Cold Hardiness of fruit trees in Vermont

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Fruit Trees

• Why?
Cold Hardiness

“The ability or capacity of a plant to survive an unfavorable environmental temperature”

Winter Hardiness

• The ability to remain dormant is important in areas of fluctuating temperatures
• Ability to withstand extreme low temperatures is important in colder climates
Cold Hardiness is a complex phenomenon

Depends on:

- Genetics
- Temperature/Photoperiods
- Physiological status of the plant
  - Maturity
  - Water Content
  - Dormancy Status
  - Nutrition
  - Physiological Age

Plants are generally injured at two major stages:

1. Early/late frosts
   - Simply ‘not ready’
   - Buds and greener tissue usually damaged

2. Mid-winter damage
   - Not properly readied
   - No mechanism to deal with freeze
   - Older tissues, xylem, and phloem
Early/late frost damage depends on acclimation status (physical and biochemical processes).

Acclimation ↔ “Dormancy” ↔ Deacclimation

- Acclimation and deacclimation are generally considered reversible biochemical processes of one another.
- Dormancy is not reversible

MID-WINTER: HOW TO HANDLE FREEZING STRESS?

- It’s all about the water.
- Death is hypothesized to occur in many ways:
  - Ice crystal puncture sensitive tissues
  - Dehydration/mechanical stress
Deep Supercooling

- Occurs in many fruit crops: peach, apple, and grapes (and other woody plants: oaks)
  - Depends on small cells and little to no intercellular space
  - Low water content
  - Barriers for nucleators/absence of nucleators/presence of anti-nucleators
  - Water leaves, freezes between cells
Freeze Damage

- Damage includes blind wood, root damage, bark cracking, crotch damage, blackheart injury
- Flower bud damage----difficult to tell
- In Burlington, VT, early and late frosts most frequently damage trees

Winter Hardiness: Dehardening

- Loss of hardiness can be very rapid if tissues are exposed to warm temperatures
  - Cherry flower buds lost 10°F of hardiness when exposed to 4hr at 75°F
  - ‘Haralson’ apple lost as much as 57°F of hardiness during one day exposure to 70°F
Vermont winters are cold…

Vermont’s winter climate has been harsh on apple tree survival. The winter of 1933-34 illustrated this point. During this winter, freezing temperatures occurred frequently in November. Extreme temperatures (-30° C) were observed as early as December 29 and 30 (Cummings, 1935).
Cold Hardiness is a complex phenomenon

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  - Water Content
  - Dormancy Status
  - Nutrition
  - Physiological Age

Winter Hardiness

- Susceptibility of species to cold injury varies according to:
  - Species
  - Cultivars
  - Tissues
Origin of Fruit Trees

- Temperate zone, deciduous trees
- Origin in areas with cold winters
- Mechanisms for winter dormancy and spring budbreak and flowering
- Generally adapted for animal dispersal
- Colorful fruit
- Often seeds are poisonous

History and Origin

- Family: Rosaceae
  - Subfamily: Pomoideae (pomes)
  - Subfamily: Prunoideae (drupes)
Origin: Pomes

- Subfamily: Pomoideae
- Pome fruits
  - *Malus* (apple)
  - *Pyrus* (pear)
  - *Cydonia* (quince)

Origin: Drupes

- Subfamily Prunoideae
- Drupes or stone fruits
  - *Prunus* (peach, nectarine, cherry, apricot, plum, and almond)
Origin: Malus

- **Malus**
  - Native to the Caucasian Mountains (Russia)
  - ~28 species, mostly European, some American (some crabapples)
  - Obligate cross-pollination
  - *Malus x domestica* - the domestic apple

Geography
Origin (Pyrus)

- Subfamily: Pomoideae
  - *Pyrus* (pear)
  - Native to most Europe, the Near East and temperate Asia
    One ornamental evergreen species in Japan
  - ~ 20 species

Origin (Pear)

- *Pyrus* (pear)
  - Obligate cross-pollination
  - *Pyrus communis* - common or European pear
  - *Pyrus pyrifolia* - Chinese or sand pear
Origin (Pear)

- *Pyrus pyrifolia*: Chinese or Sand pear
- Brought to California by Chinese immigrants

Origin (Drupes)

- Subfamily *Prunoideae*
- Drupes or stone fruit
- *Prunus*
- ~ 150 species
- Most abundant in temperate zone, but a few species are found in tropical mountains
Origin

- *Prunus*
- Subgenus: *Amygdalus*
  - *Prunus persica* (peach and nectarine)
    - Mostly self-fertile
    - Native to warm areas of China

Geography (Peach)
Origin (Almond)

- *Prunus amygdalus* - Almond
  - Obligate cross-pollination
  - Native to deserts of Western Asia
  - Not adapted for bird dispersal
  - Recessive gene for producing cyanide

Origin

**Prunophora**

- Subgenus: *Prunophora*
- Plums
- Six species are grown
- *Prunus domestica* - European plum
- *Prunus saliciana* – Asian or Japanese plum
- *Prunus americana* - North American plum
Origin (Plum)

- *Prunus domestica* - European plum
- Center of origin: Europe
  - Prunes
- *Prunus salicina* – Asian or Japanese plum
  - Least winter hardy

Origin (Plum)

- *Prunus americana* - North American plum
- *Prunus munsonisana*
- Both of these species can be as hardy as apples
  - Genes used to introduce winter hardiness into plums
Origin (Apricot)

- *Prunus armeniaca*- Apricot
- Center of origin
- Manchuria, Siberia, and Korea
- Very winter hardy, low chilling requirements
Origin (Cherry)

• Subgenus: *Cerasus*
• *Prunus avium*- sweet cherry
• *Prunus cerasus*- sour cherry

Origin (Cherry)

• *Prunus avium*- sweet cherry
• Northwestern Europe to Russia
• Obligate cross pollinator
Origin (Cherry)

- *Prunus cerasus*-sour cherry
- Origin- South Eastern Europe
- Some cultivars may be as hardy as apples

Production Statistics (Vermont)

In Vermont

Freeze damage depends on:

- Species
- Cultural practices (crop loads, N)
- Winter temperatures
- Light exposure
- Cultivar-rootstock (genetics)
- Physiological status

Fruit Tree Cold Hardiness

- Fruit trees are similar to many woody species
- Undergo acclimation/deacclimation
- Deep supercool in xylem
- Require dormant period (chilling requirement)
- Extraorgan freezing in buds (-196°C)
Chilling hour requirements

Approximately chilling hours (<7 C) to break winter rest for fruit tree species

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricot</td>
<td>300-600</td>
</tr>
<tr>
<td>Peach</td>
<td>400-700</td>
</tr>
<tr>
<td>Pear</td>
<td>500-1400</td>
</tr>
<tr>
<td>Apple</td>
<td>800-1700</td>
</tr>
</tbody>
</table>

Winter Hardiness

- Susceptibility of tissues to winter injury in apple:
- The order of acclimation and, consequently, the order of hardiness in fruit trees’ organs is as follows: buds, young tissues, phloem and then the xylem
- However, during periods of acclimation and deacclimation, buds/ shoots become more vulnerable and at risk for damage. The older xylem and pith tissues are rarely damaged during this period
## Winter Injury

- Bud damage (vegetative and reproductive)
- ‘Black heart’
- Sunscald
- Root injury
- Bark split

<table>
<thead>
<tr>
<th>Species</th>
<th>Critical temperatures in degree F at which 90% of the flower buds are killed at various stages of development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bud developmental stages</td>
</tr>
<tr>
<td></td>
<td>* Indicates full bloom</td>
</tr>
<tr>
<td>Species</td>
<td>1</td>
</tr>
<tr>
<td>Apple (Red Del)</td>
<td>2</td>
</tr>
<tr>
<td>Apple (McIntosh)</td>
<td>2</td>
</tr>
<tr>
<td>Pear</td>
<td>-0.4</td>
</tr>
<tr>
<td>Apricot</td>
<td>-0.4</td>
</tr>
<tr>
<td>Cherry</td>
<td>5</td>
</tr>
<tr>
<td>Peaches</td>
<td>1.4</td>
</tr>
</tbody>
</table>
BLACKHEART INJURY

Childers, 1995

BARK CRACKING AND SPLITTING (SW exposure)

Childers, 1995
Vermont winters

- Vermont’s winter climate has been harsh on apple tree survival. The winter of 1933-34 illustrated this point. During this winter, freezing temperatures occurred frequently in November. Extreme temperatures (-30°C) were observed as early as December 29 and 30 (Cummings, 1935).

McIntosh
McIntosh

- Ontario farm (1811)
- Brought to Newport VT in 1868

Cultivars and Rootstocks (Tree fruits)

- Most commercially sold fruit trees consist of two parts
  - Scion
  - Rootstock
  - Graft union
Cultivar and Rootstock

• What to look for in a cultivar
  • Type of fruit
  • Disease resistance
  • Type of tree
  • Cold hardiness
  • Pollination

Cultivars and rootstocks

• What to look for in a rootstock
  • Hardiness
  • Soil type adaptability
  • Pest resistance
  • Overall tree size
    • standard
    • semidwarf
    • dwarf
Study I. Responses of both cultivars, ‘Liberty’ and ‘RedMax McIntosh’, on seven dates of collection. Temperatures and method of evaluation (callus or TTC) did not affect these results. Date 1= 3 November 1999; Date 2= 2 December 1999; date 3= 30 December 1999; date 4= 11 February 2000; date 5= 5 March 2000; date 6= 12 March 2000; date 7 = 26 April 2000

Winter Hardiness Study: Results

Results of this study indicated significant cultivar differences: ‘Honeycrisp’ and ‘Pristine’ were hardier than the other cultivars.

Fig 3.1. Mean score for the five apple cultivars at the six temperatures tested on the first date of collection, 10 March 2000. There is a significant difference between the cultivars (P<0.0001; PROC GLM). Data from both evaluation methods, callus and TTC, are pooled. 0= no callus regrowth and no reduction; 10=full regrowth and full reduction.
Winter Hardiness Study: Results

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>n</th>
<th>Mean Score&lt;sup&gt;z,y,x&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>’Honeycrisp’</td>
<td>40</td>
<td>5.4</td>
</tr>
<tr>
<td>‘Pristine’</td>
<td>50</td>
<td>4.1</td>
</tr>
<tr>
<td>‘Ginger Gold’</td>
<td>50</td>
<td>4.1</td>
</tr>
<tr>
<td>‘Golden Delicious/Mk’</td>
<td>50</td>
<td>2.3</td>
</tr>
<tr>
<td>‘Golden Delicious/M9’</td>
<td>48</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<sup>z</sup> Means not sharing the same letter are significantly different (P=0.0003) according to the SNK test
<sup>y</sup> Both methods of evaluation, callus regrowth and TTC, and all temperatures (0, -5, -10, -15, -20 ºC) are pooled.
<sup>x</sup> 0= no callus regrowth and reduction; 10= full regrowth and reduction.


Winter Hardiness Study: Phenology

Rating Value (based on Cornell Development Chart: 0-6)
- Honeycrisp
- Pristine
- Golden Delicious/M9
- Golden Delicious/Mk
- Ginger Gold

Days after collection
Cultural Practices: Planting Site

• Slope
  • A 4 to 8% slope is ideal.
  • A steeper than 10% slope may make it difficult to operate machinery.
  • Avoid areas at the bottom of the hill where cold air settles and frost pockets form.

Insulating Value of Snow

<table>
<thead>
<tr>
<th>TABLE 2-4 INSULATING VALUE OF 9 in. (23 cm) OF SNOW*</th>
<th>TEMPERATURE [°F (°C)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>−14 (−26)</td>
</tr>
<tr>
<td>Snow surface</td>
<td>−1 (−18)</td>
</tr>
<tr>
<td>3-in. (7.6-cm) depth</td>
<td>16 (−9)</td>
</tr>
<tr>
<td>6-in. (15-cm) depth</td>
<td>22 (−6)</td>
</tr>
<tr>
<td>9-in. (23-cm) depth (soil surface)</td>
<td>28 (−2)</td>
</tr>
</tbody>
</table>

Source: Rutgers Cooperative Extension.
*Measurements were conducted in January in New Jersey.
Floor Management Practices

Cultural Practices

Any practice that extends growth into the fall decreases hardiness

- **Nutrition**
  - Avoid late nitrogen fertilization

- **Pruning**
  - Pruning prior to low-temperature injury tends to increase injury

- **Have ‘healthy’ trees**
  - Photosynthesis
  - Reduce pest damage
  - Paint tree trunk

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**TABLE 2.7** COMPARISON OF MINIMUM TEMPERATURES OF SOIL SURFACES UNDER VARIOUS TYPES OF FLOOR MANAGEMENT PRACTICES.*

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare, firm moist ground</td>
<td>Warmer</td>
</tr>
<tr>
<td>Shredded cover crop, moist ground</td>
<td>4°F colder</td>
</tr>
<tr>
<td>Low cover crop, moist ground</td>
<td>1-3°F colder</td>
</tr>
<tr>
<td>Dry, firm ground</td>
<td>2°F colder</td>
</tr>
<tr>
<td>Freshly disked ground</td>
<td>4°F colder</td>
</tr>
<tr>
<td>Higher cover crop</td>
<td>6-8°F colder</td>
</tr>
<tr>
<td>In some instances where high cover crop restricts air drainage</td>
<td></td>
</tr>
</tbody>
</table>

*Listed in order of increasing hazard.