Spotted wing drosophila resistance management in CA

Brian Gress & Frank Zalom
UC Davis
Drosophila suzukii

California History

• First found in a strawberry field August, 2008 in Watsonville

• High densities developed in strawberry and raspberry fields in Fall 2008

• Massive infestation of cherries in Spring 2009, with infestation of strawberries & caneberries in coastal areas

• Eventually identified as Drosophila suzukii
Reported as a pest of cherries in Japan as early as 1916 (Kanzawa, 1936)
Drosophila suzukii

Occurrence in the United States

Current US distribution

Also a problem in Europe
Drosophila suzukii

Challenges for Management

• Preference for ripening/marketable fruit
• Fast life cycle → Overlapping generations
• High fecundity
• Highly mobile adults
• Wide range of crop and non-crop hosts

Figure 3. The lifecycle of SWD.
Drosophila suzukii

Challenges for Management

• Preference for ripening/marketable fruit
• Fast life cycle → Overlapping generations
• High fecundity
• Highly mobile adults
• Wide range of crop and non-crop hosts

>130 known hosts
31 plant families
Management – sanitation

• Reduce breeding sites
• Remove and dispose of mature and overripe fruit
• Eliminate alternate habitat (culled fruit and abandoned fields) that sustains the infestation
Management – chemical

Most effective insecticides: pyrethroids, organophosphates, spinosyns

Spinosad (Entrust) critical for organic production, but may be at high risk for resistance
Drosophila suzukii

Watsonville
Drosophila suzukii

• Watsonville, CA
  • Major hub of US berry production
Drosophila suzukii

• Watsonville, CA
  • Major hub of US berry production
  • Approx 1,100 kilos of spinosyns applied to 12k ha of berry crops in 2016 (CDFA)
  • Concerns that spinosad may be losing efficacy
• Participated in national resistance monitoring survey in 2017
Spinosad resistance monitoring

• Part of USDA SCRI grant with groups from 8 states

• Bioassay protocol standardized:
  • Coat vial in insecticide solution and empty excess
  • Next morning, expose 5 male and 5 female SWD (age: 3-8 d, F1 & F2) for 6 hrs
  • Perform mortality assessment

• LC$_{50}$ (13 ppm) and LC$_{99x2}$ (929 ppm) concentrations used

• Survival at LC$_{99x2}$ raises immediate red flag
Spinosad resistance monitoring

Site selection

**Watsonville, CA:**
- 5 sites (4 organic, 1 conventional)

**USDA Wolfskill Experimental Orchard (Winters, CA):**
- 1 site (untreated)
- Mixed-fruit production
Results – spinosad resistance monitoring

<table>
<thead>
<tr>
<th>Proportion living at 6 hours</th>
<th>12.5 PPM (LC50)</th>
<th>929 PPM (LC99x2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAT-1</td>
<td>0.9</td>
<td>0.125</td>
</tr>
<tr>
<td>WAT-2</td>
<td>0.875</td>
<td>0.01667</td>
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<tr>
<td>WAT-3</td>
<td>0.725</td>
<td>0.05</td>
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<tr>
<td>WAT-4</td>
<td>0.85</td>
<td>0.14</td>
</tr>
<tr>
<td>WAT-5</td>
<td>0.867</td>
<td>0.167</td>
</tr>
<tr>
<td>WOLF</td>
<td>0.575</td>
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</table>

n = 40 – 130 flies / site / concentration
Risk assessment and dose-response analysis

1. Performed resistance risk assessment by exposing Watsonville SWD to spinosad residues for 5 generations
   • Started by screening approx. 700 Watsonville SWD (~80 survivors)
   • Each generation produced by “survivors”

2. Performed dose-response analysis to calculate spinosad LC$_{50}$ for all 3 strains (Wolfskill, Watsonville & Post-selection Watsonville)
   • 3-1100 ppm
   • 6 & 8 hr mortality assessments
Results – 6 hours

<table>
<thead>
<tr>
<th>Lethal concentrations (6 hr)</th>
<th>LC50 (PPM)</th>
<th>RR (Wolf)</th>
<th>RR (Mich)</th>
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<tbody>
<tr>
<td>Wolfskill</td>
<td>46.1</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
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<td>354.6</td>
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### Results – 6 hours

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### Results – 8 hours

#### Lethal concentrations (8 hr)

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<tr>
<td>Wolfskill</td>
<td>29.4</td>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>Watsonville</td>
<td>152.6</td>
<td>5.2</td>
<td>11.6</td>
</tr>
<tr>
<td>Post-selection</td>
<td>227.6</td>
<td>7.7</td>
<td>17.4</td>
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# Results – 8 hours

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Results – 8 hours

Spinosad resistance is emerging in Watsonville SWD population

The continued use of spinosad has potential to increase resistance

…but, relatively low response to selection

What does this mean?

• Risk assessment results provide reason to be optimistic that spinosad will maintain efficacy in near-term
• But poses major threat to organic industry
  • No current alternatives
• Additional work needed to develop resistance management and detection tools
SWD spinosad resistance – ongoing work

**Population dynamics of resistance**

1. Spatial distribution – how widespread is resistance in Watsonville?

2. Does resistance change throughout the year?
   - Increase during growing season?
   - Decline during off-season?
     - Mixing between resistant flies under hoops and susceptible flies in surrounding vegetation?
     - Fitness / survival costs of resistance?
SWD spinosad resistance – ongoing work

**Population dynamics of resistance**

**Methods**

- Sampled SWD from 4 sites in Santa Cruz county: early, mid- and late-season timepoints
- Performed dose-response bioassays on F1 and F2 flies for each site + susceptible Wolfskill SWD
# 2018 Results

<table>
<thead>
<tr>
<th>Strain</th>
<th>LC50 (ppm)</th>
<th>RR (Wolf)</th>
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</thead>
<tbody>
<tr>
<td>WOLF</td>
<td>31.3</td>
<td>1</td>
</tr>
<tr>
<td>WAT-1</td>
<td>177.1</td>
<td>5.7</td>
</tr>
<tr>
<td>WAT-2</td>
<td>174.6</td>
<td>5.6</td>
</tr>
<tr>
<td>WAT-3</td>
<td>292.2</td>
<td>9.3</td>
</tr>
<tr>
<td>WAT-4</td>
<td>143.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Resistance appears relatively stable in population.

Potential for strategic spray program that targets susceptible time of year may be limited.
SWD spinosad resistance

Where do we go from here?

What IPM tools are available for managing resistance?

• Chemical control
• Cultural & behavioral control
• Biological control
SWD spinosad resistance

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• Chemical control
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• Biological control
Chemical control

Increase efficacy of spinosad
• Feeding stimulants (sugar? Erythritol?)
• Rotational partners with synergistic effects?
  • Sanitizers (Jet-Ag / peroxyacetic acid)
Chemical control

Entrust

Increase spinosad efficacy?

Make fruit less attractive?

Clear out gut microbiome if consumed?
SWD spinosad resistance

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Cultural control – pruning

Can pruning be used to manipulate microclimate?

Diepenbrock and Burrack 2016, Journal of Applied Entomology
Rice et al. 2017, Journal of Insect Behavior
Cultural control – pruning

- **Raspberries**
- **Blackberries**
- **Blueberries**

High | Medium | Low
Cultural control – pruning

- Pruning significantly impacted canopy density early season
- No impact on canopy temperature
- No impact on yield
Cultural control – pruning

Higher larval infestation in "no pruning" plots
### Cultural control – pruning

Results inconsistent across growing regions and crops

<table>
<thead>
<tr>
<th>Year</th>
<th>MD</th>
<th>MI</th>
<th>CA</th>
<th>NC</th>
<th>GA</th>
<th>OR</th>
<th>MD</th>
<th>MN</th>
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<td>2017</td>
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<td>*</td>
<td>NE</td>
<td>*</td>
<td>*</td>
<td>TBD</td>
<td>N/A</td>
</tr>
</tbody>
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Pruning impacts on SWD infestation/survival?

**Added benefit of increased spray coverage?**

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<tr>
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<td>NE</td>
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<td>NE</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>TBD</td>
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TBD = To Be Determined, N/A = Not applicable, NE = No Effect, * = Significant Effect

LP = Low Pest Pressure
Behavioral control

Food grade gum

• Highly attractive to SWD
• Distract females from fruit and instead lay eggs in gum
• Field trials resulted in 50-76% reduction in fruit infestation

Physical control

Exclusion netting

• Physically excluding SWD from crop is very effective in preventing infestation
• Costly, but may make sense for some situations / high value crops
• Can modify high tunnels or bird netting structures
• Netting must be installed before SWD arrive
• Reduced Pollinator access?
SWD spinosad resistance

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SWD spinosad resistance

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Biological control

Use of natural enemies to target pest species

• Can provide long-term, cost-effective control that reduces reliance on insecticides
Biological control

Survey of SWD natural enemies in US and Europe

• Fungal pathogen – *Metarhizium anisopliae*

• Predators – ants, spiders, rove beetles, minute pirate bugs

• High rates of control found in lab, but no control in field

Biological control

Classical biological control
Identify and release natural predators from native region
• Must have
  • High target control
  • High specificity to target pest
  • No chance of attacking important native organisms
  • Ability to be mass-produced
Biological control

Identification of SWD parasitoids in Asia

• Collecting trips in South Korea & China led by Kent Daane (UC Berkeley) and Kim Hoelmer (USDA)
Biological control

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Biological control

Identification of SWD parasitoids in Asia

• Collecting trips in South Korea & China led by Kent Daane (UC Berkeley) and Kim Hoelmer (USDA)
• Identified 3 SWD parasitoids
  • *Ganaspis brasiliensis* (Figitidae) most promising
  • Specialist on SWD
• Initial petition to perform experimental release rejected, but will resubmit early 2019
Acknowledgements

Frank Zalom
UC Davis

Joanna Chiu
UC Davis

Antoine Abrieux
UC Davis

Kathlyne-Inez Soukhaseum
UC Davis

Mark Bolda
UC ANR