Grapevine Frost Protection
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Cooperative Extension

Mean Annual Losses to Weather Hazards in the United States

- Frost
- Flood
- Drought
- Hail
- Hurricane
- Tornado
- Windstorm
- Lightning

$ per capita

Hazard

<table>
<thead>
<tr>
<th>Hazard</th>
<th>$ per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frost</td>
<td>6</td>
</tr>
<tr>
<td>Flood</td>
<td>5</td>
</tr>
<tr>
<td>Drought</td>
<td>4</td>
</tr>
<tr>
<td>Hail</td>
<td>2</td>
</tr>
<tr>
<td>Hurricane</td>
<td>1</td>
</tr>
<tr>
<td>Tornado</td>
<td>1</td>
</tr>
<tr>
<td>Windstorm</td>
<td>1</td>
</tr>
<tr>
<td>Lightning</td>
<td>1</td>
</tr>
</tbody>
</table>

Ice Formation
- Water Freezes below the Melting Point (0°C or 32°F)
- In the temperature range for Frost Damage (-5 to 0°C or 23 to 32°F), INA bacteria cause 99% of Ice Nucleation
- Ice forms on the surface and propagates inside

In A, on a dry leaf water with *P. syringae* was placed at the arrow and deionized water at black spot. The black spot is colder because of evaporation. Ice forms first at the bacteria and propagates through the leaf (B-E). Two minutes after the exothermic response dissipates, the deionized water freezes.

Wisniewski, Lindow and Ashworth (1997)
Intercellular Ice Crystal Formation

Critical Temperatures

The values shown below were determined in the laboratory and have not been checked extensively against field injury. These values are distributed as a guide for frost sensitivity of grapevines.

<table>
<thead>
<tr>
<th>STAGE OF DEVELOPMENT DEFINITION</th>
<th>CRITICAL TEMPERATURES (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
<td>T10</td>
</tr>
<tr>
<td>Dormant closed bud, inactive.</td>
<td>&lt;0</td>
</tr>
<tr>
<td>First Swell Buds increase in size, scales separate to show brown, fuzzy, young leaf tissue.</td>
<td>13</td>
</tr>
<tr>
<td>Full Swell Bud swells further, young leaves become pink. Still closed around growing point.</td>
<td>21</td>
</tr>
<tr>
<td>Bud Burst Young Leaves separate at tip to show the growing point.</td>
<td>25</td>
</tr>
<tr>
<td>1st Leaf First leaf is out of the bud, makes right angle with stem.</td>
<td>27</td>
</tr>
<tr>
<td>2nd Leaf 2nd leaf makes right angle with stem.</td>
<td>28</td>
</tr>
<tr>
<td>3rd Leaf</td>
<td>28</td>
</tr>
<tr>
<td>4th Leaf</td>
<td>28</td>
</tr>
<tr>
<td>5th Leaf</td>
<td>28</td>
</tr>
</tbody>
</table>

*Critical temperatures for 10 percent (T10) and 90 percent (T90) kill of primary buds.

Methods of Heat Transfer

Conduction - from molecule to molecule

Convection - by movement of heated air

Radiation - energy passing from one object to another without a connecting medium

Latent Heat Transfer

Latent Heat - Chemical Heat

Energy is released to the environment as liquid water cools and freezes. Energy is removed from the environment if liquid water evaporates!
Passive Protection

- Bacteria Control
- Site Selection
- Soil Water Content
- Ground Cover

Site Selection
Cold Air Drains to Low Spots
DIVERT COLD AIR

COLD

REMOVE COLD-AIR DAMS

Cold Air

SOIL WATER CONTENT

Dry Soil
Lower Diffusivity
Reflects More

Wet Soil
Higher Diffusivity
Reflects Less

HEIGHT

Temperature

COVER CROP

With Cover
Reflects Sunlight
Drier Soil
Lower Diffusivity
INA bacteria

No Cover
Less Reflection
Wetter Soil
Higher Diffusivity

HEIGHT

Temperature

colder

warmer
Cover Crop

1. If frost is a serious problem, remove cover crop during potential frost periods.
2. Herbicide control is best
3. If mowed, remove residue
4. If cultivated, roll to compact the soil

Active Protection

- Sprinklers
- Surface Water
- Wind Machines
- Helicopters

Sprinklers

- Heat comes from freezing water
- Application rate depends on energy loss and the evaporation rate
- Start when the wet-bulb temperature is above the critical temperature
- Stop when the wet-bulb temperature is above 32°F (0°C)

Energy Exchange

<table>
<thead>
<tr>
<th>Process</th>
<th>cal g⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C to 0°C (68°F to 32°F)</td>
<td>20</td>
</tr>
<tr>
<td>Freezing at 0°C (32°F)</td>
<td>80</td>
</tr>
<tr>
<td>Evaporation</td>
<td>-597</td>
</tr>
</tbody>
</table>
Application Rate = 0.11 in./hr = 2.8 mm h⁻¹
Wind Velocity = 3.4 mph = 1.5 m s⁻¹

Starting and Stopping

When sprinklers start the temperature drops to the wet-bulb temperature.

If wetted and not re-wetted, the plants will cool to the wet-bulb temperature.

Start when $T_{\text{wet}} > T_{\text{critical}}$
Stop when $T_{\text{wet}} > 32^\circ\text{F} (0^\circ\text{C})$

Select a wet-bulb equal to the critical damage temperature and select the start and stop air temperature corresponding to the dew-point.

<table>
<thead>
<tr>
<th>Dew-point (°F)</th>
<th>Wet-bulb Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.0</td>
<td>23.0, 24.8, 26.6, 28.4, 30.2, 32.0</td>
</tr>
<tr>
<td>30.2</td>
<td>24.8, 26.6, 28.4, 30.2, 33.3</td>
</tr>
<tr>
<td>28.4</td>
<td>26.6, 28.4, 31.3, 34.3</td>
</tr>
<tr>
<td>26.6</td>
<td>28.4, 31.3, 34.3, 37.2</td>
</tr>
<tr>
<td>24.8</td>
<td>26.6, 29.5, 32.4, 35.4</td>
</tr>
<tr>
<td>23.0</td>
<td>24.8, 27.5, 30.4, 33.4, 36.3</td>
</tr>
<tr>
<td>21.2</td>
<td>23.9, 26.6, 29.3, 32.2, 35.2, 38.1</td>
</tr>
<tr>
<td>19.4</td>
<td>24.6, 27.3, 30.2, 33.1, 36.0, 39.0</td>
</tr>
<tr>
<td>17.6</td>
<td>25.5, 28.2, 30.9, 33.8, 36.7, 39.7</td>
</tr>
<tr>
<td>15.8</td>
<td>26.1, 28.9, 31.6, 34.5, 37.4, 40.5</td>
</tr>
</tbody>
</table>
Dew point Temperature

Slowly add ice cubes to the water to lower the can temperature. Stir the water with a thermometer while adding the ice cubes to insure the same can and water temperature. When condensation occurs, note the dew point temperature.

Typical Impact Sprinkler Application Rates Wine Grapes

<table>
<thead>
<tr>
<th>T_{min} °F</th>
<th>Wind Speed mph</th>
<th>30 s gpm A^{-1}</th>
<th>60 s gpm A^{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.9</td>
<td>0.0-1.1</td>
<td>36.0</td>
<td>45.0</td>
</tr>
<tr>
<td>26.1</td>
<td>0.0-1.1</td>
<td>49.5</td>
<td>58.5</td>
</tr>
<tr>
<td>23.0</td>
<td>0.0-1.1</td>
<td>67.5</td>
<td>76.5</td>
</tr>
<tr>
<td>28.9</td>
<td>2.0-3.1</td>
<td>45.0</td>
<td>54.0</td>
</tr>
<tr>
<td>26.1</td>
<td>2.0-3.1</td>
<td>58.5</td>
<td>67.5</td>
</tr>
<tr>
<td>23.0</td>
<td>2.0-3.1</td>
<td>81.0</td>
<td>90.0</td>
</tr>
</tbody>
</table>

Clear Dripping Ice

Sprinklers

Impact

Targeted

3 gph large droplets
Targeted Vs Impact

<table>
<thead>
<tr>
<th>Sprinklers</th>
<th>gpm /Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targeted</td>
<td>15.0</td>
</tr>
<tr>
<td>Impact</td>
<td>55.1</td>
</tr>
</tbody>
</table>

Equal protection at 21.6°F (-5.8°C)
Similar results from CIT Fresno State

Higher cost and more labor to keep the sprinklers properly oriented.

Fetzer (near Manton)

Wet-bulb temperature can be determined from air and dew point temperatures to estimate when to start and stop sprinklers.

With Wind Machine

Temperature Inversion (°F) 5’ to 40’

\[
\Delta T_{15} (°C) = 0.3014x + 0.1981 \\
\Delta T_{5} (°C) = 0.80
\]

After 2 full rotations

Presentation to Sonoma County Vineyard Technical Group
March 15, 2012
Turn-on Time
When exposed plant temperature nears 32\(^\circ\)F (0\(^\circ\)C)

Turn-off Time
When exposed plant is above 32\(^\circ\)F (0\(^\circ\)C).

If the fruit was frozen, operate 1-2 hours longer.

http://biomet.ucdavis.edu

The End

Thanks

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