

Identifying Common Hop Diseases in WI

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Powdery Mildew

Podosphaera macularis

Characteristics: 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.

Management: Disease incidence was low in yards with low incidence of flag shoots or that were pruned thoroughly in spring, and suggested that 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 Cone infection is greater in poorly pruned yards (Gent, *unpublished*).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 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. There is a gene-for-gene relationship between hops PM races and host resistance. Varieties resistant to Pac NW powdery mildew: 'Nugget' (R6), 'Cascade' (R5), 'Mt. Hood.' Varieties moderately resistant: 'Fuggle,' 'Perle,' 'Tettnang,' 'Hallertau.' Varieties susceptible: 'Horizon,' 'Columbus,' 'Tomahawk,' 'Zeus,' 'Cluster,' 'Chinook,' 'Willamette,' 'Liberty,' 'Chelan,' 'Eroica,' 'Symphony,' 'Galena,' and any variety with Rb resistance gene.

Fungicides can provide control of powdery mildew. Registered fungicides are listed below. An overall fungicide program for powdery and downy mildew is provided on the last page of this document.

Symptoms on foliage



Symptoms on cones



Fungicides for powdery mildew control on hops in WI, 2013

Active ingredient (FRAC code)	Rate, trade name	Pre-harvest interval in days	Comments
trifloxystrobin (11)	1.0 oz with every 15-30 gal spray volume Flint	14	Apply preventatively for best results. Apply on a 10 to 14 day interval. Follow resistance management guidelines.
pyraclostrobin and boscalid (11,7)	14.0 oz/100 gal spray volume Pristine	14	Use preventatively and apply at 14-21 day intervals as needed. Follow resistance management guidelines.
myclobutanil (3)	2.0-10.0 oz Rally	14	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)
tebuconazole (3)	4.0-8.0 fl oz Monsoon, ONSET 3.6L, Orius 3.6F, Tebustar 3.6L, Tebuzol 3.6F, Toledo 3.6F	14	Apply at 10 to 14 day intervals. Follow resistance management guidelines.
triflumizole (3)	12.0 fl oz Procure 480SC	7	Use prior to or at disease onset for best results and reapply on a 14 day schedule.
quinoxifen (13)	4.0-8.2 fl oz Quintec	21	Follow resistance management guidelines, including 'do not apply more than 4X per season.' Minimum spray interval is 7 days.
potassium bicarbonate	2.5-5.0 lb/100 gal spray volume Armicarb 100	0	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.

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Fungicides for downy mildew control on hops in WI, 2013, continued.

Active ingredient (FRAC code)	Rate, trade name	Pre-harvest interval in days	Comments
sodium bicarbonate	4.0 oz/10 gal water spray volume Milstop	0	Begin application when weather favors disease and apply at 1 to 2 week intervals. Tighten intervals when disease pressure heightens.
copper octanoate	0.5-2.0 gal Cueva in 100 gal water	14	Apply soon after training vines.
potassium bicarbonate	2.5-5.0 lb Kaligreen	1	Apply when weather conditions favor disease and repeat on a 7-10 day basis.
mono and dipotassium salts of phosphorous acid	1-3 qt/100 gal water Phosphite 1.0-3.0 qt in 20 gal of water Rampart	0	Apply at 2 to 3 week intervals. Do not apply at an interval less than 3 days.
Extract of <i>Reynoutria sachalinensis</i>	1.0-4.0 qt Regalia	0	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.
<i>Bacillus subtilis</i> QST 713 strain	4.0-6.0 qt/100 gal spray volume of Serenade ASO	0	Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.
<i>Bacillus subtilis</i> QST 713 strain	2.0-3.0 lb/100 gal spray volume of Serenade MAX	0	Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.
<i>Bacillus pumilis</i> 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.
neem oil	0.5%-1.0% in 25-100 gal water spray volume of Trilogy	0	Use when conditions favor disease and apply at a 7-14 day interval as needed. OMRI approved. Also a miticide/insecticide.

Downy Mildew

Pseudoperonospora humili

Characteristics: Cultivated hop, *Humulus lupulus* is only host. Closely related annual or Japanese hop, *H. japonicus*, seems to be resistant. Fungus-like

Symptoms on foliage



Symptoms on cones



pathogen overwinters as bud infections or as a 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. Systemic infection – systemic symptoms of shortened internodes (bunchy new growth), pale green leaves, small leaves. Disease favored by cool, wet conditions.

Management: Removal of primary basal spikes. Heavily prune and strip leaves in lower 3 ft of bine to limit 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. Varieties 'Centennial' and 'Nugget' are susceptible to downy mildew. Most (75%) of hop varieties grown in the U.S. are susceptible. 25% have some crown tolerance: 'Bullion,' 'Brewer's Gold,' and 'Cascade.' European hop varieties with resistance are 'extract' high alpha types (bitters extracted for flavoring – not directly used from plant product). Resistant varieties still require fungicide applications to control downy mildew.

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Fungicides for downy mildew control on hops in WI, 2013

Active ingredient (FRAC code)	Rate, trade name	Pre-harvest interval in days	Comments
fosetyl aluminum (33)	2.5 lb Aliette 5.0 lb/100 gal spray volume Linebacker	24	Do not tank-mix with coppers. Initiate application when weather conditions favor disease (warm and humid). Avoid mixing with foliar fertilizers or surfactants.
cymoxanil (27)	3.2 oz Curzate DF	7	Apply with a protectant fungicide such as copper hydroxide.
dimethomorph (40)	6.0 fl oz Forum	7	Do not make more than 3 applications per season. Addition of an adjuvant to spray mix is recommended.
famoxadone and cymoxanil (11,27)	8 oz Tanos	7	Use with a tank-mix partner. Apply preventatively and on a 6-8 day spray schedule. Follow resistance management guidelines.
mandipropamid (40)	8.0 fl oz Revus	7	A non-ionic surfactant is recommended with use of this product. Follow resistance management guidelines.
cyazofamid (21)	2.1-2.75 fl oz Ranman	3	Apply prior to or at first sign of disease. Follow resistance management guidelines.
pyraclostrobin and boscalid (11,7)	14.0 oz/100 gal spray volume Pristine	14	Use preventatively and apply at 14-21 day intervals as needed. Follow resistance management guidelines.
mefenoxam (4)	0.5 pt Ridomil Gold SL	45	Label allows drench and foliar applications. Follow resistance management guidelines.
Extract of <i>Reynoutria sachalinensis</i>	1.0-4.0 qt Regalia	0	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.
potassium bicarbonate	2.5-5.0 lb/100 gal spray volume Armicarb 100	0	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.
copper oxychloride and copper hydroxide	1.8 pts Badge SC 0.75 lb Badge X2	14	Treat after pruning but before training.
copper oxychloride and basic copper sulfate	C-O-C-S WDG 4.0-6.0 lb	14	Apply soon after training vines.
copper hydroxide	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	14	Apply after pruning but before training. Apply again as needed on a 10 day basis after training.
mono and dipotassium salts of phosphorous acid	1-3 qt/100 gal water Fosphite 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	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 2 nd 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 2 nd application, and during bloom.
<i>Bacillus pumilis</i> 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.

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Key diseases of concern include downy mildew and powdery mildew. 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.

Based on David Gent's recent work in Oregon, 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). 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, today April 26, 2013, in Madison, we are at GDD 100.5.

<http://www.weather.com/outdoors/agriculture/growing-degree-days/53706:4>

The tool should indicate a crop physiological status (emergence). Emergence can simply be observed, however, emergence is progressive and spans a period of time for 'complete emergence'. In theory, the 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.

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.

Below, I have outlined a general foliar fungicide program by calendar for Wisconsin hop yards with additional notes in the right-hand column. 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).

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Time of application	Fungicide selection Active ingredient (trade name examples)	Comments
Spray 1: Spike emergence (or GDD 111.3, 40C base, Feb 1 start) <i>For southern WI 2013, this was around May 1</i>	<u>Fosetyl aluminum (Aliette, Linebacker)</u> Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 2: 2 weeks after Spray 1 <i>Roughly May 15</i>	<u>Cymoxanil (Curzate)</u> <u>Copper hydroxide (Kocide)</u> Dimethomorph (Forum) Cyazofamid (Ranman) Pyraclostrobin + Boscalid (Pristine) Famoxadone + Cymoxanil (Tanos) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL)	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.
Spray 3: 2 weeks after Spray 2 <i>Roughly May 30</i>	<u>Fosetyl aluminum (Aliette, Linebacker)</u> Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 4: 2 weeks after Spray 3 <i>Roughly June 15</i>	<u>Cymoxanil (Curzate)</u> <u>Copper hydroxide (Kocide)</u> Dimethomorph (Forum) Cyazofamid (Ranman) Pyraclostrobin + Boscalid (Pristine) Famoxadone + Cymoxanil (Tanos) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL)	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.
Spray 5: 2 weeks after Spray 4 <i>Roughly June 30</i>	<u>Fosetyl aluminum (Aliette, Linebacker)</u> Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 6: 2 weeks after Spray 5 <i>Roughly July 15</i>	<i>For Powdery and Downy mildew control:</i> <u>Pyraclostrobin + Boscalid (Pristine)</u> Famoxadone + Cymoxanil (Tanos) <i>For Powdery mildew control:</i> Trifloxystrobin (Flint) Tebuconazole (Tebuzol, Orius, Toledo, Monsoon, ONSET, Tebustar) Myclobutanil (Rally, formerly Nova) Quinoxifen (Quintec) Triflumizole (Procure) Neem oil <i>For Downy mildew control:</i> Cymoxanil (Curzate) Dimethomorph (Forum) Cyazofamid (Ranman) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL)	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. If you have primarily or just a PM problem, good selections include: Flint, Tebustar, Rally, Quintec, Procure. Neem oil and other horticultural oils are good choices for PM control on organic hops. If you have primarily or just a Downy mildew problem, good selections include: Curzate, Forum, Ranman, Revus, or Ridomil Gold SL. As you start to use a reduced risk, single site fungicide multiple times over the production season, keep in mind that some fungicide labels restrict total # of applications per season (ie: Forum, do not apply more than 3X per season).
Spray 7: 2 weeks after Spray 6 <i>Roughly July 30</i>	<u>Fosetyl aluminum (Aliette, Linebacker)</u> Salts of phosphorous acids (Phostrol)	
Spray 8: 2 weeks after Spray 7 If needed – follow alternation pattern as needed based on status of disease in crop.	<u>Spray 6 program and comments</u>	