Rainfastness Attributes of Insecticides for Control of SWD in Cherries

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<table>
<thead>
<tr>
<th><strong>20th Century Insecticides</strong></th>
<th><strong>21st Century Insecticides</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated Hydrocarbons (1)</td>
<td>Insect Growth Regulators (5)</td>
</tr>
<tr>
<td>Organophosphates (3)</td>
<td>Spinosyns (2)</td>
</tr>
<tr>
<td>Carbamates (2)</td>
<td>Avermectins (2)</td>
</tr>
<tr>
<td>Synthetic Pyrethroids (6)</td>
<td>Neonicotinoids (5)</td>
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<tr>
<td></td>
<td>Oxadiazines (1)</td>
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<td></td>
<td>Diamides (4)</td>
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<td></td>
<td>Particle Film (1)</td>
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<td></td>
<td>Pyrizoles (1)</td>
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<td></td>
<td>Pyridine Carboxamides (1)</td>
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<td></td>
<td>Tetronic acid derivatives (1)</td>
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</tbody>
</table>
Expansion of Available Biopesticides in 21\textsuperscript{st} Century

**Biopesticides**

- Fermentation by-products
  - *Bts*
  - Spinosyns (Entrust, Delegate)
  - Grandevo & Venerate
- Botanical / Animal extracts
  - Azadirachtin (Neem)
  - Pyrethrins (Pyganic)
  - Sabadilla (Veratran)
  - Spider venom (Spear-T)
- Virus
Fate of insecticides on the plant surface:

1. Evaporation - The change of a liquid into a vapor at a temperature below the boiling point, leaving only the dry solid portion or deposit.
2. Photolysis - Chemical decomposition induced by light or other radiant energy.
3. Wash-off - Loss of surface residues from a wetting event.
4. Penetration – mobility into and throughout plant.
Translocation and systemic mobility:

a. Translaminar - penetration of a foliar applied pesticide from the adaxial cuticular surface of the leaf, through the epidermis layer and distributing into the mesophyll on the abaxial side.

b. Acropetal - horizontal mobility in the plant xylem from central leaf tissue to the marginal ends.

c. Basipetal - movement of the insecticide within the phloem from the site of application in the downward direction.

(image by Marlene Cameron)
Insecticide Penetration in Fruits

a. Penetration of the fruit cuticle follows the same process as described for leaves, but desorption into the epidermal cells of the hypanthium follows a simple diffusion process.
<table>
<thead>
<tr>
<th>Compound Class</th>
<th>Residual (on plant)</th>
<th>Systemic Characteristics (foliar)</th>
<th>Systemic Characteristics (fruit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organophosphates</td>
<td>Long</td>
<td>Surface Cuticle Penetration</td>
<td>Surface Cuticle Penetration</td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>Short</td>
<td>Cuticle Penetration</td>
<td>Cuticle Penetration</td>
</tr>
<tr>
<td>Neonicotinoids</td>
<td>Medium</td>
<td>Translaminar &amp; Acropetal</td>
<td>Systemic</td>
</tr>
<tr>
<td>Tetronic Acid</td>
<td>Long</td>
<td>Translaminar, Acropetal &amp; Basipetal</td>
<td>Systemic</td>
</tr>
<tr>
<td>Derivatives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGRs</td>
<td>Medium - Long</td>
<td>Translaminar</td>
<td>Cuticle Penetration</td>
</tr>
<tr>
<td>Avermectins</td>
<td>Medium - Long</td>
<td>Translaminar</td>
<td>Cuticle Penetration</td>
</tr>
<tr>
<td>Spinosyns</td>
<td>Short - Medium</td>
<td>Translaminar</td>
<td>Cuticle Penetration</td>
</tr>
<tr>
<td>Diamides</td>
<td>Medium - Long</td>
<td>Translaminar</td>
<td>Cuticle Penetration</td>
</tr>
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</table>
Bioavailability of residues on plant surfaces:

a. dislodgeable residues represent residues that have not penetrated the plant cuticle sufficiently to resist physical removal from the plant surface.

b. Bioavailability will vary according to a compound’s affinity to the plant cuticle, characteristics of leaf or fruit surface, temperature and humidity, plant penetration.

c. Behavior of insect; feeding vs grooming vs motile actions.

![Image](image_url)

Figure 7. Scanning electron micrograph of (a) leg of F. candida and (b) adaxial surface of barley leaf showing prominent wax structures.

Identifying Modes of Insecticidal Activity

- a) Oviposition deterrence
- b) Antifeedant
- c) Repellency
- d) Curative
- e) Sub-lethal

For many of the RR insecticides “Lethal and non-lethal modes of insecticidal activity work in concert to achieve the overall crop protection seen in the field.”

Lethal activity results in direct mortality of the pest

**Ovicides:**
Residue under eggs

**Larvacides:**
Residue over eggs (ovi-larvicidal)

**Adulticides:**
Contact w/ adults

Leaf or Fruit

Spray Deposition
Factors that Influence Pesticide Wash-off

- Rainfall Characteristics
- Penetrative & Translocative Properties of the Compound
- Drying time, Persistence, and Additives
Plant-Insect-Chemical TRIAD

Spotted wing drosophila (*Drosophila suzukii*)

- Invasive species from East Asia
- Has spread to North and South America, and Europe
- Wide host range, includes raspberries, strawberries, blueberries, and cherries
- Oviposit in ripening
Study Questions

• What are the effects of various rainfall amounts to insecticide control against SWD adults and infestation levels?
• What are the effects of various rainfall amounts to surface and sub-surface residue from tart cherry leaves and fruit?
Bioassay

Source: www.goodfruit.com
Bioassay

- 0, 12.7, 25.4 mm
- 5 leaves, 5 fruit, 12 flies (6 females & 6 males)
- Adult mortality was recorded
- Flies were removed
- Two-way ANOVA Tukey’s test at α=0.05

Brown sugar method. Counted for small larvae, large larvae, and pupae

Day 1: 5 leaves, 5 fruit, 12 flies
Day 3: Adult mortality was recorded
Day 5: Flies were removed
Day 9: Two-way ANOVA Tukey’s test at α=0.05

Analyzed REPEATED measure ANOVA Tukey’s test at α=0.05
Residue Analysis

10 fruit and 20 leaves

Acetonitrile

Sonicated
DCM + 4 g MgSO₄ + 1 g NaCl

Filtered through 12 gr Na₂SO₄

GCMS and HPLC

One-way ANOVA
Dunett’s test α=0.05
* Indicates significant differences compared to the 0 mm rainfall.
Zeta-cypermethrin

2018

Leaf

Fruit

Rainfall (mm)

* Indicates significant differences compared to the 0 mm rainfall
* Indicates significant differences compared to the 0 mm rainfall
* Indicates significant differences compared to the 0 mm rainfall
Cyantraniliprole

2018

Rainfall (mm)

Leaf

Fruit

ppm of AI

Leaf Surface  Leaf Subsurface  Fruit Surface  Fruit Subsurface

* Indicates significant differences compared to the 0 mm rainfall
Different lowercase letters indicate significant differences between mortality at 1 day. Different capital letters indicate significant differences between mortality at 3 day.
Different lowercase letters indicate significant differences between mortality at 1 day. Different capital letters indicate significant differences between mortality at 3 day.
2018
Cyantraniliprole

Adult mortality percentage (%)

Chromobacterium substugae

Rainfall (mm)

0 12.7 25.4

0 20 40 60 80 100

0 20 40 60 80

0 12.7 25.4

1 day 3 day
**Insecticide**: \(F_{6, 156} = 27.11; P < .001\)

**Rainfall**: \(F_{2, 118} = 29.23; P < .001\)

**Ins x Rain**: \(F_{12, 150} = 1.66; P = 0.0809\)
Conclusions

• Phosmet’s adulticide action, infestation levels, and residues were sensitive to wash-off
• Spinetoram’s adulticide action, infestation levels, and residues were sensitive to wash-off
• Zeta-cypermethrin’s adulticide action and infestation was sensitive to wash-off by simulated rain. However, its residues were more resistant against wash-off
• *C. substugae* adulticide action and infestation level were affected by simulated rainfall.
• Adulticide action, infestation level, and residues of acetamiprid were not sensitive to rainfall
• Cyantraniliprole adulticide action was affected by rainfall; however, its effect to immature stages and residues more resistant to wash-off
# Rainfastness Rating Chart

General Characteristics for Insecticide Chemical Classes

<table>
<thead>
<tr>
<th>Insecticide Class</th>
<th>Rainfastness ≤ 0.5 inch</th>
<th>Rainfastness ≤ 1.0 inch</th>
<th>Rainfastness ≤ 2.0 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit</td>
<td>Leaves</td>
<td>Fruit</td>
</tr>
<tr>
<td>Organophosphates</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>M</td>
<td>M/H</td>
<td>L</td>
</tr>
<tr>
<td>Carbamates</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>IGRs</td>
<td>M</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Neonicotinoids</td>
<td>M,S</td>
<td>H,S</td>
<td>L,S</td>
</tr>
<tr>
<td>Spinosyns</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Diamides</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Avermectins</td>
<td>M,S</td>
<td>H,S</td>
<td>L,S</td>
</tr>
</tbody>
</table>

- H – highly rainfast (≤30% loss), M – moderate (≤50% loss), L – low (≤70% loss), S-systemic residues
- [Michigan Fruit Management Guide E154](http://bookstore.msue.msu.edu/)
**Rainfastness Rating Chart (E154)**

**Cherry Insecticide Precipitation Wash-off Re-application Decision Chart**: Expected spotted wing Drosophila control in tart cherries, based on each compound’s inherent toxicity to SWD, maximum residual, and wash-off potential from rainfall.

<table>
<thead>
<tr>
<th>Insecticides</th>
<th>Rainfall = 0.5 inch</th>
<th>Rainfall = 1.0 inch</th>
<th>Rainfall = 2.0 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*1 day</td>
<td>*3 days</td>
<td>*1 day</td>
</tr>
<tr>
<td>Imidan</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mustang Max</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Exirel</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Grandevo</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Delegate</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Assail</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

* Number of days after precipitation event and presence of SWD adults (assuming rainfall no more than 24 hr after insecticide spray).

X – Insufficient insecticide residue remains to provide significant activity on the target pest, and thus an immediate re-application is recommended.

- An un-marked cell suggests that there is sufficient insecticide residue remaining to provide significant activity on the target pest, although residual activity may be reduced.
20th Century IPM: Industrial Age

“Time for another poison”

21st Century IPM: Information Age

“What optimal selection of IPM tools and delivery systems will optimize performance and best exploit the pest’s weaknesses, while reducing total inputs, minimize impacts on beneficials, and protecting human and environmental resources?”
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- FMC Corp
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