GRAPE COLD INJURY
Causes, Prevention, Assessment, and Compensation

Nevada Grape Growers
Washington Precipitation

Average Annual Precipitation
Washington
Period: 1961-1990  Units: inches

Legend (inches per year):
- Less than 10
- 10 to 15
- 15 to 20
- 20 to 25
- 25 to 30
- 30 to 40
- 40 to 60
- 60 to 80
- 80 to 100
- 100 to 140
- 140 to 160
- More than 180
Washington AVA’S
Understanding Vine Cold Injury

- Mechanics of cold injury
- Avoiding cold injury
- Prediction and protection methods
- Injury assessment and compensation
- Other considerations
Crop-Limiting Effects of Cold Temperatures

- Low heat units (<1800dd)
- Short growing season (<150 days)
- Severely cold temperatures
Two Types of Cold Events - Radiation

- Radiation most common, easiest to control.
- Exposed objects lose heat to clear night sky.
- Blossoms, buds, canes, become 1-2 degrees colder than ambient air.
- Heat rises, replaced by cold air which drifts into low areas.
- Both radiation heat and drift heat must be replaced.
Frost Events - Radiation (cont.)

- Thermal inversion develops 30-60 feet above ground.
- Temperature loss can be rapid until it reaches the dew point.
- Dew point is the temperature at which atmospheric water vapor begins condensing from a gas to a liquid.
- Evolves large amount of heat, slowing temperature drop.
Two Types of Cold Events - Advective

- Mass air movement (cold front).
- Usually accompanied by wind.
- Usually low dew points.
Critical Temperatures
Plant Reaction To Cold

- Formation of ice crystals
- Desiccation
- Solutes
- Super-cooling
Bud Cold Injury
Wood Cold Injury
Sequence of Cold Injury to Wood

**Stage 1: No Injury**
- Periderm
- Phloem Ray
- Soft Phloem
- Phloem Fibers
- Vascular Cambium
- Xylem Ray
- Wood Fibers
- Xylem Vessel

**Stage 2: Outer phloem damaged, spotty**

**Stage 3: More outer phloem injury; innermost phloem & cambium intact**

**Stage 4: All soft phloem and cambium shows some injury: phloem rays OK**

**Stage 5: Injury begins in outer xylem except**

**Stage 6: Total injury of all phloem, cambium, outer xylem, including xylem rays**

- As cold injury progresses, a greater fraction of the phloem bundles become discolored. For Gifford's stage 3 injury, the inner phloem and the vascular cambium remain uninjured.
Site Selection

- Slope
- Obstructions
- Aspect
- Soil
- Heat sinks
- Elevation
Cold Air Drainage

- Cold air flows like molasses, from higher elevations to lower and pools like water when obstructed.
Healthy Vines

- Viruses
- Stress
- Mildew
- Crown gall
- Other pests

Primary Bud Damage

Leaf Roll Infection

- None
- Mild
- Severe

- 2 strains
Crown Gall

- Large area on permanent wood with growth of soft disorganized tissue.
- Small ones slough off.
- Large ones can remain as corky growth (galls) on vine. If girdled, vine will die.
Variety Selection
### Relative Cold Hardiness

<table>
<thead>
<tr>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chenin blanc</td>
<td>Sauvignon blanc</td>
<td>Riesling</td>
</tr>
<tr>
<td>Merlot</td>
<td>Lemberger</td>
<td>Chardonnay</td>
</tr>
<tr>
<td>Sangiovese</td>
<td>Cabernet sauvignon</td>
<td>Gewurztraminer</td>
</tr>
<tr>
<td>Semillon</td>
<td>Cabernet franc</td>
<td>Pinot noir</td>
</tr>
<tr>
<td>Syrah</td>
<td></td>
<td>Pinot gris</td>
</tr>
<tr>
<td>Viognier</td>
<td></td>
<td>Pinot blanc</td>
</tr>
</tbody>
</table>
Irrigation

- Deficit
- Don’t overstress
- Post harvest
Nutrition

- “Vines have to struggle to produce high quality grapes”
- Vines use about 30-40lbs N/a
- Think nutrient replacement
Crop Load
Pruning and Training

- Prune for crop and sunlight
- Keep trellis configuration simple
- Multiple trunks
- Fan system
- Kicker canes
- Delayed pruning
Table 4. Effect of shoot exposure to sunlight on hardiness ($T_{50}$)\(^z\) and water content\(^y\) of primary buds and canes of Concord grapevines, 20 September 1979. All samples were from middle node positions (#6-8) on shoots with 3 clusters.

<table>
<thead>
<tr>
<th>Exposure status</th>
<th>Cane color</th>
<th>$T_{50}$</th>
<th>$H_2O$</th>
<th>$T_{50}$</th>
<th>$H_2O$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>Brown</td>
<td>-13.0a</td>
<td>0.90c</td>
<td>-13.5a</td>
<td>0.91c</td>
</tr>
<tr>
<td>Shaded</td>
<td>Lt. brown</td>
<td>-10.5b</td>
<td>1.11b</td>
<td>-11.5b</td>
<td>1.24b</td>
</tr>
<tr>
<td>Shaded</td>
<td>Green</td>
<td>-6.5c</td>
<td>1.69a</td>
<td>-7.5c</td>
<td>2.71a</td>
</tr>
</tbody>
</table>

\(^z\) °C; separated by Chi\(^2\) test, $p = 0.05$.

\(^y\) g $H_2O$/g dry wt; separated by Duncan’s multiple range test, $p = 0.05$. 

Bud and Cane Hardiness as Affected By Sunlight Exposure
Planting

- Timing
- Depth
- Grow-tubes
Other Cultural Practices

- Rootstocks
- Cover crops
- Wind breaks
- Early harvest
- Late pruning
Active Frost Protection

- Efforts to modify temperatures in vineyard
- Add heat
- Mix inversion into vineyard
- Conserve heat
Need to Be Able to Predict Critical Temperatures

- Temperatures at which cells of a tissue will be killed
- Usually expressed as T10, T50, or T90; temperatures at which 10, 50, or 90% of buds, tissue are killed
<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Definition</th>
<th>Critical Temperatures*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$T_{10}$ variable</td>
</tr>
<tr>
<td>Dormant</td>
<td>Closed bud, inactive. Buds increase in size, scales separate to show brown, fuzzy, young leaf tissue</td>
<td></td>
</tr>
<tr>
<td>First swell</td>
<td>Buds swell further, young leaves become pink. Still closed around growing point</td>
<td>13</td>
</tr>
<tr>
<td>Full swell</td>
<td>Young leaves separate at tip to show the growing point</td>
<td>21</td>
</tr>
<tr>
<td>Bud burst</td>
<td>First leaf is out of the bud, makes right angle with stem</td>
<td>25</td>
</tr>
<tr>
<td>1st leaf</td>
<td>2nd leaf makes right angle with stem</td>
<td>27</td>
</tr>
<tr>
<td>2nd leaf</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>3rd leaf</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>4th leaf</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>5th leaf</td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>
Critical Temperatures (cont.)

- Can be measured in a lab.
- Usually reported as temperature at which 10, 50, or 90% buds are killed.
- Temperature range narrows as get closer to bud break.
- Not absolute but growers can use reports to time protection measures.
# Critical Temperature Report

<table>
<thead>
<tr>
<th>Date</th>
<th>Variety</th>
<th>BUD10</th>
<th>BUD50</th>
<th>BUD9</th>
<th>PHL10</th>
<th>XYL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 6</td>
<td>Cabernet Sauvignon</td>
<td>+3</td>
<td>-1</td>
<td>-3</td>
<td>+8</td>
<td>-1</td>
</tr>
<tr>
<td>Mar 27</td>
<td>Cabernet Franc</td>
<td>+8</td>
<td>+5</td>
<td>+2</td>
<td>+8</td>
<td>0</td>
</tr>
<tr>
<td>Apr 10</td>
<td>Merlot</td>
<td>+13</td>
<td>+10</td>
<td>+5</td>
<td>+16</td>
<td>+11</td>
</tr>
<tr>
<td>Mar 27</td>
<td>Malbec</td>
<td>+3</td>
<td>+1</td>
<td>-2</td>
<td>+9</td>
<td>-1</td>
</tr>
<tr>
<td>Apr 7</td>
<td>Syrah</td>
<td>0</td>
<td>2</td>
<td>-3</td>
<td>+10</td>
<td>+1</td>
</tr>
<tr>
<td>Mar 20</td>
<td>Mourvedre</td>
<td>+4</td>
<td>+2</td>
<td>0</td>
<td>+8</td>
<td>+2</td>
</tr>
<tr>
<td>Mar 20</td>
<td>Grenache</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
<td>+4</td>
<td>-4</td>
</tr>
<tr>
<td>Mar 20</td>
<td>Zinfandel</td>
<td>+5</td>
<td>+2</td>
<td>-2</td>
<td>+8</td>
<td>-4</td>
</tr>
<tr>
<td>Mar 20</td>
<td>Sangiovese</td>
<td>+8</td>
<td>+6</td>
<td>+1</td>
<td>+10</td>
<td>+2</td>
</tr>
<tr>
<td>Mar 27</td>
<td>Nebbiolo</td>
<td>+2</td>
<td>0</td>
<td>-3</td>
<td>+3</td>
<td>-4</td>
</tr>
<tr>
<td>Mar 20</td>
<td>Tempranillo</td>
<td>+11</td>
<td>+9</td>
<td>+7</td>
<td>+10</td>
<td>-2</td>
</tr>
<tr>
<td>Mar 27</td>
<td>Barbera</td>
<td>+4</td>
<td>+2</td>
<td>-3</td>
<td>+9</td>
<td>0</td>
</tr>
<tr>
<td>Apr 7</td>
<td>Riesling</td>
<td>+9</td>
<td>+6</td>
<td>0</td>
<td>+13</td>
<td>+6</td>
</tr>
<tr>
<td>Apr 7</td>
<td>Chardonnay</td>
<td>+11</td>
<td>+8</td>
<td>+1</td>
<td>+13</td>
<td>+6</td>
</tr>
<tr>
<td>Mar 31</td>
<td>Concord</td>
<td>+5</td>
<td>0</td>
<td>-5</td>
<td>+2</td>
<td>-6</td>
</tr>
<tr>
<td>Mar 31</td>
<td>Sunbelt</td>
<td>+7</td>
<td>+4</td>
<td>0</td>
<td>+5</td>
<td>-5</td>
</tr>
</tbody>
</table>
Cold Hardiness of Bud and Cane Samples

Unfortunately, at this time, we do not have a large data base with which to compare different cultivars or species of grapevines. As indicated in Tables 4 and 5, some cultivars and species seem to be more susceptible to rapid temperature changes than others. However, we do not know at this time if changes in stem hardiness would occur faster than buds for these plants.

Research efforts have not provided much hope for significantly increasing grapevine cold hardiness through management practices. On the other hand, they have shown reductions in cold hardiness due to excessive irrigation and otherwise poor management practices. Thus, it appears that, under generally good management, growers must work with the hardiness

Fig. 8. Cold hardness of bud and cane samples of Cabernet Sauvignon (CS) and Syrah (SY) during the winter of 1999-2000 collected in Prosser, Washington, at the Washington State University, Irrigated Agriculture Research and Extension Center. Bud hardness is reported as the temperature at which 50% of the buds would be killed (LTE 50). Cane hardness is reported as the temperature at which 10% of either the phloem (PH) or xylem (XY) tissues would be killed after a short exposure to the indicated temperature. Differences between cultivars and tissue or organ acclimation and deacclimation are reflected in the data.
Protection Measures - Over Vine Sprinkling

- Warms vineyard by heat of fusion.
- Requires large amounts of water.
- Must uniformly cover entire vineyard and keep ice wet. One-third inch/hour.
- Must have water available. Pond, well?
- Can create disease, delayed growth problems.
Under Vine Sprinklers

- Not used much because of interference from posts and vines.
- Heated water may be new option. 1mm/hr at 100-110 degrees.
Heaters

- Only about 25% efficient, hot air rises rapidly out of vineyard.
- Works best when used with wind machines.
- Perimeter heat best.
- Smoke won't help reduce radiation.
- Costly, source of pollution.
Wind Machines

- Mixes warm air of inversion layer down into vine yard.
- One machine will cover about 10 acres.
- Works well with heaters, under vine sprinkling.
- Don’t use with over vine sprinklers.
<table>
<thead>
<tr>
<th>Method</th>
<th>Estimated costs/ha/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Stack Oil Heaters (100/ha)*</td>
<td>$ 93.08</td>
</tr>
<tr>
<td>Standard Propane Heaters (154/ha)*</td>
<td>103.98</td>
</tr>
<tr>
<td>Wind Machine (130 BHP propane)</td>
<td>33.36</td>
</tr>
<tr>
<td>Overcrop Sprinkling</td>
<td>4.10</td>
</tr>
<tr>
<td>Under Canopy Sprinkling</td>
<td>4.25</td>
</tr>
<tr>
<td>Frost-free site</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* equal total heat output
Combination Best

- Use both passive and active methods to minimize cold damage.
How to Deal With Cold Injured Vineyards

- Assessment
- Compensation
- Adjustment
Damage Assessment

- Prune as late in the spring as possible
- Assess damage before pruning
- Examine vines representative of the vineyard
- Tissue may have to be warmed to indicate damage
Bud Compensation

- **25% Injury** - Add 50% more buds
- **50% Injury** - Double bud number
- **75% Injury** - Triple bud number
- **Above 75% injury** - Wait and hedge
Trunk Injury

- Phloem
- Xylem
- Southwest injury
When To Renew Trunk

- Temperatures below – 10 degrees
- Xylem injury
- Over 75% bud mortality
Sucker Management For Trunk Renewal

- Leaving existing vine and renewing trunk usually results in poor bud break
- 4-6 Canes to disperse vigor
- Training suckers along wires best
Bottom Line

- Vines at lower end of 75-100% bud kill usually do OK
- Be prepared to thin (especially in 25-50% bud kill range)
- Hedge prune with high bud mortality
Cultural Practices for Cold Injured Vines

- Use standard cultural practices for moderate injury
- Use vigor reducing practices for severely damaged or renewed vines, i.e. reduced N fertilizer, cover crop, maintain sucker growth
- Don’t over-crop
Other Considerations

- Build cold injury into budget
- Build into wine distribution
- Acreage vs tonnage contracts
- Insurance