MICHIGAN STATE UNIVERSITY | Extension

2024

Michigan Hop Management Guide

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Using the hop management guide

Information presented here does not supersede the label directions. To protect yourself, others, and the environment, always read the label before applying any pesticide. Although efforts have been made to check the accuracy of information presented, it is the responsibility of the person using this information to verify that it is correct by reading the corresponding pesticide label in its entirety before using the product. The efficacies of products listed have not always been evaluated on hop in Michigan. Reference to commercial products or trade names does not imply endorsement by Michigan State University Extension or bias against those not mentioned.

The information presented here is intended as a guide for Michigan hop growers in selecting pesticides and is for educational purposes only. Labels can and do change. For current label and MSDS information, visit one of the following free online databases: greenbook.net, cdms.com, and agrian.com.

Endangered Species Act impacting pesticide labels

The Environmental Protection Agency is changing the way it enforces the Endangered Species Act in respect to pesticide applications. Growers must carefully read all pesticide labels and should look for changes in the 'Environmental Hazards' section which may now require growers to check the Bulletins Live! Two system to determine if there are any new pesticide use limitation on their farm. These EPA bulletins define geographically specific pesticide use limitations for the protection of threatened and endangered species and their designated critical habitat. If your pesticide label directs you to this website, you are required to follow the pesticide use limitation(s) found on your label and in the Bulletins Live! Two system for your intended application area, pesticide product, and application month. You may not see any geographically specific use limitations for the product you are applying even if your label directed you to this website. Growers should keep a copy of the bulletin with their pesticide records. Learn more by visiting https://www.epa.gov/endangered-species/endangered-species-protection-bulletins and contact MDARD with questions at MDA-Info@Michigan.gov.

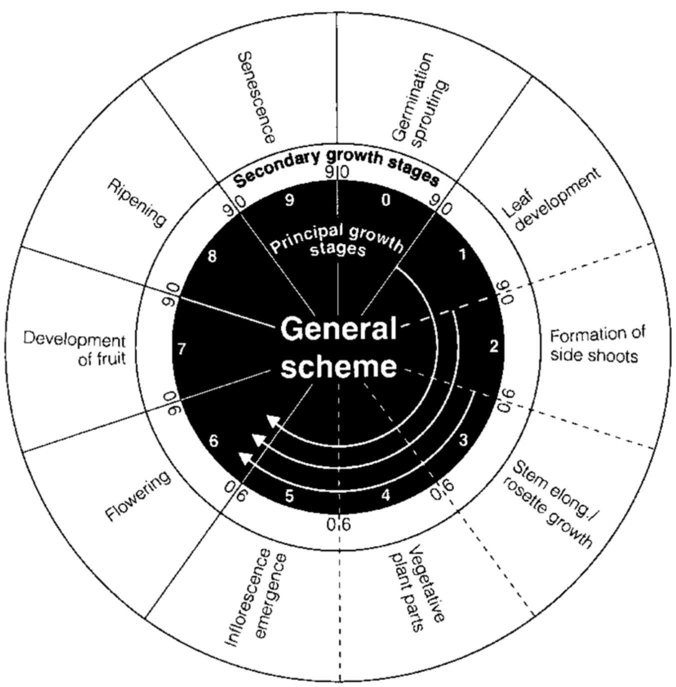
Hop exportation considerations for maximum residue levels

The US Hop Industry Plant Protection Committee has actively sought harmonization of pesticide regulatory standards (maximum residue levels or MRLs) in key customer countries for the past three decades. As US hops are exported worldwide, ensuring consistent regulatory standards between the US and export customers avoids trade issues and interruption of shipments. US HIPPC also collaborates with other hop producing countries through participation in the International Hop Growers Convention and the European Union Commodity Expert Group for Hops.

Some countries do not allow application of certain plant protection products or have lower MRLs than in the U.S. If you export hops you will need to comply with the relevant international MRLs. Export restrictions may apply to the pesticides included in this guide. Growers planning to export their hops should carefully review the Hop MRL Tracking Chart at https://www.usahops.org/growers/plant-protection.html.

Growth stages guide

October-March	April		May	June	July		August	September
Dormancy	Spring Regrowth		Vegetative Growth		Reproductive Growth			Preparation for Dormancy
	sprouting	leaf development		side shoots	burr stage	flowering	cone development	maturity of cones
		elongation of bines						



Hop Rossbauer et al., 1995

Phenological growth stages and BBCH-identification keys of hop
(*Humulus lupulus* L.)

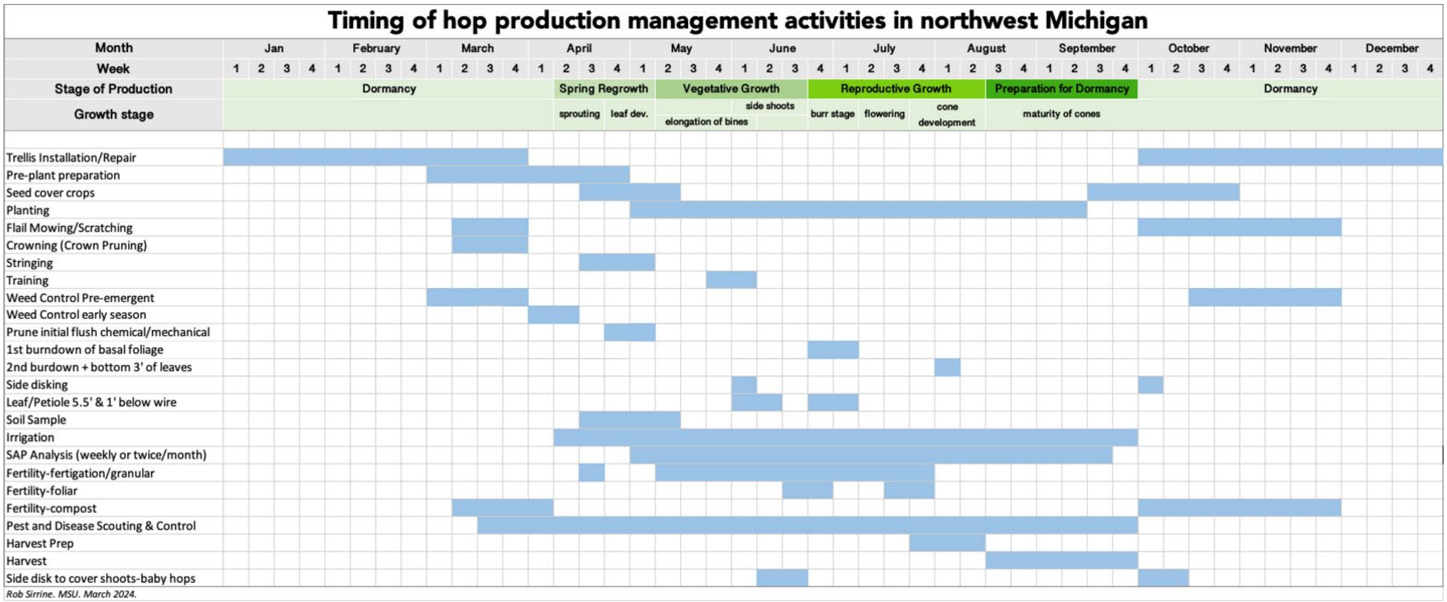
Code	Description
Principal growth stage 0: Sprouting	
00	Dormancy: rootstock without shoots (uncut)
01	Dormancy: rootstock without shoots (cut)
07	Rootstock with shoots (uncut)
08	Beginning of shoot-growth (rootstock cut)
09	Emergence: first shoots emerge at the soil surface
Principal growth stage 1: Leaf development	
11	First pair of leaves unfolded
12	2nd pair of leaves unfolded (beginning of twining)
13	3rd pair of leaves unfolded
1 .	Stages continuous till . . .
19	9 and more pairs of leaves unfolded
Principal growth stage 2: Formation of side shoots	
21	First pair of side shoots visible
22	2nd pair of side shoots visible
23	3rd pair of side shoots visible
2 .	Stages continuous till . . .
29	Nine and more pairs of side shoots visible (secondary side shoots occur)
Principal growth stage 3: Elongation of bines	
31	Bines have reached 10% of top wire height
32	Bines have reached 20% of top wire height
33	Bines have reached 30% of top wire height
3 .	Stages continuous till . . .
38	Plants have reached the top wire
39	End of bine growth
Principal growth stage 5: Inflorescence emergence	
51	Inflorescence buds visible
55	Inflorescence buds enlarged

Hop Rossbauer et al., 1995

Phenological growth stages and BBCH-identification keys of hop

Code	Description
Principal growth stage 6: Flowering	
61	Beginning of flowering: about 10% of flowers open
62	About 20% of flowers open
63	About 30% of flowers open
64	About 40% of flowers open
65	Full flowering: about 50% of flowers open
66	About 60% of flowers open
67	About 70% of flowers open
68	About 80% of flowers open
69	End of flowering
Principal growth stage 7: Development of cones	
71	Beginning of cone development: 10% of inflorescences are cones
75	Cone development half way: all cones visible, cones soft, stigmas still present
79	Cone development complete: nearly all cones have reached full size
Principal growth stage 8: Maturity of cones	
81	Beginning of maturity: 10% of cones are compact
82	20% of cones are compact
83	30% of cones are compact
84	40% of cones are compact
85	Advanced maturity: 50% of cones are compact
86	60% of cones are compact
87	70% of cones are compact
88	80% of cones are compact
89	Cones ripe for picking: cones closed; lupulin golden; aroma potential fully developed
Principal growth stage 9: Senescence, entry into dormancy	
92	Overripeness: cones yellow-brown discoloured, aroma deterioration
97	Dormancy: leaves and stems dead

Management activities guide



Weed management

Weed management tips to achieve best results

Reprinted with permission from ID-462-W Hops Production in Indiana, Integrated Pest Management Guide for Hops 2015

Weeds in the row can be a major source of competition in hops, especially in new plantings. Weeds compete for nutrients and moisture and can interfere with crop management practices. As with most crops, as weed densities increase, hop yields decrease. Consequently, it is important to manage weeds in the hop row. Most Midwest hopyards maintain permanent cover crops between the rows. The benefits of this practice include less erosion and soil compaction, better water infiltration, and habitat to attract beneficial insects.

The width of the in row weed-free strip depends on soil type, and grower preference. Generally, the strip should be wider on soils that have low moisture holding capacity. A width of 4 feet is probably adequate, but there is limited experience with hops on Michigan soils. Either mechanical or chemical means (or a combination of both methods) can be used to manage weeds in this strip. Chemical weed management of baby hops is extremely limited.

Mechanical Controls

Mechanical cultivation is very effective at reducing weed populations. However, frequent cultivation can destroy soil structure and may damage hop crowns. Avoid cultivating when soil is wet when heavier soils are particularly susceptible to compaction. Growers have also achieved some success controlling weeds with a side-mounted weed badger or “spin weeder” commonly used in orchards and vineyards. Hand hoeing and pulling are effective but labor intensive.

Chemical Controls

There are a limited number of herbicides registered for use on hops in Michigan. Normally, growers will use both pre- and post-emergent herbicides to achieve the best results. Herbicide application methods vary according to their activity. Applicators must apply pre-emergent herbicides very accurately to properly control weeds and avoid damaging the crop. An applicator must have a carefully calibrated sprayer capable of accurately maintaining pressure, flow rate, and ground speed. Applying pre-emergent herbicides with a backpack sprayer is not recommended because they cannot be applied with the precision required.

Post-emergence herbicides are easier to apply with hand-held equipment because they are applied as a dilution instead of a rate per acre. They can be applied at a volume necessary to cover the weeds without exact control over volume per acre. Backpack sprayers, wipers, and other hand-held equipment are suitable for post-emergence herbicides, but more efficient methods of application should be considered for larger yards. In general, post-emergent herbicides provide the most effective control when applied to young weeds under 6 inches in height. Some products require crop oil concentrate or an added surfactant for best results, while others may include an adjuvant. Be sure to read the label to determine what type of adjuvant (if any) is needed.

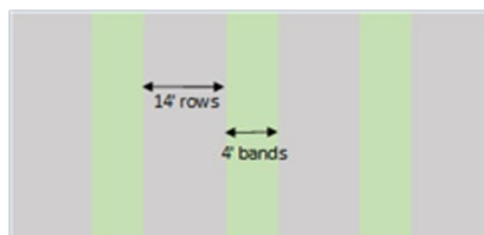
Remember that there is always a potential that herbicides can unintentionally injure the crop. Some post-emergence herbicides should not contact any portion of the green hop plant or injury will occur. 2,4-D and glyphosate are examples of herbicides that must be used very carefully and at the appropriate time to avoid injury.

APPLYING BANDED APPLICATIONS

It is very important to understand the label recommendations and the difference between broadcast rate and banded rate. Herbicide labels typically give application rates as some unit of measure (pounds, quarts, etc.) per acre. However, when applying herbicides in a hopyard, remember that only a narrow band along the row will be treated, so applicators must adjust the rate for the band width and the row spacing. An example of banded herbicide application follows.

An acre is 43,560 square feet. In this example, an acre of a hopyard has rows planted 14 feet apart. That would mean that it has 3,111 feet of row (43,560 ÷ 14). If an applicator applies a 4-foot-wide band to each row, the total area treated in the acre of hops will be 12,444 square feet (3,111 x 4), or approximately 0.28 of the total acre. So, if the herbicide label recommends a rate of 1 pound per acre and the applicator applies that full pound banded to the rows in the 1-acre hopyard, that herbicide is actually applied at 3.5 times the labeled rate, enough to severely damage the hop plants.

In the example given, 0.28 pounds of the herbicide should be applied in the appropriate volume of water to treat just the band area. Herbicide labels usually recommend application volumes of 10-40 gallons of water per acre (30 gallons per acre is a common volume). Remember, that is the broadcast volume. In the example given, the sprayer would be calibrated to apply 30 gallons per acre, and the tank filled with 8.4 gallons of water (30 x 0.28). The 0.28 pounds of product would be added and mixed with the water and applied carefully to the band beneath the hop plants.



Example for determining banded rates.

1. Divide 1 acre in sq. ft. by row spacing in ft. to determine feet of row per acre. *43,560/14 = 3,111ft*

2. Multiply the feet of row by the band width to get the area to be treated. *3,111' x 4' = 12,444 sq. ft.*

3. Divide the treated area by the area of an acre to get the percentage of acre treated. *12,444/43,560 = 0.28 = 28%*

4. Multiply the herbicide broadcast rate by the percentage of an acre as determined in step 3.
1 lb. x 0.28 = 0.28 pounds

5. Multiply the recommended volume of water for an acre by the percentage of an acre as determined in step 3. *30 gallons x 0.28 = 8.4 gallons.*

Herbicides

Registered herbicides for use on hops in Michigan, 2024

Application timing[1]	Broadleaf or grasses	Active ingredient (WSSA code[2])	Products labeled	REI/PHI[3]	Notes
Post- emergent	Broadleaf	2,4 D (4)	2,4 D Amine 4, Clean Amine, Drexel De-Amine 4, Radar AM 4, Rugged, Shredder Amine 4, Tenkoz Amine, Weedar 64,WeeDestroy AM-40 Amine Salt, Weed RHAP A 4D	see label	Controls most annual and perennial broadleaf weeds. Restricted in areas of Berrien, Van Buren and Cass County.
	Both	ammonium nonanoate	Axxe*	4h/0d	OMRI listed.
	Both	caprylic + capric acid	HomePlate 80L*	24h/	Avoid contact with crop stem and foliage. OMRI listed.
	Broadleaf	carfentrazone (14)	Aim EC[4], Antik EC	12h/7d	Use with shielded or hooded sprayers to control small broadleaf weeds and hop suckers and lower bine foliage.
	Grasses	clethodim (1)	Arrow 2 EC, Avatar, Avatar S2, Ceridian 2 EC, Cleanse, Cleanse 2 EC, Omni Brand, Clethodim 2EC, Dakota, Intensity One, Intensity Post-Emergence, Omni Brand Clethodim 2 EC, Section Three, Select Max with Inside Technology, Select 2 EC, Shadow, Shadow 3 EC, Tapout, Tide USA Clethodim 2 EC, Vaquero, Volunteer	see label	Controls annual and perennial grasses.
	Broadleaf	clopyralid (4)	Spur	12h/30d	Controls Canada thistle. Some activity on horsenettle at high rate.
	Both	glufosinate (10)	Rely 280	12h/10d	Avoid contact with hop plant. Requires sunlight for activity. For best results, make applications between sunrise and 2 hours before sunset. Weed control may be reduced by heavy dew, fog, and mist/rain.
	Both	glyphosate (9)	Abundit Edge, Buccaneer, Buccaneer Plus, Cornerstone Plus, Credit 41 Extra, Credit 5.4 Extra, Credit Xtreme, Duramax, Durango DMA, Envy, Envy Intense, Envy Six Max, Gly Star Original, Glyphogan, Gly Star Plus, Gly Star K Plus, Honcho K6 Herbicide, Makaze, Honcho Plus, Razor, Roundup PowerMAX, Roundup WeatherMAX, Showdown, Wynca USA Sunphosate 41% Herbicide	see label/14d	Apply only when green shoots, foliage or canes are not in the spray zone. Best combined with a pre-emergent early in spring for control of emerged annual and perennial weeds.
	Both	pelargonic acid (27)	Scythe	12h/see label	Uses prior to crop emergence, dormant or post harvest spray.

1. Pre-emergent herbicides should be applied to control weeds before germination takes place. Post-emergent herbicides may be applied to actively growing weeds. 2. WSSA = Weed Science Society of America mode of action code listed for resistance management planning. 3. PHI-preharvest interval, REI-restricted entry interval, expressed as h-hours or d-days. 4. Growers must print and retain a copy of supplemental or local need labels. 5. Supplemental label required.
* OMRI approved for organic production.

Registered herbicides for use on hops in Michigan, 2024

Application timing[1]	Broadleaf or grasses	Active ingredient (WSSA code[2])	Products labeled	REI/PHI[3]	Notes
Pre- emergent	Annual grasses/ broadleaf	trifluralin (3)	Cornbelt Trifluralin EC, Treflan 4L, Treflan HFP, Treflan TR-10, Trifluralin 10G, Trifluralin 4EC, Triflurex HFP, Trust	12h/see label	Rate determined by soil type- see label. Apply during dormancy.
	Broadleaf	isoxaben (21)	Trellis SC[5]	12h/see label	Apply banded applictions prior to emergence. Product is water activated.
	Both	flumioxazin (14)	Chateau Herbicide SW, Chateau EZ, Flumi 51 WDG, Flumi SX Herbicide, Flumioxazin 51% WDG, Tuscany, Tuscany SC Herbicide, Varsity, Venue, Zaltus SC	12h/30d	Apply banded to dormant hops. Controls most broadleaves and grasses, weak on horseweed.
	Both	dimethenamid-P (15)	Outlook Herbicide	12h/60d	Apply in a band over the row preemergence or directed next to rows postemergence. Use low rates on light soil.
	Both	indaziflam (29)	Alion[5]	12h/see label	Do not apply to baby hops or on sandy soils. Dormant application only.
	Both	pendimethalin	Prowl H20	24h/90d	Apply as a broadcast or banded treatment using ground equipment. Do not apply over the top of vines, leaves or cones.
	Both	norflurazon (12)	Solicam DF	12h/60d	Rate determined by soil type, wait 6 months after planting for first application.

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Disease scouting calendar

Hop Disease Scouting Calendar

Diseases	Dormancy	Sprouting	Leaf expansion	Bine elongation and sidearm formation	Flowering	Cone develoment	Cone maturity	Senescence
Downy mildew	+	+	+	+	+	+	+	+
Halo blight			+	+	+	+	+	+
Fusarium canker	+	+	+	+	+	+	+	+
Fusarium cone tip blight					+	+	+	+
Alternaria cone disorder					+	+	+	+
Gray mold					+	+	+	+
Verticillium wilt	+	+	+	+	+	+	+	+
Varios viruses	+	+	+	+	+	+	+	+
Powdery mildew	+	+	+	+	+	+	+	+

High risk; period of maximim damage risk and critical period of control.

Less risk; carefully monitor, control may be required.

\+ Potential pest activity, monitoring should occur

Fungicides

Fungicides registered for use on hop in Michigan, 2024

	Active ingredient (FRAC code[1])	Products labeled	Diseases listed on label[2]	REI/PHI[3]
Single site	cyazofamid (21)	Ranman 400 SC, RenaZ SC	DM	12h/3d
	cyflufenamid (U6)	Torino Fungicide	PM	4h/6d
	cymoxanil (27)	Curzate 60 DF	DM	12h/7d
	dimethomorph (40)	Forum	DM	12h/7d
	fluopicolide (43)	Presidio	DM	12h/24d
	fluopyram (7)	Velum Prime[5]	PM	12h/7d
	flutianil (U13)	Gatten	PM	12h/7d
	flutriafol (3)	Rhyme[5]	PM	12h/14d
	mandipropamid (40)	Revus	DM	4h/7d
	mefenoxam (4)	ReCon Bold SL, Ridomil Gold SL, Thrive 4M, Ultra Flourish	DM	see label
	metalaxyl (4)	MetaStar 2E, Metalaxyl 2E Ag, ReCon 4F, Xyler FC Fungicide	DM	see label
	metrafenone (50)	Vivando	PM	12h/3d
	quinoxyfen (13)	Quintec	PM	12h/21d
	tebuconazole (3)[5]	Buzz Ultra DF, Monsoon, Onset 3.6 L, Orius 3.6F, Tebu-Crop 3.6 F, Tebustar 3.6 L, Toledo 3.6F	PM	12h/14d
	trifloxystrobin (11)	Flint[5], Flint Extra[5]	PM	12h/14d
	triflumizole (3)	Procure 480 SC[5], Trionic 4SC[5]	PM	12h/7d
Multi-site	basic copper sulfate (M1)	C-O-C-S WDG, Cuprofix-Ultra 40 Disperss, Mastercop[O]	DM	see label
	copper hydroxide (M1)	Champ DP Dry Prill, ChampION++, Champ Formula 2 Flowable, Champ WG[O], Kentan DF, Kocide 2000-O, Kocide 3000-O, Nu-Cop HB, Nu-Cop 3L, Nu-Cop 50 DF[O], Nu Cop 50 WP[O], Nu-Cop 30 HB, Nu-Cop XLR, Previsto	DM	48h/14d
	copper octanoate (M1)	Cueva[O]	Anthracnose, DM, PM	4h/0d
	copper oxychloride + copper hydroxide (M1)	Badge SC, Badge X2[O]	DM	48h/14d
	folpet (M4)	Folpan 80 WDG	DM	24h/14d
	sulfur (M2)	Cosavet DF Edge[O], Microfine, Microthiol Disperss, Sulfur[O], Thiolux[O]	PM	see label

1. FRAC - Fungicide Resistance Action Committee (FRAC) codes are used to distinguish the fungicide groups for resistance management purposes. Consecutive applications of fungicides with the same FRAC code are not recommended. **2.** PM-powdery mildew, DM-downy mildew. **3.** PHI-preharvest interval, REI-restricted entry interval expressed as h-hours or d-days. **4.** Requires a supplemental label for use in hops. **5**. Fungicides that are in FRAC classes 3, 7 and 11 are considered systemic broad-spectrum fungicides. While they are labeled in hops specifically for powdery mildew, in other systems fungicides in FRAC classes 3, 7 and 11 have been shown to be effective on a broad range of pathogens. This is likely to include newly emerging hop diseases such as halo blight. Research is still ongoing to determine which of these products is the most effective on pathogens outside of powdery mildew**.**

[O] OMRI approved for organic production.

Fungicides registered for use on hop in Michigan, 2024

	Active ingredient (FRAC code[1])	Products labeled	Diseases listed on label[2]	REI/PHI[3]
Premix	ametoctradin (45) + dimethomorph (40)	Zampro	DM	12h/7d
	mandipropamid (40) + oxathiapiprolin (49)	Orondis Ultra	DM	4h/7d
	oxathiapiprolin (49) + mefenozam (4)	Orondis Gold	DM	48h/45d
	boscalid (7) + pyraclostrobin (11)	Pristine[5]	DM, PM	12h/14d
	famoxadone (11) + cymoxanil (27)	Tanos[5]	DM	12h/7d
	fluopyram (7) + tebuconazole (3)	Luna Experience[5]	PM	12h/14d
	fluopyram (7) + trifloxystrobin (11)	Luna Sensation[5]	DM, PM	12h/14d
Plant defense inducers	fosetyl-Al (33)	Aliette WDG, Linebacker WDG	DM	12h/24d
	phosphorous acid, mono & di-potassium salts (33)	Confine Extra, OxiPhos, Phiticide, Phostrol	DM	4h/0d
	potassium phosphite (33)	Fungi-Phite, Rampart	DM	4h/0d
Biopesticide	*Bacillus amyloliquefaciens* strain D747 (44)	Double Nickel 55[O], Double Nickel LC[O], Serifel[O]	PM	4h/0d
	Bacillus pumilus strain QST 2808 (44)	Sonata[O]	DM, PM	4h/0d
	Bacillus subtilis(44)	Serenade MAX*, Serenade ASO*	PM	4h/0d
	extract of neem oil	Trilogy[O]	DM, PM	4h/0d
	hydrogen dioxide/peroxyacetic acid	Oxidate 2.0, StorOx 2.0	DM, PM	until dry/5d
	mineral oil	BioCover MLT, Damoil Dormant, Glacial Spray Fluid, 440 Superior Spray Oil, PureSpray Green, SuffOil-X, Ultra-Pure Oil, and Summer Spray Oil	PM	see label
	paraffinic oil	Organic JMS Stylet oil[O], JMS Stylet Oil	PM	4h/0d
	potassium bicarbonate	Carb-O-Nator, Kaligreen[O], Milstop[O], Milstop SP[O]	PM, DM, anthracnose	see label
	Reynoutria sachalinensis extract (P5)	Regalia[O] Regalia CG[O]	DM, PM	4h/0d
	Streptomyces lydicus WYEC 108	Actinovate AG[O]	Verticillium wilt, DM, PM	4h/0d
	tea tree oil (F7)	Timorex Act	DM, PM	4h/48h

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Hop downy mildew management

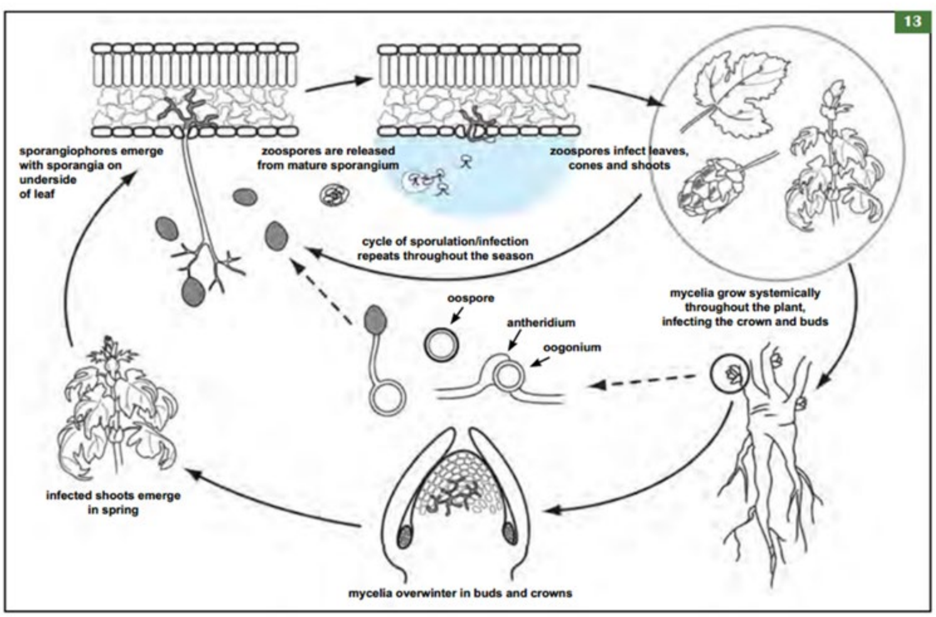
Downy mildew is caused by the fungal-like organism *Pseudoperonospora humuli* and is a significant disease of hop in Michigan, potentially causing substantial yield and quality losses. This disease affects cones, and foliage and can become systemic; in extreme cases the crown may die. Cool and damp weather during the spring provides ideal growth conditions for the pathogen. Disease severity is dependent on cultivar, environmental conditions, and management programs. Growers should focus on proactive management strategies, including 1) sourcing clean planting stock, 2) scouting regularly, and 3) utilizing a preventative fungicide program.

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, resulting in basal spikes. Infected crowns can produce uninfected shoots as well, making downy detection difficult, particularly on potted baby hop plants that have been cut back. The pathogen produces copious spores on the underside of leaves formed on infected basal spikes that move via wind and rain onto health tissue and cause new infections. These new infections produce a second source of spores which can infect all parts of the plant and reproduce continuously over the season.

Infections that occur on the terminal growing point can become systemic, growing down through the plant toward the crown where the pathogen can persist in the root system for a prolonged period. Systemic infections contribute to the spread of disease through propagation and 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.

Secondary 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.

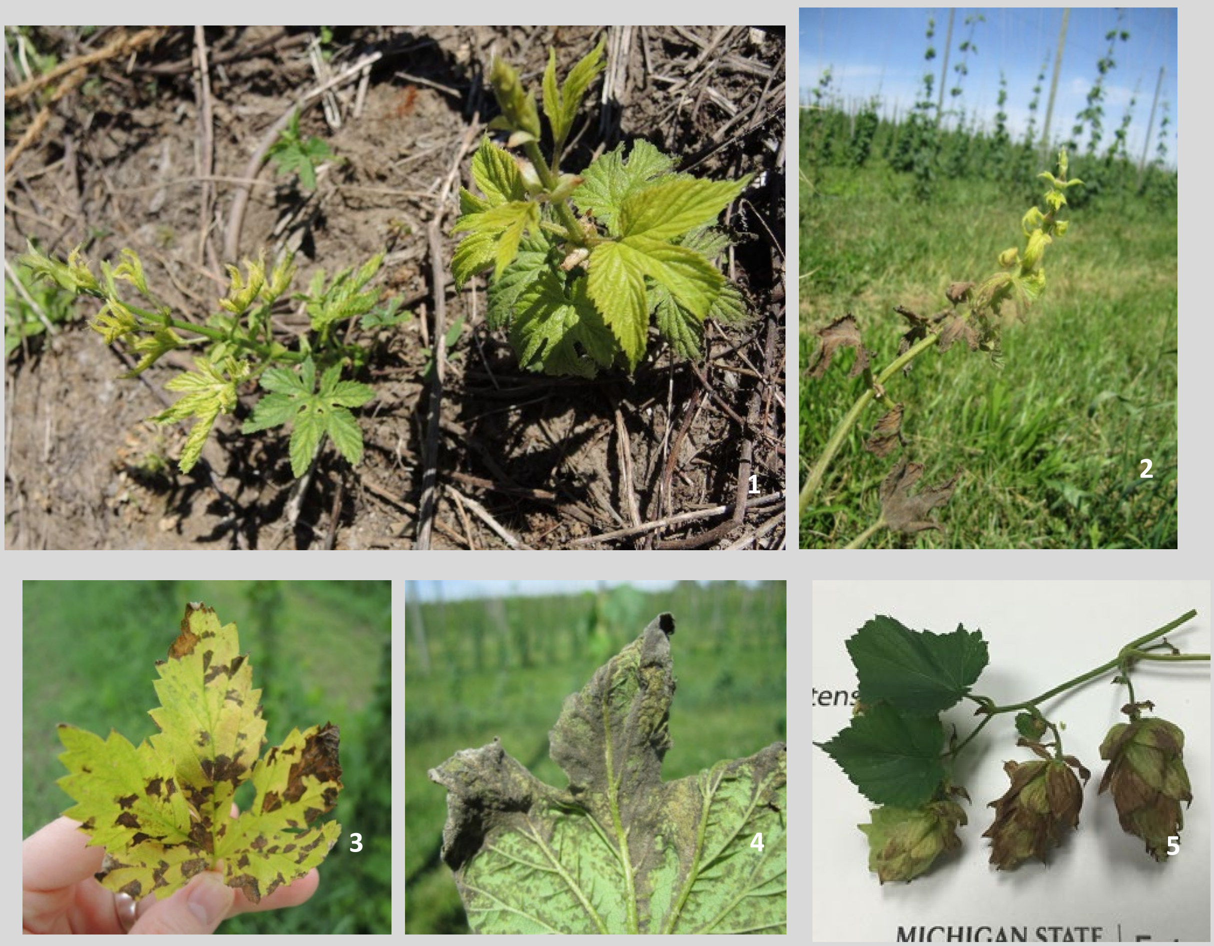


Life cycle of Pseudoperonospora humuli on hop. Prepared by V. Brewster, Compendium of Hop Diseases and Pests.

Signs and Symptoms

Primary downy mildew infections appear early in the season on emerging, infected shoots called basal spikes. Spikes are shoots growing from infected buds and appear distorted with shortened internodes that give the shoot a bushy appearance. It is easy to confuse some mild herbicide injury from glyphosate (e.g. Round Up) with downy mildew as they both produce stunted shoots. Glyphosate 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”. Downy infected shoots will develop spore masses on the underside of leaves that follow venation. Refer to the pictures below.

Secondary leaf infections form 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 become infected and brittle, falling off the string. Growers can attempt to retrain new shoots but will incur yield loss, because 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 and should not be relied upon as the sole indicator of whether infection is present.



1. Glyphosate injury on the left and downy spike on the right. Photo credit Erin Lizotte, MSU. 2. Yellow and stunted spring hop spike, systemically infected with hop downy mildew with spore masses on leaf tissue. 3. Angular lesions on the upper leaf surface of hop caused by secondary downy mildew infection. 4. 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. 5. Downy mildew infection on cones.

Scouting

Scouting for downy mildew involves monitoring the crop for signs and symptoms of disease to evaluate the efficacy of the control program being utilized and gauge the level of disease pressure throughout the season. Growers should keep records of their scouting, including maps of their fields, a record of sampling and disease pressure, and the control measures utilized. Scouting should begin as soon as plants begin to grow and should continue until the crop is dormant.

To begin scouting, section your farm off into manageable portions based on location, yard 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.

Management

Unfortunately, even when best management practices are followed, downy mildew can gain a foothold in Michigan yards due to high disease pressure, challenges with fungicide application 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. Recent research indicates that fungicide resistance in hop downy mildew is not widespread in MI for popularly used fungicides with FRAC code 40 (Higgins et al., unpublished). See the list of recommended fungicides below for more information on FRAC code 40 fungicides.

Clean planting material should be used when establishing new hop yards, since many insect and disease pests 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 number 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.

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).

On mature plants, 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 early growth should be completely removed using mechanical or chemical pruning. As bines develop (10-12'), 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 a "burndown" herbicide (eg. Rely, AIM) or concentrated nitrogen fertilizer solutions. Rely or AIM will also control smaller weeds within the row. The use of herbicide, 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. For more information on pruning, refer to the Michigan State University Extension article "Pruning hops for disease management and yield benefits".

Apply fungicide treatments on a protectant basis as soon as bines reach 6" in the spring regardless of the presence or absence of visible symptoms of downy. If growers are planning to remove the first flush of growth by pruning, the first fungicide application should occur only after regrowth. Applications should continue season long on a 7–10-day reapplication interval. The time between applications may stretch longer when the disease pressure is low, particularly after cone closure. Several periods in the season are particularly critical for disease control: immediately before and after training; when lateral branches begin to develop; bloom; and when cones are closing. Covering young, developing bracts before cones close 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.

Refer to the table on the next page for a complete listing of known hop downy mildew fungicide efficacy. Ranman, Zampro, Forum, Presidio (supplemental label), metalaxyl products and Revus make up the backbone of effective downy mildew management programs in Michigan. These products should be rotated and potentially mixed with Curzate and Tanos to prevent resistance development. Copper-based fungicides may also be rotated in during periods of low disease pressure and as tank mix partners. Note that Revus, Forum and Zampro contain active ingredients with the same mode of action and should not be tank-mixed or rotated and Presidio is only available via a supplemental label that growers must have on hand for legal application.

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 is 1 day or less, and we have no data on their efficacy.

Resistance Management

The downy mildew pathogen is at high risk of developing fungicide resistance. Careful attention to resistance management is critical. To slow the development of resistance, growers should:

1. Keep inoculum low in your yard using various cultural practices, this keeps the population lower so shifts in resistance will happen more slowly.
2. Rotate fungicides diligently within a seasonal spray program. Use FRAC codes to help with determining rotations. These codes can be found in the upper right-hand corner of most conventional fungicide labels or refer to the current Michigan Hop Management Guide.
3. Spray on-time, at the full rate and follow appropriate intervals for the product and bine development.
4. Use cultural practices to improve spray coverage.
5. Utilize multisite fungicides as rotational products such as Cueva (FRAC Multisite 1).

Hop Downy Mildew Fungicide Efficacy

Products labeled	Active ingredient (FRAC Code[1])	Efficacy[2]	REI/PHI[3]
Forum	dimethomorph (40)	E	12h/7d
MetaStar 2E, Metalaxyl 2E Ag, ReCon 4F, Xyler FC Fungicide	metalaxyl (4)	E	See label
Orondis Ultra	mandipropamid (40) + oxathiapiprolin (49)	E	4h/7d
Orondis Gold	oxathiapiprolin (49) + mefenozam (4)	E	48h/45d
Presidio	fluopicolide (43)	E	12h/24d
Ranman 400 SC, RenaZ SC	cyazofamid (21)	E	12h/3d
Revus	mandipropamid (40)	E	4h/7d
Ridomil Gold SL, Ultra Flourish	mefenoxam (4)[4]	E	48h/135d (drench) 48h/45d (foliar)
Zampro	ametoctradin (45) + dimethomorph (40)	E	12h/7d
Curzate 60DF	cymoxanil (27)	G	12h/7d
Tanos	famoxadone (11) + cymoxanil (27)	G	12h/7d
Aliette WDG, Linebacker WDG	fosetyl-Al (33)	F	12h/24d
C-O-C-S WDG, Cuprofix-Ultra 40 Disperss, Mastercop[O]	basic copper sulfate (M1)	P/F	see label
Cueva[O]	copper octanoate (M1)	P/F	4h/0d
COC DF	copper oxychloride (M1)	P/F	48h/See label
Champ DP Dry Prill, ChampION++, Champ Formula 2 Flowable, Champ WGO, Kentan DF, Kocide 2000-O, Kocide 3000-O, Nu-Cop HB, Nu-Cop 3L, Nu-Cop 50 DFO, Nu Cop 50 WPO, Nu-Cop 30 HB, Nu-Cop XLR, Previsto	copper hydroxide (M1)	P/F	48h/14d
Badge SC, Badge X2*	copper oxychloride + copper hydroxide (M1)	P/F	48h/14d
Confine Extra, OxiPhos, Phiticide, Phostrol	phosphorous acid, mono & di-potassium salts (33)	P/F	4h/0d
Fungi-Phite, Rampart	potassium phosphite (33)	P/F	4h/0d
Pristine	boscalid (7) + pyraclostrobin (11)	P	12h/14d
Luna Sensation	fluopyram (7) + trifloxystrobin (11)	P	12h/14d
Actinovate AG[O], Actinovate STOP	*Streptomyces lydicus* WYEC 108	0	
Folpan 80 WDG	folpet (M4)	U	24h/14d
Sonata[O]	*Bacillus pumilus* strain QST 2808 (44)	U	4h/0d
Trilogy[O]	extract of neem oil	U	4h/0d
Oxidate 2.0, StorOx 2.0	hydrogen dioxide/peroxyacetic acid	U	Until dry/5d
Carb-O-Nator, Kaligreen[O], Milstop[O], Milstop SP[O]	potassium bicarbonate	U	see label
Regalia[O] Regalia CG[O]	*Reynoutria sachalinensis* extract (P5)	U	see label

1. FRAC - Fungicide Resistance Action Committee (FRAC) codes are used to distinguish the fungicide groups for resistance management purposes. Consecutive applications of fungicides with the same FRAC code is not recommended.

2. 0= not effective, P = poor, F= fair, G = good, E = excellent, U = unknown. Ratings are based on published information and observations in Michigan, Oregon and Washington.

3. PHI-preharvest interval, REI-restricted entry interval expressed as h-hours or d-days.

4. Research in Michigan has shown that drench applications are more effective than foliar applications.

5. Requires a supplemental label for use in hops.

[O]OMRI approved for organic production.

Hop cyst nematode management and prevention

Hop cyst nematodes, *Heterodera humuli*, are plant-parasitic nematodes that feed on hop plants. Severe infestations of Hop Cyst Nematode (HCN) can lead to bine stunting, wilting, nutrient deficiencies and even plant death. Perennial cropping systems like hops allow generations to grow continuously year-after-year, increasing populations. HCN feeds and reproduces on the smaller, finer roots in early season which are responsible for much of the plant's nutrient uptake. These grain-of-sand sized cysts can easily transfer between fields with farming machinery or via human traffic anytime soil is passed between fields. A 2021 field survey conducted by MSU's Applied Nematology laboratory found that 50% of surveyed Michigan hopyards contained hop cyst nematodes. Because there are no known methods of effective control, growers are limited to utilizing prevention methods whenever possible. This includes avoiding the transfer of soil between fields by practicing good machinery hygiene and planting clean plant material.

In cases where new yards are planned to be established on fields with a history of growing hops, soil testing for HCN should be completed as cysts are commonly able to survive for years in the soil without a host. Growers can submit soil samples to MSU Plant and Pest Diagnostic Laboratories to determine if their fields contain hop cyst nematode or other potentially damaging plant-parasitic nematodes.

Viruses and viroids of hop in Michigan

Laura Miles, Jan Byrne, Carolyn Malmstrom and Erin Lizotte

Hops are known to host several viruses and viroids that potentially impact profitability by reducing yield, quality, and/or plant longevity. Several of these pathogens are widespread in Michigan and mixed infections of multiple viruses and viroids in a single plant are frequently found. The perennial nature of hop and common methods of propagation contribute to the accumulation of these pathogens over time.

The expression of disease symptoms caused by viruses and viroids depends on many factors including hop cultivar, environmental conditions, and the pathogen present. Symptoms of viral infection may be obvious or subtle, or not visible at all. Keep in mind that nutrient and water deficiencies can mimic viral symptoms and should be considered. If you suspect a virus or viroid problem on one or more plants in your hop yard, consider submitting a leaf sample for testing to MSU Plant & Pest Diagnostics.

General guidelines on hop leaf sample collection

- **Select and mark suspect hop plants**. A suspect hop plant usually has atypical growth or performance. For example, plants may show leaf discoloration (e.g., yellowing, light-color speckles, rings, arcs) and/or growth distortions (twisted leaves, stunting, bines that fall off the strings, poor yield, etc.). Mark the plants selected for sampling until results are received as it may be necessary to re-sample and re-test.

- **Label sample bag**. Using a black or blue permanent marker, label a gallon-size resealable plastic bag with your sample identifier. For example, "Cascade #1".

- **Avoid sample cross-contamination**. Our testing method is very sensitive, and so sap from an infected hop plant can compromise the test results of a healthy one.
  - It is highly recommended to use disposable gloves when taking samples from more than one plant. Always change your gloves before collecting samples from a different plant.
  - It is not necessary to use cutting tools for leaf collection. If you do decide to use tools, thoroughly disinfect them before collecting samples from a different plant.
  - Never touch the end of detached leaves because oozing sap may spread infection.

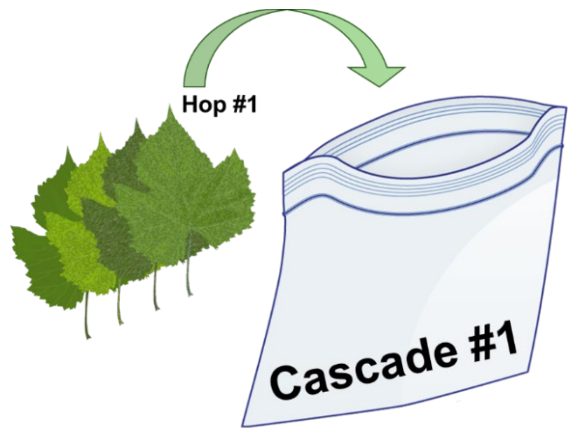
- Use only new, clean resealable plastic bags and place the sample immediately into the bag.

- **Collect living leaves with petioles, preferably in early to mid-season**. Concentrations of viruses and viroids are generally higher when plants are green and actively growing, and higher in petioles and main leaf veins, where virus particles are transported. The number of leaves to collect per hop plant depends on the sampling scheme: single-plant or multiple plant sampling.

Single-plant sampling

A sample collected from a single hop plant consists of four fully expanded leaves with attached petioles (stems). Place leaves inside a resealable plastic bag. Do not add wet paper towels or extra water to the bag. Diagram by Laura Miles, MSU.

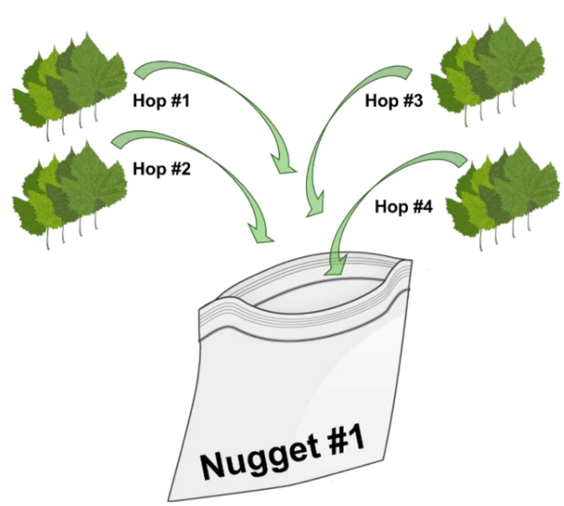
- Reach for a full-size living leaf and pull it backwards until the petiole snaps off.
- Collect a total of 4 leaves from different bines and in different positions (for example, front and back) on the suspect hop plant. You can restrict the sampling to those leaves that are easiest to reach. Include symptomatic (if present) and asymptomatic (green) leaves.
- Stack leaves on top of each other and place them immediately inside your labeled bag. Insert petioles first.
- Push some air out of the bag and seal it. Don't add extra moisture (like water or wet paper towels) to the sample or it may rot in transit.
- Keep the sample cool, but not frozen, until shipment. Heat will degrade samples. Storage in a refrigerator is ideal.



Multiple-plant sampling

An example of a composite sample from four different hop plants. In this case, the sample contains 16 fully expanded leaves with attached petioles. Leaves are stacked on top of each other and placed inside a labelled, resealable plastic bag. No wet paper towels or extra water is added to the bag. Diagram by Laura Miles, MSU.

- For cost-savings, you may consider submitting a collection of leaves from two, three or up to four hop plants to be tested together as a single unit. This combination of individual samples is called a composite sample and can facilitate screening of a greater number of plants. However, keep in mind that under some circumstances the sensitivity of tests of composite samples may be lower, due to the dilution of the signal. In other words, there is a greater chance of failing to detect an infection if it is present in only one of several plants tested together. For circumstances where the greatest diagnostic certainty is required, suspected plants should be sampled separately.
- Samples from individual hop plants are collected following the same procedure described above (read Single-plant sampling) and combined in one bag.



- Depending on the number of selected hop plants, a composite sample bag will contain 8, 12, or 16 leaves.
- Please note that 4 plants are the recommended maximum for a composite sample.

Sampling strategy	Number of plants to flag	Number of leaves to collect
Single hop plant	1	4
Multiple hop plants	2	8
Multiple hop plants	3	12
Multiple hop plants	4	16

Handling and shipping hop leaf samples

Detached leaves can rapidly deteriorate, especially in warm weather, therefore overnight shipping of the samples on the day of collection is highly recommended. Samples can also be dropped-off at MSU Plant & Pest Diagnostics' receiving area on campus. Samples should be kept cool until shipping, ideally in a refrigerator. As necessary, samples can be refrigerated for up to 48 hours.

Before shipping your sample:
- Make sure the leaves are still crisp and fresh (not wilted, brown or dead). If the sample is in poor condition, it cannot be tested.
- Fill out a *Sample Submission Form* (available online at www.pestid.msu.edu) and place it inside the box, but not in the bag with the leaves.
- To protect the leaves from damage, ship them in a box, not an envelope.
- Do not ship samples on Fridays as packages are not delivered to campus on weekends; samples will not arrive in good condition the following week.

Ship overnight (FedEx or UPS preferred) or deliver samples to:
MSU Plant & Pest Diagnostics
578 Wilson Road
East Lansing, MI 48824

Each hop sample (or composite sample) is tested for:
- *American hop latent virus* (AHLV)
- *Apple mosaic virus* (ApMV)
- *Hop latent virus* (HpLV)
- *Hop mosaic virus* (HpMV)
- *Hop latent viroid* (HLVd)
- *Hop stunt viroid* (HSVd)

Reports are sent via email and clients are billed when the testing is completed. For pricing or general questions, please contact the lab at pestid@msu.edu or (517) 355-4536.

Insect pest scouting calendar

Hop Insect Pest Scouting Calendar

Insects	Dormancy	Sprouting	Leaf expansion	Bine elongation and sidearm formation	Flowering	Cone develoment	Cone maturity	Senescence
Two spotted spider mite	+	+	+	+	+	+	+	+
Potato leafhopper			+	+	+	+	+	+
Japanese beetle				+	+	+	+	
Rose chafer				+	+			
Damson hop aphid		+	+	+	+	+	+	
European corn borer				+	+	+	+	+

High risk; period of maximim damage risk and critical period of control.

Less risk; carefully monitor, control may be required.

\+ Potential pest activity, monitoring should occur

Insecticides

Registered insecticides for use on hops in Michigan, 2024

Chemical Class (IRAC group[1])	Active Ingredient (IRAC group[1])	Products labeled	Pesticide Efficacy[2]				REI/PHI[3]
			Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	
Acequinocyl (20B)	Acequinocyl	UPL Kanemite 15SC	N	N	N	G	12h/7d
Avermectins (6)	abamectin	Abacus[R], Abacus V[R], Abacus V6[R], Abba Ultra Miticide[R], Abamex[R], Agri-Mek SC[R], Averland FC[R], Enterik 0.15 LV[R], Reaper 0.15 EC[R], Reaper Clearform[R], Reaper Advance[R]	U	G	N	E	see label/28d
Biopesticides	*Bacillus thuringiensis* (11A)	Biobit HP[O], BT Now[O], Crymax Bioinsecticide, Deliver, Dipel DF[O], Dipel ES, Javelin WG, Leptrotec, Xentari[O]	N,U	N,U	N,U	N,U	see label
	Burkholderia spp.	Venerate XC[O]	N,U	N,U	N,U	U	4h/0d
	Chromobacterium subtsugae	Grandevo CG[O], Grandevo WDG[O]	U	N	N	U	4h/0d
	Kaolin	Surround WP[O]	U	F	F	N	4h/0d
	Myrothecium verrucaria	DiTera DF[O]	N,U	N,U	N,U	N,U	4h/-
	Potassium salts of fatty acids	Des-X[O], M-Pede[O]	N	N	N	U	12h/0d
	mineral oil	Damoil, Purespray Green, 440 Superior Spray Oil[O], TriTek	N	N	N	U	4h/0d
	petroleum oil	Biocover MLT, Glacial Spray Fluid, JMS Stylet Oil, Omni Supreme Spray, Organic JMS Style Oil[O], Suffoil-X[O], Ultra Pure Oil	N	N	N	U	see label
Butenolides (4D)	flupyradifurone	Sivanto 200SL, Sivanto HL, Sivanto Prime	N	N	N	N	4h/21d
Diamides (28)	chlorantraniliprole	Coragen Insect Control	N	N	N	N	4h/0d
Flonicamid (9C)	flonicamid	Beleaf 50SG	N	N	N	N	12h/10d
Insect growth regulators	azadirachtin	Aza-Direct[O], AzaGuard, Ecozin Plus 1.2% ME[O], Molt-X, Neemix 4.5 Insect Growth Regulator[O]	U	F	F	U	4h/0d
	etoxazole (10B)	Zeal Miticide	N	N	N	E	12h/7d
	hexythiazox (10A)	Savey 50 DF	N	N	N	R	12h/0d
METI (21A)	fenpyroximate	Portal XLO, Provoke	G	N	N	G	see label
Multisite, Organophosphates (1B)	malathion	Fyfanon 57% EC, Malathion 5, Malathion 5EC, Malathion 57EC, Malathion 8 Aquamal, Malathion 8 Flowable	N	F-G	F-G	U	12h/10d
	ethoprop	Mocap EC[R]	N	N	N	N	48h/90d
	naled	Dibrom 8 Emulsive[R]	N	N	N	N	24h/7d

1. Insecticide Resistance Action Committee (IRAC) codes. **2.** Pesticide efficacy is based on trials in fruit crops, as reported by Michigan State University Extension, South Carolina State University Extension and UC Davis. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. **3.** PHI-preharvest interval, REI-restricted entry interval, expressed as h-hours or d-days.

[O]OMRI approved for organic production.

[R]Products containing these active ingredients are classified as a restricted use pesticides and require the applicator to retain a pesticide applicator license.

Registered insecticides for use on hops in Michigan, 2024

			Pesticide Efficacy[2]				
Chemical Class (IRAC group[1])	Active Ingredient (IRAC group[1])	Products labeled	Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	REI/PHI[3]
Neonicitinoids (4A)	imidacloprid	Acronyx 2 Flowable, Acronyx 4F, Admire Pro, Advise Four, Alsias 4F, Imidashot DF, Macho 2.0 FL, Macho4.0, Malice 2F, Montana 2F, Montana 4F, Midash Forte Insecticide, Nuprid 2SC, Nuprid 4.6F Pro, Nuprid 4F Max, Omni Brand Imidacloprid 4F, Prey 1.6, Sherpa, Viloprid FC 1.7, Widow, Willowood Imidacloprid 4 SC, Wrangler	G	G	G	N	see label
	thiamethoxam	Platinum 75SG	G	G	G	N	12h/65d
Pyrethroids (3)	bifenthrin	Batallion 2 EC[R], Batallion LFC[R], Bi-Dash 2E[R], Bifen 2AG Gold[R], Bifender FC[R], Bifenthrin 2EC[R], Bifenture 10DF[R], Bifenture EC[R], Brigade WSB[R], Brigade 2EC[R], Discipline 2EC[R], Fanfare ES[R], Fanfare EC[R], Lancer FC[R], Lancer 2EC[R], Reveal[R], Reveal Endurx[R], Sniper[R], Sniper Helios[R], Sniper LFR[R], Tundra EC[R]	G	U	E	U	see label, many are 12h/14d
	cyfluthrin	Tombstone[R], Tombstone Helios[R]	U	N	U	N	12h/7d
	pyrethrins	EverGreen Crop Protection EC 60-6, Pyganic EC 1.4 II[O], Pyganic EC 5.0 II[O], Pyganic Specialty, Tersus	U	F	F	U	12h/0d
	beta-cyfluthrin	Baythroid XL[R], Sultrus[R]	E	G	G	U	12h/7d
Pyridine azomethine derivatives (9)	pymetrozine	Fulfill, Seville	N	N	N	N	12h/14d
Spinosyns (5)	spinosad	Entrust[O], Entrust SC[O], GF-120 NF[O], SpinTor 2 SC[O]	N	N	N	U	4h/1d
	spinetoram	Delegate WG	N	G	N	N	4h/1d
Tetramic acids (23)	spirodiclofen	Envidor 2 SC	N	N	N	E	12h/14d
	spirotetramat	Movento	N	N	N	U	24h/7d
Premixed products	beta-cyfluthrin(3) + imidacloprid(4A)	Leverage 360[R]	U	G	G	N	12h/28d
	bifenthrin(3) + imidacloprid(4A)	Avenger S3[R], Brigadier[R], Skyraider[R], Swagger[R], Tempest[R]	N	U	U	U	12h/28d
	abamectin(6) + bifenthrin(3)	Athena[R]	U	U	U	U	12h/28d
	azadirachtin + pyrethrin(3)	Azera Insecticide[O]	U	U	U	U	12h/0d
Bifenezate (20D)	bifenazate	Acramite 4SC, Acramite 50 WS, Banter WDG, Bizate 4SC, Bizate 50WDG, Enervate 4SC, Enervate 50WSB, Vigilant 4SC	N	N	N	E	12h/14d

1. Insecticide Resistance Action Committee (IRAC) codes. **2.** Pesticide efficacy is based on trials in fruit crops, as reported by Michigan State University Extension, South Carolina State University Extension and UC Davis. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. **3.** PHI-preharvest interval, REI-restricted entry interval, expressed as h-hours or d-days.

[O]OMRI approved for organic production.

[R]Products containing these active ingredients are classified as a restricted use pesticides and require the applicator to retain a pesticide applicator license.

Miticides

Registered miticides for use on hops in Michigan, 2024						
Products labeled	**Active ingredient (IRAC code)**	**Affected stage[1]**	**Considerations**	**Residual control[2]**	**Preharvest interval**	**Impact on predatory mites[3]**
Sil-MATRIX LC[O]	potassium silicate	Moltiles	For best results, use a high analysis non-ionic surfactant.	unknown	0d	unknown
JMS Stylet-Oil, Organic JMS Stylet-Oil[O]	paraffinic oil	Eggs/larvae	Apply to dormant trees in the spring when temperatures are forecast to be above freezing.	2-6 wks.	see label	unknown
BioCover MLT, Damoil Dormant & Summer Spray Oil, Glacial Spray Fluid, SuffOil-X, TriTek, Ultra-Pure Oil	mineral oil	Eggs/larvae	Apply to dormant trees in the spring when temperatures are forecast to be above freezing.	2-6 wks.	see label	unknown
Hexamite, Onager, Savey 50 DF	hexythiazox (10A)	Egg/larvae	Apply before burr formation and adult build up. Savey will not control adults. Use higher rate for moderate to heavy pressure, large plants or longer control.	6-12 wks.	see label	1
Abacus[R], Abacus V[R], Abba Ultra Miticide[R], Abamex[R], Agri-Mek SC[R], Averland FC[R], Reaper 0.15 EC[R], Reaper Clearform[R], Reaper Advance[R]	abamectin (6)	Motiles	Ground application only. Apply at threshold and with required adjuvant. Application rate is based on bine height.	6-12 wks.	28d	3
Appollo SC Ovicide/Miticide	clofentezine (10A)	Eggs	Requires a supplemental label.	8-10 wks.	21d	1
Stifle SC, Zeal	etoxazole (10B)	Egg/larvae	Ground application. Apply when mite populations are low.	6-10 wks.	7d	2
Endomite[R], Omite 6E[R]	propargite (12C)	Motiles	For basal treatments only to control early/beginning mite populations before they move into the canopy.	unknown	14d	1
Portal, Portal XLO Miticide/Insecticide	fenpyroximate (21)	Motiles	Ground application. Apply before mites exceed 5 mites/leaf. Not recommended when temperature exceed 90F.	6-8 wks.	15d	1
Acramite 4SC, Acramite 50 WS, Banter WDG, Bizate 4SC, Bizate 50WDG, Enervate 4SC, Enervate 50WSB, Vigilant 4SC	bifenazate (20D)	Motiles	Provides quick knockdown, good coverage is key. Best positioned as soon as mites become active.	6-8 wks.	14d	1
Nealta Miticide	cyflumetofen (25)	Motiles	Requires a supplemental label.	6-8 wks.	14d	1
Magister SC[R]	fenazaquin (21)	Motiles	Provides quick knowdown. Has some activity against powdery mildew. One application per year.	3-5 wks.	7d	unknown

1.Motile forms include mite larvae, nymphs and adults. **2.** Residual control is based on studies in tree fruit and is highly dependent on rate, coverage, weather and mite pressure at the time of application. **3.** Rankings represent relative toxicity based on mortality data from studies conducted in tree fruit, hop, mint and grape following direct exposure. 1 = <30% mortality; 2 = 30-79% mortality; 3 = 79-99% mortality; and 4 = >99% mortality.

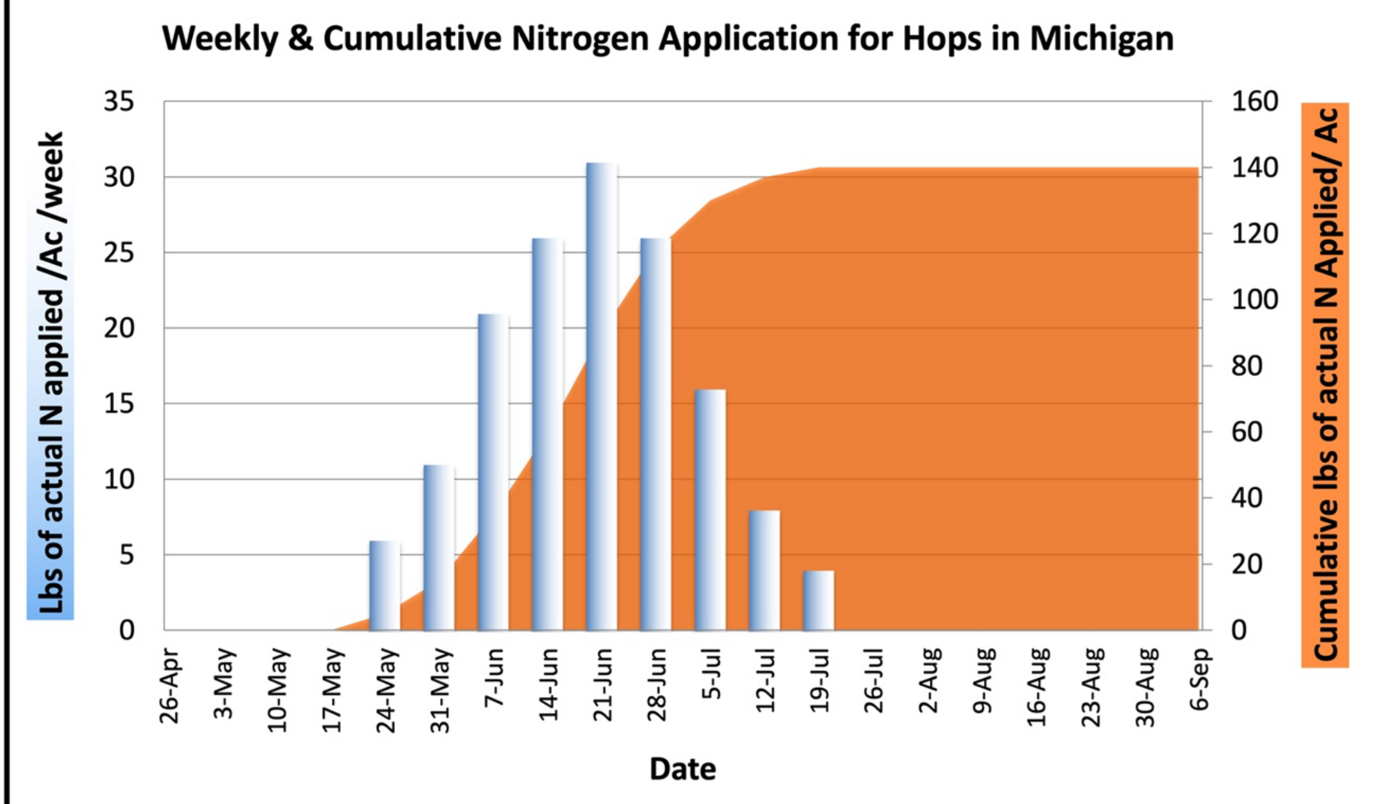
[R] Products containing these active ingredients are classified as a restricted use pesticides and require the applicator to retain a pesticide applicator license.

[O] OMRI approved for organic production.

Modified from a table by John Wise, Larry Gut and Rufus Isaacs, Michigan State University, 2015.

Nutrient management considerations

As hops reach technical maturity in August and September prior to dormancy, more carbohydrates are produced than are needed for growth; excess carbohydrates are directed toward the rootstock in preparation for the following growing season. As hops break dormancy, they rely solely on carbohydrate reserves until photosynthesis commences[1]at this time. Because fertility requirements can be cultivar-specific and each growing season can vary, growers are encouraged to collect soil and petiole/leaf samples each year to optimize plant nutrition, growth, and yield.



Weekly and cumulative nitrogen recommendation for Michigan hops. Updated 2023. Rob Sirrine, MSU Extension

Nitrogen (N)

While hops require macro and micro-nutrients, because of the rapid growth characteristics of the hop plant, effectively managing nitrogen fertility is particularly important. Nitrogen fertilizer is available in many different forms and growers should consult closely with their chosen soil testing lab to optimize N fertility. Plant demand for nitrogen peaks around the beginning of July and then falls rapidly over the rest of the season.

Nitrogen is an essential plant nutrient required for optimum cone production. The nitrogen replacement value, or the amount needed to replace what has been taken up by the plant biomass for fully-grown bines, is approximately 110 lbs./ac/year (cones-45 lbs./ac, crop residue-65 lbs./ac). By the end of July, hops have generally accumulated 80-150 lbs. of N/ac[2]. Depending upon site-specific characteristics like soil quality and management practices (fertilizer type, application method, cultural practices, etc.), the nitrogen use efficiency (NUE) for hops is roughly 65 percent[3]. This suggests that roughly 35 percent of the actual nitrogen applied *is not* taken up by the hop plant but is instead lost to the

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[1] Gingrich, G., J. Hart, and N. Christensen. 2000. Fertilizer Guide: Hops. FG 79. Oregon State University, Corvallis, OR.

[2] Sullivan, D.M., J.M. Hart, and N.W Christensen. 1999. Nitrogen Uptake and Utilization by Pacific Northwest Crops. P.10. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw513.pdf

[3] Neve. R.A. 1991. Hops. London: Chapman and Hall.

environment; usually through leaching or volatilization. If the replacement value is 110 lbs./ac/yr. and only 65 percent is taken up by the hop plant, then producers should be applying ~170 lbs. of actual N/ac/yr. *However,* this does not account for additional N inputs such as compost, plant residue, or N-fixing leguminous cover crops, which should be added the N budget, nor for the method or timing of nitrogen application. Nitrogen that is banded into the hop rows in one spring application, prior to the optimum period of uptake, is likely lost at a higher rate than liquid nitrogen fertigated on a daily basis throughout the primary vegetative growth period from late May- early July. But there may be a tradeoff between fully meeting plant demand and losing nitrogen to the environment through early season application. If growers choose to apply early season (early mid-May), it should be accompanied by light disking and/or irrigation. Growers may be able to increase N uptake and conversion efficiency by addressing micronutrient deficiencies (e.g. Sulfur, Iron, Molybdenum, Zinc, etc.), thereby reducing the amount of N fertilizer.

Sandy soils tend to have low soil organic matter levels and growers may need to apply a slightly higher rate of nitrogen to optimize growth. Based on average Michigan conditions, it is recommended that hop growers apply 135-150 lbs. of actual N/acre/yr. to mature hop plants (See Figure 2, which shows 140 lbs./ac/yr.). Baby hops require less Nitrogen ~ 75lbs/ac/yr. Near the 3^{rd}-4^{th} week of June, internode length should measure around 8 inches in length. If length is less than 8 inches, growers need to increase N. If greater than 8 inches, growers should back off on N. At the same time, growers should calculate cumulative lbs. of actual N applied YTD. It should be around 105-115 lbs. by the end of June when plants begin to transition from vegetative to reproductive growth. If early summer has been overly wet and growers have not been able to fertigate this amount, granular N can be band applied. Nitrogen needs may differ depending upon cultivar vigor and disease susceptibility. Vigorous cultivars may need less N, while weaker cultivars may need more over the season. Verticillium wilt may be more severe with excessive N application.

For organic options growers can continue with composted manure and should account for this N when developing their seasonal N budgets but should be diligent about not over applying Phosphorous. In addition to soil and plant tissue testing, MSU also offers compost analysis, which may provide growers with useful information. Other organic options include granular products like Nature safe 13-0-0, feather meal, and blood or bone meal that should be applied in early spring. Cover crops can also provide significant quantities of N but cover crops must be tilled in for N to be released. For more information on cover crops please review, *Managing Cover Crops Profitably, 3rd ed.* Via the SARE (Sustainable Agriculture Research and Education) learning center at www.sare.org/Learning-Center.

Phosphorous (P) Phosphorous is important for photosynthesis, the movement of materials across cell membranes, and cell division and growth. When P is limiting, root and fruit development are diminished. Hop plant P requirement is small when compared with the plant's need for N and potassium (K). Studies in Germany and Washington indicate a 9- to 10-bale/ac hop crop (1800-2000 lb./ac) removes an average of only 20 to 30 lb. P/ac[4]. This corresponds to other studies, which have found that hops have a low phosphorus requirement and generally do not respond to fertilizer phosphorus applications. P should be incorporated into the soil in the hop row because it is less mobile than other nutrients. Ideal Phosphorous levels are 25-40 ppm. Plant demand for phosphorous peaks around the beginning of July and then slowly declines.

Potassium (K) Potassium is a key nutrient for plant regulation. It activates enzymes involved in plant cell division and growth, is necessary for formation and transport of carbohydrates, and regulates opening and closing of stomata. Hops take up 80–150 lbs. K/ac/year on average. Hop nutrient research results from the PNW suggest that (leaf+ petiole) K levels were often inadequate, even in hopyards with sufficient soil K levels. Inefficient plant uptake might be improved by adding a second fertigation line (Taberna, 2016)[5]. Plants deficient in K are more susceptible to environmental stress and disease. Excessive K levels can result in Mg deficiency. Like P, plant demand for potassium peaks around the start of July and then slowly declines.

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[4] Gingrich, G., J. Hart, and N. Christensen. 2000. Fertilizer Guide: Hops. FG 79. Oregon State University, Corvallis, OR.
[5] Taberna, J. 2018. Hop nutrient needs for maximum production and quality. Western Labs Inc.

Sulfur (S) Sulfur activates plant enzymes and helps form plant proteins and chlorophyll. Plant Nitrogen use can be limited when Sulfur levels are below optimum. Sulfur deficiency may resemble N deficiency, though plants deficient in S generally show symptoms on the newest leaves first. Optimum soil test levels are > 20ppm. Plant demand for sulfur peaks around July 1 and remains steady through development of cones.

Calcium (Ca) Calcium is responsible for cell wall structure and strength. Calcium deficiency is possible if Potassium, Magnesium, or Sodium levels are excessive. Ca soil test levels should be >1800 ppm. Demand for Ca peaks around July 1, drops slightly, and then remains stable through the end of August.

Magnesium (Mg) Magnesium is crucial for photosynthesis and activation of plant enzymes. Because Mg is mobile in plants, older leaves will develop signs of deficiency first. Magnesium soil test levels should be >250 ppm. Like Ca, magnesium demand peaks around July 1 and remains stable through the end of August.

Copper (Cu) Copper is responsible for plant metabolism and is important in the formation of chlorophyll. Copper is immobile; deficiency symptoms will develop first in younger leaves. Soil with high pH results in copper deficiency, whereas copper toxicity can occur in very acidic soils. Optimum levels of copper in the soil are 0.8-2.5 ppm.

Boron (B) Boron helps facilitate carbohydrate transport and metabolism and activates growth regulators. Boron is important in plant reproductive phases (fruit development). Boron deficiency can occur in acidic soils. Boron levels can often be inadequate mid-late season (Taberna, 2016). Boron soil test levels should be 0.7-1.5 ppm. Plant demand for boron increases rapidly during June and then slowly plateaus through August.

Zinc (Zn) Zinc is the most common micronutrient deficiency. Zinc is an enzyme activator and required for optimum growth. It also plays a role in internode elongation. Zn deficiency is associated with high soil pH >7.5. Zinc levels in the soil should be 1.0-3.0 ppm. Growers may find foliar micronutrient applications that include Zinc to be beneficial. Plant demand for zinc gradually increases until the beginning of July and then slowly declines.

Manganese (Mn) Manganese is an enzyme activator, important for carbohydrate synthesis, and for photosynthesis. Calcareous soils and high pH soils often show signs of Manganese deficiency. Ideal soil levels of Manganese are 6-30 ppm. In addition to Potassium and Boron, Manganese was often inadequate in the soil solution in PNW research trials (Taberna, 2016). Like boron, plant demand for manganese appears to steadily increase through the beginning of July before leveling off.

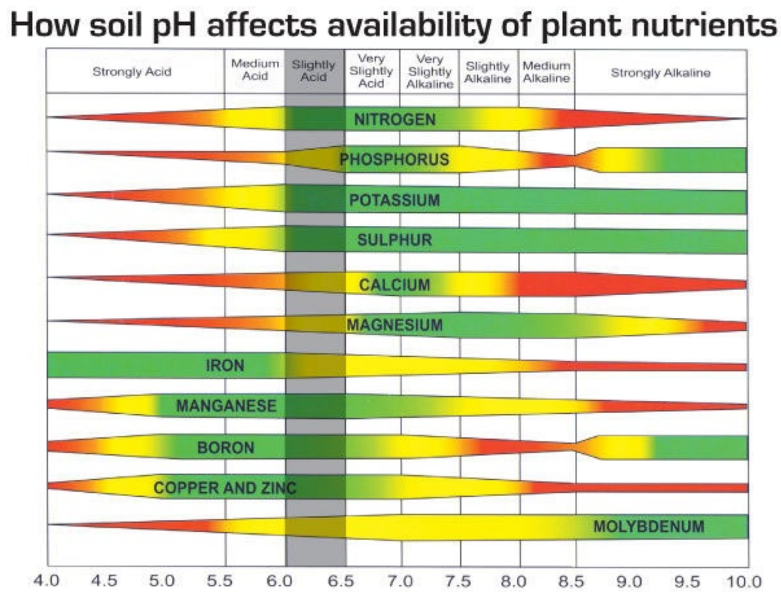
Iron (Fe) Iron plays a role in metabolic processes and is required for many plant biological processes. While Iron is generally abundant in soils, in neutral-high pH and aerobic soils, it can be unavailable for plant uptake resulting in interveinal chlorosis. Soil Iron levels should be >7 ppm. Iron uptake appears to increase rapidly through June and then slows through the end of August.

Sodium (Na) Though non-essential, Sodium is important for metabolic processes and chlorophyll synthesis. Excessive Na can lead to toxicity, generally demonstrated by leaf margin and tip necrosis. Soil Sodium levels should be <225 ppm**.**

*Ratios amongst certain nutrients can be very important and should be discussed with your soil test laboratory.

pH

Soil pH is a measure of soil acidity or alkalinity. Soil pH is determined by soil parent material, rainfall, and past fertilization practices. Soil pH affects nutrient availability (see figure)[6]. A value of "7" is considered neutral. Optimum plant growth and yield is achieved under appropriate soil pH levels; different plant species require different soil pH levels. Hops prefer slightly acidic soils ~6.5. Soil pH can be adjusted to optimize plant growth and yield. Ground limestone is generally recommended to increase soil pH if it is too acidic. Soil texture, crop, and type of lime should all be considered. Limestone contains calcium and Dolomitic limestone contains both calcium and magnesium. In general, lime should be applied in the fall and incorporated into the soil prior to planting. If soil pH is too alkaline, sulfur can be applied to reduce the soil pH. Certain fertilizers can also increase the acidity of the soil over time.



Nutrients	Role	Deficiency Symptoms	Excess Symptoms
Nitrogen (N)	Facilitates plant growth, provides the "green" response in plant, necessary for photosynthesis, increases yields (up to point of diminishing returns)	Poor growth, stunting, yellow leaves, cones are small an undeveloped,	Internodes are too long, increased insect and disease issues
Phosphorous (P)	Photosynthesis, cell division, nucleus formation, stimulates root growth and energy transfer	downward curling of lower leaves, dull appearance	Can cause zinc deficiency in alkaline soils, water quality issues
Potassium (K)	Role in metabolic process, production and translocation of carbohydrates, water intake, respiration, positive effect on cone ripening, production of lupulin, and resin and essential oil content	Weak bine growth and reduced burr formation, bronzing between veins, reduced N use efficiency	Can induce Mg deficiency
Sulfur (S)	Activates plant enzymes	Stunted growth, spindly stems, yellow leaves, usually in coarse textured soils prone to leaching	
Calcium (CA)	Root and leaf growth, cell wall structure and strength, does not move in plant-deficiency develops on new leaves, counteracts the effects of alkali salts	Young tissue and growing points, yellowing and death of leaf margins	Can induce deficiencies in other + charged ions (ammonium, K, Mg)
Magnesium (Mg)	Essential for photosynthesis, helps activate plant enzymes needed for growth, role in the quality and quantity of hop cones, can increase lupulin levels,	Older leaves yellowing between veins, most common in acid soils	
Iron (Fe)	Mainly concentrated in the leaves, essential for synthesis of chlorophyll	Yellowing on young leaves between veins while veins remain green, most common in alkaline soils	
Manganese (Mn)	Activates plant enzymes, mainly concentrated in hop leaves	Becomes limited in high alkaline soils, yellowing of young leaves and white speckling	In low pH soils can interfere with iron uptake
Zinc (Zn)	Concentrated in apices and young organs such as leaves, enzyme activator, hops are very sensitive to zinc deficiency	Weak growth, short laterals, poor cone production. Leaves are small misshapen, yellow, curled upwards, common when pH is greater than 7.5	
Copper (Cu)	Functions as a catalyst in photosynthesis and respiration, is a constituent of several enzyme systems involved in building and converting amino acids to proteins		
Boron (B)	regulates metabolism of carbohydrates, cell wall component	Delayed shoot emergence, stunting, distortion and crinkling of young leaves. Most common in acid/sandy soils	
Molybdenum (Mo)	Used by enzymes, important for N metabolism, high sulfates can reduce plant uptake of Mo.	Young leaves become chlorotic with light brown spots, speckling around veins. Deficiencies have been reported in acidic soils (pH <5.8)	

https://www.superior.net.nz

Optimum Nutrient Ranges					
NUTRIENTS	JIH[1]	Plant Analysis Handbook IV[2]		Western Labs[3] Leaf+Petiole	CSIRO Australia[4] (from Bergmann) Mid-season (YML)
		Vegetative Stage-Pre-Bloom (YML)*	Reproductive stage & Full Bloom (YML)		
Nitrogen (%)		3.2 - 5.6	2.13 - 3.93	>4.5	2.5 to 3.5
Phosphorous (%)	0.29 - 0.6	0.27 - 0.54	0.18 - 0.43	>0.33	0.35 to 0.60
Potassium (%)	1.49 - 2.5	1.6 - 3.4	0.97 - 2.55	>2.8	2.8 to 3.5
Calcium (%)	0.79 - 1.2	1.03 - 2.57	3.09 - 6.05	>0.6	1.0 to 2.5
Magnesium (%)	0.24 - 0.8	0.29 - 0.67	0.55 - 1.71	>0.35	0.3 to 0.6
Manganese (ppm)	25 - 150	45 - 125	50 - 150	>36	30 to 100
Iron (ppm)	30 - 60	44.3 - 97.9	35.4 - 151		
Copper (ppm)	10 - 25	8 - 29	5.7 - 16.6	>7	6 to 12
Boron (ppm)	24 - 75	17.6 - 63.2	48 - 150	>18	25 to 70
Zinc (ppm)	24 - 50	23.2 - 108	19.4 - 57.1	>25	35 to 80
% Sulfur Sampled Basis	0.16 - 0.32	0.2 - 0.34	0.18 - 0.30	>0.23	
% Sulfur Dry Matter Basis	0.16 - 0.32	0.2 - 0.34	0.18 - 0.30		
Mo		0.5 - 3	1 - 5		0.2 to 2.5
Na	0 - 1400				
NO3 ppm	4000-12000				

[1]Del Moro, S. 2014. Great Lakes Hop and Barley Conference. John I Haas.
[2]Plant Analysis Handbook IV. 2015. Bryson and Mills (eds). P. 301
[3]Taberna, J. 2017. Leaf + Petiole collected at 5.5' when plant is 8' and from 1' below wire when plant reaches wire
[4]CSIRO. Plant Analysis: An Interpretation Manual. 2nd Ed. Reuter, D.J. and & Robinson, J.B. (eds). 1997. p149
W. Bergmann, Ernährungsstörungen bei Kulturpflanzen, 3rd ed. Jena: Gustav Fischer Verlag, 1993, pp. 384–394.
*YML= Youngest Mature Leaf

Plant SAP analysis

What is plant sap?

Most plants have vascular systems that are responsible for transporting nutrients throughout the plant. Xylem carries water and minerals up from roots to stems and leaves, and phloem transports sugars and proteins from leaves to roots and stems. Plant sap is the fluid transported in the xylem or phloem. While plant tissue tests show the amount of nutrients that a plant has metabolized from an analysis of the entire leaf sample, measuring sap carefully extracted from plant leaves provides a much more specific picture of plant-available nutrients. Plant SAP analysis can help growers correct nutrient deficiencies in a timely matter and provide insight into anticipated deficiencies and/or nutrient imbalances so growers can fine-tune nutrient supply with crop plant demand.

Sample Collection

The sampling protocol for SAP analysis is extremely important. The preferred method for SAP analysis is to compare nutrient levels in both new and old leaves. Growers collect a composite sample of new, healthy, fully developed leaves and a composite sample of old, healthy leaves. Leaves should be dry. To optimize production, it is recommended to sample plants weekly or every other week at a minimum during the growing season. Samples must be collected in the morning, ideally before 9am, throughout the season. Samples should also be consistently collected from the same side of the plant (e.g. sunny or shady) each time. Temperatures should be below 80° F. Always refer to lab-specific protocol for instructions on leaf selection, amount/weight of leaves, packaging, cooling, and mailing. The cost for analysis of a "set" (old leaves + new leaves) is approximately $90. Labs also generally offer discounts for purchasing multiple sets (E.g. $70 for 10 sets). Rates may have changed by the time of this publication.

Interpretation

Labs will generally develop a report like the one below. Lab staff will help growers interpret results and recommend nutrient additions if necessary. Foliar or fertigation applied nutrients can help quickly correct deficiencies or imbalances.

Potential Benefits

SAP should allow growers to fine-tune nutrient management to increase yields. For example, SAP can identify deficiencies prior to visible symptoms on the plants. SAP can also potentially reduce fertilizer use, and often pest issues associated with overfertilization. Sap should not be seen as "quick fix" for growers looking to save money in the short-term.

SAP Analysis Labs

Agro-K, Minneapolis, MN	https://www.agro-k.com/sapanalysis/
Crop Health Labs, Bellville, OH	https://www.crophealthlabs.com/
New Age Laboratories, South Haven, MI	https://newagelaboratories.com/plant-sap-analysis/

MSU plant and pest diagnostics

Visit www.pestID.msu.edu for additional information and submittal forms.

1. Plant Health Analysis

Basic Sample Submission, In-state – $20.00, Out-of-state – $40.00

Samples submitted for Plant Health Analysis are charged a basic submission fee according to the place of origin. This fee includes visual and microscopic inspection of the plant sample for infectious/non-infectious diseases, assessment of insect-feeding injury and insect identification, culturing for bacteria, fungi, and oomycetes, and measurement of soil pH and soluble salts. Additional testing services will be charged as described below.

2. Plant / Weed Identification

Out-of-state samples are charged double.

Plant ID – $10.00

Plants may be mailed in or dropped off for identification.

Digital plant ID

Please note that specific identification is not always possible from digital images.
We reserve the right to limit identifications via digital images based on current sample volume.
Digital ID of 1-3 different plants – No charge
Digital ID of additional plant – $10.00 each

Hay examination – Starting at $20.00

We will examine hay samples suspected of containing toxic plants as related to the health and safety of animals. Fees for this service begin at $20.00 and increase depending on the size of the sample submitted to the lab. We are not able to examine an entire bale of hay. To ensure the appropriate sample size is submitted, please contact Erin Hill <hiller12@msu.edu> or Angie Tenney <millera3@msu.edu> at MSU Plant & Pest Diagnostics.

3. Herbicide Resistance in Weeds

Out-of-state samples are charged double.

Herbicide resistance screening – $90.00

Testing includes multiple sites of action, based on seed quantity and quality.

MI soybean growers qualify for free testing of the following species courtesy of the Michigan Soybean Committee:

- Palmer amaranth
- Waterhemp
- Horseweed/marestail
- Common lambsquarters
- Common ragweed
- Giant ragweed

We reserve the right to limit herbicide-resistance samples based on current sample volume and space limitations.

4. Nematode Analysis

Out-of-state samples are charged double.

Basic nematode analysis – $25.00

Includes the identification of all plant-parasitic nematodes found in the soil and roots. This is the standard nematode analysis most clients request.

Foliar nematode analysis – $25.00

Reports any nematodes detected in leaf tissue submitted to the lab.

Garlic bloat nematode - $25.00

Reports any nematodes detected on garlic bulbs.

Pinewood nematode analysis - $25.00

Reports any nematodes detected from wood samples submitted to the lab.

Nematode trophic composition – $50.00

In addition to the counting and identification of plant-parasitic nematodes (basic nematode analysis), beneficial nematodes, mycorrhizal fungi, and microscopic earthworms are also counted. The nematodes are separated out into functional or trophic groups such as bacterial-feeding, fungal-feeding, and predatory.

Full SCN type testing – $120.00

Screens against 7 sources of soybean cyst nematode (SCN) resistance.

Mini SCN type testing – $75.00

Screens against 4 sources of soybean cyst nematode (SCN) resistance.

5. Verticillium Soil Analysis

Out-of-state samples are charged double.

Wet sieving – $25.00

Ten grams of air-dried soil are plated for counting colonies of *Verticillium dahliae*.

6. Insect, Spider, Tick, or Other Arthropod Identification

Common insect ID – No charge

Arthropod specimens may be mailed in or dropped off for identification. Photos of arthropods may also be sent via email free of charge. We reserve the right to limit identifications via digital images based on current sample volume.

Key-out insect ID – $20.00

Out-of-state samples are charged double.

There is usually no charge for insect identification. If the specimen requires extra time and effort (Key-out ID), the lab will contact you before proceeding.

Additional hop resources

Hops.msu.edu

MSUE Extension News Digest (subscribe to hops)

Plant and Pest Diagnostics (pestid.msu.edu)

Hop Production in the Midwest and Eastern North America (MSU Online Course)

Enviroweather.msu.edu

Usahops.org

For more information on safe pesticide handling and use, visit the MSU Pesticide Safety and Education resources at ipm.msu.edu.

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