Methods of Vineyard Frost Protection

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<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage</th>
<th>$T_{10}$</th>
<th>$T_{50}$</th>
<th>$T_{90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Bloom</td>
<td>28</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Pear</td>
<td>Bloom</td>
<td>28</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Peach</td>
<td>Bloom</td>
<td>27</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Tart Cherry</td>
<td>Bloom</td>
<td>28</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Plum</td>
<td>Bloom</td>
<td>27</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Bloom</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Grape</td>
<td>Shoot emerg.</td>
<td></td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>
### Critical Temperatures (F) of Developing ‘Concord’ Buds

<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Bud Surface Moisture Status</th>
<th>Wet</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale-crack</td>
<td></td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>First-swell</td>
<td></td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>Full-swell</td>
<td></td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>Burst</td>
<td></td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>Exposed Shoot</td>
<td></td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

* Values are LT50, where 50% of the growing buds were killed.
Factors to Consider When Investing in Frost Protection

- The crop.
  - Sensitivity & risk (time of bud break & bloom)
  - Value
- Frequency of spring frosts.
- Site conditions.
- Cost of the frost control system.
- Availability of resources required by the frost control system.
- Adaptability of the frost control system to the crop.
- Versatility of the frost control system (other uses).
Advection Freeze

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Advection Freeze

Very dry, cold air mass moving in.

Wind

Plant tissue is warmer than the air.
Radiation Freeze
Radiation Freeze

Inversion Layer

- Very dry air mass.
- Little or no wind.
- Clear sky

Warm Air

Temperatures can be from 3 to 10° warmer at 50 ft above the ground.

Cold Air

Plant tissues become colder than the air.
Frost Injury
Radiation Chilling

Example of exposed leaves cooling below the critical temperature.
Radiation chilling

Cold air settling
Clouds reflect the radiant energy back.
Methods of Frost Protection

- **Proper Site Selection**
- **Heat**
  - Heaters
  - Other
- **Wind**
  - Wind machines
  - Helicopters
- **Water**
  - Sprinklers
- **Covers ???**
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Slope & Elevation

Under radiation freeze conditions

Frost Pocket

Plant at least 50 ft above the valley floor.
Obstructions
Under radiation freeze conditions

Clear out under-story plants to improve drainage.
Cultural Measures

• Lay out planting rows parallel to the prevailing direction of the cold air drift.
• Prune trees & vines properly to avoid blocking air movement. Removing low hanging dense branches is a must.
• Prune out the lower portions of windbreaks to allow air to pass through.
• Keep natural swales & other air drainage pathways open to insure good air drainage.
## Influence of the Soil Surface Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Greater Risk</th>
<th>Lower Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>Dry</td>
<td>Moist</td>
</tr>
<tr>
<td>Soil Texture</td>
<td>Light/sandy</td>
<td>Dark/loamy</td>
</tr>
<tr>
<td>Vegetation under crop</td>
<td>Present</td>
<td>Bare soil</td>
</tr>
<tr>
<td>Mulch</td>
<td>Present</td>
<td>Absent</td>
</tr>
</tbody>
</table>
Heaters

Return stack heaters
Inversion Layer

Heaters

Convective energy

Radiant energy

Heat the air up to the inversion layer
Plants must be in a direct line to the heat source.
Heaters

Advantages:
• Only method that is effective under advection freeze conditions.

Disadvantages:
• Very expensive
  – Requires many @ ~ $90 ea
  – Fuel costs
  – Labor intensive
• Environmental concerns
  – Air quality
  – Spills
Bonfires

Inversion Layer

Can break the inversion layer.

Draw in colder air.

Can do more harm than good.
Smoke shows where the inversion layer is located.

Smoke is of no value in frost control.
Wind Machine

Inversion Layer

Warm Air

Cold Air

Draw down warmer air from above & mix it with the colder air to prevent stratification.

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Forced Cold Air Displacement (Tower-less) Systems

SIS Frost Protection System
SIS Frost Protection System

Inversion Layer

Warm Air

Cold Air

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Frost Fan
Wind Machines

Characteristics:

• Should be started before the temp. drops below freezing.

• Head rotates to cover the surrounding area.

• A single machine can protect up to 10 A with a 10° F inversion differential at 50 ft.
  – Dependent on the height & differential of the inversion.
Wind Machines

- Contour heads are available for variable terrain.
- Because of cold air drift, the effective pattern is not circular.
- Machine placement should be done by qualified professionals.
  - Contour of the land
  - Cold air drift
Wind Machines

- Most have a 35 ft tower.
- Powered by:
  - **Electric**: less expensive initially, req. 440/480 v 3-phase
  - **Gasoline**: most popular, less operating expense than electric, fuel theft
  - **LP**: Additional cost for conversion, burn more fuel, avoids fuel theft.
  - **Diesel**: Highest initial cost, not warranted unless engine can be used for another purpose.
  - **PTO**: Least expensive initially, convenience of attaching a tractor.

- **Cost**:
  - New gas powered ~ $30,000
  - Used ~ $15,000, fob
Wind Machines

Not recommended for use under advection freeze conditions.

- Plant tissues are warmer than the air.
- Winds associated with an advection freeze can damage most wind machines.
Wind Machine plus Heaters

**Inversion Layer**

- An effective combination.
- Expensive.
- Heaters reduce the area of protection.

**Warm Air**

**Cold Air**
Helicopters
Helicopters

• Height & differential of the inversion layer is not as critical as with a wind machine.

• Most effective when hovering or passing over at slow speeds (5-10 mph) & can cover 40-50 A.

• Must be able to return over an area about every 5-6 minutes before air stratification re-occurs.
Helicopters

Expensive to operate.

- > $500 per hour, plus stand-by charges.
- 1987 New York study found that if the annual average need for frost protection for 10 acres of apples exceeded 5 hours at $350 per hour, it was better to invest in a wind machine.
Sprinklers

Terra Vitae Vineyards
Hawkes Bay, NZ

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Sprinklers

Principle:

• Relatively warm water gives up heat upon contact with the colder air and plant tissues.

• Additional energy is released when the water freezes - heat of fusion.
Sprinklers

- Must be started before the temperature drops to freezing and run until the danger has passed.
  - If stopped before the danger has passed, super cooling can occur & cause more damage than if nothing was done.
  - With overhead systems, there is a risk of breakage with ice accumulation on trees, shrubs and vines.

Olmstead Orchards, Inc
Grandview, WA

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Sprinklers

- Cost effective if the system is also used for irrigation (strawberries).

- Can be set up:
  - Overhead:
    - Most frost protection
    - Faced with ice loads.
  - Under the plant:
    - Less protection
    - No ice build up.
Sprinklers

- Because of the potential for frequent use when irrigation is not required, must consider soil’s internal drainage characteristics.
  - Use lower output sprinkler heads
    - Irrigation: .25 - .33 in/hr
    - Frost: .10 - .20 in/hr
Sprinklers

- Must be aware of the predicted dew point temperature.
  - If it is 5° below the predicted low temperature, sprinklers will cause evaporative cooling and cause more damage.
Covers

Thermal Blankets

Poly hoop covers

Weaver's Orchard
Berks Co., PA
Covers

- Allow sunlight to penetrate during the day.
- Trap radiation at night.
Covers

Effective under advection freeze conditions.
Thermal Blankets

Fibrous, semi-porous materials.

- Allow sunlight and moisture to penetrate.
- Trap heat at night.
- Used to advance strawberry crop development.
- Can be used in combination with sprinklers for frost control.
Polyethylene Film Covers

- Allow sunlight to penetrate, but block moisture.
- Trap heat at night.
- Under radiation freeze conditions, all surfaces radiate energy equally.
  - Any plant tissue touching the poly will chill to the temperature of the outside surface of the poly.
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  – Heaters
  – Other
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  – Wind machines
  – Helicopters
• Water
  – Sprinklers
• Covers