Methods for monitoring and managing fungicide resistance in fungal pathogens of pome and stone fruits

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Fungicide 101

What is resistance?

The best ways to manage resistance
Fungicide 101

• Fungicide Basics
  • Protectant v. Penetrant
  • Mode of action: single site v. multi-site

• Fungicide Resistance Action Committee (FRAC): Group codes
  • Knowing the fungicides
    • Group – Fungicide Family – Common Name – Trade Name
Fungicide 101

Fungicide Basics: Protectant v. Penetrant

**Protectant**
- “Contact”
- No movement into plant
- Applied *prior* to infection
- **Needs to be re-applied**
  - New growth
  - Not rainfast

*Examples*: Manzate, captan, copper

**Penetrants = Systemics**
- **Absorbed** into plants following application
  - Rainfast
- Less thorough coverage to be effective
- Protectant and/or “curative”:
  - **Inhibit/slow fungal growth**
    - During early stage of infection

*Examples*: Vangard, Flint, Pristine

Disease Management Strategies-Purdue Extension
**Fungicide Basics**: Mode of action (MOA)
The specific way fungicide poisons the fungus

- Nucleic acid synthesis
- Mitosis and cell division
- Sterol synthesis
- Respiration
- Signaling

**Site-specific**
Systemics/Penetrants

**Multi-site**
Protectants
Fungicide Resistance Action Committee (FRAC) [http://www.frac.info](http://www.frac.info)

Established codes for fungicides based on their **mode of action** (FRAC Code)

Get to know your fungicide label:
Importance of FRAC group codes on fungicide labels

**DuPont™**
**Fontelis™**
fungicide

**Suspension Concentrate**

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penthiozyd</td>
<td>20.4%</td>
</tr>
<tr>
<td>Other Ingredients</td>
<td>79.6%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Contains 1.67 pounds of penthiozyd per gallon of product
EPA Reg. No. 352-834

**RESISTANCE MANAGEMENT**
Repeated use of products for control of specific plant pathogens may lead to selection of resistant strains of fungi and result in a reduction of disease control. Penthiozyd, the active ingredient in FONTELIS™, is one of EPA's Target Site of Action Group 7 fungicides (carboxamides). A disease management program that includes rotation and/or tank mixing with non-Group 7 fungicides is essential to reduce the risk of fungicide resistance development. For guidance on a particular crop and disease control situation, consult your state extension specialist for official state recommendations.
# Fungicide 101

## Knowing the fungicides

<table>
<thead>
<tr>
<th>Mode of Action</th>
<th>FRAC Group</th>
<th>Fungicide Family</th>
<th>Common Name</th>
<th>Trade Name</th>
<th>Protectant /Systemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitosis/cell division</td>
<td>1</td>
<td>Benzimidazole/MBC</td>
<td>Thiophanate-methyl</td>
<td>Topsin M®</td>
<td>Systemic</td>
</tr>
<tr>
<td>Sterol biosynthesis</td>
<td>3</td>
<td>DMI /SBI (demethylation inhibitor)</td>
<td>fenarimol fenbucanazole myclobutanil</td>
<td>Rubigan® Indar® Rally®</td>
<td>Systemic</td>
</tr>
<tr>
<td>Respiration</td>
<td>7</td>
<td>Carboxamide/SDHI (sucinate dehydrogenase inhibitor)</td>
<td>boscalid pentiopyrad</td>
<td>Pristine® (7 + 11) Fontelis®</td>
<td>Systemic</td>
</tr>
<tr>
<td>Amino acids and proteins</td>
<td>9</td>
<td>AP (Anilinopyrimidine)</td>
<td>cyprodinil pyrimethanil</td>
<td>Vangard® Scala®</td>
<td>Systemic</td>
</tr>
<tr>
<td>Respiration</td>
<td>11</td>
<td>Strobularin/QoI (quinone outside inhibitor)</td>
<td>pyraclostrobin trifloxystrobin</td>
<td>Pristine® (7 + 11) Flint®</td>
<td>Systemic</td>
</tr>
<tr>
<td>Multi-site</td>
<td>M3</td>
<td>Dithiocarbamate (EBDC)</td>
<td>Carbamate Mancozeb</td>
<td>Ferbam® Dithane®, Manzate®</td>
<td>Protectant</td>
</tr>
</tbody>
</table>

Products with the **same FRAC number**: Behave similarly = cross resistance  
*Except “M” = multi-site

Products with **different FRAC numbers**: Act differently
What is resistance?

- What is resistance?
- FRAC codes and “risk”
- Knowing the fungicides: risk
What is resistance?

“Change in sensitivity of a **pest population** to a particular pesticide”

Why does it develop?

• Genetic mutations at low frequencies
• Naturally occurring sub-populations of resistant individuals

How does it develop?

• **Selection**: Favoring resistant populations
  • Using the same fungicide or similar ones with the same single mode of action over and over
    • **Selection pressure**: Intensity of the selection
      ➢ Exerted by the fungicide
What is resistance?

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

Resistance development: depends on whether fungicide affects a single metabolic site or multiple sites within the fungus

At-risk/High: Products having single-site of action
Disease resistant populations have been discovered

Medium: Mutation of more than one target site
Resistance formation is less frequent

Low: Very rare or undocumented occurrence of resistance
### What is resistance?

**Knowing the fungicides**

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<th>FRAC Group</th>
<th>Fungicide Family</th>
<th>Common Name</th>
<th>Trade Name</th>
<th>Protectant /Systemic</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitosis/cell division</td>
<td>1</td>
<td>Benzimidazole/MBC</td>
<td>Thiophanate-methyl</td>
<td>Topsin M®</td>
<td>Systemic</td>
<td>High</td>
</tr>
<tr>
<td>Sterol biosynthesis</td>
<td>3</td>
<td>DMI /SBI</td>
<td>fenarimol fenbucanazole myclobutanil</td>
<td>Rubigan® Indar® Rally®</td>
<td>Systemic</td>
<td>Medium Medium Medium</td>
</tr>
<tr>
<td>Respiration</td>
<td>7</td>
<td>Carboxamide/SDHI</td>
<td>bosalid penthioyrd</td>
<td>Pristine® (7 + 11) Fontelis®</td>
<td>Systemic</td>
<td>Low – Med Med – High</td>
</tr>
<tr>
<td>Amino acids and proteins</td>
<td>9</td>
<td>AP</td>
<td>cyprodinil pyrimethanil</td>
<td>Vangard® Scala®</td>
<td>Systemic</td>
<td>Medium Medium</td>
</tr>
<tr>
<td>Respiration</td>
<td>11</td>
<td>Strobulfuran/Qol</td>
<td>pyraclostrobin trifloxystrobin</td>
<td>Pristine® (7 + 11) Flint®</td>
<td>Systemic</td>
<td>Low – Med High</td>
</tr>
<tr>
<td>Multi-site</td>
<td>M3</td>
<td>Dithiocarbamate (EBDC)</td>
<td>Carbamate Mancozeb</td>
<td>Ferbam®, Dithane®, Manzate®</td>
<td>Protectant</td>
<td>Low</td>
</tr>
</tbody>
</table>

Products with the **same FRAC number**: Behave similarly = cross resistance
Products with **different FRAC numbers**: Act differently
The best ways to manage resistance

How to proactively avoid fungicide resistance

• Cultural Control

• Chemical Control
Managing resistance

Cultural Control
Good plant health practices = Reduce reliance on fungicides

- Planting: Disease resistant varieties
- Proper pruning
- Minimize stress
- Sanitation
Managing resistance

Cultural Control: Sanitation = Free from pathogens

Development of disease is dependent on the amount of initial inoculum available

- Remove/destroy infected tissue: pathogens overwinter
- Applying Urea to fallen leaves in the fall or spring
  - *Adjust nitrogen fertilizer accordingly
- Shredding leaf litter with a flail mower
- Control weeds
Managing resistance

Chemical Control

- Dormant copper sprays

- Apply fungicides only when necessary
  - Tank mixing
  - Alternate fungicides using FRAC codes

- Follow fungicide label information
  - Number of applications
  - Using recommended doses

- Example: Brown Rot
Managing resistance

**Chemical Control:** “Dormant copper” sprays

Development of disease is dependent on the amount of initial inoculum available

**Goal:** Destroy as much of that initial inoculum early spring

- Initial inoculum: Composed of populations that survived previous year’s spray program
- Copper destroys overwintered inoculum
- Decreases resistant isolates for the new season

Example: Apple Scab

Copper applications reduced DMI resistant isolates present

- Apple scab
- Fire blight
- Bacterial spot
- Peach leaf curl

Pfeufer and Ngugi Phytopathology 2012
Managing resistance

**Chemical Control:**

*Tank mixing fungicides* = high risk (site-specific) + low/negligible risk (multi-site)

**Using a “premix”**: Adament, Pristine, Luna Sensation/Tranquility

* Read labels to determine fungicide compatibility

**Alternate fungicides** with different modes of action, NOT just different label names

*Monitor your orchards to determine how well the fungicides worked and for any signs of failure*

### “Spray by the Numbers”

<table>
<thead>
<tr>
<th>FRAC Group</th>
<th>Fungicide Family</th>
<th>Common Name</th>
<th>Trade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>DMIs /SBIs</td>
<td>fenarimol fenbucanazole myclobutanil</td>
<td>Rubigan®, Indar®, Rally®</td>
</tr>
<tr>
<td>7</td>
<td>Carboxamidess/SDHI s</td>
<td>bosalid pentiopyrad</td>
<td>Pristine® (7 + 11) Fontelis®</td>
</tr>
<tr>
<td>9</td>
<td>APs</td>
<td>cypadinil pyrimethanil</td>
<td>Vangard®, Scala®</td>
</tr>
<tr>
<td>11</td>
<td>Strobulurins/Qols</td>
<td>pyraclostrobin trifloxystrobin</td>
<td>Pristine® (7 + 11) Flint®</td>
</tr>
<tr>
<td>M3</td>
<td>Dithiocarbamates (EBDCs)</td>
<td>Carbamate Mancozeb</td>
<td>Ferbam®, Dithane®, Manzate®</td>
</tr>
</tbody>
</table>
Managing resistance

**Chemical Control:** Follow fungicide label information

- Use at the recommended dose with adequate coverage
- Cutting the rate results in a sublethal dose
- ineffective for disease management
- increases the risk of resistance
- Limits = total for fungicide class

### Table 1. Crop-specific Restrictions and Limitations (continued)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Minimum Time from Application to Harvest (PHI) (days)</th>
<th>Maximum Rate per Acre per Application (ozs product)</th>
<th>Maximum Number of Applications per Season</th>
<th>Maximum Rate per Acre per Season (ozs product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pecan</td>
<td>14</td>
<td>14.5</td>
<td>4</td>
<td>58</td>
</tr>
<tr>
<td>Pome Fruits</td>
<td>0</td>
<td>18.5</td>
<td>4</td>
<td>74</td>
</tr>
<tr>
<td>Stone Fruits</td>
<td>0</td>
<td>14.5</td>
<td>5</td>
<td>72.5</td>
</tr>
<tr>
<td>Prune</td>
<td>0</td>
<td>14.5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Pome Fruits**

**Resistance Management:** To limit the potential for development of resistance, **DO NOT** make more than four (4) applications of Pristine per season.

**DO NOT** make more than two (2) sequential applications of Pristine before alternating to a labeled fungicide with a different mode of action.

**Stone Fruits**

**Resistance Management:** To limit the potential for development of resistance, **DO NOT** make more than five (5) applications of Pristine or other Group 7 or 11 fungicides per season.

**DO NOT** make more than two (2) sequential applications of Pristine before alternating to a labeled fungicide with a different mode of action.
Managing resistance

Chemical Control: Alternate fungicides

Example: Controlling late season Brown Rot*

3 sprays: 18, 9, 1 day preharvest
• Final spray before or after first picking
• >95% control of heavy disease

<table>
<thead>
<tr>
<th>Days before harvest</th>
<th>FRAC code</th>
<th>Fungicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>GROUP 11</td>
<td>Gem® (QoI)</td>
</tr>
<tr>
<td>9</td>
<td>GROUP 7</td>
<td>Fontelis® (SDHI)</td>
</tr>
<tr>
<td>1</td>
<td>GROUP 3</td>
<td>Indar® (DMI)</td>
</tr>
</tbody>
</table>

If you use Pristine...

* From N. Lalancette (Rutgers) “Controlling late season fruit rots” Mid-Atlantic Fruit and Vegetable Conference, Hershey, PA, January 30, 2013
Fungicide failures **may not be** due to resistance

1st: Eliminate other possible causes
   - Fungicide application
   - Environmental and plant growth conditions
   - Fungi characteristics

When other possible causes have been eliminated, ask:
   - Does the field have a history of extensive at-risk fungicide use?
   - Has *little to no* nonchemical control methods been used?

When in doubt:
   - Contact your local Extension Specialist
**Take home messages:**

★ Pay attention to FRAC codes on the fungicide label
  - Site-specific = systemic = Risk for resistance
  - Multi-site = protectant = Low risk for resistance

**Mindful Fungicide Resistance Management**
  - “Spray By The Numbers”
  - Fungicides: Dormant sprays, Tank Mix
  - Keep your orchards healthy and clean

**If you have a fungicide failure**
  - Eliminate other causes first
  - Have you been following a resistance management program?
  - Contact your local Extension Specialist

**Questions?**