Basics of Strawberry Disease Management and Late-season Bunch Rot

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Outline

- Multi-year monitoring of fungicide resistance in *Botrytis species* from strawberries

- Anthracnose crown and fruit rot on strawberries

- Last season bunch rot
Gray Mold of Strawberry

Fungus overwinters in organic plant debris and comes in on nursery stock. Conidiophore with conidia infects aging blossom parts. Conidia are spread by wind during periods of prolonged moisture. Infections spread from flower into fruit. Direct infection of mature fruit can occur. Mature fruit are covered with fuzzy conidial masses. Fungus infects aging blossom parts.
**Gray Mold Disease of Strawberry**

![Botrytis cinerea](image)

**Botrytis cinerea**

**HIGH RISK pathogen for fungicide resistance development**

<table>
<thead>
<tr>
<th>Mode of Action</th>
<th>Group name</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methionine biosynthesis</td>
<td>Anilinopyrimidines (FRAC 9)</td>
<td>Single-site</td>
</tr>
<tr>
<td>Mitosis and cell division</td>
<td>Benzimidazole Carbamates (FRAC 1)</td>
<td></td>
</tr>
<tr>
<td>Signal transduction</td>
<td>Dicarboxamides (FRAC 2)</td>
<td></td>
</tr>
<tr>
<td>Membrane sterol biosynthesis</td>
<td>Hydroxyanilides (FRAC 17)</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>Quinone Outside Inhibitors (FRAC 11)</td>
<td></td>
</tr>
<tr>
<td>Signal transduction</td>
<td>Phenylpyrroles (FRAC 12)</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>Succinate Dehydrogenase Inhibitors (FRAC 7)</td>
<td></td>
</tr>
<tr>
<td>Chitin biosynthesis</td>
<td>Polyoxin D zinc salt (FRAC 19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dithiocarbamates (thiram, M3)</td>
<td>Multi-site</td>
</tr>
<tr>
<td></td>
<td>Phthalimides (captan, M4)</td>
<td></td>
</tr>
</tbody>
</table>
Two Faces of Reduced-Risk Fungicides

Pristine
(FRAC 7 + FRAC 11)

Sensitive strain

Resistant strain
Multifungicide Resistance in B. cinerea from Strawberry (North and South Carolina)

Li et al, Plant Dis. 2014
Initiation of Regionwide Fungicide Resistance Monitoring
**What Growers are Getting**

- Latest Recommendations
- Latest Efficacy Table
- E-mail with Summary of Results and Personalized Recommendations
- Resistance Profile Results - Details in Spreadsheet
Have Your Strawberry Samples Test for Resistance

Flower/leave samples (early season)  Fruit samples (maturing stage)

Mailing your samples:

Attach the Resistance Profile Form to the corresponding sample and send either by regular mail OR overnight to:

Dr. Guido Schnabel
Clemson University 105
Collings St./220 BRC
Clemson, SC 29634 Cell 864-643-7131
Frequency of Fungicide Resistance in B. cinerea from Strawberry Flowers from East Coast

![Graph showing frequency of fungicide resistance in B. cinerea from strawberry flowers from East Coast. The x-axis represents different active ingredients, and the y-axis shows the frequency of resistant isolates (%). The graph includes data for the years 2011-12 to 2016-17, with sample sizes ranging from 220 to 820 isolates.]
Multifungicide Resistance in the Same Isolates

Frequency of multifungicide resistant phenotypes (%)

Resistant phenotypes

0CCR 1CCR 2CCR 3CCR 4CCR 5CCR 6CCR 7CCR

2011-12 n = 220
2012-13 n = 440
2013-14 n = 820
2014-15 n = 650
2015-16 n = 740
2016-17 n = 440
## Mutations in 7CCR Isolates in the Eastern US

<table>
<thead>
<tr>
<th>FRAC code</th>
<th>Gene</th>
<th>Isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td>7, bosalid</td>
<td><em>SdhB</em></td>
<td>H272R, H272R</td>
</tr>
<tr>
<td>9, cyprodinil</td>
<td>N/A</td>
<td>N/A, N/A</td>
</tr>
<tr>
<td>17, fenhexamid</td>
<td><em>Erg27</em></td>
<td>T63I, F412S</td>
</tr>
<tr>
<td>12, fludioxonil</td>
<td><em>Mrr1/Atrb</em></td>
<td>MDR1h, MDR1h</td>
</tr>
<tr>
<td>2, iprodione</td>
<td><em>Bos1</em></td>
<td>I365N, I365S</td>
</tr>
<tr>
<td>11, pyraclostrobin</td>
<td><em>Cytb</em></td>
<td>G143A, G143A</td>
</tr>
<tr>
<td>1, T-methyl</td>
<td>β-tubulin</td>
<td>F200Y, E198A</td>
</tr>
</tbody>
</table>
Fludioxonil (Switch), Currently a Favorite With Growers

- Fewer resistance issues
- Very good efficacy against gray mold AND some efficacy against anthracnose fruit rot
- >48 h post infection activity
- But: expensive, inbuilt resistance management (cyprodinil) is failing, not available as solo product
- increased usage WILL select for resistance
**Newer FARC7 (SDHI) fungicide**

**Kenja** (a.i.: isofetamid)
- Few resistance issues; PHI = 0 days
- Very good efficacy against gray mold
- Increased usage WILL select for resistance

**Luna Series** (Privilege, Sensation, and Tranquility; a.i.: fluopyram)

**Fontelis** (a.i.: penthiopyrad)

**Merivon** (a.i.: fluxapyroxad)
Conclusions

• After more than a decade of applying fungicides of multiple FRAC codes, resistance to many FRAC codes is now common in *B. cinerea*

• Resistance management recommendations need to be adjusted
  – Spray less frequently
  – Use primarily multi-site fungicides
  – Limit each FRAC code to 2 applications per season
  – Avoid using single-site fungicides alone during critical stages
Strawberry Anthracnose

Fungal Pathogen

1. *Colletotrichum acutatum*
   - Primarily causes anthracnose fruit rot
   - Also infects runners, peduncles, and pedicels
   *Very common

2. *Colletotrichum gloeosporioides*
   - Primarily causes anthracnose crown rot
   *More serious but less common*
Effective fungicides for anthracnose control

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Active Ingredient</th>
<th>FRAC Code</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFTERSHOCK</td>
<td>Fluoxastrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>AZAKA</td>
<td>Azoxystrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>ABOUND</td>
<td>Azoxystrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>Cabrio</td>
<td>Pyraclostrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>Evito</td>
<td>Fluoxastrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>Gatten</td>
<td>Mandestrobin</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>Luna Sensation</td>
<td>Fluopyram, trifloxystrobin</td>
<td>7, 11</td>
<td>E</td>
</tr>
<tr>
<td>Merivon</td>
<td>Fluxapyroxad, pyraclostrobin</td>
<td>7, 11</td>
<td>E</td>
</tr>
<tr>
<td>Pristine</td>
<td>Boscalid, pyraclostrobin</td>
<td>7, 11</td>
<td>E</td>
</tr>
<tr>
<td>Quadris Top</td>
<td>Difenoconazole, Azoxystrobin</td>
<td>3, 11</td>
<td>E</td>
</tr>
<tr>
<td>QuiltXcel</td>
<td>Propiconazole, Azoxystrobin</td>
<td>3, 11</td>
<td>E</td>
</tr>
<tr>
<td>Switch</td>
<td>Cyprodinil, Fludioxonil</td>
<td>9, 12</td>
<td>G</td>
</tr>
<tr>
<td>Captan</td>
<td>Captan</td>
<td>M4</td>
<td>G</td>
</tr>
<tr>
<td>Captec</td>
<td>Captan</td>
<td>M4</td>
<td>G</td>
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</tbody>
</table>

Resistance to FRAC 11 is common
Colletotrichum spp. Affecting peach

1. *Colletotrichum gloeosporioides* *
   - *C. siamense*
   Isolates from peach resistant to FRAC 1 & FRAC 11
   - *C. fructicola*

2. *Colletotrichum acutatum* *
   - *C. nymphaeae*
   - *C. fioriniae*
   - *C. fioriniae-like*
     Inherently resistant to FRAC 1

3. *Colletotrichum truncatum* *

   *Inherently resistant to most FRAC 7 fungicides*
Sensitivity of Colletotrichum Species to FRAC 3 Fungicides

Chen et al., Plant Dis. 2016
## Summary Sensitivity Chart

<table>
<thead>
<tr>
<th>Species/subspecies</th>
<th>FRAC 1</th>
<th>FRAC 11</th>
<th>Dif</th>
<th>Pro</th>
<th>Teb</th>
<th>Met</th>
<th>Flu</th>
<th>Fen</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. gloeosporioides</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>C. siamense</em></td>
<td>S/R</td>
<td>S/R</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td><em>C. fructicola</em></td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td><em>C. acutatum</em></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td><em>C. nymphaeae</em></td>
<td>R</td>
<td>S</td>
<td>S</td>
<td>R</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td><em>C. fioriniae</em></td>
<td>R</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td><em>C. fioriniae-like</em></td>
<td>R</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><em>C. truncatum</em></td>
<td>S</td>
<td>S</td>
<td>RS</td>
<td>RS</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

* Dif = difenoconazole, pro = propiconazole, teb = tebuconazole, met = metconazole, flu = flutriafol, fen = fenbuconazole; S = sensitive, R = resistant (>2ppm)
Late-season bunch rots

1. *Botrytis bunch rot* (caused by *Botrytis cinerea*)

**Diagnostic symptoms**
-Fruit turning brown at first followed by production of gray spores
-Often occurs after varaison as fruit is nearing harvest
-Overwinter as sclerotia in berry mummies or as dormant mycelium in plant debris
-Largely relies on fungicide control, but resistance issues are common

**Effective fungicides:** Captan, Switch, Kenja, Luna Experience etc.
2. Ripe rot (caused by Colletotrichum spp.)
Symptoms: berry shriveling and browning; black specks on surface
Overwinters in mummified fruit or plant debris
Dispersal by water splash and/or wind
Infection can occur anytime from bloom to harvest
3. *Sour rot (disease complex)*

- Characterized by sour odor
- Considered to be a disease complex, consisting of insect damage (fruit flies), bacterial and fungal infections.

- No fungicides available
  - Good control of fruit flies after 15° Brix may be helpful
4. Other late season rots

In an association with secondary pathogens such as Alternaria, Aspergillus, and Penicillium....
Secondary pathogens normally need entry points to infect
When do you manage fungal fruit diseases? It depends on the disease!

Preventative sprays are of paramount importance!