

4. Hops

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Hops: Diseases

Mizuho Nita, Extension Plant Pathologist, Alson H. Smith Jr. AREC

Nonchemical Approaches

Preplanting Considerations

Site Selection and Evaluation

Air circulation and water drainage are the two key factors when it comes to disease management. Poorly drained soil promotes some soilborne pathogens, such as black root rot (caused by *Phytophthora citricola*) and crown gall (caused by *Agrobacterium tumefaciens*). Poor air circulation will promote diseases such as downy mildew and Botrytis gray mold because the pathogens for these diseases thrive in moist environments. Also, please note that variety selection can depend on site characteristics. For example, cultivars such as Magnum and Perle have been grown for centuries in European countries with well-drained and low pH (5.5-6.2) soil conditions. Therefore, it is recommended that you examine characteristics of your site, such as water drainage, pH, air circulation, sun exposure, availability of nutrients, etc., prior to the selection of cultivars.

Cultivar Selection

Both downy mildew (caused by *Pseudoperonospora humuli*) and powdery mildew (caused by *Podosphaera macularis*) are destructive diseases of hop. Considering environmental conditions during the growing season, it is best to select varieties that are not susceptible to these two diseases. Cascade, Fuggle, Magnum, Newport, and Perle are considered resistant to downy mildew. Comet, Crystal, First Gold, Newport, and Nugget are resistant to powdery mildew, and other cultivars, such as Cascade, Centennial, Hallertauer Tradition, Liberty, Pioneer, and Teamaker are moderately resistant to powdery mildew. On the other hand, cultivars such as Cluster, East Kent Golding, Tolhurst, and Vanguard are known to be susceptible to both powdery and downy mildew; thus, these cultivars should be avoided.

Quality of Rhizomes

The downy mildew pathogen as well as viral pathogens can survive in plant tissues. Therefore, it is very important to obtain certified rhizomes from reputable sources. Unfortunately, even certified, disease-tested rhizomes have a chance of carrying pathogens; however, certified rhizomes will be much cleaner than noncertified rhizomes and will greatly minimize the risk of disease development in young hop yards.

Other Cultural Practices

Row spacing and row orientation need to be carefully planned, not only to maximize production per acreage, but also to achieve good air circulation. For example, higher planting density with Cascade is known to increase the risk of downy and powdery mildew development. If irrigation is considered for your hop yards, overhead irrigation should be avoided because it will create an environment that is conducive to disease development. Also, excessive nitrogen can make hop plants more susceptible to some diseases.

In-Season Considerations

Dormant Season Disease Management

Both downy mildew and powdery mildew pathogens can overwinter in infected dormant buds and crowns. The emerging buds can be infected during the winter and spring. Thus, it is important to manage downy mildew and powdery mildew as the season starts. Spring pruning can be done in late winter or early spring by removing all basal shoots to remove potentially infected shoots from the previous season. Also, “crowning,” the removal of the top 1-2 inches of the crown prior to training, and “scratching,” the removal of buds from within 1-2 inches of the soil surface using a special device, can be done. The timing of pruning is variety-specific and can affect yield potential; follow recommendations for your varieties.

Stripping

After the trained vines grow to a certain height, the lower 4-5 feet of the leaves and lateral branches need to be removed to minimize the spread of downy and powdery mildew. The process is called “stripping” and can be done mechanically.

Chemical Control Recommendations

Pathogen Biology and Timing of Fungicide Application

Use of fungicides depends on other factors, such as site, weather, cultivar, cultural practice, etc. However, in general, preventative application of fungicides with 10-14-day intervals is recommended to minimize the risk of disease outbreak. The frequency of application depends on the growth of the vines as well as environmental conditions. For example, the downy mildew pathogen becomes active when the temperature is above 41 degrees Fahrenheit (F), and rain events promote their infection process. The powdery mildew pathogen becomes active at temperatures above 46° F, and the optimal temperature for pathogen growth is 64-70° F. The infection risk is very high when the minimum nighttime temperature is above 50° F and the daily high temperature is below 68° F. Once temperatures increase in the summer (3 or more hours above 86° F per day), the risk of powdery mildew infection decreases. Another disease to be considered is Botrytis gray mold, caused by *Botrytis cinerea*. When a prolonged wetness event is expected at burr development, a specific application against Botrytis may be needed.

Fungicide Resistance Management

Use sufficient water to ensure complete coverage of the foliage. Make sure to (1) tank mix, (2) rotate the Fungicide Resistance Action Committee (FRAC) mode of action groups (www.frac.info), and (3) limit the use of the same FRAC group to 2-3 times per season (with exceptions for copper, sulfur, and oil) to minimize the risk of fungicide resistance development. Tank mixing of fungicide can be done by placing two or more fungicidal chemicals into a spray tank. It is recommended to mix two or more different mode of action groups in order to reduce development of fungicide resistance. The mode of action of a chemical is the way(s) for the chemical to either kill or deactivate the target pathogens, and its classification is listed on the label as FRAC group. Fungicides with the same FRAC group share the same mode of action and are essentially the same in terms of the risk of fungicide resistance. In order to minimize the cost of application, it is often recommended to mix a material with a single mode of action and a broad-spectrum material, such as copper. Also, please note that some combinations of fungicides, oils, and plant nutrients are not compatible when mixed in the same tank, which may cause injury to your plant. Some labels list tank mixing partners.

In the case of a prolonged rain event, you may use either phosphorous acid (FRAC group 33) and/or metalaxyl (FRAC group 4) to control ongoing infection of downy mildew. However, application of the material has to be done within a few days of rain, prior to symptom development. Application of these materials against actively sporulating downy mildew colonies can increase the risk of fungicide resistance development. The same principle applies to fungicide resistance management of powdery mildew. Avoid the application of group 3, 11, 13, or 27 fungicide onto actively sporulating powdery mildew colonies. Potassium salt or oil-based products are recommended in such a case.

Table 4.1 Fungicides Registered for Control of Hop Diseases in Virginia

Pest	Fungicide	Rate/Acre	FRAC* Grouping	Spray Timing and Remarks
Before bine training				
Downy mildew	Metastar 2E	1 qt	4	A soil-drench application in a minimum of 20 gal of water or liquid fertilizer. Apply after pruning but before bine training (shoot length less than 6 inches).
From the beginning of bine training				
Downy mildew	Curzate 60DF	3.2 oz	27	Ten-14-day interval application (depends on the environmental conditions).

Table 4.1 Fungicides Registered for Control of Hop Diseases in Virginia (cont.)

Pest	Fungicide	Rate/Acre	FRAC* Grouping	Spray Timing and Remarks
Downy mildew	Fixed copper (various formulations)	See label	M1	<p>With other crops, downy mildew strains that are resistant to Flint, Pristine, and other strobilurin (aka Qol) and Metastar (metalaxyl) fungicides are common. Rotating and tank mixing with a different anti-downy-mildew material (e.g., copper) is highly recommended.</p> <p>There are many formulations of phosphorous acid and fosetyl-AI (both are FRAC group 33) and copper products; refer to the label for the rate for the product. A high concentration of a phosphorous acid may cause plant injury. Also, some formulations of phosphorous acid and copper may cause plant injury.</p> <p>Group 40 materials (Forum, Revus, and Zampro) provide very good protection against downy mildew; however, as with others, tank mix, rotation, and limited usage (2-3 times/year) are recommended.</p> <p>Cruzate, Metastar, or Tanos has to be tank mixed with another broad-spectrum fungicide active against downy mildew, such as copper.</p>
	Flint	4 oz	11	
	Forum	6 oz	40	
	Fosetyl-AI (various formulations)	See label	33	
	Metastar 2E	1 qt	4	
	Phosphorous acid (various formulations)	See label	33	
	Pristine	14 oz	7+11	
	Revus	11-14 oz	40	
	Tanos	8 oz	11+27	
	Zampro	8 fl oz	40 + 45	
Powdery mildew	Fixed copper (various formulations)	See label	M1	<p>10-14-day interval application (depends on the environmental conditions).</p> <p>Due to the risk of fungicide resistance development, do not use sterol inhibitors (aka DMI; FRAC group 3) or strobilurins (aka Qol; FRAC group 11) continuously; rotate with other groups of fungicides. It is recommended that sterol inhibitors and strobilurins be tank mixed with sulfur or copper material, and limit the use of FRAC groups 3 and 11 to 2-3 times/season. Pristine contains a strobilurin along with a different active chemical (SDHI) that has an efficacy against Botrytis gray mold.</p> <p>Avoid using sterol inhibitors or strobilurins when there is a powdery mildew outbreak. Potassium bicarbonate products are recommended for an ongoing powdery mildew issue.</p> <p>The rate for sulfur is generally 2-3 lb/100 gal, but it can be increased to as high as 6 lb/100 gal. Severe disease pressure may warrant this, but beware of possible plant injury at higher rates.</p> <p>Mineral and neem oil products can control powdery mildew; however, there is some evidence of plant injury with the use of oil. See the label for detailed instructions. Also, avoid using oil and sulfur within two weeks of each other because it may cause injury to the plants.</p>
	Flint	4 oz	11	
	Mineral oil, neem oil	See label	NC	
	Potassium bicarbonate (Kaligreen, etc.)	See label	NC	
	Pristine	14 oz	7+11	
	Procure 480 SC	4-8 oz	3	
	Quintic	4.0-8.2 oz	13	
	Rally 40WSP	2-10 oz	3	
	Tanos	8 oz	11+27	
	Tebuconazole (various formulations)	2-8 oz	3	
	Wettable sulfur (various formulations)	2-6 lb	M2	
	<i>After burr development</i>			
Botrytis	Pristine	14 oz	7+11	Although Pristine contains two different FRAC groups, strains of Botrytis that can overcome both FRAC groups are present in Virginia. Make sure to tank mix with a broad-spectrum fungicide, such as copper. Also, applications of Pristine should be limited to 2-3 times/season.
<i>After harvest</i>				

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Table 4.1 Fungicides Registered for Control of Hop Diseases in Virginia (cont.)

Pest	Fungicide	Rate/Acre	FRAC* Grouping	Spray Timing and Remarks
Downy mildew and powdery mildew	Fixed copper (various formulations)	See label	M1	Once or twice after harvest. It is important to keep vines healthy after harvest to ensure the accumulation of carbohydrates into the rhizome for winter survival. Copper products should be sufficient to provide protection against both downy mildew and powdery mildew in most cases, but you may need to use sulfur to control powdery mildew. If there is a prolonged rain event and your hop yards have a history of downy mildew, you may need to use either phosphorous acid or fasetyl-Al.
	Fosetyl-Al (various formulations)	See label	33	
	Phosphorous acid (various formulations)	See label	33	
	Wettable sulfur (various formulations)	2-6 lb	M2	

* Fungicide Resistance Action Committee.

Table 4.2 Chemical Names, Restricted Entry Interval (REI), and Preharvest Interval (PHI)

Chemical (other names)	Manufacturer	REI (hours)	PHI (days)
Actinovate AG (<i>Streptomyces lydicus</i> ; WYEC 108)	Natural Industries	1	0
Bio-Tam (<i>Trichoderma gamsii</i> , strain ICC 080, and <i>Trichoderma asperellum</i> , strain ICC 012)	Agraquest	1	0
Carbon Defense (potassium silicate)	FBSciences	4	0
Copper (various formulations: Champ WG, Cueva, Kocide, Nordox 75WG, etc.)	Various	4-48 (see label)	0-14 (see label)
Curzate 60DF (cymoxanil)	Dupont	12	7
Double Nickel 55 and LC (<i>Bacillus amyloliquefaciens</i> , strain D747)	Certis USA	4	0
Flint (trifloxystrobin)	Bayer Cropscience	12	14
Forum (dimethomorph)	BASF	12	7
Fosetyl-Al (aluminum tris; Aliette WDG, Linebacker WDG)	Various	12	24
JMS Stylet-Oil (paraffinic oil)	JMS Flower Farms	4	0*
Metastar 2E and 2E Ag (metalaxyl)	LG International	48	45
Mineral oil (various formulations: Damoil, Omni oil, etc.)	Various	4	0
Neem oil (various formulations: Trilogy, Green Light, etc.)	Various	4	0
Phosphorous acid (phosphite; various formulations: Agri-Fos, Prophyt, Phostrol, etc.)	Various	4	0
Potassium bicarbonate (various formulations: Armicarb, Kaligreen, etc.)	Various	4	0-1 (see label)
Pristine (pyraclostrobin + boscalid)	BASF	12	14
Procure 480 SC (triflumizole)	Chemtura	12	7
Quintec (quinoxifen)	Dow Agrosciences	12	21
Rally 40WSP (myclobutanil)	Dow AgroSciences	24	14
Regalia, Regalia PTO, and Regalia Rx (<i>Reynoutria sachalinensis</i>)	Marrone Bioinnovations	4	0
Revus (mandipropamid)	Syngenta	4	7

Table 4.2 Chemical Names, Restricted Entry Interval (REI), and Preharvest Interval (PHI) (cont.)

Chemical (other names)	Manufacturer	REI (hours)	PHI (days)
Suffoil-X (aliphatic petroleum solvent)	Bioworks	4	0
Sulfur (various formulations: Acoidal, Kumulus DF, Microthiol D, etc.)	Various	24	0
Tanos (cymoxanil + famoxadone)	Dupont	12	7
Tebuconazole (various formulations: AmTide Tebu 3.6 F, Orius, etc.)	Various	12	14
Zampro (amedoctradin + dimethomorph)	BASF	12	7

*Label recommends termination of use at burr development.

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Hops: Insects

Douglas G. Pfeiffer, Fruit Entomologist, Virginia Tech

Nonchemical Approaches

Site Selection

The likelihood that some insects will develop into pest status in a commercial planting is affected by environmental factors. This is true for the Japanese beetle. Larvae of the Japanese beetle feed on grass roots; consequently, if a planting is adjacent to pastureland, there is a nearby breeding ground. Plantings surrounded by woods will have less immigration pressure

Biological Control

Some pests, such as the twospotted spider mite, are excellent candidates for biological control. A complex of native predators will feed on the twospotted spider mite and can maintain its populations below damaging levels unless disrupted by chemical controls for other pests. Toxicity to natural enemies should be considered when deciding on a chemical control program. If disruptive materials are to be used, pay close attention to twospotted spider mite populations.

Chemical Control Recommendations

Resistance Management

Several factors affect the likelihood of resistance to pesticides, notably the number of generations per season and the number of offspring per female (fecundity). Spider mites are notorious for developing resistance to acaricides because they have a large number of generations annually and they produce many eggs. It is important to (1) rely on natural controls as much as possible and (2) obtain maximum coverage and rotate insecticides of different modes of action when chemical control is needed. Modes of action are indicated by the Insecticides Resistance Action Committee (IRAC) grouping (www.iraac-online.org/documents/moa-classification/?ext=pdf).

Table 4.3. Insecticides Registered for Control of Hop Insect Pest Control in Virginia

Pest	Insecticide	Rate/Acre (unless noted)	IRAC* Grouping	Spray Timing and Remarks
Variegated cut-worm, loopers	Baythroid XL	3.2 fl oz	3A	An action threshold has not been established for these pests. Larvae may cause defoliation on the plant and may feed on cones directly, especially late in the season. Larval population should not be allowed in the upper canopy in the late season. Sample by spreading a sheet on the ground and shaking the bine vigorously for about 15 seconds. Dipel and Entrust are OMRI-approved, suitable for organic production.
	Brigade 2SC	3.8-6.4 fl oz	3A	
	Coragen 1.67EC	3.5-5 fl oz	28	
	Delegate 25WG	2.5-4 oz	5	
	Dipel DF	1 lb	11A	
	Entrust 2SC	4-6 fl oz	5	
Twospotted spider mite	Acramite 50WS	0.75-1.5 lb	UN	Do not spray for spider mites preventatively in order to prevent the development of resistance. If multiple sprays are needed, rotate to a different IRAC class. Savey is strictly an ovicide and will not immediately reduce a high population. An action threshold has not been established, but a tentative threshold is 2-3 female mites/leaf until mid-July and 10 mites/leaf thereafter. Use a 10x hand lens when counting mites. Natural enemies often control spider mites, so sprays should not be used against sub-economic populations. Use of pyrethroid insecticides will often induce mite outbreaks.
	Agri-Mek 8SC	1.75-3.5 fl oz	6	
	Envidor 2SC	18-24.7 fl oz	23	
	Portal 0.4E	2-3 pt	21A	
	Savey 50DF	4-6 oz	10A	
	Zeal	3-4 oz	10B	

Table 4.3. Insecticides Registered for Control of Hop Insect Pest Control in Virginia (cont.)

Pest	Insecticide	Rate/Acre (unless noted)	IRAC* Grouping	Spray Timing and Remarks
Aphids	Baythroid XL	3.2 fl oz	3A	Before flowering, use a tentative action threshold of 5-10 aphids/leaf. Control is difficult if aphids become established on cones. BotaniGard is OMRI-approved, suitable for organic production.
	BotaniGard ES	1 qt	N/A	
	Brigade 2SC	3.8-6.4 fl oz	3A	
	Fulfill 50WDG	4-6 oz	9B	
	Malathion 57EC	1 pt	1B	
	Movento 2EC	5-6 fl oz	23	
Japanese beetle	Brigade 2SC	3.8-6.4 fl oz	3A	Surround, Neemix, Trilogy, and PyGanic are all OMRI-approved. Neemix and Trilogy are to be applied together.
	Neemix 4.5 + Trilogy	1-2 gal Neemix + 7-16 fl oz Trilogy/100 gal	UN	
	PyGanic 5EC	16-32 fl oz/100 gal	3A	
	Surround	25-50 lb	UN	
Potato leafhopper	Malathion 57EC	1 pt	1B	Potato leafhopper may be more common if alfalfa is grown nearby, especially after alfalfa cutting. M-Pede is OMRI-approved.
	M-Pede	2% solution	--	
	Movento 2SC	5-6 fl oz	23	

*Insecticides Resistance Action Committee

Table 4.4. Insecticide Names, Restricted Entry Interval (REI), and Preharvest Interval (PHI)

Pesticide	Manufacturer	REI (hours)	PHI (days except where noted)
Acramite (bifenazate)	Chemtura	12	14
Agri-Mek (abamectin)	Syngenta	96	28
Baythroid (beta-cyfluthrin)	Bayer	12	7
BotaniGard ES (Beauveria bassiana)	LAM International	4	0
Brigade (bifenthrin)	FMC	12	14
Coragen (chlorantraniliprole)	Dupont	4	0
Delegate (spinetoram)	Dow	4	1
Dipel (Bacillus thuringiensis)	Valent	4	0
Entrust SC (spinosad)	Dow	4	1
Envidor (spirodiclofen)	Bayer	12	14
Fulfill (pymetrozine)	Syngenta	12	14
Malathion (malathion)	Loveland	12	10
Movento (spirotetramat)	Bayer	24	7
M-Pede (insecticidal soap)	Gowan	12	0
Neemix (azadirachtin)	Certis	4	0
Portal (fenpyroximate)	Nichino	12	15
PyGanic (pyrethrins)	MGK	12	0
Savey 50DF (hexythiazox)	Gowan	12	Until burr formation
Surround (kaolin)	NovaSource	4	0
Trilogy (clarified extract of neem oil)	Certis	4	0
Zeal (etoxazole)	Valent	12	7

Hops: Weed Management

Jeffrey Derr, Extension Weed Scientist, Hampton Roads AREC

Nonchemical Approaches

Apply mulch at a 2-4 inch depth using a mulch that is free of weed seed or use shallow cultivation (2-4 inches).

Chemical Control Recommendations

Organic Production

Acetic acid (Weed Pharm) can be applied as a directed spray for nonselective contact control of small annual weeds. This will suppress perennial weeds; repeat treatments will be needed to control regrowth. Do not allow spray to contact hops foliage.

Conventional Production

Table 4.5. Herbicide Common and Trade Names, Rate per Acre, and Comments

Application	Common Name (Trade Name)	Rate of Active Ingredient per Acre (Rate of Product per Acre)	Timing and Remarks
Preemergence to weeds	Flumioxazin (Chateau)	3 oz (6 oz)	Apply to dormant hops in January-March as a 1-1.5-foot strip on each side of the row. Make only 1 application/year. For small areas, apply 0.13 oz Chateau/1,000 sq ft. Controls a range of annual weeds
	Norflurazon (Solicam)	2-4 lb (2.5-5.0 lb)	Apply as a directed spray to hops established at least 6 months. Use lower rates on sandy soils. For small areas, apply 0.9-1.8 oz Solicam/1,000 sq ft. Controls a range of annual weeds and suppresses yellow nutsedge.
	Trifluralin (Treflan 4EC or other labeled formulation)	0.50-0.75 lb (1.0-1.5 pt)	Apply as a directed spray to dormant, established hops, avoiding hops crowns. Immediately incorporate 1-2 inches deep. Do not spray over hops. For small areas, apply 0.37-0.55 fl oz Treflan 4EC/1,000 sq ft. Controls annual grasses and certain small-seeded annual broadleaf weeds.
Postemergence to weeds	Clethodim (Select Max)	0.07-0.12 lb (9-16 fl oz)	Apply to actively growing annual and perennial grassy weeds. Will not control nongrass monocots or any broadleaf weeds. Perennial grasses like johnsongrass and bermudagrass generally will require retreatment. Add a nonionic surfactant at 0.25% V/V. There is a 21-day PHI.
	2,4-D (2,4-D Amine 4 or other labeled formulation)	0.48 lb ae (1 pt)	Make a directed spray to the row middles. Use a shielded or hooded sprayer to prevent contact with hops foliage. Controls certain annual broadleaf weeds. The PHI is 28 days.

4-10 Hops: *Weed Management*

Table 4.5. Herbicide Common and Trade Names, Rate per Acre, and Comments (cont.)

Application	Common Name (Trade Name)	Rate of Active Ingredient per Acre (Rate of Product per Acre)	Timing and Remarks
Postemergence to weeds (cont.)	Glyphosate	0.39-3.70 lb ae	Apply only when there are no green shoots of hops within the spray zone. For small areas, mix 2 fl oz/gallon and lightly wet the weed foliage. There is a 14-day PHI. Controls annual and perennial weeds. Use a shielded spray to avoid contact with hops foliage.
	(Roundup PowerMAX or other labeled formulation)	(11.0 fl oz-3.3 qt)	

Table 4.6. Herbicide, Manufacturer, Restricted Entry Interval (REI), and Preharvest Interval (PHI)

Herbicide Trade Name	Manufacturer	REI (hours)	PHI (days)
2,4-D Amine 4	WinField Solutions	48	28
Chateau	Valent	12	30
Roundup PowerMAX	Monsanto	4	14
Select Max	Valent	24	21
Solicam	Syngenta	12	60
Treflan 4EC	Helena	12	—