HOP DISEASE MANAGEMENT

Michigan growers will need to implement early, preventative fungicide programs and pruning practices for both powdery and downy mildew management.

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Downy mildew management will remain a major point of focus for Michigan hop growers in 2017, but with damaging powdery mildew infections in 2017, growers will need to add new fungicides to their disease management program. The downy and powdery mildew pathogens are completely unrelated and are not generally controlled by the same fungicides; growers that have not been applying preventative sprays for powdery mildew will need to increase fungicide applications this season.

Clean planting material should be used when establishing new hop yards, since both mildew species are readily spread via nursery stock. Growers should consider purchasing a few plants from prospective nurseries and have them tested for diseases including mildews and viruses before committing to a large numbers of plants. Additionally, any other signs of poor handling at the propagator level may be used as an indicator of plant quality. Other signs of poor handling would include mite or aphid infestations, spray damage, or poor root development and would be grounds for rejecting a delivery of plants.

Scouting

Scouting for downy and powdery mildew involves monitoring the crop for signs and symptoms of disease to evaluate the efficacy of the control program being utilized. Downy and powdery mildew management begins as soon as plants emerge and growers should not wait until they see disease to start fungicide applications or cultural practices. Growers should keep records of their scouting, including maps of their fields, a record of sampling and disease pressure, as well as the control measures utilized. Scouting should begin as soon as plants begin to grow and should continue until the crop is dormant.

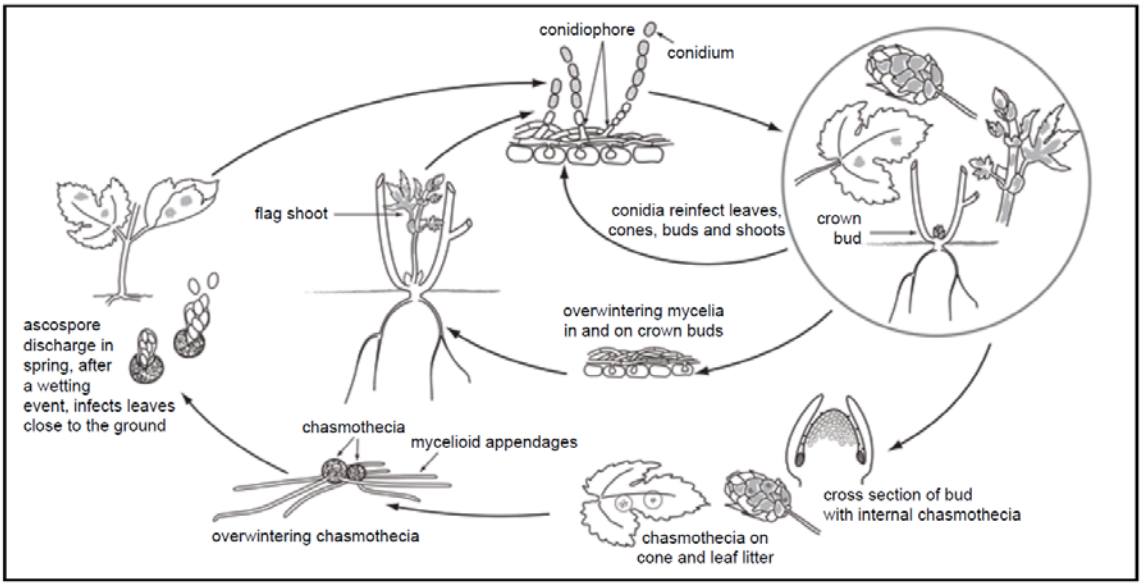
Section your farm off into manageable portions based on location, size and variety and scout these areas separately. It is more practical to deal with blocks that are of the same variety, age and spacing. Walk diagonally across the yard and along an edge row to ensure you view plants from both the edge and inner portion of the block. Change the path you walk each time you scout to inspect new areas. Reexamine hotpots where you have historically encountered high mildew pressure. Weekly scouting is recommended at a minimum. Refer to the Seasonal Pest Occurrence Guide for more information.

HOP POWDERY MILDEW

Powdery mildew *(*caused by the fungus *Podosphaera macularis*) is an emerging disease in Michigan that has serious implications for growers. Powdery mildew was confirmed in Michigan in 2014, and has been a concern on greenhouse/nursery plants for years. It was rarely an issue in the field until 2017, when mild spring conditions and likely introduction of the pathogen from greenhouse plants resulted in significant powdery mildew disease on mature plants in hopyards without a history of disease.

Disease cycle

Powdery mildew overwinters as fungal threads inside buds and in association with plant debris infected during the previous season. Shoots emerging from infected buds can be covered with spore masses, appearing white, stunted, and with distorted leaves. These 'flag shoots' are rare, and healthy shoots quickly outgrow infected shoots, making detection difficult. The spore masses on flag shoots spread to adjacent healthy tissue causing new infections. Sexual spores (ascospores) may also be present in spring. Ascospores are discharged and land on newly emerged shoots where they germinate, infect the plant, and eventually produce a new spore mass of asexual spores (conidia). Conidia are produced in large numbers over multiple cycles and are dispersed via wind, rain splash, insects, tractors, equipment, and humans.



The lifecycle of Podosphaera macularis, the causal agent of hop powdery mildew. Prepared by V. Brewster, Hop IPM Field Guide, 3rd edition.

Conditions that favor powdery mildew are reported to include low light levels resulting from cloud cover, canopy density, excessive fertility, and high soil moisture. Leaf wetness from dew or rain does not directly impact powdery mildew infection, but results from high humidity and cloud cover, which favors disease. Temperatures from 46° to 82°F allow powdery mildew to develop, but disease is favored by temperatures of 64° to 70°F; disease risk decreases when temperatures consistently exceed 86°F for 6 hours or more.

Symptoms

Powdery mildew resulting from bud infection appears in the spring on white, stunted shoots called flag shoots. As leaf tissue expands, lesions first appear as raised blisters on leaves, which quickly develop into white, round colonies. Infected burrs and cones can also support white fungus or may exhibit a reddish discoloration if infected later in development. Burrs and young cones are very susceptible to infection, which can lead to cone distortion, substantial yield reduction, diminished alpha-acids content, color defects, premature ripening, off-aromas, and complete crop loss. Cones become somewhat less susceptible to powdery mildew with maturity, although they never become fully immune to the disease. Infection during the later stages of cone development can lead to browning and hastened maturity. Alpha-acids typically are not influenced greatly by late-season infections, but yield can be reduced by 20% or more due to shattering of overly dry cones during harvest resulting from accelerated maturity. Late-season powdery mildew can be easily confused with other diseases such as Alternaria cone disorder, gray mold, or spider mite damage. Several weak pathogens and secondary organisms can be found on cones infected by powdery mildew; limiting powdery mildew reduces these secondary organisms.

LEFT: Hard to spot white flag shoot emerging in spring, with powdery mildew. David Gent, ARS. MIDDLE: Powdery mildew on leaves, causing raised lesions and white fungal colonies to be visible. Erin Lizotte, MSU. Powdery mildew on cones and leaves. Erin Lizotte

Management

Limiting powdery mildew is best approached by integrating resistant varieties, sourcing clean planting material, following crop sanitation practices, limiting early season disease establishment, optimizing fertilization and irrigation, and well-timed fungicide applications. While growers may not be able to select resistant varieties because of market factors, some resistant varieties are available. The reaction of a hop variety to powdery mildew varies depending on where it is grown and which isolates of the fungus are present. Generally, Columbus, Cashmere and Galena are considered susceptible; Centennial and Chinook are

intermediate; Nugget, Newport, and Cascade are resistant although races of the fungus present in Pacific Northwestern U.S. can overcome the resistance in the varieties as well.

Powdery mildew management begins in early spring with the thorough removal of all green tissue during pruning. The goal of this early pruning is to remove the hard to locate flag shoots and delay or prevent infection. Eliminating flag shoots and early season disease requires the removal of all shoots, including those closest to the ground, on sides of hills, and around poles or anchors. Through mechanical pruning has been shown to be more effective than chemical pruning in eliminating flag shoots. Pruning has not been widely adopted in Michigan, but should be considered to minimize risk, particularly if growers are experiencing intense powdery or active infections are reported in the region. Pruning should be avoided on baby hop plants (less than 3 years old). Stay tuned for a forthcoming article on pruning and canopy management.

Regular fungicide applications are needed to prevent infection. Appropriate timing of the first fungicide application after pruning is important to keep disease pressure at manageable levels. This application should be made as soon as possible after shoot emergence or regrowth in pruned yards. Different fungicides are utilized for powdery mildew control during three distinct periods of the season: emergence to mid-June; mid-June to bloom; and bloom to preharvest. The Fungicide Resistance Action Committee (FRAC) mode of action classification codes are included to help growers make resistance management decisions.

- Emergence to mid-June

  Growers can consider a combination of applications of sulfur (FRAC M2), oils, Flint (trifloxystrobin, FRAC 11), Rhyme (flutriafol, FRAC 3), Procure 480 SC (triflumizonle, FRAC 3), or Unicorn DF (tebuconazole + sulfur, FRAC 3 + M2). Under high pressure, growers should tank mix with oils and integrate copper (FARM m1) into their downy mildew programs when possible. Avoid tank mixes of copper and sulfur as phytotoxicity may occur.

- Mid-June to Bloom

  Growers can consider Rhyme (flutriafol, FRAC 3), Procure 480 SC (triflumizole, FRAC 3), Luna Experience (fluopyram + tebuconazole, FRAC 7 + 3), Vivando (metrafenone, FRAC U8), and Torino (cyflufenamid, FRAC U6, supplemental label here http://www.cdms.net/ldat/ldAPM007.pdf). Under high pressure, growers should tank mix with oils and integrate copper into their downy mildew programs when possible.

- Bloom to preharvest

  Growers may use a combination of Quintec (quinoxyfen, FRAC 13, 21 day preharvest interval), Pristine (pyraclostrobin + boscalid, FRAC 11 + 7, 14 day preharvest interval), Luna Sensation (fluopyram + trifloxystrobin, FRAC 7 + 11, 14 day preharvest interval) and Torino

(cyflufenamid, FRAC U6, 6 day preharvest interval, supplemental label here http://www.cdms.net/ldat/ldAPM007.pdf).

Many fungicide programs can give adequate disease control on leaves when applied preventively under low disease pressure. On cones, however, differences among fungicides are substantial. Mid-July through early August is an essential disease management period. The fungicide Quintec (quinoxyfen) and Luna Sensation (fluopyram + trifloxystrobin) are especially effective during this time and should be utilized in regular rotation when burrs and cones are present.

Fungicide applications alone are not sufficient to manage the disease. Under high disease pressure, mid-season removal of diseased basal foliage delays disease development on leaves and cones. Desiccant herbicides should not be applied until bines have grown far enough up the string so that the growing tip will not be damaged and bark has developed. In trials in Washington, removing basal foliage three times with a desiccant herbicide (e.g. AIM) provided more control of powdery mildew than removing it once or twice. Established yards can tolerate some removal of basal foliage without reducing yield. This practice is not advisable in baby plantings (less than 3 years), and may need to be considered cautiously in some situations with sensitive varieties such as Willamette. The potential for quality defects and yield loss increases with later harvests when powdery mildew is present on cones.

The cultural recommendations above apply to both hops produced for conventional commercial markets and those grown under guidelines for organic production. Under the additional constraints imposed by organic production guidelines, particular attention must be paid to selection of disease-resistant varieties. This is the foundation upon which organic production will succeed or fail with respect to the major fungal diseases. Available fungicide options for organic production are minimal and generally mediocre under high disease pressure. Although frequently cited in popular literature, optimal fertilization, soil health, and water management alone are inadequate for disease control. Likewise, biorational compounds, biological controls, manure teas, and various botanicals and natural products have shown minimal to no efficacy against this pathogen under moderate to severe disease pressure. Organic producers should consider a sulfur or oil-based fungicides. Sulfur and oil should not be tank mixed due to phytotoxicity issues.

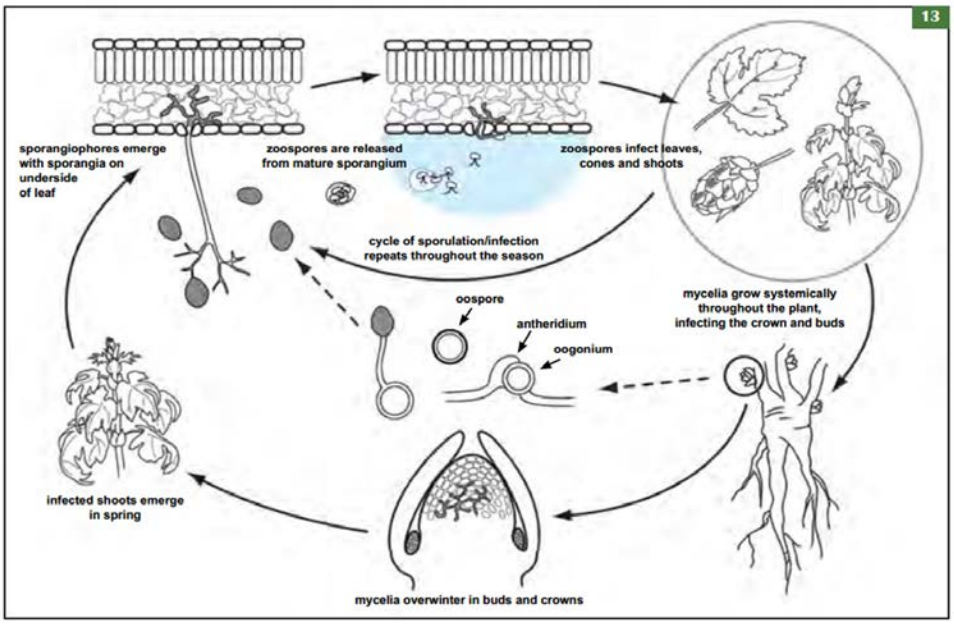
HOP DOWNY MILDEW

Downy mildew is caused by a fungus-like organism called *Pseudoperonospora humuli* and is the most significant disease of hop in Michigan, causing significant yield and quality losses. In extreme cases, cones can become infected and the crown may die. Cool and damp conditions during the spring provide ideal growth conditions for the pathogen. Disease severity is dependent on variety, environmental conditions, and management programs.

Disease cycle

The causal agent of downy mildew, Pseudoperonospora humuli, overwinters in dormant buds or crowns and can emerge on infected shoots in early spring. This results in the so-called basal "spike". Infected crowns can produce uninfected shoots as well, making detection of spikes difficult, particularly on potted baby hop plants that have been cut back. The pathogen produces copious spores on the underside of infected leaves which infect new tissue through open stomata. These new infections produce a second source of spores which can infect all parts of the plant. Infections occurring on the terminal growing point become systemic and grows down the plant toward the crown, where the pathogen can persist in the root system a prolonged period. Systemic infections contribute to the spread of infection through propagation and also allow for the pathogen to survive winter, contributing to disease pressure in subsequent seasons. The pathogen can also produce a resting spore and overwinter, but it is unclear how or if these resting spores contribute to infection and how readily they are produced under Michigan conditions.

Infection is favored by mild to warm temperatures (60 to 70°F) when free moisture is present for at least 1.5 hours, although leaf infection can occur at temperatures as low as 41 °F when wetness persists for 24 hours or longer.



Life cycle of Pseudoperonospora humuli on hop. Prepared by V. Brewster, Compendium of Hop Diseases and Pests.

SYMPTOMS

Downy mildew appears early in the season on emerging, infected shoots (the basal spikes). Spikes growing from infected crowns or buds may be distorted with shortened internodes that give the shoot a stunted appearance. It is easy to confuse some mild herbicide injury from Round Up applications with downy mildew as they both produced stunted shoots. Round Up

injury on the first flush of growth is very common so it is important that growers recognize the difference. Herbicide injury will cause chlorosis that follows leaf venation and leaves will be misshapen and appear more “strappy”. Glyphosate injured growth will also lack the signs of downy including the spore masses on the underside of leaves. Infected shoots develop spore masses on the underside of leaves that follow venation. As secondary infections occur, leaves develop angular water soaked lesions that follow leaf venation. Eventually, the water-soaked lesions turn brown and necrotic with fuzzy and grey-black asexual spore masses developing on the underside of infected lesions. As bines continue to expand new shoots becomes infected, brittle, and fall away from strings. Growers can attempt to retrain new shoots but often incur yield loss as a result of missing the ideal training timing. As the season progresses, symptoms may include stunted side-arm growth, tip die-back and cone discoloration. The fuzzy, visible growth of downy mildew is not always present on cones and should not be relied upon as the sole indicator of whether infection is present.

Glyphosate injury on the left and downy spike on the right. Photo credit Erin Lizotte, MSU.

Angular lesions on the upper leaf surface of hop caused by downy mildew infection. Photo credit Erin Lizotte

Yellow and stunted spring hop spike, systemically infected with hop downy mildew with spore masses on leaf tissue. Photo credit Erin Lizotte

The downy mildew pathogen spore masses on the underside of a hop leaf, note the small angular water-soaked lesions where sporulation has not yet occurred. Photo credit Erin Lizotte

Stunted side-arm growth and distorted, pale leaves caused by downy mildew infection on hop. Photo credit Erin Lizotte

Stunted side-arm growth and distorted, pale Downy mildew infection on cones. Photo credit Erin Lizotte

Management

Unfortunately, even when we follow best management practices, downy mildew can gain a foothold in Michigan yards due to high disease pressure, challenges with fungicide timing, suboptimal spray coverage, fungicide wash-off, cultivar susceptibility or a combination of these factors. In addition, fungicide resistance and infected nursery plants may play a role in some disease control failures.

It takes a multipronged approach to manage for downy mildew. Growers should utilize a protectant fungicide management strategy to mitigate the risks of early and severe infections but can also utilize cultural practices to reduce disease. Keep in mind that varieties vary widely in their susceptibility to downy mildew and select the more tolerant varieties when possible (refer to Table 2 in the Field Guide for Integrated Pest Management in Hops).

Removal of the first flush of growth can help suppress disease development if disease is already present in the yard from the previous season. The flush of growth should be completely removed using mechanical or chemical pruning. As bines develop (8-10’), the removal of superfluous basal foliage and lower leaves to promote air movement in the canopy and to reduce the duration of wetting periods is recommended. This is commonly achieved through multiple applications of Aim herbicide or concentrated nitrogen fertilizer solutions. Aim will also control smaller weeds within the row. The use of Aim, pruning, and/or crowning should NOT be performed on baby hop plants (less than 3 years old). If there is a cover crop, it should be mowed close to the

ground. If yards have no cover crop, cultivation can help to dry the soil and minimize humidity. Keep nitrogen applications moderate.

Apply fungicide treatments on a protectant basis as soon as bines emerge in the spring regardless of the presence or absence of visible symptoms of downy. Dormant applications are not recommended. Applications should continue season long on a 7-10 day reapplication interval until harvest. The time between applications may stretch longer when the weather is dry and if hop yards don't have active infections. Several periods in the season are particularly critical for disease control: immediately before and after training; when lateral branches begin to develop; bloom; and cone development. Covering young, developing bracts before cones close up is critical to protecting against downy mildew when conditions for disease are favorable. Getting adequate coverage on undersides of bracts where infection occurs becomes increasingly difficult as cones mature.

Ranman (cyazofamid, FRAC 21), Zampro (ametoctradin + dimethomorph, FRAC 45 + 40), and Revus (mandipropamid, FRAC 40) make up the backbone of effective downy mildew management programs in Michigan. These products should be rotated and potentially mixed with Curzate (cymoxanil, FRAC 27), Tanos (famoxadone + cymoxanil, FRAC 11 +27), and phosphonate products such as Aliette (fosetyl-Al, FRAC 33) to help prevent resistance development. Copper-based fungicides may also be rotated in during periods of low disease pressure and as tank mix partners. Revus and Zampro contain active ingredients with the same mode of action and should not be tank-mixed or rotated.

Organic growers have fewer options and will need to focus on keeping tissue protected, selecting downy mildew tolerant varieties, and following cultural practices to limit downy infection. Copper-based products are the mainstay of downy mildew management in organic hop yards and offer 5-7 days of protection but no post-infection activity. Copper should be applied ahead of any wetting events as available. The pre-harvest intervals for copper formulations vary, refer to the label. Actinovate, Eco-mate, Armicarb-O and Sonata are additional products that list downy mildew on the label and are approved for organic use in hop. The pre-harvest interval for these products are 1 day or less, at this time we have no data on the efficacy of these products.

RESISTANCE MANAGEMENT

Both the powdery and downy mildew pathogens are at high risk of developing fungicide resistance, therefore careful attention to resistance management is critical. To slow the development of resistance, growers should rotate between fungicides with different modes of action within the season and not apply the same mode of action consecutively. Growers can refer to the fungicide FRAC codes, found in the upper right hand corner of most conventional fungicide labels or refer to the current Michigan Hop Management Guide. Fungicides with two numbers contain more than one fungicide and mode of action.

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