The ability of dormant grapevine tissue to survive freezing temperatures during autumn and winter is a measure of their cold hardiness. Grape vines withstand these temperatures via two processes. Cane & trunk tissues tolerate ice outside living cells, which results in desiccation of the cytoplasm inside the cells. Buds avoid freezing injury by keeping their cell contents in a liquid state at below freezing temperatures, a process called supercooling. (1) Cryoprotectants (antifreeze sugars, proteins and amino acids) accumulate in the cells. A plug preventing water movement develops just below the bud in the cane. (2) Cold hardiness of grapevines is typically measured by the highest temperature that kills 50% of the primary bud population in midwinter, termed “lethal temperature 50” or (LT 50). (1)

Vines gain cold hardiness in the fall as the result of decreasingly lower temperatures, a process called “cold acclimation”. The stem tissue turns from green to brown in autumn beginning from the shoot base to the shoot tip. This browning is the result of new tissue composed of cork cells created in the outer phloem layer now called the periderm. These cork cells secrete a waxy substance and then die leaving an almost waterproof layer. The first stage of cold acclimation is induced by cooling temperatures in late summer and early fall and shortening day lengths. During the first stage of cold acclimation the primary buds can survive temperatures in the (LT 50 -5°F to 20°F) range. The second stage of cold acclimation occurs during the first fall frost when temperatures drop below 32°F. Vine cold hardiness increases dramatically as temperatures decline below freezing and continue to decrease until temperatures reach their lows in midwinter. (1)

Periderm formation, mobilization of carbohydrate reserves to canes, trunks and roots; and isolation of dormant buds from the vascular tissues in canes and trunks are complete shortly after leaf fall. After leaf fall the remaining woody stem is called a cane. (1)

Increasing temperatures in the spring begin the process of deacclimation, a transition to a cold hardy to a cold tender state. Deacclimation can occur more quickly than cold acclimation. Fluctuating warm to cold temperatures during midwinter can cause cold injury to occur at above normal critical temperatures. (1)
As vines deacclimate, some of the changes inside the cells that allowed them to survive very cold temperatures are reversed. The vascular plugs are digested by enzymes, allowing water to move into proximity of the buds. Hormone levels that kept the cells dormant decline and some of the cryoprotectants that helped dehydrate the cells are metabolized. This allows the cells to rehydrate and freeze at higher temperatures. Water starts to move into the roots and trunk as storage starches are metabolized into sugars in the xylem. (2)

Cold climate grapes tend to deacclimate more quickly than *Vitis vinifera* grapes. After budbreak, temperatures just slightly below freezing can be lethal to grapevine tissues. (1)

**Cold Damage Assessment**

Cold damage assessment can be taken early in the spring after a week or two of above freezing temperatures. The cell contents of winter damaged cells will have leaked out between the cell walls and have begun the process of oxidative browning that can be accessed by using a pocket knife on the trunks and cordons. Undamaged live phloem cambium and xylem tissue should have a white cream coloration. The worst damage normally occurs on the south or southwest side of the trunk so look at these separately. The good news is that cambium cells are more resistant to cold than the outside phloem cells. Surviving cambium cells can make new phloem cells that can repair minor cold damage. (1)

Randomly checking for green bud tissue is also critical in the spring. A razor blade can be used to slice horizontally across the bud scale to expose all three of the inner buds (primary, secondary and tertiary). If more than 20% of the primary buds are brown on the initial assessment, a more intensive survey of the vines should be made. Once again you will be looking for oxidative browning in

![Profile of Grape Bud Hardiness](image)

**Figure 1.** Profile of grape bud hardiness, Zabadal 2007.

**Compound grape bud:** A – live secondary, B – dead primary and C – live tertiary bud.
the bud tissues. If the vines have not experienced prolonged above freezing temperatures, allow the sampled vines to be placed in a heated area for 24-48 hours prior to checking for winter damage. The following guidelines can be used to adjust your pruning severity in response to cold injury: (1), (3)

**Primary bud mortality and suggested corresponding modifications in pruning.**

<table>
<thead>
<tr>
<th>Primary Bud Mortality %</th>
<th>Modification of Pruning Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14</td>
<td>None</td>
</tr>
<tr>
<td>15-34</td>
<td>Leave 35% more buds</td>
</tr>
<tr>
<td>35-50</td>
<td>Double the normal bud number</td>
</tr>
<tr>
<td>50+</td>
<td>Minimal or no dormant pruning.</td>
</tr>
</tbody>
</table>

Figure 2. Categories of primary bud mortality and suggested modifications of pruning severity, Zabadal 2007.

**Management Options to Prevent Winter Injury**

There are some very good and long standing management practices that can help reduce the risk of incurring cold damage during the winter. Below is a list of some these cold injury prevention options one can consider:

1. *Cultivar Cold Hardiness:* Planting cold hardy cultivars in their respective cold hardiness adapted zone is the essential first step is reducing the risk of winter cold damage occurring. (see attached page 8 2012 USDA North Central U.S. Cold Hardiness Zone Map)

2. *Site:* Stresses derived from wet soils, dry soils, improper pH, very low fertility, too much organic matter, shallow rooting capacity or inadequate light can all reduce a grapevine’s ability to withstand cold damage.

3. *Topography:* can also make a big difference. Vineyards should be placed on upland areas or on slopes where cold air can drain away.

4. *Aspect:* South and southwest facing slopes are great for maturing the crop during the growing season but can increase the risk of trunk injury in the winter. Temperature spikes in midwinter combined with full sun exposure can deacclimate the south and southwest portions of the truck resulting in cold injury.

5. *Reflective Paint:* Painting silver or white paint on the south and southwest sides of trunks is a common practice used in the horticulture industry on trees and vines to reduce the effect of direct sunlight deacclimating trunk tissue in winter. (1)

6. *Grow tube Removal:* Grow tubes should be removed soon after veraison to allow the plant to acclimate normally through the fall.
7. **Vine Balance:** Too much leafy vigor indicates a plant that may not be able to harden off in the fall leaving it very susceptible to cold injury. Too much crop load indicates a stressed plant that may not be able to recover from a severe cold period.

8. **Excessive Leaf Removal:** through the season to correct shading problems can result in reduced fruitfulness and reduced winter hardiness of the basal buds.

9. **Cordon Height:** The lowest temperatures from radiation freezes in midwinter occur at the ground level or at the snow level. Mid-wire cordon training systems have a higher potential of freeze damage versus high cordon systems in these situations. (1)

10. **Reduction in Woody Tissue:** The greater amount of permanent and semi-permanent tissues you have above ground, the greater the risk of freeze damage to this tissue. It may be best to consider a fan training system where canes originate at a ground level head area for very cold climates and/or when growing cold sensitive cultivars.

11. **Shoot Devigoration:** Combing shoots downward reduces photosynthesis which in turn reduces the carbohydrate status which is a major factor in winter hardiness. Upward oriented cultivars will show more devigoration than downward growing procomitant cultivars when shoots are positioned downwards. (1)

12. **Delayed Pruning:** Pruned vines tend to experience greater levels of winter injury than unpruned vines. Fall pruning is not recommended. Mid to late winter pruning seems to have no effect on winter injury. (1)

13. **Double or Multiple Trunked Vines:** tend to have one or more surviving trunks when winter cold injury occurs. This allows for the vines to still produce a crop and hold back vigor.

14. **Crown Gall:** Remove vine trunks showing signs of crown gall because these vines tend to be less healthy and less apt to survive a severely cold winter.

15. **Sucker Retention:** Retaining suckers as renewal shoots each year provides insurance if needed for trunk renewal next season.

16. **Leaf Disease Control:** Downy Mildew and Powdery Mildew can prematurely defoliate vines late in the season interfering with the winter acclimation process.

17. **Herbicide Drift:** Grapes are very sensitive to phenoxy herbicides. These herbicides act as hormones and tend to slow the fall acclimation process. Other herbicides can directly affect the health of the vine going into winter. Notifying neighbors, signage, registering your vineyard with Drift Watch or a Sensitive Crops Directory and planting vegetative buffers can reduce the risk of herbicide drift into vineyards.

18. **Glyphosate (Roundup) Injury:** Glyphosate is the #1 herbicide used in vineyards. Vines become more sensitive to accidental applications hitting suckers as the season progresses. Mid to late season sucker applications can reduce the health of the plant going into winter.
19. *Windbreaks*: Windbreaks planted around a vineyard allow more snow to drift into the vineyard. This blanket of snow acts to insulate the soil and lower trunk.

20. *Moist Soils*: Dry soils freeze deeper and get colder than moist soils. Severe root damage can occur in frozen soils. Vineyards with irrigation should consider wetting dry soils under the wire prior to soil freeze up.

21. *Trench Planting*: Planting vines in shallow 6” to 8” trenches can be utilized to catch snow into the trench for insulation. An option considered in very cold climates.

22. *Graft Union Protection*: Hilling up with soil or covering the base of the plant with mulch helps to protect the graft union of cold sensitive *Vitus vinifera* cultivars.

23. *Burying Vines*: This is a very labor intensive practice that is used to protect *Vitus vinifera* vines planted in cold climates. Each winter the vines are removed from the trellis and laid on the ground to be covered with approximately one foot of soil or mulch for insulation.


25. *Nitrogen Applications*: Apply nitrogen applications sparingly just prior to or after bloom if recommended by soil and/or petiole tests. Too much nitrogen can slow the acclimation process in the fall. Nitrogen applications made after vine dormancy will not affect winter acclimation. (1)

26. *Irrigation*: Unless severely drought stressed, irrigation should be shut down after veraison.

27. *Weed or Cover Crops*: Allowing late season germinating weeds to remain or planting cover crops under the wire after veraison can help hasten the winter acclimation process.

28. *Rootstocks*: can impart varying levels of vigor to vines. Low to moderate vigor rootstocks are preferred to minimize the risk of winter injury to vines. There is also some evidence that cold hardy rootstocks can impart some cold hardiness to the scion. (1)

29. *Harvest Timing*: When fruit is removed from the vine, the postharvest acclimation process is accelerated. A delayed harvest may reduce vine hardiness when other stresses are affecting vine performance. (1)

30. *Vineyard Row Middle Vegetation*: Allowing vegetation in vineyard row middles to grow taller after veraison provides more nutrient and water competition to the vines which tend to accelerate the cold acclimation process. (1)

**Winter Injury Management**

The strategy for coping with extensive winter injury should start with delaying pruning as long as possible during the dormant period. The delay should be used to assess the extent
of winter injury and then adjusting the pruning strategies in relation to bud and vine damage and mortality levels. Therefore, before pruning grape growers should carefully evaluate each cultivar and site. (5) With severely damaged vines, the #1 priority is to produce leaf matter in the new season for survival. Crop production is of secondary importance. Here are some management options to consider:

1. **Replanting**: Vine count is key to vineyard productivity. Individual dead plants should be replaced. Serious consideration should be taken to replace cold sensitive cultivars that are not adapted to the site.

2. **Abandon Vineyard Site**: Consideration should be given to abandoning poor vineyard sites or installing practices that improve site conditions.

3. **Double or Multiple Trunk Systems**: Consideration should be made to develop single trunks into double or multiple trunks when there is a high potential of cold sensitive cultivars incurring winter cold damage. These multiple trunk systems tend to have a higher survival rate when dealing with winter cold injury. (4)

4. **Remove Damaged Parts**: Removal of known or suspected damaged parts should be part of the pruning process. However, do not remove old trunks if they are supporting canes to provide a better balance of bud number during the recovery period. There is no need to prune out a crown gall infected trunk if it is supporting some needed buds. Remove the crown gall infected trunk once the new trunk is established. (4)

5. **Preliminary Bud Assessment**: should be done to determine potential damage and pruning level.

6. **Prune Cold Hardest First**: A classical recommendation in cool-cold climate viticulture is to prune cold-hardy cultivars first and the cold tender varieties last. Generally, secondary bud mortality is similar to that of the primary bud for each single variety. However, some indication of secondary buds percentage is important, especially when primary bud mortality is above 60 percent. When primary bud mortality is over 70 percent, pruning efforts should be directed to reestablish the fruit-bearing zone of the vines and balance the growth of the vines during the spring and the summer.

7. **Double Pruning (aka: long pruning) or No Pruning**: Producing leaf area is the #1 priority for vine recovery. Over pruning a winter damaged vine with a large root system only increases the risk of winter damage the following year. Have patience, watch for bud break and prune accordingly.

8. **Look for Basal Buds to Break Later**: When vines are severely damaged, base buds close to pruning cuts have the potential to break bud and grow. This physiological phenomenon is very useful for increasing the number of shoots per vine during the spring and consequently increasing the total leaf area. Having a higher number of shoots in established vines with large root systems and plenty of reserves in the permanent structures of the vine will avoid excessive shoot growth (bull canes). (5)

9. **Cane Selection**: Select high quality canes of pencil sized diameter with dark periderm color. Avoid large diameter ½” or greater bull canes that tend to be less hardy.
10. **Sucker Retention:** Bringing up several suckers will allow for better balance of shoot growth for severely damaged vines and establish new trunks. Non-needed suckers can be removed the following year at pruning time. (4)

11. **Cultural Management:** Proper overall husbandry of cold damaged vines will bring them back into production sooner.

**Summary**

Attempting to grow grapes in a cold climate will always pose the additional risk of winter injury no matter how well adapted the grape cultivar is to the climate. Starting out with the proper cultivar(s) and site selection are the first two steps in reducing the risk of winter injury. Seasonal cultural management practices can then be used to lessen the impact of winter injury that has occurred and reduce the potential of future winter injury.

**References:**


6. USDA Plant Winter Hardiness Zone Map – attached.

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Above: USDA Plant Winter Hardiness Zone Map:
http://planthardiness.ars.usda.gov/PHZMWeb/