Powdery mildew management for melons:
Fungicide mode of action

Mike Matheron
Extension Plant Pathologist
University of Arizona
Yuma Agricultural Center

<table>
<thead>
<tr>
<th>Melon powdery mildew caused by:</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Podosphaera xanthii</em></td>
</tr>
<tr>
<td>formerly known as</td>
</tr>
<tr>
<td><em>(Sphaerotheca fuliginea)</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Powdery Mildew Management Chemistries: Mode of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological mode of action</td>
</tr>
<tr>
<td>Effect on spore germination</td>
</tr>
<tr>
<td>Effect on fungus growth</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Biological</td>
</tr>
<tr>
<td>• Physiological</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biological mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The activity of a product on a fungus can be expressed in a physically visible manner</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physiological mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>What happens at the cellular level to cause the visible effects on spore germination and fungal growth</td>
</tr>
</tbody>
</table>
Physiological mode of action

What happens at the cellular level to cause the visible effects on spore germination and fungal growth?

Awareness of the physiological mode of action is important for resistance management and preservation of fungicide effectiveness.

The physiological mode of action

- Fungicides are metabolic pathway inhibitors
- Fungicides can be placed in groups with respect to their general mode of action
  - This has been done by the Fungicide Resistance Action Committee (FRAC)

Fungicide groups, based on mode of action, as created by the Fungicide Resistance Action Committee

- Multi-site contact activity
- Nucleic acids synthesis
- Mitosis and cell division
- Respiration
- Amino acids and protein synthesis
- Signal transduction
- Lipids and membrane synthesis
- Sterol biosynthesis in membranes
- Glucan and cell wall synthesis
- Melanin synthesis in cell wall
- Host plant defense induction

Fungicide groups containing products active against powdery mildew on melons

- Multi-site contact activity
- Mitosis and cell division
- Respiration
- Signal transduction
- Sterol biosynthesis in membranes
- Host plant defense induction
Multi-site contact activity

- Chemical group: Inorganics
  - Sulfur:
    - Disrupts electron transport along the cytochromes
  Resistance risk: Low

Multi-site contact activity

- Chemical group: Inorganics
  - Potassium bicarbonate (Armicarb, Kaligreen)
    - Kills pathogen and spores by a combination of osmotic pressure, pH and specific carbonate and bicarbonate ion effects
    Resistance risk: Low

Multi-site contact activity

- Chemical group: Chloronitriles
  - Chlorothalonil (Bravo)
    - Inactivates amino acids, proteins and enzymes by combining with amino and thiol groups
    Resistance risk: Low

Inhibition of mitosis and cell division

- Group name: MBC (Methyl benzimidazole carbamates)
  - Thiophanate-methyl (Topsin)
    - Inhibits DNA synthesis (nuclear division)
      - β-tubulin assembly in mitosis
    Resistance risk: High

Inhibition of respiration (in mitochondria)

- Group name: Carboxamides
  - Boscalid (Endura)
    - Complex II: inhibits succinate dehydrogenase
    Resistance risk: Medium
Inhibition of respiration (in mitochondria)

- Group name: Qol-fungicides - Quinone outside inhibitors
- Strobilurins: Azoxystrobin (Quadris);
  Pyraclostrobin (Cabrio); Trifloxystrobin (Flint)

- Complex III: blocks the cytochrome bc₁ at the Qo site
- Resistance risk: High

Inhibition of respiration (in mitochondria)

- Group name: Qol-fungicides - Quinone outside inhibitors
- Strobilurins:
  - Azoxystrobin (Quadris)
  - Pyraclostrobin (Cabrio)
  - Trifloxystrobin (Flint)

Structural organization of a mitochondrial

Electron transfer chain in the inner membrane of mitochondria

Electron transfer chain in the inner membrane of mitochondria

Signal transduction disruption

- Group name: Quinolines
- Quinoxyfen (Quintec)
  - G-proteins in early cell signalling (proposed)
- Resistance risk: Medium
**Inhibition of sterol biosynthesis in membranes**
- Ergosterol is the major sterol in most fungi
- It is essential for membrane structure and function

**Group name: DMI (Demethylation inhibitors)**
- Myclobutanil (Rally)
- Triflumazole (Procure)
- Inhibits C14-demethylase in sterol biosynthesis
  - Resistance risk: Medium

**Host plant defense induction** *(Plant activators)*
- In contrast to conventional fungicides, plant activators have no direct effect on pathogens
- Plant activators induce plants to produce natural disease-fighting compounds

**Plant activators**
- Acibenzolar-S-methyl (Actigard)
- Harpin (Messenger)
- Some biological control organisms (Serenade)
  - Also may control plant diseases by production of compounds directly toxic to the pathogen

**Plant activators stimulate natural plant defense mechanisms**
- **Salicylic acid pathway** – Induces SAR (systemic acquired resistance), a natural biological defense response to pathogen attack
- **Jasmonic Acid Pathway** - Induces the production of disease and insect defense compounds

**Salicylic Acid Pathway**
- Production of active oxygen (hydrogen peroxide, peroxidase)
  - Peroxidases have been associated with fungal cell wall degradation and pathogen defense signaling
- Thickening plant cell wall
  - Increasing lignification
  - Production of phenolic esters that strengthen cross linking
**Salicylic Acid Pathway**

- Systemic and local accumulation of Pathogenesis Related Proteins (PR-Proteins)
  - chitinases
  - β-1,3 Glucanase
- Systemic accumulation of anti-microbial compounds called phytoalexins

**Chitinases**

- Chitin is the major component of all fungal cell walls except for the Oomycetes
- Chitinases break down fungal cell walls
- Chitinases can break down insect exo-skeletons
- Activity is greatly enhanced by Glucanase

**β-1,3 Glucanases**

- Glucans and cellulose are the major components of Oomycete cell walls
- Antifungal activity is most often in combination with Chitinase
  - Direct defense: Degrade fungal cell walls
  - Indirect defense: Promoting the release of oligosaccharides that act as elicitors of defense reactions

**Jasmonic Acid Pathway**

Jasmonic acid induces the production of disease and insect defense compounds

- Defense Proteins
- Phytochemicals

**Phytochemicals**

- Different from phytoalexins in that phytochemicals are induced by wounding
  - Phenolics
    - Furanocoumarins, Coumarins, Tannins, Lignin, other phenolics
  - Terpenoids
  - Alkaloids

**Examples of plant activators**

- Acibenzolar-S-methyl (Actigard)
- Harpin (Messenger)
- Some biological control organisms (Serenade)
  - Also may control plant diseases by production of compounds directly toxic to the pathogen
Concluding thought: Why is it important to know the physiological mode of action of fungicides?

- For resistance management and preservation of fungicide effectiveness
- Incorporate fungicides with different modes of action into a disease management program
  - In alternation or as a mixture

This presentation will be available online at the Arizona Crop Information Site (ACIS)
http://ag.arizona.edu/crops