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Pesticide Resistance Management

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Pesticide Resistance Management

by K. Ghantous, H. Sandler, and L. McDermott.

With special thanks to:

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

- Pesticide use “selects” for resistance:
  - Kills susceptible individuals (those *without* the gene)
  - “Selects” those with the gene to survive

- Pests *with* gene live, reproduce, and pass on the genes for resistance to their offspring

- The pest population has increasing numbers of resistant individuals
Why do pests become resistant?

- Pre-adaptation
- High fertility
- Short generation time

Intrinsic properties of pest species. Can’t be controlled.

Selection pressure

Under human control!
Natural pest population

- Some individuals have genes that make them less sensitive to a pesticide
Pesticide application

- Individuals that are susceptible die
Pesticide application

• Individuals with naturally occurring genes that make them less sensitive to a pesticide survive...
After pesticide application

- Humans applied selection pressure
- Less sensitive pests reproduce
- The offspring have genes
Resistance takes time to develop!

On farm
After pesticide application

- Resistance takes time to develop!

On farm
Resistance takes time to develop!
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
Example of weed resistance

*Roundup Ready® soybean system*

- Ag scientists created soy plants unaffected by glyphosate
- Soy growers could spray glyphosate over their crop and kill all weeds
- Simplified weed management

BUT...increasing glyphosate use (frequency and number of acres treated) increases the probability of selecting an herbicide-resistant plant....
After glyphosate application in a soybean field

Glyphosate-resistant horseweed

Glyphosate-susceptible horseweed
Glyphosate-resistant horseweed now infests millions of acres from Delaware to Illinois.

• Plus pigweed/amaranth, ragweed, and others...
Why is Managing Resistance Important?

- Pesticide resistance is increasing
- Currently:
  - 520 insect and mite species
    - At least 17 insect species are resistant to all major classes of insecticides
  - 273 weed species
  - 150 plant diseases
  - 10 rodent species
Number Resistant Species for Several Herbicide Sites of Action (WSSA Codes)

- ACCase Inhibitors (1)
- ALS Inhibitors (2)
- EPSP Synthase Inhibitors (9)
- Synthetic Auxins (4)
- PSII Inhibitors (5,6,7)

Note: PSII Inhibitors Combined

Dr. Ian Heap, WeedScience.org 2015
Why is Managing Resistance Important?

• Need pesticides to provide effective control of pests

• New products for pest control hard to develop
  o If current technology stops working, it might be a long time until something replaces it!

• Environmental stewardship
  o Pest are mobile, resistance that develops in one crop can spread to others
  o Using ineffective pesticides causes unnecessary risk
What Products are Resistant Prone?

- All pesticides have some risk, BUT not to the same extent
- Compounds most as risk - those with single-site mode of action, targeted and narrow-spectrum
High Risk

- Repeated applications of the same pesticide
- Alternating applications of different pesticides
- Spraying based on an economic threshold
- Spot and perimeter treatment
- Treating whole field

Low Risk
Mode of action (MoA)

- The chemical structure of a pesticide defines:
  - **Target site** - the physical location within an organism where the pesticide acts
  - **Mode of action** - the action of a pesticide at its target site. The way in which it causes physiological disruption at the target site.

- Each pesticide has a **Group Number** to help growers make resistance management decisions
- Group number is clearly marked on all labels
All types of pesticides are at risk for resistance!

**Herbicides**
Herbicide Resistance Action Committee (HRAC)
http://www.hracglobal.com

**Fungicides**
Fungicide Resistance Action Committee (FRAC)
http://www.frac.info

**Insecticides**
Insecticide Resistance Action Committee (IRAC)
http://www.irac-online.org

International groups founded by the agrochemical industry for a cooperative approach to resistance management. Sources for info and education materials.
# 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 clodinafop-methyl fenoxaprop-P-ethyl fluazifop-P-butyl haloxyfop-R-methyl propazifop quinalofop-P-ethyl</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyclohexanedione ‘DIMs’</td>
<td>alocycloxydim butoxydim clethodim cyclodixim propanoxydim sethoxydim tepoxydim tralkoxydim</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenylpyrazoline ‘DEN’</td>
<td>pinoxaden</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfonyleurea</td>
<td>amidosulfuron azimsulfuron bensulfuron-methyl chlorimuron-ethyl chlorimuron-ethyl chlorosulfuron cinosulfuron cyclosulfuron</td>
<td>2</td>
</tr>
</tbody>
</table>

**Active Ingredient**

* Clethodim ......................... 12.6%
Other Ingredients ..................... 87.4%
Total ................................... 100.0%
## Insecticides - IRAC codes

**IRAC MoA Classification Version 8.1, April 2016**

See section 7.4 for further information on sub-groups.  
See section 7.3 for criteria for descriptors of the quality of MoA information.

<table>
<thead>
<tr>
<th>Main Group and Primary Site of Action</th>
<th>Chemical Sub-group or exemplifying Active Ingredient</th>
<th>Active Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Acetylcholinesterase (AChE) inhibitors</td>
<td>1A Carbamates</td>
<td>Alanycarb, Aldicarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbophuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isopropcarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Triazamate, Trimethacarb, XMC, Xylycarb</td>
</tr>
<tr>
<td>Nerve action</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LORSBAN® 75WG Insecticide**

For control of listed insects infesting certain field, fruit, nut, and vegetable crops.

**ACTIVE INGREDIENT:**
- Chlorpyrifos: \( O, O\text{-diethyl} \ O-(3,5,6\text{-trichloro-2 pyridinyl}) \) phosphorothioate: \( 75.0 \% \)

**OTHER INGREDIENTS**
- Endosulfan: \( 25.0 \% \)
- Other ingredients: \( 100.0 \% \)
Fungicides - FRAC codes

Abound®
Flowable Fungicide

Broad spectrum fungicide for control of plant diseases

Active Ingredient:
Azoxystrobin: methyl (E)-2-{2-[6-(2-cyanophenoxy) pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate* ........................ 22.9%

Other Ingredients: .......................................................... 77.1%

Total: .......................................................... 100.0%
Consult the label for RM info

RESISTANCE MANAGEMENT

GROUP 11 FUNGICIDE

Abound (azoxyrstrobib) is a Group 11 fungicide. The mode of action for Abound is the inhibition of the Qol (quinone outside) site within the electron transport system [Group 11]. Fungal pathogens can develop resistance to products with the same mode of action when used repeatedly. Because resistance development cannot be predicted, use of this product should conform to resistance management strategies established for the crop and use area. Consult your local or State agricultural authorities for resistance management strategies that are complementary to those in this label. Resistance management strategies may include alternating and/or tank-mixing with products having different modes of action or limiting the total number of applications per season. Syngenta encourages responsible resistance management to ensure effective long-term control of the fungal diseases on this label.

Follow the crop specific resistance management recommendations in the directions for use.

If no resistance recommendation on number of applications is specified in the directions for use, follow the recommendations in the table below.

<table>
<thead>
<tr>
<th>If planned total number of fungicide applications per crop is:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended Solo Qol fungicide sprays</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Recommended Qol fungicide sprays in</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
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</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>11</td>
<td>Abound</td>
<td>azoxystrobin</td>
<td>C3: cytochrome bc1 at Qo site</td>
<td>QoI-fungicides</td>
<td>methoxy-acrylates</td>
<td>High Risk</td>
</tr>
<tr>
<td></td>
<td>Aftershock</td>
<td>fluoxastrobin</td>
<td></td>
<td></td>
<td>Strobilurins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evito</td>
<td></td>
<td></td>
<td></td>
<td>dihydrodioxazines</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Indar</td>
<td>fenbuconazole</td>
<td>G1: c14-demethylase in sterol biosynthesis</td>
<td>DMI-fungicides (DeMethylation Inhibitors)</td>
<td>triazoles</td>
<td>Medium Risk</td>
</tr>
<tr>
<td></td>
<td>Proline</td>
<td>prothioconazole</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>OSO Ph-D</td>
<td>polyoxin</td>
<td>H4: chitin synthase</td>
<td>polyoxins</td>
<td>peptidyl pyrimidine nucleoside</td>
<td>Medium Risk</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Aliette</td>
<td>fosetyl-Al</td>
<td></td>
<td></td>
<td>ethvl</td>
<td></td>
</tr>
</tbody>
</table>
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>Chemicals</th>
<th>MoA Classes</th>
<th>Risk Level</th>
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<td></td>
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<td></td>
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<td><strong>dihydrodioxazines</strong></td>
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<td></td>
<td></td>
<td><strong>(DeMethylation Inhibitors)</strong></td>
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<td></td>
<td><strong>triazoles</strong></td>
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<td></td>
<td><strong>Ph-D</strong></td>
<td><strong>polyoxins</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>peptidyl pyrimidine nucleoside</strong></td>
<td></td>
</tr>
</tbody>
</table>
Applications must be timed correctly

• Target the most vulnerable life stage of the pest
• Use spray rates and application intervals recommended by the manufacturer and in compliance with local agricultural extension regulations.
  o A high rate can take out pests that might be somewhat resistant, but using a rate too low may allow them to survive
Key Points About Managing Resistance

• Goal is delaying development of resistance, not managing resistant pest biotypes once detected

• Use Integrated Pest Management (IPM) program

• Minimize use of at-risk products
Do not rely on pesticides alone

Integrate different controls!

- synthetic pesticides
- biological pesticides
- beneficial insects (predators/parasites)
- cultural practices
- chemical attractants/deterrents
Challenges to Managing Resistance

Do not have adequate tools

- Not enough registered products to rotate
- The program may not be as effective
- The program may be more expensive
Challenges to Managing Resistance

• Products with resistance risk for one pest are also used for others
  o Pesticides don’t work only on target!
    o Delegate for BHFW...may expose Spag too!
Questions?