Irradiation Quarantine Treatments for Deciduous Tree Fruits

A REVIEW OF RESEARCH IN THE PACIFIC NORTHWEST

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The Players

- Art Burdett: Research Entomologist
- Hal Moffitt: Research Entomologist
- Harold Toba: Research Entomologist
- Stephen Drake: Research Postharvest Physiologist
- Lisa Neven: Research Entomologist
The Commodities

- Apples
- Sweet Cherries
- Pears
- Peaches
- Nectarines
The Pests

- Codling moth

- Western Cherry fruit fly

• Burditt, A.K. Food irradiation as a quarantine treatment of fruits. Food technology, 1982, 36 (11), 51-54, 58-60, 62


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• Drake, S.R.; Moffitt, H.R.; Eakin, D.E. Low dose irradiation of 'Rainer' sweet cherries as a quarantine treatment. Journal of food processing and preservation; 1994; 18 (6); 473-481


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Toba

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- Burditt, J.A.; Toba, H.H. Gamma irradiation of codling moth (Lepidoptera: Tortricidae) eggs as a quarantine treatment. Journal of economic entomology; 1992; 85 (2); 464
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Drake, S.R.; Neven, L.G. Quality response of 'Bing' and 'Rainier' sweet cherries to low dose electron beam irradiation. Journal of food processing and preservation; 1997; 21 (4); 345-351

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Neven, L.G.; Drake, S.R. Comparison of alternative postharvest quarantine treatments for sweet cherries. Postharvest biology and technology; 2000; 20 (2); 107-114

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Neven

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- Neven, L.G.; Morford, M. Effects of Irradiation on Phenoloxidase Levels in Codling Moth (Lepidoptera: Tortricidae) Larvae. Journal of economic entomology; 1998; 91 (2); 534-538
- Neven, L.G. Postharvest management of insects in horticultural products by conventional and organic means, primarily for quarantine purposes. Stewart postharvest review; 2010; 6 (1); 1-11
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- Neven, L.G.; Drake, S.R. Comparison of alternative postharvest quarantine treatments for sweet cherries. Postharvest biology and technology; 2000; 20 (2); 107-114
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Results: Insect Control

- **Codling Moth**: Burditt 1989.
- Eggs most sensitive. 100 Gy prevent hatch.
  - **Source**: Cobalt$_{60}$
    - No pupation at 200 Gy.
    - Diapausing CM required 230 Gy.
    - Dose rate affected efficacy.
    - Dose of 187 Gy prevented adult emergence.
      - Treated 79,540 immature larvae
        - 15,501 formed cocoons
        - 256 pupated
        - Zero adult emergence.
Results: Insect Control (continued)

- **Western Cherry Fruit fly:** Burdett & Hungate 1988.
  - >124,000 naturally infested cherries @ 97 Gy
    - Zero normal adults out of est. 84,369 treated.
    - **Source:** Cobalt$\text{\textsubscript{60}}$

- **WCFF:** (Neven, unpublished)
  - Determined 3$\text{rd}$ instar most tolerant.
  - Dose response resulted in 1 pupae, no adults, at 200 Gy.
    - **Source:** Cobalt$\text{\textsubscript{60}}$
Status of Doses for Insect Control

- Codling Moth – 200 Gy (ISPM 28 PT 6)
- Western Cherry Fruit Fly – 150 Gy (ISPM 28 PT 7)
- Apple Maggot – 150 Gy (ISPM 28 PT 7)
- Oriental Fruit Moth – 232 Gy (ISPM 28 PT 10)
- Spotted Winged Drosophila – 80 Gy (Follett 2014, in press)
Results: Bio-Markers for Irradiation

- Phenoloxidase
  - Nation et al. 1995, PO was indicator for irradiated Caribbean fruit fly.
  - Neven & Morford, 1998:
    - 5th instar CM did not show consistent delay of melanization, decrease in PO protein concentration, or enzyme activity.

- DNA Repair Enzymes: *(Neven, unpublished)*
  - Study on the dose and time after treatment indicated changes in the DNA repair enzymes pattern of expression.
  - Further confirmation of results on other species pending.
Phenylooxidase in Irradiated Codling Moth

Fig. 1. Melanization of 5th-instar codling moth at 0, 1, 4, and 8 h following removal from −80°C (melanization method).

Fig. 3. Effects of irradiation on phenoloxidase activity in the hemolymph of 5th instar codling moth. Values are mean (n = 40) units of phenoloxidase/mg protein ± SE. ■, day 0; ●, day 2; ▲, day 4; ▼, day 6. Results were similar for all instars tested.
Results: Apple Quality

- Fuji & Granny Smith. *Drake et al. 2003.*
  - Carbohydrate levels were not significantly changed at doses up to 900 Gy.

- Fuji, Gala, Granny Smith. *Drake et al 1999.*
  - Firmness decreased as dose increased from 150 to 600 Gy.
  - Firmness did not drop below WA standards (54 N) at 900 Gy.
  - No significant loss TA with Granny Smith or Fuji.
  - Gala did lose TA at doses ≥ 600 Gy.
  - Irradiation had no effect on external color in all 3 cultivars.
Results: Pear Quality

- **d’Anjou & Bosc.** *Drake et al. 1999.*
  - Bosc lost firmness in a dose dependent manner.
  - Scald increased in d’Anjou in a dose dependent manner.
  - Both cultivars ripened normally after irradiation.
  - Some reduction in decay was noted.

- **d’Anjou & Bosc.** *Drake et al. 2003.*
  - *Doses up to 900 Gy not affect carbohydrate levels.*
Results: Sweet Cherry Quality

- **Bing.** Drake & Neven 1995. MBAO.
  - No quality change up to 300 Gy.
  - At ≥ 600 Gy was 14% loss firmness
  - At ≥ 600 Gy increased Hunter L values
  - No other changes in hue or visual fruit color
  - No change in stem color.

- **Rainier.** Drake & Neven 1995. MBAO.
  - Loss in firmness ≥ 300 Gy.
  - At ≥ 600 Gy increase hue values.
  - Stem color improved with increasing dose
  - Loss in TA ≥ 900 Gy

- Overall, little loss of market quality at doses used for disinfestation.
Results: Sweet Cherry Quality

- **Bing.** *Drake & Neven 1997.*
  - No changes in defects related to dose.
  - No change in SS, TA or flavor
  - More red color with increasing dose
  - No change in stem color related to dose
  - Slight decrease in firmness at doses ≥ 600 Gy

- **Rainier.** *Drake & Neven 1997.*
  - Increase in defects at doses ≥ 600 Gy
  - No change in SS, TA or flavor
  - Reduction in red color at doses ≥ 600 Gy
  - Stem color improved at doses ≥ 600 Gy
  - Slight decrease in firmness at doses ≥ 600 Gy
TABLE 1.
QUALITY ATTRIBUTES OF 'BING' AND 'RAINIER' CHERRIES AFTER QUARANTINE TREATMENT WITH METHYL BROMIDE OR IRRADIATION

<table>
<thead>
<tr>
<th>Quarantine Treatment</th>
<th>Firmness (N)</th>
<th>Soluble solids (%)</th>
<th>Titratable acidity (% malic)</th>
<th>SS/TA ratio</th>
<th>Condition(^{6})</th>
<th>Fruit</th>
<th>Stem</th>
<th>Bruising(^{7})</th>
<th>Pitting(^{7})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8.2a*</td>
<td>22.8</td>
<td>0.85b</td>
<td>27.0a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.2a</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>MeBr</td>
<td>7.9ab</td>
<td>22.7</td>
<td>0.91a</td>
<td>25.0a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>300 gy</td>
<td>7.2c</td>
<td>22.2</td>
<td>0.85b</td>
<td>26.1a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.2a</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>600 gy</td>
<td>7.5bc</td>
<td>22.5</td>
<td>0.85b</td>
<td>26.4a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.3a</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>'Rainier'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>6.2ab</td>
<td>23.4</td>
<td>0.63ab</td>
<td>37.1b</td>
<td>1.2b</td>
<td>1.1c</td>
<td>1.3b</td>
<td>1.1b</td>
<td></td>
</tr>
<tr>
<td>MeBr</td>
<td>6.3a</td>
<td>23.8</td>
<td>0.67a</td>
<td>35.5c</td>
<td>1.3ab</td>
<td>1.3bc</td>
<td>1.3b</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>300 gy</td>
<td>6.0b</td>
<td>23.0</td>
<td>0.61b</td>
<td>37.7b</td>
<td>1.4a</td>
<td>1.5a</td>
<td>1.5a</td>
<td>1.2a</td>
<td></td>
</tr>
<tr>
<td>600 gy</td>
<td>5.7c</td>
<td>23.3</td>
<td>0.59b</td>
<td>39.5a</td>
<td>1.4a</td>
<td>1.4ab</td>
<td>1.5a</td>
<td>1.1b</td>
<td></td>
</tr>
</tbody>
</table>

\(^{6}\)Condition of fruit and stem graded on a scale of 1 to 3 (1=good, 2=fair, 3=poor).
\(^{7}\)Bruising and pitting graded on a scale of 1 to 3 (1=none, 2=slight, 3=severe).
\(^{*}\)Means in a column, within cultivars, not followed by a common are significantly different (P=0.05).
<table>
<thead>
<tr>
<th>Quarantine Treatment</th>
<th>Fruit</th>
<th>Stem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hunter L</td>
<td>hue</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>'Bing'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>34.9a¹</td>
<td>10.9bc</td>
</tr>
<tr>
<td>MeBr</td>
<td>28.7c</td>
<td>12.9a</td>
</tr>
<tr>
<td>300 gy</td>
<td>32.2b</td>
<td>9.4c</td>
</tr>
<tr>
<td>600 gy</td>
<td>34.0a</td>
<td>11.0b</td>
</tr>
<tr>
<td>'Rainier'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>61.1ab</td>
<td>64.9a</td>
</tr>
<tr>
<td>MeBr</td>
<td>58.6b</td>
<td>56.8b</td>
</tr>
<tr>
<td>300 gy</td>
<td>58.1b</td>
<td>62.0a</td>
</tr>
<tr>
<td>600 gy</td>
<td>62.3a</td>
<td>64.6a</td>
</tr>
</tbody>
</table>

¹Means in a column, within cultivars, not followed by a common letter are significantly different (P=0.05).
Results: Stone Fruit Quality

Drake & Neven 1998.

- ‘Bing’ sweet cherries:
  - Slight loss in firmness @300 Gy, but not at 600 Gy.
  - No change in SS or TA
  - No significant changes in visual fruit or stem scores

- ‘Rainier’ sweet cherries:
  - Slight loss of firmness
  - No change in SS or TA
  - No significant changes in visual fruit or stem scores
Results: Stone Fruit Quality

Drake & Neven 1998.

- ‘Perfection’ apricots:
  - No negative effects on exterior color, SS or TA
  - Decrease in firmness & increase internal breakdown ≥ 600 Gy

- ‘Rival’ apricots:
  - No negative effects on exterior color, SS or TA.
  - Decrease in firmness & increase internal breakdown > 300 Gy

- ‘Regina’ peaches:
  - No negative effects on exterior color, SS or TA.
  - Loss of firmness at 600 & 900 Gy.
  - Exterior finish affected at 900 Gy.
  - Exterior finish OK at 300 & 600 Gy.
# Quality Attributes of 'Perfection' and 'Rival' Apricots as Influenced by the Interaction of Irradiation and Storage Time

<table>
<thead>
<tr>
<th>Storage (days)</th>
<th>Irradiation (gy)</th>
<th>Firmness (N)</th>
<th>Internal Breakdown (%)</th>
<th>Interior Color Hunter L</th>
<th>Hue</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0</td>
<td>'Perf.' 6.2ab, 'Rival' 9.4bc</td>
<td>32bc, 6e</td>
<td>55.5ab, 63.4abc</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td>'Perf.' 6.1b, 'Rival' 11.3ab</td>
<td>15d, 6e</td>
<td>56.1a, 63.4abc</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td>'Perf.' 7.4a, 'Rival' 12.3a</td>
<td>20cd, 12de</td>
<td>55.5ab, 64.3ab</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>'Perf.' 4.5c, 'Rival' 9.4bc</td>
<td>22cd, 22cd</td>
<td>54.4bc, 64.7a</td>
<td></td>
</tr>
<tr>
<td>900</td>
<td></td>
<td>'Perf.' 3.4cd, 'Rival' 7.8cde</td>
<td>48a, 30bc</td>
<td>52.5d, 64.1ab</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>0</td>
<td>'Perf.' 3.7cd, 'Rival' 7.0def</td>
<td>33abc, 22cd</td>
<td>56.5a, 64.3ab</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td>'Perf.' 4.5cd, 'Rival' 7.8cde</td>
<td>28bcd, 15cde</td>
<td>54.4bc, 63.4abc</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td>'Perf.' 4.5cd, 'Rival' 8.1cd</td>
<td>43ab, 28bc</td>
<td>55.5ab, 62.3c</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>'Perf.' 3.5cd, 'Rival' 6.1ef</td>
<td>48a, 42ab</td>
<td>51.9d, 64.1ab</td>
<td></td>
</tr>
<tr>
<td>900</td>
<td></td>
<td>'Perf.' 3.3d, 'Rival' 5.3f</td>
<td>43ab, 53a</td>
<td>53.4cd, 63.1bc</td>
<td></td>
</tr>
</tbody>
</table>

*Means in a column not followed by a common letter are significantly different (P=0.05).*
**TABLE 4.**
QUALITY ATTRIBUTES OF ‘PERFECTION’ AND ‘RIVAL’ APRICOTS AS INFLUENCED BY THE INTERACTION OF IRRADIATION AND RIPENING TIME

<table>
<thead>
<tr>
<th>Ripe (days)</th>
<th>Irradiation (gy)</th>
<th>Firmness (N)</th>
<th>Internal Breakdown (%)</th>
<th>Internal Color Hunter L</th>
<th>Internal Color hue</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>'Perf.' 7.1a</td>
<td>'Rival' 11.8b</td>
<td>'Rival' 5de</td>
<td>'Rival' 56.1ab</td>
</tr>
<tr>
<td>150</td>
<td></td>
<td>'Perf.' 7.1a</td>
<td>'Rival' 14.0a</td>
<td>'Rival' 2e</td>
<td>'Rival' 56.4a</td>
</tr>
<tr>
<td>300</td>
<td></td>
<td>'Perf.' 8.3a</td>
<td>'Rival' 15.0a</td>
<td>'Rival' 2e</td>
<td>'Rival' 56.6a</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>'Perf.' 4.8b</td>
<td>'Rival' 11.6b</td>
<td>'Rival' 8cde</td>
<td>'Rival' 54.8bcd</td>
</tr>
<tr>
<td>900</td>
<td></td>
<td>'Perf.' 4.0bc</td>
<td>'Rival' 8.8c</td>
<td>'Rival' 23bc</td>
<td>'Rival' 54.4cd</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>'Perf.' 2.8cd</td>
<td>'Rival' 4.7d</td>
<td>'Rival' 23bc</td>
<td>'Rival' 55.9abc</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>'Perf.' 3.5cd</td>
<td>'Rival' 5.0d</td>
<td>'Rival' 20cd</td>
<td>'Rival' 54.1d</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>'Perf.' 3.6bcd</td>
<td>'Rival' 5.4d</td>
<td>'Rival' 38b</td>
<td>'Rival' 54.5cd</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>'Perf.' 3.3cd</td>
<td>'Rival' 3.9d</td>
<td>'Rival' 55a</td>
<td>'Rival' 51.5e</td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>'Perf.' 2.6c</td>
<td>'Rival' 4.3d</td>
<td>'Rival' 60a</td>
<td>'Rival' 51.5e</td>
</tr>
</tbody>
</table>

*Means in a column not followed by a common letter are significantly different (P=0.05).*
<table>
<thead>
<tr>
<th>Irradiation (gy)</th>
<th>Firmness (N)</th>
<th>Soluble solids (%)</th>
<th>Titratable acidity (% malic)</th>
<th>Exterior Hunter Color L</th>
<th>hue</th>
<th>Interior Hunter Color L</th>
<th>hue</th>
<th>Fruit Finish$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>23.3a$^*$</td>
<td>13.3a</td>
<td>0.84a</td>
<td>46.3a</td>
<td>43.3a</td>
<td>70.1a</td>
<td>88.7a</td>
<td>1.5c</td>
</tr>
<tr>
<td>150</td>
<td>24.2a</td>
<td>13.1a</td>
<td>0.85a</td>
<td>46.3a</td>
<td>44.4a</td>
<td>69.8a</td>
<td>88.9a</td>
<td>1.5c</td>
</tr>
<tr>
<td>300</td>
<td>21.9a</td>
<td>13.1a</td>
<td>0.80a</td>
<td>47.2a</td>
<td>46.3a</td>
<td>70.1a</td>
<td>88.4a</td>
<td>2.0b</td>
</tr>
<tr>
<td>600</td>
<td>17.4b</td>
<td>13.4a</td>
<td>0.80a</td>
<td>46.8a</td>
<td>46.9a</td>
<td>69.1a</td>
<td>87.7a</td>
<td>2.0b</td>
</tr>
<tr>
<td>900</td>
<td>16.5b</td>
<td>13.4a</td>
<td>0.78a</td>
<td>46.0a</td>
<td>44.1a</td>
<td>69.8a</td>
<td>87.7a</td>
<td>2.3a</td>
</tr>
</tbody>
</table>

$^2$Fruit finish graded on a scale of 1 to 3 (1=good, 3=poor).

$^3$Means in a column not followed by a common letter are significantly different (P=0.05).
Overall Consensus of Irradiation as a Quarantine Treatment

- Industry is not interested in irradiation until it is accepted by key trading partners for which they are currently fumigating fruit.
  - Australia, Japan, Indonesia, South Korea, New Zealand
- Irradiation will not replace cold treatments.
- Dosages already worked out for key pests and fruits.
- Want to talk about delivery of the technology.
What’s Fumigated?

- Sweet cherries to Australia
- Sweet cherries to Indonesia
- Apples to Japan
- Sweet Cherries to Japan
- Nectarines to Japan
- Sweet Cherries to South Korea
- Sweet Cherries to New Zealand
## 2013 Top Export Markets Sweet Cherry

<table>
<thead>
<tr>
<th>Country</th>
<th>Volume (20 lb. Cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>1,573,592</td>
</tr>
<tr>
<td>China</td>
<td>567,333</td>
</tr>
<tr>
<td><strong>Korea</strong></td>
<td><strong>491,890</strong></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>446,984</td>
</tr>
<tr>
<td>Taiwan</td>
<td>367,591</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td><strong>251,453</strong></td>
</tr>
<tr>
<td>Australia</td>
<td>161,133</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>73,422</td>
</tr>
</tbody>
</table>

All other data provided by the Northwest Cherry Growers, 2013 Foreign Market.
## Dollar Value of Sweet Cherry Crop

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>$670,914,353</td>
<td>$211,904,418</td>
</tr>
<tr>
<td>2012</td>
<td>$759,505,935</td>
<td>$283,254,304</td>
</tr>
<tr>
<td>2011</td>
<td>$783,013,504</td>
<td>$257,098,218</td>
</tr>
<tr>
<td>2010</td>
<td>$572,624,738</td>
<td>$178,367,963</td>
</tr>
<tr>
<td>2009</td>
<td>$541,494,490</td>
<td>$159,458,538</td>
</tr>
<tr>
<td>2008</td>
<td>$436,388,970</td>
<td>$127,847,518</td>
</tr>
</tbody>
</table>
## 2012 Fumigated Sweet Cherries

<table>
<thead>
<tr>
<th>Country</th>
<th># 20# boxes</th>
<th>Value (est)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>682,325</td>
<td>$ 13,646,500.00</td>
</tr>
<tr>
<td>Japan</td>
<td>217,386</td>
<td>$ 4,347,720.00</td>
</tr>
<tr>
<td>Australia</td>
<td>465,118</td>
<td>$ 9,302,360.00</td>
</tr>
<tr>
<td>New Zealand</td>
<td>8,326</td>
<td>$ 166,520.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>907,431</strong></td>
<td><strong>$ 27,463,100.00</strong></td>
</tr>
</tbody>
</table>
Bottom Line

- Doses worked out for key pests & commodities.
- Need importing countries to accept irradiation.
- Technology needs to be accessible.
- Technology needs to be affordable.
- Technology has to handle short season & lot loads.