NW CROPS & SOILS PROGRAM
UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

Managing Powdery Mildew of Hops in the Northeast

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Powdery mildew (*Podosphaera macularis (Wallr.) U. Braun & S. Takam*) is one of the predominant fungal diseases that you might encounter in your hopyard. Any pest issue in your crop can be daunting but a diligent integrated pest management (IPM) approach can help overcome many issues. The goal of integrated pest management is to integrate a multipronged approach including prevention, observation, and various intervention strategies to reduce or eliminate the use of pesticides while at the same time managing pest populations at an acceptable level. This article will provide you with some guidelines on how to manage powdery mildew in your hopyard.

Disease Symptoms

One of the most critical steps to IPM is proper pest identification. The powdery mildew that infects hops only infects *Humulus* spp. Hops powdery mildew is a different species than what you can find in your squash patch, vineyard or strawberries, so you don't have to worry about cross-contamination. Powdery mildew can occur on all green tissue of a hop plant. The infection will first express itself on the underside of the leaf, often first showing up as pale, chlorotic spots on the upper surface. Aging colonies will appear dull and granular, with necrotic areas under the colony. The most obvious symptoms of powdery mildew are the circular, blister-like, glistening powdery white colonies on leaves, stems, or cones (Figure 1). These white colonies are powdery mildew hyphae and spores. The hop cones can also become infected with powdery mildew. Infected burrs and young cones will be white and powdery, and then develop brown necrotic spots (Figure 2). If cones are infected early in development you may observe cones that are reduced in size or distorted in appearance (Figure 3). These cones may also mature earlier than normal. If the cones are infected later in development, you might not be able to visibly tell until near harvest, or after the hops have gone into the oast, where the cones will have a reddish-brown discoloration, an altered aroma, or little to no green color. If you do notice that your hops start to dry down unseasonably early, the best way to reduce losses is to harvest early, which will affect overall yield, but should help preserve cone quality (Mahaffee 2009). Remember many symptoms are dependent on variety (Mahaffee et al. 2009).

Figure 1. Circular, blister-like, glistening powdery white colonies on leaves. Photo courtesy of Dr. John Henning.

Figure 2. Cones infected with powdery mildew. Photo courtesy of Jason Perrault.

The initial stages of powdery mildew may be difficult to identify. Do not wait to treat a yard until the characteristic white powder is observed. If you would like to confirm that powdery mildew has infected the hop plants, you can submit a sample to a University Extension Plant Diagnostic Laboratory. Visit their website or call them for specifications on how to prepare and submit a sample. A diagnosis will cost between $15 and $30 depending on the lab. Contact information for local Plant Diagnostic Labs can be found at the end of this article.

Figure 3. Distorted hop cone infected with powdery mildew. Photo courtesy of Jason Perrault.

Powdery Mildew Lifecycle:

Understanding the powdery mildew lifecycle is important when developing a pest management plan. In order for disease infection to occur there must be pathogen inoculum, specific environmental conditions, and a susceptible host. If these conditions are present and ideal, hop powdery mildew can become a problem in the hopyard.

Hop powdery mildew overwinters as fused mycelia (chasmothecia) or mycelia in the buds. If you were unlucky enough to purchase infected rhizomes, or if your hill became infected in the last growing season, powdery mildew will overwinter in the buds, bud scales, or in the soil and plant residue surrounding the hills. The disease will manifest itself as the hop shoots emerge. Shoots that emerge from infected buds form what is called a "flag shoot". The flag shoot will be covered with sporulating masses and will be white; looking like it has been dusted with powdered sugar. The shoots will be stunted, the leaves distorted, and the uninfected shoots will quickly outgrow the infected shoots, possibly hiding them from view. The sporulating masses on the flag shoots can help the disease spread to the rest of the hill, but usually the infection doesn't spread any further than that because of limited exposure to wind, unless you move from an infected hill to an uninfected hill when working in the hopyard. If there is a really warm spring, sometimes the flag shoot will grow faster than the mildew, so that only the bracts on each node of the shoot will show signs of infection, as opposed to the whole structure being white. This can bring the infection up high enough so that the wind can carry spores to other hills in the yard (Mahaffee et al. 2009). Pruning will help to manage infected buds, and keep the disease from spreading (Beaton et al. 2009).

In the early spring, if conditions are right, ascospores are discharged from the chasmothecia. With early infection, the ascospores land on newly emerged shoots early in the spring. Production of asexual spores (conidia) during the season will be dispersed through wind and rain splash. Spores can also be dispersed by insects, tractors, equipment, and humans. Periods of rapid plant growth will favor infection. In addition, the period of lateral branch development and burr formation are very susceptible times for the hop plant if the environment is favorable for disease development. The environmental conditions more conducive to powdery mildew propagation and infection include low light levels, either due to cloudy days or canopy density; excessive fertility, especially too much nitrogen; and high soil moisture (Mahaffee et al. 2009). Leaf wetness from dew or a light rain, has been found to be neither detrimental nor conducive to powdery mildew infection, but is considered to have more of an indirect effect, associated predominantly with high humidity and lack of sunshine (Engelhard 2005). Infection is possible at temperatures ranging from 46° to 82°F, with optimal infection from 64° to 70°F (Engelhard 2005, Mahaffee et al. 2009). Periods with small differences between night and day temperatures, with a minimum nightly temperature of greater than 50°F, and a daily high of 68°F, are the most dangerous times. Caution is advised when there are many hours of light rain, high humidity, and thus little or no sun, and a light wind, which can blow spores throughout the hopyard. The irradiation from the sun's rays can kill released spores, preventing infection, but as the hops reach their full growth, the sun can't penetrate the dense canopy, and infection can occur (Engelhard 2005). Once temperatures get higher than 75°F, infection becomes less probable, and the chance of infection is reduced by up to 50% if temperatures exceed 86°F for more than three hours (Mahaffee et al. 2009). Keep an eye on the weather, and if the risk of infection runs high, it might be best to spray a preventative fungicide, as discussed later.

Strategies for Controlling Powdery Mildew

There are three main ways that powdery mildew will be most likely to enter your hopyard: infected rhizomes, windblown spores, or through the grower accidently carrying it into their field on their clothes or tools after visiting another hop-growing friend. In order to control the disease, scouting should be conducted on a regular basis (weekly) to determine degree of infection as well as to evaluate if the pathogen is spreading further. In addition, monitoring the weather conditions will help to determine if the environment is right for disease infection. Control options are both preventative and remediative in nature. A multipronged approach should be used to have the best success.

Table 2. Disease Susceptibility and Chemical Characteristics of the Primary Public Hop Varieties Grown in the U.S.

Variety	Usage	Disease Susceptibility[a]		
		Powdery Mildew	Downy Mildew	Verticillium Wilt
Brewers Gold	Bittering	S	MR	MR
Bullion	Bittering	S	MR	R
Cascade	Aroma	MR	MR	MR
Centennial	Bittering	MR	S	U
Chinook	Bittering	MS	MR	R
Columbia	Aroma	MS	MR	S
Comet	Bittering	R	S	R
Crystal	Aroma	R	S	R
East Kent Golding	Aroma	S	S	MR
First Gold	Bittering	R	S	MR
Fuggle	Aroma	MS	R	S
Galena	Bittering	S	S	R
Glacier	Aroma	S	S	U
Hall. Gold	Aroma	MS	R	S
Hall. Magnum	Bittering	S	R	MR
Hall. Mittelfrüh	Aroma	MS	S	S
Hall. Tradition	Aroma	MR	R	MR
Horizon	Bittering	MS	S	MR
Late Cluster	Aroma	S	S	R
Liberty	Aroma	MR	MR	U
Mt. Hood	Aroma	MS	S	S
Newport	Bittering	R	R	U
Northern Brewer	Bittering	S	S	R
Nugget	Bittering	R	S	S
Olympic	Bittering	S	MS	R
Perle	Aroma	S	R	MR
Pioneer	Bittering	MR	MR	U
Saazer	Aroma	S	MS	S
Saazer 36	Aroma	S	MS	S
Spalter	Aroma	S	R	MR
Sterling	Aroma	MS	MR	U
Teamaker	Aroma	MR	MR	S
Tettnanger	Aroma	MS	MS	S
Tolhurst	Aroma	S	S	U
U.S. Tettnanger	Aroma	MS	MS	S
Vanguard	Aroma	S	S	U
Willamette	Aroma	MS	MR	S

[a] Disease susceptibility ratings are based on greenhouse and field observations in experimental plots and commercial yards in the Pacific Northwest as of 2009. Disease reactions may vary depending on the strain of the pathogen present in some locations, environmental conditions, and other factors, and should be considered approximate. S = susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant; U= unknown

Figure 4. Reproduced from Field Guide for Integrated Pest Management in Hops, a Cooperative Publication Produced by Oregon State University, University of Idaho, U.S. Department of Agriculture - Agricultural Research Service, and Washington State University.

Cultural/Mechanical Control:

Growing powdery mildew-tolerant varieties is one of the primary means of reducing disease in your hopyard. (Henning et al. 2009). Figure 4 is a table of public varieties and their relative resistance to powdery mildew. Concentrate intensive scouting on the most susceptible varieties initially and expand to more frequent scouting of less susceptible varieties once powdery mildew is confirmed in the hopyard. There is no reason to treat all varieties in a hopyard the same for powdery mildew control. The time spent scouting in the hopyard can easily be paid for in saved fungicide applications.

Pruning, crowning, and/or scratching will help reduce the inoculum of both powdery and downy mildew. This usually occurs in late winter and early spring, depending on the variety. The purpose is to remove the previous season's bines as well as the first buds and young shoots. This can be done through pruning, in which shoots are removed prior to training; crowning, in which the top one to two inches of the crown are removed prior to budbreak; or scratching, in which the soil surface is disturbed to remove the top one to two inches of buds (Beaton et al. 2009). Keep in mind that if you move from a diseased hill to a non-diseased hill, you run the risk of spreading the infection with your hoe or pruning shears. If you are working with an infected plant you should sanitize your tools using a dilute bleach solution. If you choose to crown or scratch, most growers will hill around the crown in mid-season to encourage the development of roots and rhizomes near the top of the crown. Hilling also helps to suppress downy mildew in the current season, since this buries the diseased shoots that usually pop up next to the crown. You can also use a chemical desiccant to remove the young shoots and reduce the density of the plant material in the hill, either combined with, or in the absence of, mechanical cultivation (Beaton et al. 2009).

Basal growth and superfluous growth of leaves and lower laterals should be periodically removed from the bottom 4-5 feet (depending on the height of your trellis), either mechanically or chemically, once the bines are over 8 feet tall to promote air circulation in the yard, and to minimize the spread of both downy and powdery mildew up to the canopy. Basal growth that is less than 3 feet from the soil is frequently the culprit for spreading the disease up trained bines. In Australia and New Zealand, lower-lateral stripping is sometimes done with sheep, but organic growers be aware that there is a 90 day livestock-free harvest interval. After harvest, compost can be applied to bury any spore-carrying litter (Beaton et al. 2009).

Lastly, to avoid encouraging powdery mildew establishment, try to manage the fertility and irrigation in your yard so that sufficient levels are achieved. Excess of either can cause a flush of succulent growth, which is very susceptible to infection.

Chemical Control:

Intensive preventative spraying is how powdery mildew is controlled in the Pacific Northwest, where successful control is dependent on early, continuous intervention throughout the growing season. Best management practices are to keep the disease presence as low as possible (Mahaffee et al. 2009). There are both organic and conventional chemical options that can help a grower combat powdery mildew. Most of these are preventative, meaning they will help stop the disease from establishing on your plants, but can do little to combat a full-blown infection. When using a fungicide, be sure to read the fungicide label in its entirety! It is illegal to use a chemical on a crop or on a pest for which it is not specifically labeled, and can often do more harm than good. Keep in mind that not all chemicals are legal in every state; be sure to check with your local Extension or Agency of Agriculture. It is also important to remember that while a chemical may be legal and labeled for use in a state there is no assurance that the material is effective against a particular pest, even if it is on the label. Consult your local extension staff, university research staff and fellow growers to get an idea of the efficacy of a product and how best to use it. Also be sure to adhere to pre-harvest intervals and use proper personal protection equipment. When using fungicides it is very important to diversify the fungicide class and mode of action to prevent disease resistance from developing. Each class should only be used a few times per season, which is usually specified on the label. If the label permits, it can be very beneficial to tank mix fungicides that have a high risk for resistance development with fungicides that have a low risk (Mahaffee et al. 2009). Be sure to read the label carefully, as some mixtures are phytotoxic to some crops but not others. For example, using both oil and copper products in an apple orchard will result in phytotoxicity, but will work fine with tomatoes. See Table 1 for a list of approved fungicides on hops in NY and VT for 2011.

Table 1. Approved fungicides on hops in NY and VT for 2011.

Trade Name	EPA Reg. No.	Active ingredient	Group	Protectant	Systemic	Curative	OMRI approved	Target pest					Registered		
								Powdery mildew	Downy mildew	Mites	Aphids	Other	MA	NY	VT
Actinovate AG	73314-1	*Streptomyces lydicus* WYEC 108		X		X	Y	X	X					X	X
Badge SC	80289-3	copper oxychloride, copper hydroxide		X					X				X	X	
Basic Copper 50W HB	42750-168	basic copper sulfate	M1	X			Y		X					X	
Biocover UL	34704-806	petroleum oil	NC					X		X			X	X	
Bonide Liquid Copper Fungicide Concentrate	67702-2-4	liquid copper	M	X				X	X			X	X		X
Bonide Liquid Copper Fungicide Ready to Use	67702-1-4	liquid copper	M	X				X	X			X	X		X
Carbon Defense	84846-1	potassium silicate	M	X				X		X	X	X		X	
Champ DP Dry Prill (Agtrol)	55146-57	copper hydroxide	M	X					X				X	X	
Champ Formula 2 Flowable (Agtrol)	55146-64	copper hydroxide	M	X					X				X	X	
Champ WG	55146-1	copper hydroxide	M	X			Y		X					X	
Champion Wettable Powder (Agtrol)	55146-1	copper hydroxide	M	X					X					X	
C-O-C-S WDG	34704-326	copper oxychloride, basic copper sulfate	M1	X					X				X	X	X
Cueva Fungicide Concentrate	67702-2-70051	copper octanoate		X			Y	X	X			X	X	X	X
Cuprofix Ultra 40 Disperss	4581-413-82695	basic copper sulfate	M1	X					X					X	
Cuprofix Ultra 40 Disperss	70506-201	basic copper sulfate	M1	X					X				X	X	X
Drexel Damoil	19713-123	petroleum oil	NC					X		X			X	X	X
DuPont Kocide 101	352-681	copper hydroxide	M	X					X				X	X	X
DuPont Kocide 2000	352-656	copper hydroxide	M	X					X				X	X	X
DuPont Kocide 3000	352-662	copper hydroxide	M	X					X				X	X	X
DuPont Kocide 4.5LF	352-684	copper hydroxide	M	X					X				X	X	X
DuPont Kocide DF	352-688	copper hydroxide	M	X					X				X	X	X
Ecomate Armicarb "0"	5905-541	potassium bicarbonate	NC			X		X	X			X		X	X
Flint Fungicide	264-777	trifloxystrobin	11	X		X		X	X				X	X	X
Fosphite Fungicide	68573-2	phosphorous acid mono- and di-potassium salts	33	X		X		X	X			X	X	X	X
Fungi-phite	83472-1	phosphorous acid mono- and di-potassium salts	33	X		X			X				X	X	X
Glacial Spray Fluid	34704-849	white mineral oil		X			Y	X		X			X	X	X
JMS Stylet Oil	65564-1	paraffinic oil	NC					X		X			X	X	X
JMS Stylet Oil, Organic	65564-1	paraffinic oil	NC				Y	X		X			X	X	X
Kaligreen	11581-2	potassium bicarbonate	NC	X			Y	X					X		X
Kentan DF	80289-2	copper hydroxide	M	X					X				X	X	
Kphite 7LP Systemic Fungicide Bactericide (Ag Label)	73806-1	phosphorous acid mono- and di-potassium salts	33	X		X		X	X				X	X	X
Kumulus DF	51036-352-66330	sulfur	NC	X			Y	X					X	X	X
MilStop Broad Spectrum Foliar Fungicide	70870-1-68539	potassium bicarbonate	NC	X				X					X	X	X
Monsoon	34704-900	tebuconazole	3	X	X			X					X		X
Nordox 75 WG	48142-4	cuprous oxide		X			Y		X					X	
Nu-Cop 3L	42750-75	copper hydroxide	M	X					X				X	X	X
Nu-Cop 50DF	45002-4	cupric hydroxide	M	X					X				X	X	X
Nu-Cop 50WP	45002-7	copper hydroxide	M	X			Y		X				X	X	X
Nu-Cop HB	42750-132	cupric hydroxide	M	X					X				X	X	
Nutrol	70644-1	potassium dihydrogen phosphate		X				X					X	X	X
Omni Oil 6E	5905-368	mineral oil		X				X		X			X	X	X
Omni Supreme Spray	5905-368	mineral oil		X				X		X			X	X	X
Prev-AM Ultra	72662-3	sodium tetraborohydrate decahydrate						X		X				X	
Pristine Fungicide	7969-199	boscalid, pyraclostrobin	7,11	X				X	X				X	X	X
Procure 480SC	400-518	triflumizole	3	X		X		X	X				X	X	X
Purespray 10E	69526-5	petroleum oil	NC					X		X			X	X	X
Purespray Green	69526-9	petroleum oil	NC				Y	X		X			X	X	X
Quintec	62719-375	quinoxyfen	13	X				X					X	X	X
Rally 40WSP	62719-410	myclobutanil	3	X	X	X		X					X		X
Rampart	34704-924	phosphorous acid mono- and di-potassium salts	33	X		X		X	X					X	X
Regalia	84059-3	extract of *Reynoutria sachalinenis*		X			Y	X	X				X	X	X
Saf-T-Side	48813-1	petroleum oil	NC	?		?	Y	X		X	X	X	X	X	X
Serenade ASO	69592-12	QST 713 strain *Bacillus subtilis*		X			Y	X					X	X	X
Serenade Max	69592-11	QST 713 strain of dried *Bacillus subtilis*		X			Y	X					X	X	X
Sil-Matrix	82100-1	potassium silicate	M	X				X		X	X	X		X	X
Sonata	69592-13	*Bacillus pumilus* strain QST 2808		X			Y	X	X				X	X	X
Tebuzol 3.6F	70506-114	tebuconazole	3	X	X			X					X		X
Trilogy	70051-2	clarified hydrophobic extract of neem oil	NC	X			Y	X						X	

Keep in mind that there is a lot of variation in how a hop cultivar will react to a given chemical. It is best to trial a small amount of the pesticide on a few plants before spraying the whole yard. The burr is very susceptible to mechanical damage during pesticide applications, so if at all possible, try to avoid spraying during burr development. Instead spray a product that is a very effective protectant with a long residual just prior to flowering. Basal growth should also be removed just prior to flowering to minimize the spread of disease (Mahaffee et al. 2009).

The biggest economic losses from powdery mildew infection are the cost of control and reduction in yield and quality due to cone infection. Severe leaf infections don't affect bine growth, but are correlated with cone infection. High disease pressure during flowering can result in cone and burr abortion, malformed cones, and/or complete cone loss. Even low disease levels, particularly in aroma varieties, can result in a loss of cone quality to the point where the crop will be rejected by brewers (Mahaffee et al 2009).

Contact your local Plant Diagnostic Lab by following the links below or contacting your local Extension office.

Cornell University Plant Disease Diagnostic Clinic
334 Plant Science Building
Ithaca, NY 14853

UMass Plant Diagnostic Lab
101 University Drive, Suite A7
Amherst, MA 01002

University of Vermont Plant Diagnostic Clinic
201 Jeffords Building
63 Carrigan Drive
University of Vermont
Burlington, VT 05405

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