Managing Disease in Wisconsin Hops
Fungicide & Project Updates

Amanda J. Gevens, Ruth Genger, Kenneth Frost, Michelle Marks

Plant Pathology

University of Wisconsin-Madison

Hop Production Seminar
March 1, 2014 - 10:30-11:15AM
The Great Dane Brewery, Wausau, WI

Photo courtesy (left-right): NC State Coop. Ext.; Oregon Dept. of Ag.; David Gent
Components of an Integrated Pest Management Program

- Monitoring and Sampling (inspect)
- Pathogen Identification (what pathogen)
- Decision-making (what action(s))
- Intervention (take action(s))
- Follow-up (re-inspect)
- Record-keeping (write it down, history)
- Education (learn)
Integrated Disease Management
Options for Disease Management – not all available in hops

- Cultural controls
- Grafting
- Transgenic plants
- Host resistance
- Reduced-Risk Fungicides
- Biological controls

IPM
Powdery Mildew
*Podosphaera macularis*

PM disease develops at 64 to 70°F and reduced when >75°F. Infection can be greatly reduced by short intervals (> 2 h) of temperatures >86°F. Higher temperatures reduce the susceptibility of leaves to infection.

No known detections of powdery mildew on hops in WI in 2013 or recent years.

Photo courtesy: David Gent
Powdery Mildew Management

Low disease incidence in yards with few flag shoots or that were pruned thoroughly in spring. Disease management practices prior to pruning likely were not needed if the pruning was done such that no green plant tissue was left (Washington study, Turechek 2001)

Potential savings with early pruning practice are estimated at $60-$120/acre, depending on the method of pruning and irrigation. Pruning must be done very well if fungicide applications are to be delayed until after spring pruning, which can be difficult to achieve in practice because of logistical constraints (Gent et al., 2008)

Cone infection is greater in poorly pruned yards (Gent, unpublished).

Management of powdery mildew in cones is dependent on the success and thoroughness of early season control measures.
A hop variety can carry a gene or genes for resistance to powdery mildew (PM)

There are 7 resistance genes to PM in hops

- Rb
- R1
- R2
- R3
- R4
- R5
- R6

Gene-for-gene relationship between hops PM races and host resistance
Varietal resistance to powdery mildew in hops

- Varieties resistant to Pac NW PM:
  - ‘Nugget’ (R6)
  - ‘Cascade’ (R5)
  - ‘Mt. Hood’

- Varieties moderately resistant to Pac NW PM:
  - ‘Fuggle’
  - ‘Perle’
  - ‘Tettnang’
  - ‘Hallertau’

- Varieties susceptible to Pac NW PM include:
  - ‘Horizon’
  - ‘Columbus’
  - ‘Tomahawk’
  - ‘Zeus’
  - ‘Cluster’
  - ‘Chinook’
  - ‘Willamette’
  - ‘Liberty’
  - ‘Chelan’
  - ‘Eroica’
  - ‘Symphony’
  - ‘Galena’
  - Any variety with Rb PM resistance gene
<table>
<thead>
<tr>
<th>Fungicides for hop powdery mildew control, WI Feb 28, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Powdery mildew (Podosphaera macularis and humili)</strong></td>
</tr>
<tr>
<td>trifloxystrobin 11</td>
</tr>
<tr>
<td>1.0 oz with every 15-30 gal spray volume Flint</td>
</tr>
<tr>
<td>14 DAYS PHI</td>
</tr>
<tr>
<td>Apply preventatively for best results. Apply on a 10 to 14 day interval. Follow resistance management guidelines.</td>
</tr>
<tr>
<td>pyraclostrobin and boscalid 11, 7</td>
</tr>
<tr>
<td>14.0 oz/100 gal spray volume Pristine</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>Use preventatively and apply at 14-21 day intervals as needed. Follow resistance management guidelines.</td>
</tr>
<tr>
<td>myclobutanil 3</td>
</tr>
<tr>
<td>2.0-10.0 oz Rally</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>Emergence to training label rate is 2-4 oz/training to wire is 4-6 oz/wire to 14-day prior to harvest is 6-10 oz. Follow resistance management guidelines. (Old product name was Nova)</td>
</tr>
<tr>
<td>tebuconazole 3</td>
</tr>
<tr>
<td>4.0-8.0 fl oz Monsoon, ONSET 3.6L, Orius 3.6F, Tebustar 3.6L, Tebuzol 3.6F, Toledo 3.6F</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>Apply at 10 to 14 day intervals. Follow resistance management guidelines.</td>
</tr>
<tr>
<td>triflumizole 3</td>
</tr>
<tr>
<td>12.0 fl oz Procure 480SC</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>Use prior to or at disease onset for best results and reapply on a 14 day schedule.</td>
</tr>
<tr>
<td>quinoxyfen 13</td>
</tr>
<tr>
<td>4.0-8.2 fl oz Quintec</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>Follow resistance management guidelines, including ‘do not apply more than 4X per season.’ Minimum spray interval is 7 days.</td>
</tr>
</tbody>
</table>
## Powdery mildew (*Podosphaera macularis* and *humili*)

<table>
<thead>
<tr>
<th>Fungicide Type</th>
<th>Active Ingredient</th>
<th>Rate and Application</th>
<th>PHI</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>potassium bicarbonate</td>
<td>2.5-5.0 lb/100 gal spray volume Armicarb 100</td>
<td>0 DAYS PHI</td>
<td>Do not exceed mix rate of 5.0 lb/100 gal of water. Do not store unused portion of spray for more than 12 hours prior to use.</td>
<td></td>
</tr>
<tr>
<td>sodium bicarbonate</td>
<td>4.0 oz/10 gal water spray volume Milstop</td>
<td>0</td>
<td>Begin application when weather favors disease and apply at 1 to 2 week intervals. Tighten intervals when disease pressure heightens.</td>
<td></td>
</tr>
<tr>
<td>copper octanoate</td>
<td>0.5-2.0 gal Cueva in 100 gal water</td>
<td>14</td>
<td>Apply soon after training vines.</td>
<td></td>
</tr>
<tr>
<td>potassium bicarbonate</td>
<td>2.5-5.0 lb Kaligreen</td>
<td>1</td>
<td>Apply when weather conditions favor disease and repeat on a 7-10 day basis.</td>
<td></td>
</tr>
<tr>
<td>mono and dipotassium salts of phosphorous acid</td>
<td>1-3 qt/100 gal water Phosphite</td>
<td>0</td>
<td>Apply at 2 to 3 week intervals. Do not apply at an interval less than 3 days.</td>
<td></td>
</tr>
<tr>
<td>Extract of <em>Reynoutria sachalinensis</em></td>
<td>1.0-4.0 qt Regalia</td>
<td>0</td>
<td>Use preventatively and apply at 7 day intervals as needed. Emergence to wire-touch 1.0-2.0 qt recommended/wire-touch through harvest 2.0-4.0 qt. OMRI approved.</td>
<td></td>
</tr>
</tbody>
</table>
Fungicides for hop powdery mildew control, WI Feb 28, 2014

<table>
<thead>
<tr>
<th>Powdery mildew (<em>Podosphaera macularis</em> and <em>humili</em>)</th>
<th>Bacillus subtilis QST 713 strain</th>
<th>4.0-6.0 qt/100 gal spray volume of Serenade ASO</th>
<th>0 DAYS PHI</th>
<th>Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus subtilis QST 713 strain</td>
<td>2.0-3.0 lb/100 gal spray volume of Serenade MAX</td>
<td>0</td>
<td>Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.</td>
<td></td>
</tr>
<tr>
<td>Bacillus pumilis QST 2808</td>
<td>2.0-4.0 qt/100 gal spray volume of Sonata</td>
<td>0</td>
<td>Use when conditions favor disease and apply at 7-14 day intervals as needed. OMRI approved.</td>
<td></td>
</tr>
<tr>
<td>neem oil</td>
<td>0.5%-1.0% in 25-100 gal water spray volume of Trilogy</td>
<td>0</td>
<td>Use when conditions favor disease and apply at a 7-14 day interval as needed. OMRI approved. Also a miticide/insecticide.</td>
<td></td>
</tr>
</tbody>
</table>
# Fungicide Resistance Mitigation

http://www.frac.info/index.htm

## FRAC Fungicide Resistance Action Committee

<table>
<thead>
<tr>
<th>MOA</th>
<th>TARGET SITE AND CODE</th>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>COMMON NAME</th>
<th>COMMENTS</th>
<th>FRAC CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1:</td>
<td>complex I NADH Oxido-reductase</td>
<td>pyrimidinines</td>
<td>pyrimidinines</td>
<td>diflumetrol</td>
<td>Resistance not known.</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>phenyl-benzamides</td>
<td>phenyl-benzamides</td>
<td>benodanil</td>
<td>Resistance known for several fungal species in field populations and lab mutants.</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pyridyl-ethyl-benzamides</td>
<td>pyridyl-ethyl-benzamides</td>
<td>fluopyram</td>
<td>Medium to high risk.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>furan-carboxamides</td>
<td>furan-carboxamides</td>
<td>fenfuram</td>
<td>See FRAC SDHI Guidelines for resistance management.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oxathioli-carboxamides</td>
<td>oxathioli-carboxamides</td>
<td>carboxin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>thiazole-carboxamides</td>
<td>thiazole-carboxamides</td>
<td>thiulfuram</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>pyrazole-carboxamides</td>
<td>pyrazole-carboxamides</td>
<td>benzonil</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pyridine-carboxamides</td>
<td>pyridine-carboxamides</td>
<td>bosalid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2:</td>
<td>complex II succinate-dehydrogenase</td>
<td>SDHI (Succinate dehydrogenase Inhibitors)</td>
<td>methoxy-acrylates</td>
<td>azoxystrobin</td>
<td>Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms.</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>methoxy-carbamates</td>
<td>methoxy-carbamates</td>
<td>pyraclostrobin</td>
<td>High risk.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oxmino acetals</td>
<td>oxmino acetals</td>
<td>kresoxim-methyl</td>
<td>See FRAC Qol Guidelines for resistance management.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oxmino-acetamides</td>
<td>oxmino-acetamides</td>
<td>dimethoxynitrofen</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oxazolidine-diones</td>
<td>oxazolidine-diones</td>
<td>fludioxonil</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>dihydro-oxazinones</td>
<td>dihydro-oxazinones</td>
<td>famoxadone</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>imidazolinones</td>
<td>imidazolinones</td>
<td>fenamidone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>benzyl-carbamates</td>
<td>benzyl-carbamates</td>
<td>pyribencarb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3:</td>
<td>complex III cytochrome bc1 (ubiquinone oxidase) at Qo site (cyt b gene)</td>
<td>Qo1-fungicides (Quinone outside Inhibitors)</td>
<td>cyano- imidazole</td>
<td>cyazofamid</td>
<td>Resistance risk unknown but assumed to be medium to high (mutations at target sites known in other organisms), Resistance management required.</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sulfamoyl-triazole</td>
<td>sulfamoyl-triazole</td>
<td>amisulbrom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4:</td>
<td>complex III cytochrome bc1 (ubiquinone oxidase) at Ql site</td>
<td>Ql - fungicides (Quinone Inside Inhibitors)</td>
<td>dinitrophenyl-crotonates</td>
<td>bnapacryl</td>
<td>Resistance not known. Also acaridial activity, low risk.</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,6-dinitro-</td>
<td>2,6-dinitro-</td>
<td>meptyldinocap</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MOA**
- C1: Mitochondrial electron transport chain
  - Complex 1
  - Complex 2
  - Complex 3
- C4: NADH Oxido-reductase
  - Complex 1
- C5: Uncouplers of the proton gradient
# Powdery Mildew Fungicides

## Standard protectants
- Coppers (Nu-Cop, Kocide, Cueva, etc.)

## Reduced risk fungicides
- **boscalid (7) + pyraclostrobin (11) (Pristine)**
- trifloxystrobin (Flint)
- **boscalid (7) + pyraclostrobin (11) (Pristine)**

<table>
<thead>
<tr>
<th>Group</th>
<th>SDHIs</th>
<th>QoI inhibitors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 7</td>
<td>Group 11</td>
</tr>
</tbody>
</table>
Powdery Mildew Fungicides (continued)

Reduced risk fungicides

- tebuconazole (Folicur, Tebusart, etc.)
- myclobutanil (Rally)
- triflumizole (Procure)

Group 3 triazoles

- quinoxyfen (Quintec)

Group 13 quinoline
Downy Mildew
*Pseudoperonospora humili*

Cultivated hop, *Humulus lupulus* is only host.
Closely related annual or Japanese hop, *H. japonicus*, is resistant.

Fungus-like pathogen overwinters as bud infections or systemically infected crown.

In spring, infected shoots, called primary spikes, emerge from the crown and are stunted, pale-green to yellow, upright, and brittle with downward cupped leaves.

Few detections of downy mildew in WI in 2013 and recent years.

Photo courtesy: North Carolina State Univ. Cooperative Extension.
Downy Mildew
*Pseudoperonospora humili*

Systemic infection - systemic symptoms of shortened internodes (bunchy new growth), pale green leaves, small leaves

Disease favored by cool, wet conditions - Prediction models aid in proactive management

Photo courtesy: North Carolina State Univ. Cooperative Extension
Downy Mildew Management - Initial phase

Removal of primary basal spikes

Heavily prune and strip leaves in lower 3 ft of bine

Limits downy mildew from moving up the bine and infecting cones

Pruning and thinning also helps reduce moisture in lower canopy which further aids in limiting disease

Degree-day model to predict emergence of basal spikes

Accumulation of 111 degree-days, base 6°C
‘Centennial’ and ‘Nugget’ are susceptible to downy mildew

Most (~75%) of hop varieties grown in U.S. are susceptible to DM

Remaining ~25% have some crown tolerance to DM (‘Bullion’, ‘Brewer’s Gold’, ‘Cascade’)
Downy Mildew
Management - Initial phase

Downy mildew is likely systemic in most hop yards, meaning that the pathogen is inside the rhizomes and can ‘awaken’ when spikes emerge in the spring.

As such, fungicides are important for early season control of this pathogen so as to limit the amount of initial inoculum that can become available to the developing crop.

The start of a preventative fungicide program for downy mildew should begin at spike emergence. This timing is based on temperature or growing degree days, aligning with growing degree days (GDD) of 111.3. Notes below provide further explanation and directions for determining this number for your location.
The time to initiate a fungicide program for preventative downy mildew control in hops is at predicted spike emergence (emergence of basal shoots in spring, growing degree day 111.3 air temperature) (Gent).

This is calculated using growing degree days starting from February 1 (base 6.5 degrees C). To get to this emergence date, there is a GDD calculator (link below) that can be used with your specific zip code. Base 6.5C can be defaulted to 40F. With this tool, you select current day's date for 'end'. For example, on April 26, 2013, in Madison, we had GDD 100.5.

http://www.weather.com/outdoors/agriculture/growing-degree-days/53706:4
Downy Mildew Management

Spike emergence tool enables you to identify the earliest phase of emergence and as such aids in timing of preventative downy mildew control.

When to follow up with fungicide sprays will vary on the weather. There is a disease risk index utilized by some Pacific northwestern hop growers that has not yet been validated for WI.

The premise is that the more rainfall and relative humidity present under moderate temperatures (46-86F) the greater the disease pressure.

Under high pressure times, fungicides should be applied on a 5-7 day spray program.

When rainfall is reduced, relative humidity is low and we experience either temps cooler than 46 or higher than 86F, disease pressure is low and fungicides should be applied on a 10-14 day program.
Downy Mildew
Fungicide Program

A good fungicide for use in a 14-day calendar program is fosetyl aluminum or Aliette/Linebacker. Phostrol also provides similar extended control as it upregulates resistance in the plant.

Use of an 'Aliette' type product alternated with a tank mix of copper hydroxide plus cymoxanil (Curzate) creates a sound program.

Western states also alternate with copper hydroxide (ie: Kocide) and trifloxystrobin (Flint) in control of powdery mildew.

If you raise other crops and have familiarity with common base protectant fungicides, remember that you **cannot use captan, chlorothalonil, or mancozeb on hops**. These fungicides do not have EPA Section 2 or any other special labeling to permit their use on this crop. The only base protectant, broad spectrum fungicide for hops is copper (or copper containing formulations such as Kocide).
<table>
<thead>
<tr>
<th>Time of application</th>
<th>Fungicide selection</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray 1: Spike emergence</td>
<td>Fosetyl aluminum (Aliette, Linebacker)</td>
<td>The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with copppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.</td>
</tr>
<tr>
<td>(or GDD 111.3, 40C base,</td>
<td>Salts of phosphorous acids (Phostrol)</td>
<td></td>
</tr>
<tr>
<td>Feb 1 start)</td>
<td></td>
<td></td>
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<tr>
<td>For southern WI 2013,</td>
<td></td>
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<tr>
<td>this was around May 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray 2: 2 weeks after</td>
<td>Cymoxanil (Curzate)</td>
<td>The Curzate + Kocide tank-mix program is used in the Pacific northwest with good results. Curzate and Kocide are good downy mildew fungicides across multiple vegetable crops. Pre-mixes that have good downy mildew and powdery mildew control are: Pristine and Tanos. Price point and availability of products in this list may influence selection. All listed have performed well on downy mildews of various crops.</td>
</tr>
<tr>
<td>Spray 1</td>
<td>Copper hydroxide (Kocide)</td>
<td></td>
</tr>
<tr>
<td>Roughly May 15</td>
<td>Dimethomorph (Forum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cyazofamid (Ranman)</td>
<td></td>
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<tr>
<td></td>
<td>Pyraclostrobin + Boscalid (Pristine)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fenoxadone + Cymoxanil (Tanos)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mandipropamid (Revus)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mefenoxam (Ridomil Gold SL)</td>
<td></td>
</tr>
<tr>
<td>Spray 3: 2 weeks after</td>
<td>Fosetyl aluminum (Aliette, Linebacker)</td>
<td>The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with copppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.</td>
</tr>
<tr>
<td>Spray 2</td>
<td>Salts of phosphorous acids (Phostrol)</td>
<td></td>
</tr>
<tr>
<td>Roughly May 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray 4: 2 weeks after</td>
<td>Cymoxanil (Curzate)</td>
<td>The Curzate + Kocide tank-mix program is used in the Pacific northwest with good results. Curzate and Kocide are good downy mildew fungicides across multiple vegetable crops. Pre-mixes that have good downy mildew and powdery mildew control are: Pristine and Tanos. Price point and availability of products in this list may influence selection. All listed have performed well on downy mildews of various crops.</td>
</tr>
<tr>
<td>Spray 3</td>
<td>Copper hydroxide (Kocide)</td>
<td></td>
</tr>
<tr>
<td>Roughly June 15</td>
<td>Dimethomorph (Forum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cyazofamid (Ranman)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin + Boscalid (Pristine)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fenoxadone + Cymoxanil (Tanos)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mandipropamid (Revus)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mefenoxam (Ridomil Gold SL)</td>
<td></td>
</tr>
<tr>
<td>Spray 5: 2 weeks after</td>
<td>Fosetyl aluminum (Aliette, Linebacker)</td>
<td>The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with copppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.</td>
</tr>
<tr>
<td>Spray 4</td>
<td>Salts of phosphorous acids (Phostrol)</td>
<td></td>
</tr>
<tr>
<td>Roughly June 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray 6: 2 weeks after</td>
<td>For Powdery and Downy mildew control:</td>
<td>Powdery mildew (PM), if present, may be problematic at this time of the year. We often see PM on cucurbits and other crops at this time (earlier in hot years). Pristine and Tanos are good pre-mix selections for both PM and Downy mildew. Products with individual disease activity can be tank-mixed.</td>
</tr>
<tr>
<td>Spray 5</td>
<td>Pyraclostrobin + Boscalid (Pristine)</td>
<td></td>
</tr>
<tr>
<td>Roughly July 15</td>
<td>Fenoxadone + Cymoxanil (Tanos)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>For Powdery mildew control:</td>
<td></td>
</tr>
<tr>
<td>Fungicide</td>
<td>Rate</td>
<td>Brand Name</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-----------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>fosetyl aluminum 33</td>
<td>2.5 lb Alieete</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.0 lb/100 gal spray</td>
<td>Linebacker</td>
</tr>
<tr>
<td></td>
<td>volume</td>
<td></td>
</tr>
<tr>
<td>cymoxanil 27</td>
<td>3.2 oz Curzate DF</td>
<td></td>
</tr>
<tr>
<td>dimethomorph 40</td>
<td>6.0 fl oz Forum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>famoxadone and cymoxanil 11, 27</td>
<td>8 oz Tanos</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mandipropamid 40</td>
<td>8.0 fl oz Rebus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cyazofamid 21</td>
<td>2.1-2.75 fl oz Ranman</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pyraclostrobin and boscalid 11, 7</td>
<td>14.0 oz/100 gal spray</td>
<td>Pristine</td>
</tr>
<tr>
<td></td>
<td>volume</td>
<td></td>
</tr>
<tr>
<td>mefenoxam 4</td>
<td>0.5 pt Ridomil Gold SL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metalaxyl 4</td>
<td>1.0 qt MetaStar 2E</td>
<td></td>
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</tr>
</tbody>
</table>
### Downy mildew (Pseudoperonospora humili)

<table>
<thead>
<tr>
<th>Fungicide Combination</th>
<th>Rate</th>
<th>PHI</th>
<th>Application Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ametoctradin + dimethomorph (45+40)</td>
<td>11-14.0 fl oz Zampro</td>
<td>7 DAYS PHI</td>
<td>Use a spreader or penetrating adjuvant. Do not use more than 3X per acre/production season for resistance management. Do not make more than 2 sequential applications before alternating to a different mode of action (different FRAC group).</td>
</tr>
<tr>
<td>Extract of Reynoutria sachalinensis</td>
<td>1.0-4.0 qt Regalia</td>
<td>0</td>
<td>Use preventatively and apply at 7 day intervals as needed. Emergence to wire-touch 1.0-2.0 qt recommended/wire-touch through harvest 2.0-4.0 qt. OMRI approved.</td>
</tr>
<tr>
<td>Potassium bicarbonate</td>
<td>2.5-5.0 lb/100 gal spray volume Armicarb 100</td>
<td>0</td>
<td>Do not exceed mix rate of 5.0 lb/100 gal of water. Do not store unused portion of spray for more than 12 hours prior to use.</td>
</tr>
<tr>
<td>Copper oxychloride and copper hydroxide</td>
<td>1.8 pts Badge SC 0.75 lb Badge X2</td>
<td>14</td>
<td>Treat after pruning but before training.</td>
</tr>
<tr>
<td>Copper oxychloride and basic copper sulfate</td>
<td>C-O-C-S WDG 4.0-6.0 lb</td>
<td>14</td>
<td>Apply soon after training vines.</td>
</tr>
<tr>
<td>Copper hydroxide</td>
<td>1.33 lb Champ Dry Prill 1.33 lb Champ Formula II Flowable 1.06 lb Champ WG 0.75-1.5 lb Kocide 3000 1.5 lb Kocide 2000 2.0 lb Kentan DF 1.33-2.67 pt NuCop 3L</td>
<td>14</td>
<td>Apply after pruning but before training. Apply again as needed on a 10 day basis after training.</td>
</tr>
</tbody>
</table>
## Fungicides for hop downy mildew control, WI Feb 28, 2014

### Downy mildew (*Pseudoperonospora humili*)

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Application Details</th>
<th>PHI</th>
</tr>
</thead>
</table>
| Mono and dipotassium salts of phosphorous acid | 1-3 qt/100 gal water Fospite  
1.0-2.0 qt/acre in a spray volume of 25 gal water Fungi-phite  
2.0-4.0 pt Helena Prophyt  
2.5 pt Phostrol | 0  
DAYS PHI | Apply at 2 to 3 week intervals. Do not apply at an interval less than 3 days.  
Apply when conditions favor disease when shoots are 6-12 in high, after training at 5-6 ft tall, about 3 weeks after 2nd application, and during bloom. |
| Mono potassium phosphate and mono potassium phosphite | 2.0-4.0 qt Phorcephite  
1.0-3.0 qt in 20 gal of water Rampart | 0 | Apply when conditions favor disease when shoots are 6-12 in high, after training at 5-6 ft tall, about 3 weeks after 2nd application, and during bloom. |
| *Bacillus pumilis* QST 2808 | 2.0-4.0 qt/100 gal spray volume of Sonata | 0 | Use when conditions favor disease and apply at 7-14 day intervals as needed. OMRI approved. |
Clean Rhizome Project

Tissue culture and greenhouse production of pathogen-free hop rhizomes

Dr. Ruth Genger, Plant Pathology, UW-Madison
Outline

- Why is a clean rhizome system needed?
- How do hop pathogens spread?
- How do hop pathogens affect productivity?
- Plans for clean rhizome research to support the Wisconsin hop industry
Why is a clean rhizome system needed?

- Hop diseases can be carried in rhizomes
- Hop viruses and viroids
  - Hop Latent Virus
  - Hop Mosaic Virus
  - American Hop Latent Virus
  - Apple Mosaic Virus
  - Hop Stunt Viroid
  - Hop Latent Viroid
- Fungal and oomycete diseases:
  - Hop Downy Mildew
  - Verticillium wilt

http://www.grapesandgrainsnyc.com
How do hop viruses and viroids spread?

- Hop Latent Virus
- Hop Mosaic Virus
- American Hop Latent Virus
- Apple Mosaic Virus
- Hop Stunt Viroid
- Hop Latent Viroid
- Hop Downy Mildew
- Verticillium wilt
Many perennial crops have virus and viroid diseases. The rate of spread in hops is often much higher than in other perennials such as tree fruit. Why is spread so rapid compared to other perennials?

- Rapid annual growth - more than 15 feet of main stem growth in 3-4 months
- Slashing basal growth
- Close spacing
- Aphid infestations

Hop latent viroid was detected in WI in 2013.
How do hop downy mildew and Verticillium wilt spread?

- **Downy mildew**
  - infected rhizomes
  - airborne spores

- **Verticillium wilt**
  - infected rhizomes
  - in soil and plant debris

Photos: David Gent, USDA ARS

plantmanagementnetwork.org

hopmintstress.wsu.edu
How are hops affected?

- Viruses and viroids
  - Yield losses can be severe
  - Reduced acid levels
  - Shift in ratio of α:β-acids
  - Stunting, chlorosis, slower growth
- Downy mildew and Verticillium wilt
  - Plant mortality
  - Reduced cone quality

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Downy mildew effects on cones

Hop stunt viroid

David Gent, USDA ARS

B. Engelehard
Start clean - stay clean!

- Plant disease-free rhizomes and plugs
- Sanitation for pruners and other tools
- Prevent movement of soil/infected plants onto your property
- Plant disease resistant cultivars

Planting stock production & certification programs

- Self-sustaining programs that serve grower needs
- Responsive to grower priorities
- Foster research and education
- Training opportunities
Wisconsin ‘clean rhizome’ research

- Establish a pathogen-free tissue culture collection of hop varieties, and produce pathogen-free planting material for on-farm variety evaluations.

- Trial hop rhizome production methods to optimize productivity and economic sustainability.

- Coordinate participatory variety trials in Wisconsin hop yards, and evaluate disease incidence in existing plantings

- Work funded by the WI Specialty Crop Block Grant Program for 2013-2014
Sources of tissue culture plants

National Clonal Germplasm Repository
- Corvallis, OR
- 185 cultivars and selections
- Some have viral or viroid infections
- Only uninfected plants will be distributed

Clean Plant Center of the Northwest
- http://healthyplants.wsu.edu/
- Limited distribution

Hop yards and native/feral hops
- Bine cuttings or rhizomes can be put into culture
- Challenging to eliminate pathogen infections
Varieties requested

- Survey circulated in fall 2013 to prioritize requests
- Not all requested varieties available
- Request for 23 varieties submitted in September

<table>
<thead>
<tr>
<th>Brewer’s Gold</th>
<th>Hallertauer Gold</th>
<th>Nugget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade</td>
<td>Hallertauer Magnum</td>
<td>Perle</td>
</tr>
<tr>
<td>Chinook</td>
<td>Hallertauer mf tetraploid</td>
<td>Saazer 36</td>
</tr>
<tr>
<td>Crystal</td>
<td>Hallertauer mittelfruher</td>
<td>Saazer 38</td>
</tr>
<tr>
<td>Fuggle H</td>
<td>Hallertauer Tradition</td>
<td>Santiam</td>
</tr>
<tr>
<td>Fuggle Tetraploid</td>
<td>Liberty</td>
<td>Spalter Select</td>
</tr>
<tr>
<td>Galena</td>
<td>Mt. Hood</td>
<td>Tettnanger</td>
</tr>
<tr>
<td></td>
<td>Northern Brewer</td>
<td>Willamette</td>
</tr>
</tbody>
</table>

- Multiple strains for some varieties - Fuggle, Hallertauer, Saazer
Varieties just received!

- Cascade
- Fuggle Tetraploid
- Hallertauer Gold
- Hallertauer Tradition
- Hallertauer mitterfruher
- Santiam

Next steps:
- Maintain these (and others as they arrive) in tissue culture
- Transfer to greenhouse for plug and rhizome production
Plant tissue culture to greenhouse plug and rhizome production

Compare productivity of standard and “NFT” methods

Standard

- transfer tissue culture plants to potting mix (nuclear stock)
- take softwood cuttings and root in misting chamber (propagation stock)

Nutrient film technique

- Nuclear stock will be maintained in an NFT system
- since NFT systems allow access to parts of the plant normally covered by soil, it may be possible to take both softwood cuttings and rhizome cuttings from these plants
Future production possibilities

Growers
- Multiplication (hoophouse/greenhouse)
- Hop Production

Growers
- Multiplication
- Hop Production

Potential for Wisconsin to become a leader in supplying pathogen-free hop rhizomes
North Central Regional SARE Grant
High Quality Beverage Raw Materials for the Craft Brewing Industry

Overall hops research objective

- Develop a season-long IPM program for enhanced productivity of Wisconsin hops
- PhD Student Michelle Marks
- Post-doctoral Research Associate Dr. Kenneth Frost
Specific Project Components Addressed by UW-Plant Pathology

1. **Hop Yard Surveys**
   - Survey bine health and pathogen pests in commercial hop yards over space and time
   - Also, insect and weed pests

2. **Fungicide Program Development**
   - Using disease forecasting and pathogen detection to optimize product applications for WI

3. **Development of Best Practices Handbook**
   - Aggregate results of proposed and current research, as well as specialist recommendations

4. **Optimize Bine Training Dates**
   - Based on growing degree days
Disease Forecasting Updates

- Completed models from Oregon/Washington work
- Degree-day model to predict emergence of basal spikes
  - Accumulation of 111 degree-days, base 6°C
    - As of 2/27 we are at 0 growing degree-days
- Risk index predicts infection events
  - Primary parameters are rain, relative humidity, and temperature
  - Accumulation of 500 (risk index) indicates time of likely infection
- Validation for Wisconsin is needed and will be conducted in 2013-15
DM risk index calculates an index that correlates with infection.

Index is based on rain, relative humidity, and temperature.

For Oregon - An empirical threshold of 500 “risk” units was considered to indicate a severe infection event.

Days with weather conducive for infection may group together (i.e. days above 500 is not a suitable measure for # sprays needed to achieve control).
Not possible to predict likely time of weather favorable for hop downy mildew based on calendar alone.
Variation of DM risk also occurs in space.

Risk averaged for the whole year.

2010 was a year with higher risk for DM infection according to the model.
Web-based disease forecasting

Information available in 2014
- useful tool to aid in disease control decision making
- requires validation for WI

Information Resources

Blitecast & Tomcast estimates (from remotely sensed weather data), 2013

We recently initiated a project to develop and validate Blitecast (potato) and Tomcast (on cacao) for Wisconsin, based on remotely sensed and forecasted weather data. The goals of this work were to provide the benefits of disease forecasting to a broader grower/user group and to utilize forecasted weather data to better anticipate accumulation of risk values for enhanced, proactive disease management.

We are still in the process of validating the use of this style of disease forecasting for Wisconsin. However, the data is useful in visualizing statewide disease risk trends and general 72-hour outlooks for accumulation of risk. We appreciate your feedback on this work. You can contact me at: gevers@wisc.edu.

Need-to-know concepts to make the maps useful

Blitecast and DSVs: Blitecast forecasts the risk for late blight in potato (can be extrapolated for tomatoes) based on accumulation of favorable weather. Accumulation of 15 disease severity values (DSVs) is the threshold. (read more detailed information)

Tomcast and DVs: Tomcast forecasts the risk for foliar diseases in tomatoes and cacao (has been extrapolated and/or modified for several other vegetable diseases) based on accumulation of favorable weather. (read more detailed information)

UWEX Veg Crop Updates Newsletter
- weekly updates with disease forecasting information
Thank you!

Information Resources

UW Vegetable Extension Team Website
http://vegetables.wisc.edu/vegetable-team

University of Wisconsin Vegetable Disease Website (newsletter access)
http://www.plantpath.wisc.edu/wivegdis/

http://www.cals.uidaho.edu/pses/Research/r_event_hoppest_powderymildew.htm