2018 Pesticide Safety - Pesticide Resistance Management in Cranberry

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Pesticide Resistance Management in CRANBERRY

by Katie Ghantous and Marty Sylvia

with input from
Hilary Sandler and Laura McDermott

With special thanks to:

- Dr. Margaret McGrath, Cornell University
- Dr. Andrei Alyokhin, University of Maine
- Dr. Richard Bonanno, University of Massachusetts

NE-SARE Professional Development Program
ENE15-140-29994
What is Pesticide Resistance?

Inheritable (genetic) characteristic of a pest that makes it less sensitive to a pesticide

- Can occur in **all** types of pests
  - weeds, insects, fungi, etc.

- Pest is able to survive pesticide exposure that would kill those without the genes
What is Pesticide Resistance?

- Genes naturally occur in pest population
  - Not mutations caused by chemical

- Pesticide use “selects” for resistance
  - Kills susceptible individuals - those *without* the gene to protect them die
  - Those with the gene don’t die, and are “Selected” for by killing off other types
What is Pesticide Resistance?

- Pests *with* gene live, reproduce, and pass on the genes for resistance to their offspring
- The pest population has increasing numbers of resistant individuals
- Over time, population as a whole is more resistant to the pesticide
Why is Managing Resistance Important?

• All types of pesticides are at risk for resistance!
• Pesticide resistance is increasing
Mode of action (MoA)

The chemical structure of a pesticide defines:

- **Target site** - the “where” - physical location within an organism where the pesticide acts

- **Mode of action** - the “how” - action of a pesticide at its target site.
Pesticide Groups

• Each pesticide has been assigned a **Group Number** to help growers make resistance management decisions

• Pesticides in a group share similar characteristics and risk cross-resistance

• Group number is clearly marked on most labels
Herbicides - HRAC and WSSA groups

HRAC (letters) and WSSA (Weed Science Society of America, #’s) codes, differ slightly but very similar

GROUP 1 HERBICIDE

Valent

SELECT MAX

Active Ingredient
* Clethodim .............................................. 12.6%
Other Ingredients ....................................... 87.4%
Total ..................................................... 100.0%
### Herbicides - HRAC and WSSA groups

HRAC (letters) and WSSA (Weed Science Society of America, #’s) codes, differ slightly but very similar

<table>
<thead>
<tr>
<th>HRAC Group</th>
<th>Site of Action</th>
<th>Chemical Family</th>
<th>Active Ingredient</th>
<th>WSSA Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Inhibition of acetyl CoA carboxylase (ACCase)</td>
<td>Aryloxyphenoxy-propionate ‘FOPs’</td>
<td>clodinafop-propargyl, cyhalofop-butyl, diclofop-methyl, fenoxaprop-P-ethyl, fluazifop-P-butyl, haloxyfop-R-methyl, propaquizafop, quizalofop-P-ethyl</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyclohexanedione ‘DIMs’</td>
<td>allobromdim, butroxydim, clethodim, cycloxydim, profospidim, sethoxydim, tepraloxydim, tralkoxydim</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenylpyrazoline ‘DEN’</td>
<td>pinoxaden</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Inhibition of acetolactate synthase ALS (acetohydroxyacid synthase AHAS)</td>
<td>Sulfonyleurea</td>
<td>amidosulfuron, azimsulfuron, bensulfuron-methyl, chlorimuron-ethyl, imazalin</td>
<td>2</td>
</tr>
</tbody>
</table>
Consult the label for RM info
In addition to group numbers, many labels have specific info or instructions regarding RM

RESISTANCE MANAGEMENT
Select Max Herbicide with Inside Technology is a Group 1 herbicide. Any weed population may contain or develop plants naturally resistant to Select Max Herbicide with Inside Technology and other Group 1 herbicides. Weed species with acquired resistance to Group 1 may eventually dominate the weed population if Group 1 herbicides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by Select Max Herbicide with Inside Technology or other Group 1 herbicides. Repeated use of Select Max Herbicide with Inside Technology (or similar postemergence grass herbicide with the same mode of action) may lead to the selection of naturally occurring biotypes that are resistant to these products in some grass species.

If poor performance occurs and cannot be attributed to adverse weather or application conditions, a resistant biotype may be present. This is most likely to occur in fields where other control strategies such as crop rotation, mechanical removal and other classes of herbicides are not used from year to year.

To delay herbicide resistance consider:
• Avoiding the consecutive use of Select Max Herbicide with Inside Technology or other target site of action Group 1 herbicides that have similar target site of action, on the same weed species.
• Using tank mixtures or premixes with herbicides
Consult the Cranberry Chart book!

## 6 RESISTANCE MANAGEMENT

Fungicide Resistance Action Committee (FRAC) Grouping for cranberry fungicides

<table>
<thead>
<tr>
<th>FRAC GROUP</th>
<th>TRADE NAME</th>
<th>COMMON NAME</th>
<th>MODE OF ACTION</th>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>Resistance Development Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Metastar</td>
<td>mefenoxam</td>
<td>A1: RNA polymerase I</td>
<td>PA – fungicides (PhenylAmides)</td>
<td>acylalanines</td>
<td>High Risk</td>
</tr>
<tr>
<td></td>
<td>Ridomil</td>
<td>metalaxyl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultra Flourish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flourish</td>
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<td></td>
<td>Ph-D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aliette</td>
<td>fosetyl-Al</td>
<td></td>
<td></td>
<td>ethvl</td>
<td></td>
</tr>
</tbody>
</table>
# Resistance to sites of action used in cranberry

<table>
<thead>
<tr>
<th>Site of action (examples)</th>
<th>Resistant weed species</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPPD inhibitor (mesotrione)</td>
<td>2</td>
</tr>
<tr>
<td>LCFA inhibitor (napropramide)</td>
<td>5</td>
</tr>
<tr>
<td>Cellulose inhibitor (dichlobenil)</td>
<td>3</td>
</tr>
<tr>
<td>Carotenoid biosynthesis (norflurazon)</td>
<td>6</td>
</tr>
<tr>
<td>ACCase (clethodim, sethoxydim)</td>
<td>48</td>
</tr>
<tr>
<td>Synthetic auxin (2,4-D, clopyralid)</td>
<td>36</td>
</tr>
</tbody>
</table>
| EPSP synthase (glyphosate)                      | 41                     

[Slide courtesy of Jed Colquhoun, University of Wisconsin-Madison]
Should cranberry growers be concerned about herbicide resistance?

• We rely on just a few herbicides for weed control
• New herbicide options are few and far between
• The rate range is broad for several herbicides, allowing for sub-lethal doses
• We can’t rotate crops and cultural practices are limited
• Many perennials in cranberry are prolific seed producers, such as goldenrod
So, what can we do about it?

- Monitor for weeds that escape control
- Eliminate survivors
  - We have more tools for managing weeds!
- Rotate herbicide within and across growing seasons
- Guard against contaminated inputs that can spread resistant weeds
- If you suspect resistance, get assistance immediately!
Challenges to Managing Resistance

- Products with resistance risk for one pest are also used for others
  - Pesticides don’t work only on target!
    - Delegate for BHFW...may expose Spag too!
Challenges to Managing Resistance

• Not always something to rotate to, even if you try!

• Not many cranberry herbicides
  o i.e. clethodim and sethoxydim for grasses
Do not rely on pesticides alone
Integrate different controls!

- synthetic pesticides
- biological pesticides
- beneficial insects (predators/parasites)
- cultural practices
- chemical attractants/deterrents
Insecticide Resistance Action Committee
http://www.irac-online.org/
Insecticide Mode of Action Classification

Insecticide Resistance Action Action Committee  www.irac-online.org

Introduction
Insecticide Resistance Action Committee (IRAC) promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Review and reclassified periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides.

Nerve & Muscle Targets

Group 1: Acetylcholine receptor (AChR) channel blockers
- 1A: Organophosphates (e.g., chlorpyrifos)
- 1B: Carbamates (e.g., carbaryl)
- 1C: Pyrethroids (e.g., cypermethrin)

Group 2: GABA-gated chloride channel blockers
- 2A: Cycloate (e.g., cydiate)
- 2B: Phenylpyrazoles (e.g., fenpropathrin)

Group 3: Sodium channel modulators
- 3A: Pyrethroids (e.g., lambda-cyhalothrin)
- 3B: DDT, DDT-like compounds

Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators
- 4A: Nicotine (e.g., nicotine)
- 4B: Neonicotinoids (e.g., imidacloprid, clothianidin)
- 4C: Sulfonamides (e.g., sulfadimethoxine)

Group 5: Nicotinic acetylcholine receptor modulators
- 5A: Pyridyl-derivative compounds (e.g., pyridacine)
- 5B: Other nAChR agonists (e.g., dichlorvos)

Group 6: Glutamate-gated chloride channel (GluCl) allosteric modulators
- 6A: Neonicotinoids (e.g., acetamiprid)
- 6B: Beta-N-methylcarbamates (e.g., acetamiprid)

Group 7: Chordotonal organ TRPV channel blockers
- 7A: Pyridyl-derivative compounds (e.g., pyridacine)
- 7B: Other TRPV channel blockers (e.g., tetramethrin)

Group 8: Nicotinic acetylcholine receptor (nAChR) channel blockers
- 8A: Isocyanuric acid (e.g., fipronil)
- 8B: Octylisocyanuric acid (e.g., flumethrin)

Group 9: Octopamine receptor agonists
- 9A: Amitraz

Group 10: Voltage-gated sodium channel blockers
- 10A: Pyrethroids (e.g., deltamethrin)
- 10B: Etoxazole

Group 11: Chordotonal organ modulators - undefined target site
- 11A: Pesticides (e.g., chlorpyrifos)
- 11B: Endosulfan

Midgut Targets

Group 12: Microsomal enzymes and midgut membranes
- 12A: Aryl hydrocarbon receptor (AhR) agonists
- 12B: Eicosanoids

Miscellaneous non-specific (multi-site) inhibitors

Group 8: A: Alkyl hydrazines, B: Chloropicrin, C: Fluorides, D: Botanics
- 8A: Alkyl hydrazines (e.g., propamocarb)
- 8B: Tetrachloroethylene (e.g., pentaerythritol tetraethyl ether)

MoA Sequences & alternations

IRAC recommends alternations, sequences or rotations of compounds from different MoA groups to provide a sustainable and effective approach to IRM. Three groups (8, 13 and UN) are exempt from the recommendations as they do not contain compounds acting at a common target site.

This poster is for educational purposes only. Details are accurate to the best of our knowledge but IRAC and its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors and health and safety recommendations followed.

Designed & produced by the IRAC MoA Team, Dec. 2015. Ver. 4. Based on MoA Classification Ver. 8.5. Photograph courtesy of K. Armes. For further information visit the IRAC website: www.irac-online.org. IRAC document protected by © Copyright

BD- Dipel

Bt: Dipel

PYGANIC
AVAUNT
ALFACTOR
BY
DIELTHET
RIMON
KNACK or ESTEEM
CONFIRM, INTREPID
MOVEMENT...
**Insecticide Mode of Action Classification:**
Diversity is a key to successful resistance management

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**IRAC**

IRAC promotes the use of a mode of action classification of insecticides as the basis for effective and sustainable insecticide resistance management. Insecticides are allocated to specific groups based on their target site. The use of sequences or alternations of insecticides with different modes of action reduces selection pressure on individual target sites. This prevents, delays or reverses resistance and helps maintain product diversity and efficacy.

**Midgut**

*Group 11* Microbial disruptors of insect midgut membranes
The midgut is the target for the toxins produced by the bacteria *Bacillus thuringiensis* (Bt) toxins cause fatal lesions in the midgut wall. Transgenic crops such as Bt-cotton express high levels of specific toxins. The Bt also contains such toxins.

**Stimulatory Nervous System**

The nervous system is the target for most current insecticides, but within this system are many target sites. Insecticides with specific modes of action act at these targets:
- *Group 1 new cholinesterases (AChE)*
- Carbamates and organophosphates act as inhibitors of AChE at nerve synapses.
- This results in hyperactivity in the nervous system.
- *Group 4 Acetylcholine (ACh) agonists and antagonists*
- The Cholinomimetics act as agonists or antagonists at the post-synaptic N-methyl-D-
- ACh receptor (nAChR). This leads to neuronal overstimulation and hyperactivity.
- *Group 5 Acetylcholine receptor modulators*
- Spinosyns are nAChR antagonists interfering with nerve transmission.
- *Group 3 Sodium channel modulators*
- Sodium channels are involved in the propagation of action potentials along nerves.
- Pyrethroids rapidly inactivate voltage-sensitive action, causing synaptic and nerve block.
- *Group 22 Voltage dependent sodium channel blockers*
- Indoxacarb blocks sodium channels leading to neural dysfunction.

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**Cuticle Synthesis**

*Groups 15, 16 and 17*
Inhibitors of chitin biosynthesis
New cuticle is synthesised during the life cycle. The Benzoylureas in Group 15 are broadly active and inhibit a key part of this process, leading to insect death. Similar inhibitors of Homoptera and Diptera chitin biosynthesis are in Groups 16 (Buprofezin) and 17 (Cyromazine).

**Moulting & Metamorphosis**

Controlled by two hormones, juvenile hormone (JH) and ecdysone.
- *Group 18 Ecdysone agonists and antagonists*
- Termed moulting, the ecdysone agonist Group 18 promotes metamorphosis.
- Applied in the pre-metamorphic instar, disrupt and prevent metamorphosis.

**Metabolic Processes**

Acting on a wide range of metabolic processes:
- *Group 12 Inhibitors of oxidative phosphorylation, disruptors of ATP*
- Diazinon and Organotin miticides
- *Group 12 Uncoupler of oxidative phosphorylation via disruption of H+ proton gradient - Chlorfenapyr*
- *Group 20 Site I electron transport inhibitors – Hydramethylnon and Dicrofim*
- *Group 21 Site II electron transport inhibitors – Rotenone, METI acaricides*

**Inhibitory Nervous System**

In the insect nervous system system GABA is an inhibitory neurotransmitter. The GABA receptors are a target for a number of insecticide groups.
- *Group 2 GABA-gated chloride channel antagonists*
- The Cyclodienes and Fiproles bind to the GABA receptor complex and inhibit the action of GABA causing neuronal hyperactivity.
- *Group 8 Chloride channel activators*
- Avermectin, Emamectin Benzoate and Milbemycin. The mectins bind to the GABA receptor complex, mimicking GABA and causing paralysis.
We have seen this in cranberry already….

**Weevil**
- Resistant to organophosphates
- Worried developing resistance to Avaunt

**Spag**
- Resistant to organophosphates
- May be developing to Delegate
Good news....

**BHF – Blackheaded fireworm**
- Not likely to develop resistance

**CFW – Cranberry Fruitworm**
- Not likely to develop resistance

*photos by C. Armstrong*
Cranberry Weevil

- Avaunt 2007  SPRING
  Indoxacarb

- Actara 2005  SPRING OR SUMMER
  Thiamethoxam
  neonicotinoid, high bee toxicity
  Zone II Restricted

- Belay 2010  SUMMER
  Clothianidin
  neonicotinoid, high bee toxicity

Resistant to organophosphates in 2000

- Lorsban
- Guthion
- Parathion
- Diazinon

- Imidan
- Orthene
- Sevin
Avaunt (indoxacarb)

Spring population
Superb!
weevil control!
May have to retreat
as more weevil come in from woods

Summer population
NOT EFFECTIVE
Do not use Avaunt
New generation can metabolize the pesticide
Cranberry Weevil

Resistant to organophosphates in 2000
- Lorsban
- Guthion
- Parathion
- Lorsban
- Imidan
- Orthene
- Sevin

• Avaunt 2007 SPRING
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Cranberry Weevil

- **Avaunt** 2007  
  Indoxacarb
  - SPRING

- **Actara** 2005  
  Thiamethoxam  
  neonicotinoid, high bee toxicity  
  - Zone II Restricted

Resistance trials likely this year!
Sparganothis fruitworm

Comes in different styles— the wriggler
Sparganothis resistance to organophosphates

- Began ca. 20 years ago in Carver area
- Spread throughout industry
- Lorsban, Imidan, Orthene, Sevin no longer effective on most populations
SPAG Spring Spray Options

- Altacor
- Assail
- Avaunt
- **Intrepid**, Confirm
  - Invertid (Loveland)
- **Delegate**
  - Diazinon
  - Imidan
  - Lorsban
  - Orthene
  - Sevin

- Best management approach is to focus on the spring
- Summer populations much harder to monitor and manage
- Delegate and Intrepid best (only) choices for spring management
- Med-large larvae – Delegate?
- Some growers have better luck with Intrepid even on larger larvae!
SPAG Spring Spray Options

- Altacor
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- **Intrepid**, Confirm
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  - Diazinon
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  - Lorsban
  - Orthene
  - Sevin

So if you are only using Delegate for Sparganothis, you are part of the problem!!

Best management approach is to focus on the spring summer population as much harder to monitor and manage.

Delegate and Intrepid best (only) choices for spring management.

Med/large larvae: Delegate?

Some growers have better luck with Intrepid for larger larvae!
Fungicide Resistance Risk

<table>
<thead>
<tr>
<th>Fungicide Class</th>
<th>FRAC Code</th>
<th>High Risk</th>
<th>Medium Risk</th>
<th>Low Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI</td>
<td>Code 3</td>
<td>Indar</td>
<td>Proline</td>
<td></td>
</tr>
<tr>
<td>chloronitriles</td>
<td>Code M5</td>
<td>Bravo (and</td>
<td>many others)</td>
<td></td>
</tr>
<tr>
<td>QoI</td>
<td>Code 11</td>
<td>Abound</td>
<td>Evito</td>
<td></td>
</tr>
<tr>
<td>polyoxins</td>
<td>Code 19</td>
<td>OSO, Ph-D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fungicide resistance is a very real and serious threat!
In vitro assays by F. Caruso in 2012

- 2 different locations in MA, 4 fruit rot pathogens
- High to low concentrations of fungicide
- Reduced sensitivity to Indar and Abound
- Cross-resistance (Indar & Proline & new one coming)
  - all in same FRAC group
FUNGICIDES - Alternate, rotate, or sequence different pesticide MoA classes

Use FRAC, IRAC, and HRAC when choosing chemicals!

- Do not rely on product names
- Do not rely on active ingredients
  - Many different products and active ingredients can be in the same group!

<table>
<thead>
<tr>
<th></th>
<th>Abound</th>
<th>Aftershock</th>
<th>Evito</th>
<th>QoI-fungicides</th>
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**mysteryconazole**
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**FUNGICIDES** - Alternate, rotate, or sequence different pesticide MoA classes

<table>
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<tr>
<th>MoA Code</th>
<th>Product Name</th>
<th>Mechanism of Action</th>
<th>Class</th>
<th>Risk Level</th>
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<td>Peptidyl pyrimidine nucleoside</td>
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*Depend on chart book RM section*
<table>
<thead>
<tr>
<th>Number</th>
<th>Fruit</th>
<th>Type</th>
<th>Fungicides</th>
<th>Mode of Action</th>
<th>Risk Level</th>
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<tr>
<td>11</td>
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Mix together and Rotate Broad Spectrum