OREGON STATE UNIVERSITY EXTENSION SERVICE

Managing Powdery Mildew in Hop

Best Practices

D. H. Gent, B. Claassen, M. Wiseman and L. Santamaria

Powdery mildew is one of the most important diseases of hop. If not managed appropriately, powdery mildew can lead to complete loss of marketable crops. Disease management is difficult and often incomplete in susceptible varieties. This is because, in part, no single tactic is adequate. Successful management requires an integrated set of practices — from cultural, biological and chemical tactics to the planting of resistant varieties. These best management practices can help growers minimize damage from the disease.

Before planting

- **Select the least susceptible variety available**

  Powdery mildew susceptibility varies widely among hop varieties, ranging from entirely resistant to

David H. Gent, research plant pathologist, U.S. Department of Agriculture, Agricultural Research Service; Briana Claassen, faculty research assistant, Department of Botany and Plant Pathology, Oregon State University; Michele Wiseman, faculty research assistant, Department of Botany and Plant Pathology, Oregon State University; and Luisa Santamaria, associate professor, Department of Botany and Plant Pathology, Oregon State University.

Photos: David H. Gent

Powdery mildew on hop cones (above) and leaves (left)

Oregon State University

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Table 1. Powdery mildew susceptibility in a range of hop varieties

Resistant *Limited or no fungicides required*	**Moderately susceptible** *Typically <4 fungicide applications/year*	**Susceptible** *Typically 4–8 fungicide applications/year*	**Highly susceptible** *>8 applications/year*
Crystal	Centennial	Cascade	Apollo
Comet	Fuggle	Cashmere	Columbus/Tomahawk/ Zeus
Lotus	Mt. Hood	Nugget	
Pahto	Newport	Simcoe	

extremely susceptible. Planting resistant or less susceptible varieties is the most efficient means of managing powdery mildew. When markets allow, choose varieties that are least susceptible to the disease (Table 1). In general, most hop varieties are more susceptible to powdery mildew when grown in western Oregon than when grown in south-central Washington.

Susceptibility and fungicide inputs depend on prevailing weather conditions and which race of the fungus is present. For example, Apollo, Mt. Hood and Nugget are resistant to many races of the powdery mildew fungus and require fungicides only when virulent races of the pathogen are present. However, the powdery mildew fungus can develop new races, eventually overcoming resistance in the host. Susceptibility also varies with climate. Varieties in the moderately susceptible and susceptible categories often require more intensive management in cooler climates such as the Willamette Valley of Oregon, as opposed to warmer climates such as the Yakima Valley in Washington.

Photo: David H. Gent

Figure 1. Powdery mildew flag shoots produced on potted plants grown in a greenhouse

- **Ensure that planting material is free of powdery mildew**

  The powdery mildew fungus spreads easily on planting material. Genetic evidence indicates that the powdery mildew fungus spread across the U.S. in association with infected planting material. If plants are produced in a nursery or greenhouse, verify that the planting material is free of powdery mildew. Conduct a close visual inspection or a grow-out to confirm disease-free status (Figure 1).

Cultural measures after planting

Cultural practices after planting are the foundation of disease management. These practices help to delay disease development and create an environment less conducive to the disease, reducing the rate of disease spread.

- **Thoroughly prune yards in spring**

  In the western U.S., the powdery mildew fungus must survive the winter on living host tissue, which is provided by crown buds. In spring, thorough mechanical pruning is the most effective means of reducing overwintering inoculum of the pathogen (Table 2, page 3). Two pruning operations are often necessary to ensure all green tissue is removed thoroughly. For instance, it is more effective to follow a mechanical pruning with a later chemical desiccation of remaining shoots. Consider variety, plant age and weather when pruning to avoid injuring the plants.

- **Prune as late as possible in spring**

  In addition to thorough pruning, pruning as late as possible in spring can reduce the severity of powdery mildew. How late pruning can occur depends on variety, plant vigor and other factors (Figure 2, page 3).

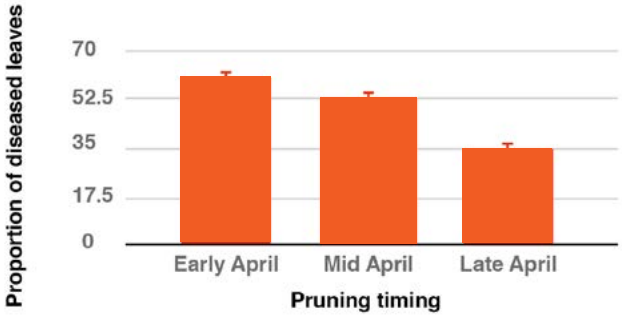
- **Reduce canopy density**

  Powdery mildew is favors dense canopies, shade, rapid growth rate of the plant, moderate

Table 2. Association of pruning method and pruning thoroughness on occurrence of powdery mildew flag shoots in Oregon hop yards

	Total yards	Yards with flag shoots	Yards without flag shoots	Flag shoot prevalence (%)
Pruning method				
Chemical/unpruned	360	22	338	6.1
Mechanical	129	1	128	0.8
Pruning thoroughness				
Poor or moderate	283	23	250	8.1
Excellent	206	4	202	1.9

Figure 2. Decrease in powdery mildew on leaves with delayed spring pruning



temperatures (50–85°F) and high humidity. Reduce canopy density where possible by training few shoots per plant, ensuring adequate spacing of plants and strings, and avoiding excessive fertility.

- **Moderate nitrogen rates**

  Late-season powdery mildew on leaves and cones is associated with the amount of nitrogen applied (Figure 3). Reduce nitrogen rates as low as feasible for yield goals; avoid nitrogen applications after bloom. For well-managed crops, less than 200 pounds per acre of nitrogen generally is adequate for maximizing yield and cone quality.

- **Remove midseason basal foliage**

  When powdery mildew is present, removing basal foliage at least twice during the late spring and summer months reduces the severity of powdery mildew, especially on cones. Scout basal foliage regrowth late in the season for signs of disease.

- **Manage weeds, cover crops and irrigation to reduce humidity**

  Powdery mildew favors high humidity and moderate temperatures. Manage other vegetation in the yard to promote air flow and reduce humidity where possible. Excessive irrigation also favors powdery mildew. Matching irrigation to plant demand can help to reduce disease levels.

- **Promote root health**

  There is a general correlation between root health, late-season water stress and the impact of powdery mildew on cones. Areas of hop yards with rocky soil or other factors that limit root development tend to be most severely impacted when powdery mildew occurs on cones. That is because diseased cones mature more rapidly than healthy cones. Cultural practices that promote a larger root system can help to delay this accelerated maturation of cones. Irrigating for longer periods does not compensate for poor root health.

Figure 3. Powdery mildew levels on leaves and cones late in the season tend to increase with higher nitrogen fertility

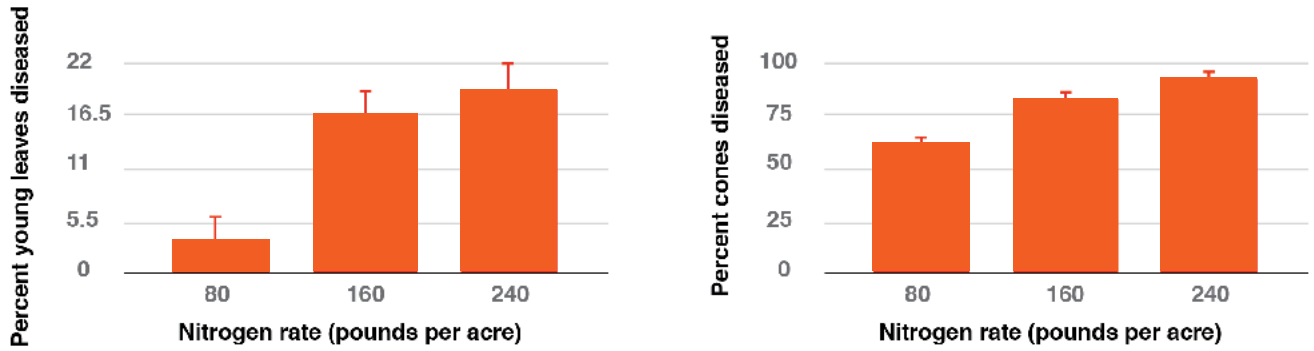


Table 3. Seasonal calendar of management considerations for powdery mildew

The timeframe shown here is approximate. The necessity of any given practice depends on variety, disease pressure and other factors.

	Off-season	March	April	May	June	July	Aug	Sept
Before planting								
Variety selection	●							
Plant population/spacing	●							
Ensure planting material is disease-free	●	●	●	●				
Cultural practices								
Scouting/monitoring				●	●	●	●	●
Thorough spring pruning; adjust timing		●	●	●	●			
Training density				●	●	●		
Reduce nitrogen fertilization as much as feasible				●	●	●	●	●
Remove basal foliage						●	●	●
Manage cover crops/weeds				●	●	●	●	●
Avoid excessive irrigation				●	●	●	●	●
Chemical controls								
First fungicide application				●	●			
Incorporate fungicides with contact activity				●	●	●	●	●
Incorporate copper into downy mildew program				●	●	●	●	
General period for use of sulfur fungicides				●	●	●	●	
Use of drip-applied fungicides					●	●	●	
Use of foliar-applied fungicides with excellent residual and post-infection activity						●	●	
Use of most efficacious fungicides on cones							●	●
Apply fungicides up to preharvest interval for maximum disease control								●
Quantity coverage; adjust sprayer for maximum coverage				●	●	●	●	●
Other considerations								
Communicate disease levels				●	●	●	●	●
Monitor dry matter to time harvest								●

Chemical controls

In susceptible varieties, it is usually necessary to apply fungicides in regions where disease pressure is high. Find an updated list of registered fungicides at *pnwhandbooks.org/plantdisease*. An online risk index can help you determine disease hazard levels (see *uspest.org/risk/models*). Note that fungicides alone are not enough to manage the disease in the absence of cultural practices or other control measures.

- **Ensure timely fungicide application**

  The efficacy of fungicide programs depends on disease pressure. The timing of the first fungicide application is critical to keeping disease levels low. In high disease-risk situations, this corresponds to when disease is present on less than 1% of plants.

- **Incorporate products with contact activity in fungicide programs**

  Most synthetic fungicides have limited or no postinfection (kick-back) activity. Using fungicides with postinfection activity can enhance disease control. Examples of fungicides with postinfection activity include horticultural oils, bicarbonates and, to a lesser extent, sulfur.

- **Apply the right fungicide at the right time**

  Using the most effective fungicides during bloom and the early stages of cone elongation can significantly enhance control of powdery mildew on hop cones at harvest. Fungicides containing quinoxyfen (Quintec), fluopyram (Luna products), and flutriafol (TopGuard Specialty Crops) have been shown to be most effective during this period (Figure 4). You'll need short intervals of the most effective fungicides for maximal disease control. Fungicides applied after mid-August can reduce disease levels on cones and improve cone color, but these improvements tend to be marginal. The timing of the last fungicide application depends on disease pressure, variety susceptibility and harvest date.

Figure 4. Impact of fungicide

Summary data from 2001 to 2012 illustrating the impact of using a highly effective fungicide such as quinoxyfen during the early stages of cone development, as compared to other times of season, or not using quinoxyfen at all.

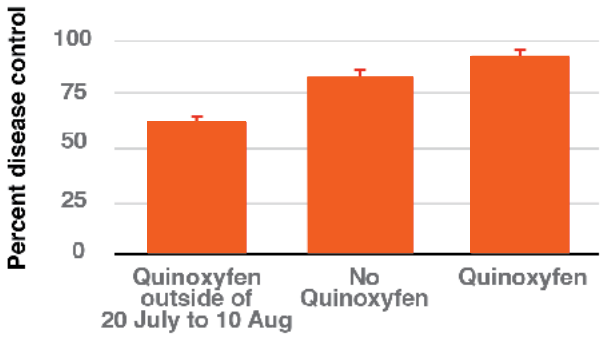


Photo: David H. Gent

Figure 5. Extensive powdery mildew on cones in the interior portion of the crop canopy associated, in part, with inadequate fungicide coverage

- **Consider other fungicide factors**

  Postharvest fungicide applications for powdery mildew generally are not recommended in established yards in the western U.S. Information is not available on the benefit of fungicides applied after harvest in first-year plantings or where the sexual stage of the fungus (forming chasmothecia) occurs.

- **Ensure thorough application coverage**

  It is exceedingly difficult to obtain adequate spray coverage on hop (Figure 5). Measure actual spray coverage using dyes and water-sensitive paper at various heights in the canopy and in the interior of plants. Where permitted, include a surfactant to improve coverage. Always apply fungicides at rates specified on the product label.

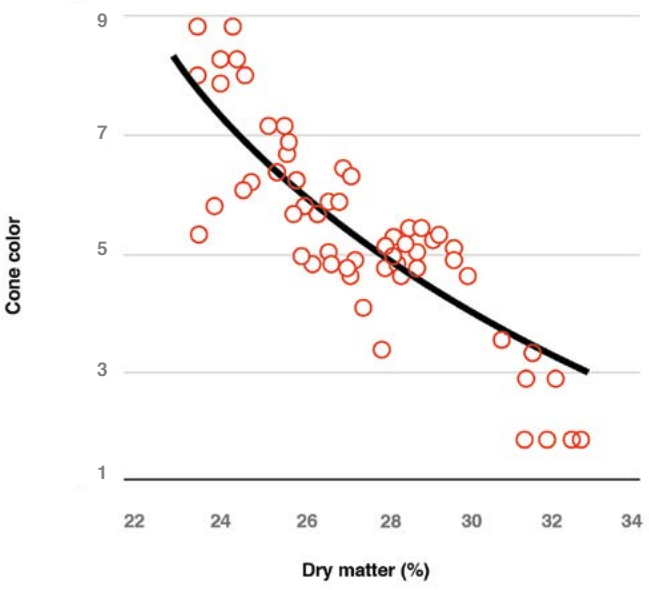
Other considerations

- **Scout, sample and monitor for disease**

  Disease outbreaks are more easily managed when discovered early. Monitor powdery mildew levels throughout the growing season to ensure timely and appropriate application of various disease management strategies (Table 3, page 4). Disease scouting is critical for identifying problems with fungicide applications, such as spray coverage issues or disease control failures due to fungicide

Figure 6. Association between cone color and dry matter

Cone color is shown on a scale of 1 to 10, where 10 is the greenest possible color. In the presence of powdery mildew, it is important to harvest before dry matter exceeds about 25.5%. That way, you can maximize color and reduce cone shatter during picking.



resistance. Sampling should ideally be conducted weekly. Carefully examine at least 100 to 200 plants in a hop yard. Spread out sampling over the entire yard, but specifically target known problem areas.

- **Communicate disease risks to neighbors**

  The powdery mildew fungus can travel long distances — multiple miles — as airborne spores. Knowing where the disease is present in the region helps growers gauge the hazard of infection due to inoculum originating from other yards or farms. Disease spread is mostly localized to a few miles in spring. Later in the summer, it can disperse over longer distances.

- **Harvest in a timely manner**

  Cone dehydration and maturation accelerate in the presence of powdery mildew. In varieties such as Galena and Zeus, monitor dry matter early and harvest before dry matter exceeds approximately 25.5% to maintain cone color and minimize crop losses during picking (Figure 6).

Resources

Gent, D.H., G.G. Grove, M.E. Nelson, S.N. Wolfenbarger and J.L. Woods. 2014. Crop damage caused by powdery mildew on hop and its relationship to late season management. *Plant Pathology* 63(3):625–639.

Gent, D. H., C. Probst, M.E. Nelson, G.G. Grove, S.T. Massie and M.C. Twomey. 2016. Interaction of basal foliage removal and late season fungicide applications in management of hop powdery mildew. *Plant Disease* 100(6):1153-1160.

Gent, D.H., W.F. Mahaffee, W.W. Turechek, C.M. Ocamb, M.C. Twomey, J.L. Woods and C. Probst. 2019. Risk factors for bud perennation of *Podosphaera macularis* on hop. *Phytopathology* 109(1):74-83.

Nelson, M.E., D.H. Gent and G.G. Grove. 2015. Meta-analysis reveals a critical period for management of powdery mildew on hop cones. *Plant Disease* 99(5):632-640.

Probst, C., M.E. Nelson, G.G. Grove, M.C. Twomey and D.H. Gent. 2016. Hop powdery mildew control through alteration of spring pruning practices. *Plant Disease* 100(8):1599-1605.

Twomey, M.C., S.N. Wolfenbarger, J.L. Woods and D.H. Gent. 2015. Development of partial ontogenic resistance to powdery mildew in hop cones. *PloS ONE* 10(3):e0120987.

Wolfenbarger, S., S.T. Massie, E.B. Eck, G.G. Grove, M.E. Nelson, C. Probst, M.C. Twomey and D.H. Gent. 2016. Distribution and characterization of *Podosphaera macularis* virulent on hop cultivars possessing R6-based resistance to powdery mildew. *Plant Disease* 100(6):1212-1221.

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