GRAPE MILDEW MANAGEMENT:
MORE THAN "WHAT'S IN THE TANK?"

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PROGRAM APPROACH

Understanding the fundamentals of host, pathogen, and sprayers.

THE HOST

- Indeterminate shoot growth
- Zone of fruit development
- Bark and latent buds
**ONTOGENIC RESISTANCE – LEAVES**

- Transitioning leaves are simultaneously sources and sinks
- Newest (and oldest) leaves are *not* the most susceptible

Arrow indicates the leaf that is no longer importing assimilates

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**LOOKING DIRECTLY AT HISTORY**

When did these infections happen?

Can you “correct” this?
ONTOGENIC RESISTANCE – GRAPE BERRIES

THE CATCH – WHEN IS “BLOOM”?

Synchronous Bloom

Asynchronous Bloom
THE PATHOGEN


HOW DISEASE STARTS

WHEN DISEASE SHOWS UP

Cleistothecia: The disease kick-starter

- Can release spores from mid-winter to late spring
- Practical timing for management:
  1. Release after budbreak
  2. With 0.1” rain (or heavy fog);
  3. and temperature >50ºF
- The timing of formation influences the timing of release

IN-SEASON DISEASE DEVELOPMENT
**THE GOLDILOCKS PRINCIPLE**

- **PM doesn't like it hot or cold**
- **PM doesn't like it dry**
- **PM doesn't like it sunny**

**MICROCLIMATES – WHAT IS OUTSIDE IS NOT INSIDE**

Canopy microclimate is a major influence on disease development

- **Fruit-zone leaf removal BEFORE**
- **Fruit-zone leaf removal AFTER**
SPRAY PRACTICES CAN INFLUENCE MANAGEMENT

Poor “Timing” or Technique

Poor Maintenance or Operation

WHAT DO YOU LOOK FOR IN A SPRAYER?

- **Ease of use**
  - Longevity of the machine
  - Can it be customized?
- **User Friendly**
  - How well does it work?
- **Maintenance**
  - Mechanical preferences
  - Parts availability
- **Fit for the farm**
  - Tank size
  - Is it compatible with my crops?
- **Tehs and Specs**
  - Machine size
  - Compatible products?
  - Nozzle style
  - Suitable droplet size
  - Deposition pattern?
  - Is drift an issue?
  - Air volume and direction
**NOZZLE STYLE**

**Exchangeable**
- Disc-Core
- One piece
- Air Induction

**Stationary Pneumatic**
- Air shear
- Electrostatic

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**NOZZLE MATERIAL AND MAINTENANCE**

<table>
<thead>
<tr>
<th>Spray Nozzle Material</th>
<th>Resistance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>1</td>
</tr>
<tr>
<td>Brass</td>
<td>1</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Steel</td>
<td>1.5 - 2</td>
</tr>
<tr>
<td>Monel®</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>4 - 6</td>
</tr>
<tr>
<td>Hastelloy®</td>
<td>4 - 6</td>
</tr>
<tr>
<td>Hardened Stainless Steel</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Stellite®</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Silicon Carbide (Nitride Bonded)</td>
<td>90 - 130</td>
</tr>
<tr>
<td>Ceramics</td>
<td>90 - 200</td>
</tr>
<tr>
<td>Carbides</td>
<td>180 - 250</td>
</tr>
<tr>
<td>Synthetic ruby or sapphire</td>
<td>800 - 2000</td>
</tr>
</tbody>
</table>

- Having a low ratio value indicates material wearing easier then high values.
  - Corrosive materials
- Stationary pneumatic nozzles do not have resistance ratios.

*Source: How to Pre-empt a Significant Profit Drain: Nozzle Wear*
DROPLET SIZE VMD: ASABE-572.1 STANDARD

**Droplet size matters**

>300 um will bounce

<150 um will drift

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Color Code</th>
<th>Approx. VMD Range (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Fine</td>
<td>XF</td>
<td>Purple</td>
<td>&lt;60</td>
</tr>
<tr>
<td>Very Fine</td>
<td>VF</td>
<td>Red</td>
<td>60-145</td>
</tr>
<tr>
<td>Fine</td>
<td>F</td>
<td>Orange</td>
<td>145-225</td>
</tr>
<tr>
<td>Medium</td>
<td>M</td>
<td>Yellow</td>
<td>226-325</td>
</tr>
<tr>
<td>Coarse</td>
<td>C</td>
<td>Blue</td>
<td>326-400</td>
</tr>
<tr>
<td>Very Coarse</td>
<td>VC</td>
<td>Green</td>
<td>401-500</td>
</tr>
<tr>
<td>Extremely Coarse</td>
<td>EC</td>
<td>White</td>
<td>501-650</td>
</tr>
<tr>
<td>Ultra Coarse</td>
<td>UC</td>
<td>Black</td>
<td>&gt;650</td>
</tr>
</tbody>
</table>

Slide courtesy of Gwen Hoheisel, WSU

GENERAL SPRAYER MAINTENANCE AND OPERATION

- **Maintenance**
  - Change nozzles at least every other year (annually preferred)
  - Adjust nozzle/spray head position
  - Don’t blindly trust rate controllers

- **Operation**
  - Gear up, throttle down
  - [Early season]: Do you really need air?
  - Spray at the speed you calibrate
  - Direct vs. angled spraying
  - Calibrate routinely
MANAGEMENT TIMING

What influences the *WHEN*?

INFLUENCE OF VINE DEVELOPMENT ON MGMT

- Rate of vine growth
- Cold / frost damage = latent and count bud break
- When 6 inches is really 12 inches…
INFLUENCE OF SPRAY PRACTICES ON MGMT

• S-T-R-E-T-C-H-E-D spray intervals early season

• Low water volume on large canopies late season

LET’S TALK A LITTLE MORE ABOUT WATER…

What is “low volume”?  Optional vs. Required

- 300 gal → 100 gal  - Changing water volume with canopy size
- 100 gal → 50 gal  - Low-volume specification for sprayer
- 50 gal → 30 gal
- 30 gal → 10 gal
PRE-SEASON ERADICATION VS. IN-SEASON MGMT

• Eradicating mildew before the season starts can help you...if you do nothing else
  – But you always do something else. Nothing beats a good in-season program
• Spend your money on starting early (3” shoot growth)

TIMING FOR DISEASE MANAGEMENT

Early Management
Early intervention (post bud break) critical in keeping inoculum levels down.

Critical Window
Will provide majority of your disease control. This is a time where errors become obvious.
WHAT TO USE EARLY SEASON?

**Contacts**
- **Pros:**
  - Many have eradicant properties
  - Canopies are small so coverage is good
- **Cons:**
  - Only effects what it touches
  - Short efficacy intervals

**Synthetic/Systemics**
- **Pros:**
  - Longer efficacy windows
  - Poor coverage is overcome by movement
- **Cons:**
  - Dilution with rapid plant growth
  - Protectants, not eradicants

INFLUENCE OF ENVIRONMENT ON MANAGEMENT

<table>
<thead>
<tr>
<th>Powdery Mildew Information</th>
<th>Conventional</th>
<th>Latent Period (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budbreak</td>
<td>8-Apr</td>
<td></td>
</tr>
<tr>
<td>Date of 1st infection</td>
<td>17-Apr</td>
<td>13</td>
</tr>
<tr>
<td>Date to sporulation of next generation</td>
<td>30-Apr</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>9-May</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>18-May</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>26-May</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2-Jun</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>9-Jun</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>18-Jun</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>25-Jun</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2-Jul</td>
<td>9</td>
</tr>
</tbody>
</table>

- Powdery mildew can start off slow in the spring
- But disease can rapidly pick up
- Environment not only influences pathogen biology, but will also influence control options

<table>
<thead>
<tr>
<th>Month</th>
<th>$T_{max} &gt;95^\circ F$</th>
<th>$T_{min} &lt;40^\circ F$</th>
<th>$T_{ave} &lt;65^\circ F$</th>
<th>Ave Wind Speed &gt; 8 mph</th>
<th>Wind Gusts above 12 mph</th>
<th>Measurable Precip*</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>9</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>May</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>8</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>June</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>12</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>July</td>
<td>19</td>
<td>0</td>
<td>31</td>
<td>7</td>
<td>22</td>
<td>2</td>
</tr>
</tbody>
</table>

*Total for period: 1.07 inches
WIND – WHEN TO SPRAY

<table>
<thead>
<tr>
<th>Wind Condition</th>
<th>Wind Speed</th>
<th>Description</th>
<th>Spray?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still</td>
<td>0-1.25mph</td>
<td>Vapor drift, and evaporation</td>
<td>Do Not Spray</td>
</tr>
<tr>
<td>Gusty</td>
<td>N/A</td>
<td>Missed target and high drift</td>
<td>Do Not Spray</td>
</tr>
<tr>
<td>Light air</td>
<td>1.25-2mph</td>
<td>Suitable for spraying</td>
<td>Spray</td>
</tr>
<tr>
<td>Light to gentle breeze</td>
<td>2-5mph</td>
<td>Ideal for spraying</td>
<td>Spray</td>
</tr>
<tr>
<td>High wind</td>
<td>6-10mph</td>
<td>High drift and missed target, wasted spray</td>
<td>Do Not Spray</td>
</tr>
</tbody>
</table>

TEMPERATURE AND HUMIDITY

- High temps and low humidity cause the droplets to evaporate
- Small droplets drift!

PRODUCTS

How they work.

FUNGICIDE HISTORY (ABRIDGED)

<table>
<thead>
<tr>
<th>Year</th>
<th>Product</th>
<th>Year</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1824</td>
<td>sulfur dust</td>
<td>1992</td>
<td>azoxystrobin, kresoxim-methyl</td>
</tr>
<tr>
<td>1833</td>
<td>lime sulfur</td>
<td>1997</td>
<td>quinoxyfen</td>
</tr>
<tr>
<td>1885</td>
<td>Bordeaux Mix</td>
<td>1998</td>
<td>trifloxystrobin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>pyraclostrobin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2006*</td>
<td>metrafenone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012*</td>
<td>cyflufenamid</td>
</tr>
<tr>
<td>1968</td>
<td>benomyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>thiophanate methyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>fenarimol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>penconazole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>myclobutanil, tebuconazole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>difenoconazole tetraconazole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Synthetic fungicide use is relatively new.

Humans generally have better hindsight that foresight.

Modified from: http://www.asn-net.org/publications/academicfeatures/Pages/Fungicides.aspx
CLASSIFICATION – ROLE IN PROTECTION

OVERVIEW – FUNGICIDES / INSECTICIDES

Two main groups of pesticides:

• **Contact** pesticide
  - Remains outside of the plant
  - May redistribute

• **Penetrant** pesticide
  - May be locally systemic
  - May move throughout the plant.

## FUNGICIDE RISK

<table>
<thead>
<tr>
<th>RISK of Resistance</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulfur, oils, potassium bicarbonates, materials of biological origin</td>
<td>metrafenone, fenhexamid, quinoxyfen</td>
<td>cyflufenamid</td>
<td></td>
</tr>
<tr>
<td><strong>DMIs:</strong></td>
<td><strong>SDHIs:</strong></td>
<td><strong>Qols / strobilurins:</strong></td>
<td></td>
</tr>
<tr>
<td>difenoconazole, myclobutanil triflumizole, tetraconazole, tebuconazole, fenarimol</td>
<td>bosalid → fluopyram</td>
<td>azoxystrobin, pyraclostrobin, kresoxim-methyl, trifloxystrobin,</td>
<td></td>
</tr>
</tbody>
</table>

High-risk products are not bad; **poor fungicide stewardship** is.

## TYPES OF RESISTANCE

- **Qualitative (sudden)**
  - QoI
  - Flint
  - Pristine

- **Quantitative (gradual/rate dependent)**
  - DMI
  - Procure
  - Rally
  - fenarimol
  - tebuconazole

HOW FIELD RESISTANCE EMERGES

Qualitative Resistance (FRAC 11)

Quantitative Resistance (FRAC 3)

WHY ROTATION MATTERS

When you DON’T rotate

When you DO rotate
MANAGEMENT…

Without, or with, resistance challenges.

CULTURAL PRACTICES WILL HELP
### SELECTING SPRAY RATES

**Table 1. Use Directions for Grapes**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Target Disease</th>
<th>Fluid Ounces of Product (lb a) per Acre</th>
<th>Maximum Product Rate per acre per season</th>
<th>Last Application Days to Harvest</th>
</tr>
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<tbody>
<tr>
<td>Grapes</td>
<td>Powdery mildew</td>
<td>10.3 to 15.4 (0.20 to 0.30)</td>
<td>48.2 fl oz (0.6 lbs a)</td>
<td>14</td>
</tr>
</tbody>
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**Why are there rate ranges?**
- Role of fungicide (protectant, curative)
- Timing relative to plant growth

### SELECTING SPRAY INTERVALS

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</tbody>
</table>

**Why are there interval ranges?**
- Duration of efficacy influenced by rate
- Duration of efficacy influenced by activity against fungus
Tank Mixing

MANAGEMENT CONSIDERATIONS: WITH RESISTANCE

- Tank-mixing involves applying 2 MOAs simultaneously in the field
- Some product formulations already do this for you
  - Pristine, Unicorn, Inspire Super, etc.
- A cheap tank mix is the addition of a contact
  - Example: 3 lbs sulfur, 0.5%-1% oil
  - Check for phytotoxicity
  - Check for chemical incompatibility

Rotations

MANAGEMENT CONSIDERATIONS: WITH RESISTANCE

- Within a season
  - Disease management principles still apply
  - Synthetics early season vs. late season
    - Early season --- may not have all resistant isolates, but might lose disease control if subsequent sprays are inappropriate…
    - Late season --- may avoid disease control loss during “critical window” but might select for more resistant isolates for next year…
- Within a rotation
  - Tank mix with contact products (if appropriate)
  - Ensure proper coverage and water volume
### Management Considerations: With Resistance

1. Use FRAC 11 fungicides early *(but not the first spray!)* if you cannot avoid their use, and apply with a product of another mode of action.

2. **Avoid** the use FRAC 11 fungicides during the critical window if you have had confirmed resistance in your vineyard.

3. Consider an every-other-year rotation option?

---

### The Silver Lining to Our Current Situation

The forever optimist.
WE CAN TEST FOR FRAC 11 RESISTANCE

- Sometimes, being ahead of your time is a challenge
- Historically, resistance is dealt in hindsight
- Do we have the foresight to manage resistance as it's happening?

REDUCED FITNESS WITH RESISTANCE?

- Some resistance is durable
- Some resistance has a cost
  - Reduced growth
  - Reduced sporulation
  - Longer latent periods
- Fitness costs may be exploited to help manage resistance?

Preliminary data is encouraging--- the return of sensitive populations

- But how much “return” is needed before we can confidently use those products?
- How many years will that take?

Is there always a few resistant isolates in a population?

How does drift (of pathogen, of product) affect this?

HOW TO MAXIMIZE MANAGEMENT PRACTICES

1. Plan ahead – program, parts, products
2. Have enough equipment to do the job well (… to do the job right!)
3. Make sure your equipment works like you think it should
4. Communicate your management practices and goals
5. Follow-up: Things do not always go according to plan.
QUESTIONS?

VITICULTURE EXTENSION
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