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Hop Downy Mildew

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Hop downy mildew is one of hops most destructive pests. Managing this disease requires integration of cultural and chemical controls.

Hop downy mildew, first found in Nebraska in 2017 and caused by the oomycete *Pseudoperonospora humuli*, has the ability to greatly impact hop yards across Nebraska. Mild temperatures and significant rainfall in the spring provide the ideal conditions for the disease to proliferate. The potential economic damage to hop yards is extremely significant and ranks as one of most destructive pests to hops in the United States. Management of downy mildew requires an integrated approach incorporating both cultural and chemical controls. Growers should take measures to learn about, scout for, and treat downy mildew to limit yield loss caused by the disease.

Symptoms

The first signs of downy mildew in the spring appear on emerging shoots from the crown. Rhizomes of infected plants may have reddish-brown to black flecks and streaks. These basal shoots (or “spikes”) are bright, chartreuse green; have shortened nodes and small, curling leaves; and appear stunted (*Figure 1*). Leaf infections manifest themselves as water-soaked lesions between veins, which become brown and necrotic (*Figure 2*). Given ideal environmental conditions, asexual spores (sporangia) may develop in a mass underneath infected leaves and spikes with a fuzzy, gray to black appearance. However, as these masses are not always present, growers should not consider them the only sign of the disease.

If the pathogen is not treated, new plant tissue will become infected as it grows up the coir. While new shoots can be trained, yield loss may still occur. In the transition from vegetative to reproductive growth, side arms will emerge, similar in appearance to the spring basal spikes (*Figure 3*). Infected flowers shrivel and may fall off. Cones become discolored, harden, and cease development if infected early in the season; if infection occurs later in the season, only the bracts may be discolored (*Figure 4*).

Disease Cycle

Pseudoperonospora humuli overwinters as mycelium in dormant crowns and buds, and may spread into developing buds in the early spring. Uninfected shoots are able to

Figure 1. Bright green and stunted basal spike infected with downy mildew.

Figure 2. Localized, interveinal water-soaked lesions on hop leaf.

emerge from infected crowns as well. The pathogen emerges on the underside of infected shoot leaves, releasing the infective spores (zoospores). These spores enter new plant tissue through the stomata, forming new infection sites. All growing points, buds, leaves, and cones are prone to infection. While leaf infections provide an additional source of spores, this spread of spores is limited to splashing due to rain events. Infections at growth points can be detrimental as the pathogen can systemically infect the hops through this entrance. Systemic infections grow down a plant, and establish themselves for long periods of time.

Temperatures between 60–70 °F (including nighttime temperatures) and the presence of free moisture for

1 ½ hours can result in an infection, although leaf infections can occur under wet conditions lasting 24 or more hours and at temperatures down to 41 °F. The recent, mild winters and more severe rain events in the spring have the potential to increase disease pressure and damage if the pathogen is able to cause infection earlier in the season.

Management

Cultural Practices. Although no variety is completely resistant, planting varieties that are more tolerant to downy mildew is critical to managing the disease. Varieties such as Magnum, Perle, Orion, and Wye Challenger have proven to be more tolerant to the pathogen, while varieties in more demand by brewers such as Chinook, Centennial, and Columbus have greater susceptibility. When sourcing new plants, growers should ensure that plants and rhizomes are clean and healthy as plant material may provide a haven for the pathogen.

In established yards, pruning as late as possible without affecting the training date and removing all spring foliage significantly reduces later-season infections. In the case of disease already existing in a hop yard, removing infected shoots and side arms by hand should be done immediately throughout the season, followed by retraining of new bines, if necessary. The practice of mounding or hilling to bury basal shoots a few weeks after training helps to reduce humidity around the crown.

As the growing season progresses, other efforts to reduce humidity in the hop yard, such as removing lower leaves of bines and any basal growth around the crown, help increase air movement between the bines and decrease leaf surface during wet periods to help combat infections.

Figure 3. Aerial "spike" caused by systemic infection of downy mildew.

Figure 4. Infected bract due to late season infection of downy mildew.

Stripping the lower leaves is recommended for areas where growers experienced heavy disease pressure in previous seasons. Controlling weeds, especially those surrounding the base of the hop plants, and keeping cover crops mowed low to the ground help to reduce infections. Removal of any dead plant material that may provide tissue for downy mildew to survive or overwinter on is essential.

Cultivation and other practices that improve soil drainage will minimize downy mildew pressure. Excess nitrogen promotes growth of succulent tissue that is more susceptible to infection and should be kept at moderate levels. Proper irrigation management is essential to reduce downy mildew infections. Overhead irrigation should be avoided. If individual or groupings of plants are severely infected, growers should consider removing them from the yard.

Protective Treatments. Applications of fungicides at critical points throughout the growing season and when environmental conditions favor infection are also effective in hop downy mildew management. *Table 1* provides a list of registered fungicides shown to be effective. Preventative applications beginning in the establishment year in areas known for downy mildew infections may reduce crown infections and disease pressure in future seasons. Applications may be made by various types of sprayers, but the fungicide must reach the underside of the leaves where infection occurs for dependable protection against the pathogen.

Preventative sprays should be applied at spring emergence, whether symptoms are visible or not, followed with a tank-mix reapplication every 7 to 10 days until harvest. Dormant sprays are not recommended. If the environmental conditions are dry, and infections are not visible, the interval between sprays may increase. Between eastern and western Nebraska, growers should anticipate intervals to vary significantly. Other critical points during the growing season for downy mildew control include before and after spring training, during lateral branch development, and during flowering and cone development. Applications on the flowers as the cones develop and close is also important to prevent cone infections. In addition, preventative sprays should be applied before anticipated rain events if the fungicide label allows. Preventative fungicide applications are key due to their limited activity once an infection is present.

Table 1. Foliar fungicides[1] labeled for *Pseudoperonospora humuli* control on hops.

Active Ingredients (%)	Product Name	FRAC Code	Rate	Comments
Aluminum tris 80%	Aliette®	33	2.5 lb/ac	Upregulates plant resistance. Do not tank-mix with coppers. 24 day PHI.
Ametoctradin 26.9% + Dimethomorph 20.2%	Zampro®	45, 40	11–14 fl oz/ac	Systemic and protectant. Do not apply more than 40 fl oz/season. Use higher rate when pressure is high. 7 day PHI.
Bacillus pumilus QST 713	Sonata®	44	2.0–4.0 qt/100 gal	Preventative. Can be applied at 7–14 day intervals. OMRI[2] approved. 0 day PHI.
Copper hydroxide 46.1%	Kocide® 3000	M1	0.75–1.5 lb/ac	Protectant. Apply at 10 day intervals after training. Do not apply more than 8.8 lb/season. OMRI[2] approved. 14 day PHI.
Copper sulfate 27.1%	Cuproxat®	M1	2.25 pt/ac	Protectant. Can be applied to crowns after pruning, but before training. 14 day PHI.
Cyazofamid 34.5%	Ranman®	21	2.1–2.75 fl oz/ac	Protectant with limited systemic activity. Do not apply more than 16.5 fl oz/season. 3 day PHI.
Cymoxanil 60%	Curzate® 60 DF	27	3.2 fl oz/ac	Locally systemic with post-infection activity. Must be used in combination with another protectant. 7 day PHI.
Cymoxanil 25% + Famoxadone 25%	Tanos®	11, 27	8 fl oz/ac	Protectant and curative activity. Must be tank-mixed with a different protectant fungicide. 7 day PHI.
Dimethomorph 43.1%	Forum®	40	6 fl oz/ac	Systemic. Do not apply more than 18 fl oz/season. 7 day PHI.
Extract of *Reynoutria sachalinensis*	Regalia®	P5	1.0–4.0 qt/ac	Preventive. Contact activity can be applied at 7 day intervals. OMRI[2] approved. 0 day PHI.
Mandipropamid 23.3%	Revus®	40	8 fl oz/ac	Systemic. Do not apply more than 24 fl oz/season. 7 day PHI.
Mefenoxam 45.3%	Ridomil Gold® SL	4	0.5 pt/ac	Systemic protectant. Allows soil drench and foliar applications. Foliar applications must be tank-mixed with a copper fungicide. 45 day PHI.
Metalaxyl	MetaStar 2E	4	1 qt/ac	Can also be applied as soil drench. 45 day PHI.
Phosphonate 45.8%	Agri-Fos®	33	0.33–1.0 oz/gal	Protectant. May have post-infection activity. 0 day PHI.

1. Product list is not comprehensive and is intended for information purposes only. No criticism is intended for products not listed nor endorsement for products listed. Always read and follow label directions when applying any pesticide; 2. OMRI: Organic Materials Review Institute approves products that are appropriate for organic production. Several copper formulations may be approved for organic use, but this status can change. It is recommended to check with an organic certifying agency prior to selection of fungicides for the production season.

Post-Infection Treatments. In instances where preventative applications were missed or coverage was insufficient, a post-infection application may be made. Products such as those containing the active ingredient cymoxanil offer some post-infection protection, but have limited forward protection. If growers fail to apply a preventative spray before a rain event, they have the option to tank-mix a protectant fungicide with an extended residual to increase protection in the coming days. For example, Tanos®, which contains cymoxanil and a protectant, famoxadone, is an option providing post-infection coverage and five to seven days of preventative protection. A combination of dimethomorph and mandipropamid also offers the same curative and preventative coverages.

Phosphorous acid fungicides have been shown to provide less protection and post-infection activity. Strobilurin fungicides have the active ingredient trifloxystrobin or pyraclostrobin/boscalid and are not recommended for hop downy mildew management due to less post-infection activity.

Organic Treatments. Due to limited fungicide treatments available for organic growers, prevention is emphasized through cultural practices and proper plant selection. Some copper-based products are labeled, but do not offer any post-infection action. Though little efficacy data is available, bioprotectants or biofungicides are an option that can boost plants' internal defenses. The University of Vermont found that Regalia®, a bioprotectant that contains extract of *Reynoutria sachalinensis* (giant knotweed) plus a copper product, adequately controlled downy mildew. For downy mildew, this combination is recommended in a tank-mix that is applied every seven days. As with all applications, read and follow label instructions carefully to prevent damage and pathogen resistance development.

Fungicide Resistance Management. The downy mildew pathogen has a high potential for developing fungicide resistance. It is important to rotate fungicides and active ingredients throughout the season to delay the development of resistance. The ability of *P. humuli* to sexually reproduce and cause multiple infections in a given year and the need for repeated fungicide applications increase the likelihood of developing resistance to common pesticides.

In the Pacific Northwest, the pathogen has developed resistance to phenylamide fungicides such as mefenoxam and has reduced sensitivity to phosphonate fungicides. The fungicide resistance action committee (FRAC) assigns a number and/or letter to group active ingredients that have the same mode of action and target site. Repeated application with the same mode of action and target site greatly increases a pathogen's ability to develop resistance.

Refer to pesticide labels and FRAC codes for assistance in rotating active ingredients. These codes can often be found in the upper corner of a fungicide label. Rotating active ingredients and modes of action, using tank-mixes with multisite activity, and integrating nonchemical controls assist in managing fungicide resistance.

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