To Freeze or Not to Freeze

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Cold Hardiness and Freeze Resistance of Cherry Buds

Cherries = ‘Van’
Objectives

• Determine the critical, lethal temperatures of sweet cherry floral buds

• Determine critical temperatures according to calendar date and phenology stage

• Screen important modern cultivars

• Describe the variability around phenology and its influence on ‘crop’ mortality following freeze events

• Provide producers with accurate data for current cultivars to make informed frost control decisions (i.e., decision-support)
Application of Differential Thermal Analysis (DTA) to Detect Ice Nucleation Events in Floral Buds
Whole spurs sampled - buds removed, placed in foil & pressed against TEM
Each tin 6-8 buds*7 reps=~150-200 flowers
1 thermocouple per tray; 4 trays per run
Temp reduced 1°C/hr in a programmable chamber
Freeze Detection - DTA (Cherry)
Freeze Detection - DTA (Cherry)
Freeze Detection - DTA (Cherry)
Freeze Detection - DTA (SWD)

• Determination of critical temps for overwintering SWD
Lethal Temperatures: Dormancy

-70 DFFB

Regina
Feb 14, The Dalles
*buds from seven spurs*

Latent Heat (relative signal)

Freezer Temperature (C°)

°F
Critical Temperatures for Bud Kill

Critical Values for Regina
14-Feb, C°

Lower Tail Area (<=) Normal

- 0.1 -24.6
- 0.5 -22.9
- 0.9 -21.1
## Cultivar Differences: Feb 14 2013

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>No. buds</th>
<th>Avg. flowers per bud</th>
<th>No. of flowers</th>
<th>Number of peaks</th>
<th>Avg. peak height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bing</td>
<td>39</td>
<td>2.7</td>
<td>105</td>
<td>30</td>
<td>0.23</td>
</tr>
<tr>
<td>Sweetheart</td>
<td>31</td>
<td>3.0</td>
<td>93</td>
<td>108</td>
<td>0.20</td>
</tr>
<tr>
<td>Skeena</td>
<td>35</td>
<td>3.0</td>
<td>105</td>
<td>101</td>
<td>0.16</td>
</tr>
<tr>
<td>Regina</td>
<td>48</td>
<td>3.3</td>
<td>158</td>
<td>155</td>
<td>0.07</td>
</tr>
</tbody>
</table>

- Peak height is a measure of $H_2O$ volume & flower size
- Number of peaks closely matches flower count
  - Except for Bing...

*Note: Cultivar Differences include: Bing, Sweetheart, Skeena, Regina.*
DTA Limitations: Benefits Summary

- DTA loses the capacity to determine nucleation events as bud development advances.
- DTA is an objective measure that can accurately identify the transition from eco-dormancy to growth and development.
Phenology: Asynchronous movement

- RWC gives an independent measure of bud stage and potentially is a sensitive indicator of advancing development

- ‘Bing’ was first to break dormancy as indicated by an increase in RWC and a loss of DTA peaks (14-Feb)
Freeze Detection - Visual Rating

- Indication of injury/death is oxidative browning
- Buds/flowers/fruitlets from 12 spurs per foil pouch
- Total observations: 150-200 flowers
- 1 °C per hour freeze rate
- 24 hour incubation period at room temperature
Freeze Detection - Visual Rating

- Provide a range of test temperatures per sample date to capture the critical temperature range of interest.

**Sweetheart-The Dalles, March 11**

\[ y = 0.0926x^3 + 3.5408x^2 + 33.527x + 95.121 \]

\[ R^2 = 0.9916 \]

-16.5 °C

-8.5 °C

-12.5 °C
Critical Temperatures by Stage

- All varieties and locations combined by stage (visual scoring)
  - Dormant series - DTA with some visual scoring
  - DTA and visual scoring during break of dormancy (stages 0 to 1)
### Critical Temperatures by Date

<table>
<thead>
<tr>
<th>Bud Stage</th>
<th>Phenology Description</th>
<th>10% bud kill</th>
<th>50% bud kill</th>
<th>90% bud kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>dormant</td>
<td>3.2</td>
<td>-4</td>
<td>-21.2</td>
</tr>
<tr>
<td>1</td>
<td>first swell</td>
<td>15.1</td>
<td>3.7</td>
<td>-7.8</td>
</tr>
<tr>
<td>2</td>
<td>side green</td>
<td>24.5</td>
<td>13.1</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>green tip</td>
<td>28.5</td>
<td>17.8</td>
<td>7.1</td>
</tr>
<tr>
<td>4</td>
<td>tight cluster</td>
<td>28.8</td>
<td>22.2</td>
<td>15.6</td>
</tr>
<tr>
<td>5</td>
<td>open cluster</td>
<td>28.4</td>
<td>24.1</td>
<td>19.8</td>
</tr>
<tr>
<td>6</td>
<td>first white</td>
<td>28</td>
<td>23.5</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>balloon stage</td>
<td>28.6</td>
<td>25.1</td>
<td>21.7</td>
</tr>
<tr>
<td>8</td>
<td>full bloom</td>
<td>28.7</td>
<td>25.2</td>
<td>21.7</td>
</tr>
<tr>
<td>9</td>
<td>post-bloom</td>
<td>28.2</td>
<td>25.6</td>
<td>23</td>
</tr>
</tbody>
</table>

- At an equivalent phenology stage cultivars did not differ
- Calendar date differences attributed to development
Phenology: Asynchronous Movement

**Bing**
- Full bloom: 8-Apr.

**Regina**
- Full bloom: 24-Apr.

**Bing bud stages**
- 0-DORMANT
- 1-FIRST SWELLING
- 2-SIDE GREEN
- 3-GREEN TIP
- 5-OPEN CLUSTER
- 6-FIRST WHITE
- 7-BLOOM
- 9-POST BLOOM

**Regina bud stages**
- 0-DORMANT
- 1-FIRST SWELLING
- 2-SIDE GREEN
- 3-GREEN TIP
- 5-OPEN CLUSTER
- 6-FIRST WHITE
- 7-BLOOM
- 9-POST BLOOM
Large differences observed by date
Attributed to differences in bud development
Late developing cultivars...cold sites
Field Validation: April 17 Freeze Events

The Dalles: 27.7°F

- **Skeena**: Actual Mortality
- **Bing**: Predicted Mortality
- **Sweetheart**: Actual Mortality

Mt Adams, WA: 27.5°F

- **Skeena**: Actual Mortality
- **Regina**: Predicted Mortality
Field Validation: April 17 Freeze Events

- Bloom-period freeze events produced mortality rates similar to the predicted values.
De-hardening and Re-hardening
Sweet Cherry Bud Hardiness: Pre-conditioning × Freeze Rate of Regina, Feb 2013

<table>
<thead>
<tr>
<th>Preconditioning Regime (56 hrs)</th>
<th>50% kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>14F pre-cond, 1.8F per hr rate</td>
<td>-14 F</td>
</tr>
<tr>
<td>14F pre-cond, 7.2F per hr rate</td>
<td>-7 F</td>
</tr>
<tr>
<td>30F pre-cond, 1.8F per hr rate</td>
<td>-7 F</td>
</tr>
<tr>
<td>30F pre-cond, 7.2F per hr rate</td>
<td>1 F</td>
</tr>
<tr>
<td>50F pre-cond, 1.8F per hr rate</td>
<td>-7 F</td>
</tr>
<tr>
<td>50F pre-cond, 7.2F per hr rate</td>
<td>-1 F</td>
</tr>
</tbody>
</table>

• The gain of \(~3.5\,^\circ F\) per day is consistent with previous work
• Increased exposure to non-lethal, sub-zero temps increases freeze resistance \(\rightarrow\) water moves to ice
• Rapid freeze rates markedly affect freeze resistance of buds
Field Validation: Dec 2013 Freeze Events

![Graph showing mortality against temperature for different varieties of berries (Sweetheart, Rainier, Skeena, Bing, Regina) during a freeze event in December 2013. The graph indicates a significant increase in mortality as temperature decreases.]
KILLING TEMPERATURE & AIR TEMPERATURE °C

1968

MAX.

MIN.

( ) - DAYS DEHARDENED
□ - DAYS REHARDENED AT 5°F

DAYS
Increasing our Capacity to Study De-hardening and Re-hardening

January 29, 2014

To: Einhorn, Todd  
MCAREC

From: L.J. Koong, Executive Director  
Agricultural Research Foundation  
Jean McKinney, Chair  
Competitive Grants Program

**Congratulations!** The Agricultural Research Foundation Board of Directors has awarded **$12,350** to fund your research proposal, **“Developing New Cherry Bud Hardiness Charts to Aid Crop Protection Decisions.”** This project has been assigned account number **ARF8281A**. Funds will be available effective February 1, 2014. The project should be completed and funds expended within two years. I will look forward to a brief progress report on January 31, 2015 and a final report by January 31, 2016.

Thank you for submitting a proposal to ARF’s Competitive Grant Program – and again, congratulations on your success.

Jean McKinney ■ Chair, Competitive Grants Program ■ jmckinney@gorge.net ■ 70546 McKinney Rd., Wasco, OR 97065 ■ Ph 541.442.5412 ■ Cell 541.980.7150 ■ Fax 541.442.5552
Cultural Factors That Contribute to Hardiness

- Nitrogen
  - With the exception of over-fertilizing, N has been positively related to cold hardiness
- Pruning
  - Pruning stimulates metabolism
- Site/elevation - regionally, minimal effects during development
- Soil/water
  - Greater hardiness conferred by course-textured soils, compared to loams and heavier soils
  - Differences attributed to WHC
Environmental & Genetic Factors That Contribute to Hardiness

• Weather (preceding events)
  • The single-most important regulator of hardiness prior to green-tip
• Freeze Rate/Snow/Wind
• Cultivar
  • Within a degree (+/-), with the exception of Regina
• Phenology- Development
  • After Stage 2 all bets off (limited-to-no re-hardening)
Thanks for your attention!

Special thanks to our grower collaborators, the Oregon Sweet Cherry Commission, the Washington Tree Fruit Research Commission, and the Columbia Gorge Fruit Growers Commission.