timing, so while kill temperatures post budbreak may be similar, earlier developing cultivars would be exposed to frost risks for a longer period.

How to prevent frost damage. Frost control methods are typically divided into active and passive (or cultural management) categories. Active frost control methods involve using energy during a frost event to alter the microclimate in the vineyard through wind machines, overhead sprinklers, or heaters. Passive methods involve vineyard design, trellis/training system design, and cultural practices to reduce frost risk.

Wind machines are the most common form of active frost protection in Oregon since radiation frosts are the most common, and access to early season water supplies for overhead sprinklers may be inconsistent or inaccessible. Wind machines disrupt the inversion layer of radiation frosts by mixing the warmer air above the vineyard with the cooler air near the vineyard floor. However, the effectiveness of the wind machine is strongly dependent on the strength of the inversion and its height above the vineyard. Under normal inversion conditions, wind machines can provide approximately 1-3˚F of warming (Sugar et al. 2003). An article by Poling (2008) provides valuable information on wind machine operation.

Overhead sprinklers for frost protection can be effective down to temperatures in the low 20s (˚F). Therefore, it might be the preferred method of active frost control with consistent access to water early in the season. The principle behind sprinkler frost control is latent heat in liquid water that is released upon freezing. Constant application of water to sensitive tissues during frost events results in constant freezing and subsequently keeps succulent tissues at temperatures near 32˚F. The main downsides of sprinkler frost protection systems are that they are expensive to install and require an ample, consistent water supply during a frost event. Furthermore, the colder and more prolonged the frost event, the more water is needed.

There are some other active forms of frost protection, such as the use of vineyard heaters and helicopter services, but they are much less common. Heaters can be combined with wind machines to increase heating capacity during more severe frost events associated with dry air and low dewpoints.

Preventing frost by vineyard design. The first and most crucial consideration for minimizing frost risk is site selection. Since cold air flows downhill like a liquid, it can drain and pool in low-lying areas, a dynamic that can be exaggerated by any barrier like a tree line (Figure 1). Therefore, planting in low-lying spots should be avoided under ideal conditions unless successful frost control measures can be implemented.

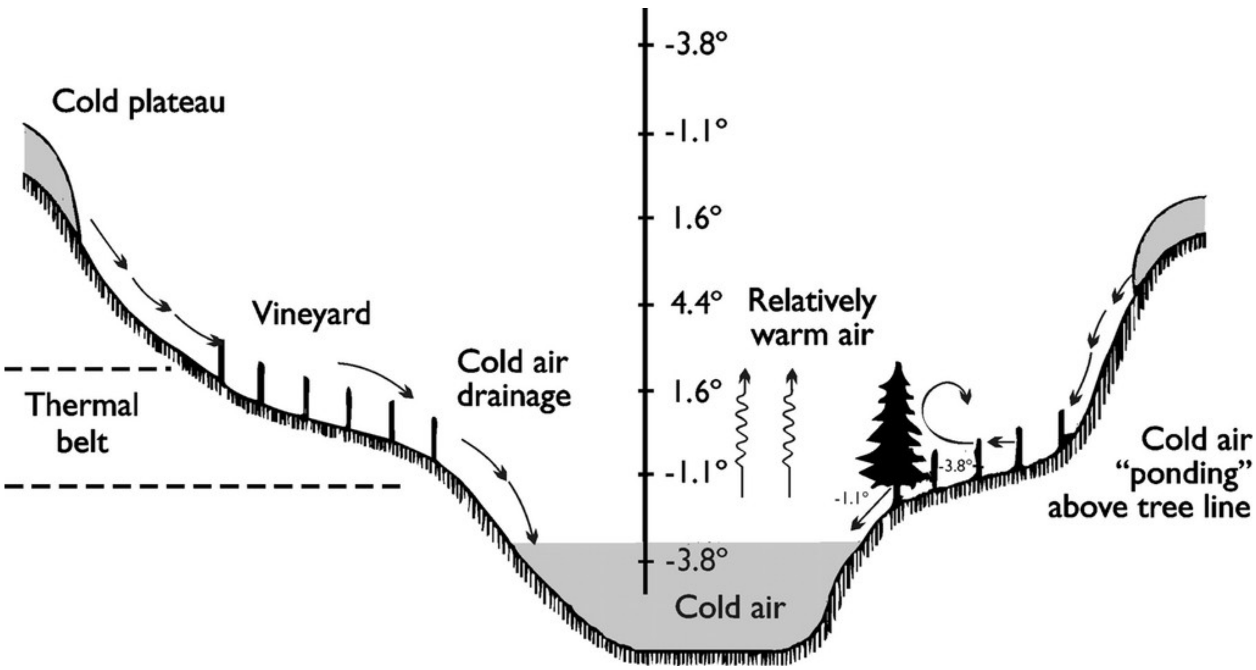

Figure 1. Effect of vineyard site topography on air temperature stratification during a radiation frost. Image source: Poling (2008).

After site selection, cultivar selection and training system selection are important considerations in the vineyard development phase. Cultivars that break bud earlier are at risk of frost for a longer period compared to late budding cultivars. Training fruiting positions higher off the ground by raising the height of the fruiting wire or choosing a training system with a high head height can also help to mitigate effects of radiation frosts.

Vineyard floor management as a frost protection method. While the previously mentioned passive frost protection considerations are limited to vineyard development and thus occur once in the lifetime of a vineyard, an essential annual practice is vineyard floor management. The condition of the vineyard floor during frost events will significantly impact the temperature near the developing buds, and this should be managed in frost-prone vineyards.

During the day, the sun heats the vineyard floor, and some of the heat is conducted downward and stored in the soil to be later radiated into the atmosphere at night. Accordingly, vegetation on the vineyard floor reduces the amount of heat that can be absorbed by the soil and re-radiated at night. Clean-cultivated vineyards generally are 1 to 2˚F warmer than vineyards covered by vegetation (Sugar et al. 2003). Heat absorption is maximized by keeping a clean, moist, smooth, and firmly packed soil free of vegetation. In the absence of clean cultivated floors, closely mowing the ground cover is the next best choice, with a tall, dense cover crop being the worst-case scenario (Figure 2).

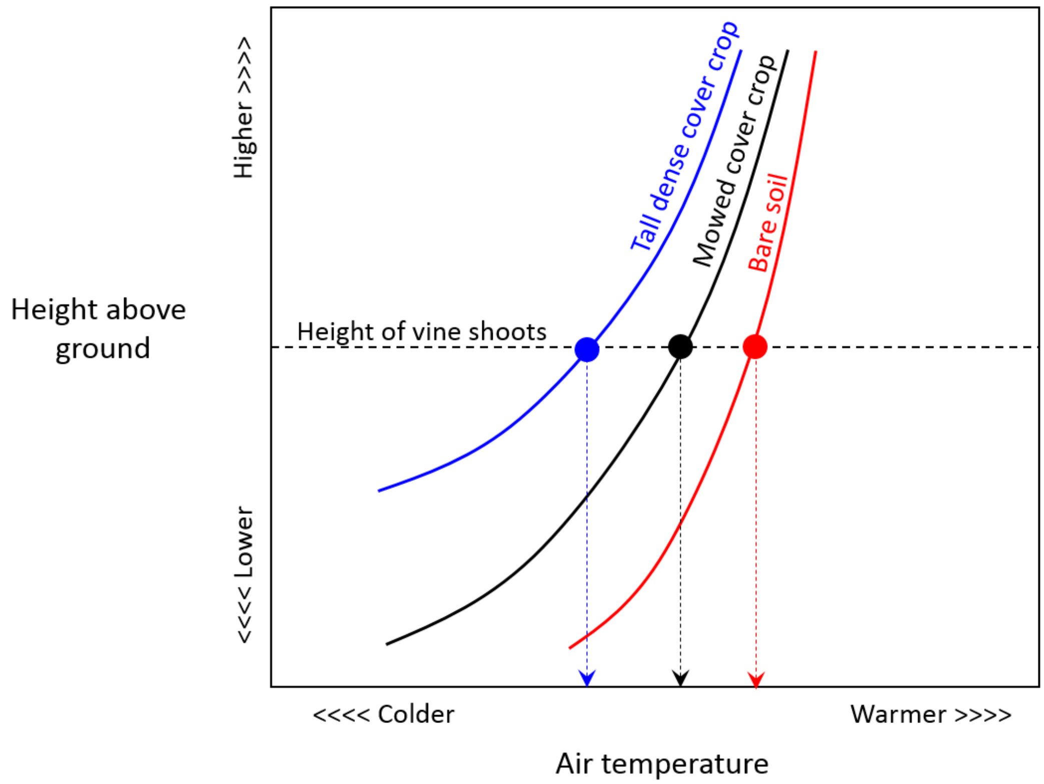

Figure 2. Effect of vineyard floor management on theoretical temperature profiles. Taken from Battany (2016).

Late pruning to prevent frost damage. Delayed dormant or double pruning can help delay budbreak enough that frost risk is minimized for young shoots. Along a cane, apical buds develop earlier compared to basal buds. Thus, waiting to prune until apical shoots are 2-4 in. long can delay budbreak by 1 to 2 weeks (Sugar et al. 2003). However, this may not be logistically possible given the labor-intensive pruning operation, particularly for cane-pruned vineyards. For spur-pruned vineyards, canes can be more easily left long ('pre-pruned') until 2-4 in. shoot growth at apical nodes, and then finished pruning after the threat of frost has passed (Figure 3).

Figure 3. Grapevine that had double pruning applied in a frost-prone spur-pruned vineyard in southern Oregon. Note that basal buds are less developed and escaped the frost damage found on apical shoots. (Photo by D. Marca)

Sprays for frost protection. Recently, there has been renewed interest in sprayable products that might offer some frost protection for grapevine buds. Researchers have tested vegetable oil-based adjuvants, plant growth regulators, foliar fertilizers, and newly developed proprietary products (Persico et al. 2021, Wang and Dami 2020, Centinari et al. 2017). It is important to note that these products are typically applied at the delayed-dormant stage and marketed as budbreak inhibitors. Therefore, their ability to offer "frost protection" is a consequence of delaying budbreak and shortening the frost risk window. Ultimately, few of the tested products offered any substantive delay in budbreak (and ultimately reduced frost risk) compared to traditional practices such as double pruning.

Summary. With climate change, spring frosts (and increasingly early fall frosts) may become more common across Oregon, so it is important to understand the risks to manage them better. From the wooly bud stage onward, grapevine bud and shoot tissues are at risk when temperatures drop below 30˚F. Fortunately, there is a wealth of resources for growers (some links below) on the types of frost control. Currently, the most common active frost control measures are wind machines. Vineyard site and cultivar selection remain the most important primary cultural decisions, though the latter may be more limited by market forces. Vineyard design characteristics such as higher fruiting wire height or training systems are also useful to consider in the development phase. Finally, annual cultural practices in frost-prone sites, such as clean cultivation, close mowing alleys, and double pruning, can significantly reduce the risk of frost damage to sensitive tissues early in the growing season.

Further Reading

Evans RG. 2000. The art of protecting grapevines from low temperature injury. *In* Proceedings of the ASEV 50th Anniversary Annual Meeting, Seattle, WA, June 19-23. 13:60-72. URL: https://www.ars.usda.gov/ARSUserFiles/21563/Art%20of%20Protecting%20Grapevines%20from%20Low%20Temp.pdf

Minton V, Howerton H, and Cole B. 2017. Vineyard Frost Protection: a Guide for Northern Coastal California. *In* Sonoma RCD, Santa Rosa, CA. Heckert et al. (eds.). URL: https://sonomarcd.org/wp-content/uploads/2017/06/Vineyard-Frost-Protection.pdf

Snyder RL. 2001. Principles of frost protection. Atmospheric Science, University of California, Davis. URL: https://biomet.ucdavis.edu/principles-of-frost-protection/

Literature Cited

Battany M. 2016. Vineyard floor management and frost risk. Grape Notes Newsletter. San Luis Obispo and Santa Barbara Counties. Agriculture and Natural Resources, University of California. URL: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20698

Centinari M, Gardner DM, Smith DE, and Smith MS. 2018. Impact of Amigo oil and KDL on grapevine postbudburst freeze damage, yield components, and fruit and wine composition. *Am J Enol Vitic* 69:77-88. DOI: 10.5344/ajev.2017.17030

Fuller MP and Telli G. 1999. An investigation of the frost hardiness of grapevine (Vitis vinifera) during bud break. *Ann Appl Biol* 135:589-595. DOI: https://doi.org/10.1111/j.1744-7348.1999.tb00891.x

Ferguson JC, Moyer MM, Mills LJ, Hoogenboom G, and Keller M. 2013. Modeling dormant bud cold hardiness and budbreak in 23 Vitis genotypes reveals variation by region of origin. *Am J Enol Vitic* 65:59-71. DOI: 10.5344/ajev.2013.13098

Gardea AA. 1987. Freeze damage of Pinot noir (Vitis vinifera L.) as affected by bud development, INA bacteria, and bacterial inhibitor. Oregon State University, Corvallis. MS Thesis. URL: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/gt54kq01r

Persico MJ, Smith DE, and Centinari M. 2021. Delaying budbreak to reduce freeze damage: seasonal vine performance and wine composition in two *Vitis vinifera* cultivars. *Am J Enol Vitic* 72:346-357. DOI: 10.5344/ajev.2021.20076

Poling EB. 2008. Spring cold injury to winegrapes and protection strategies and methods. *HortScience* 43(6):1652-1662. DOI: https://doi.org/10.21273/HORTSCI.43.6.1652

Sugar D, Gold R, Lombard P, and Gardea A. 2003. Strategies for frost protection, p. 213–217. *In* Hellman EW. (ed.). Oregon Viticulture. Oregon State University, Corvallis. URL: https://osupress.oregonstate.edu/book/oregon-viticulture

Wang H and Dami IE. 2020. Evaluation of budbreak-delaying products to avoid spring frost injury in grapevines. *Am J Enol Vitic* 71:181-190. DOI: 10.5344/ajev.2020.19074