MICHIGAN STATE UNIVERSITY | Extension

2026

Michigan Hop Management Guide

USDA

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Contents

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 hops 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 change 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 'Directions for Use' 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.

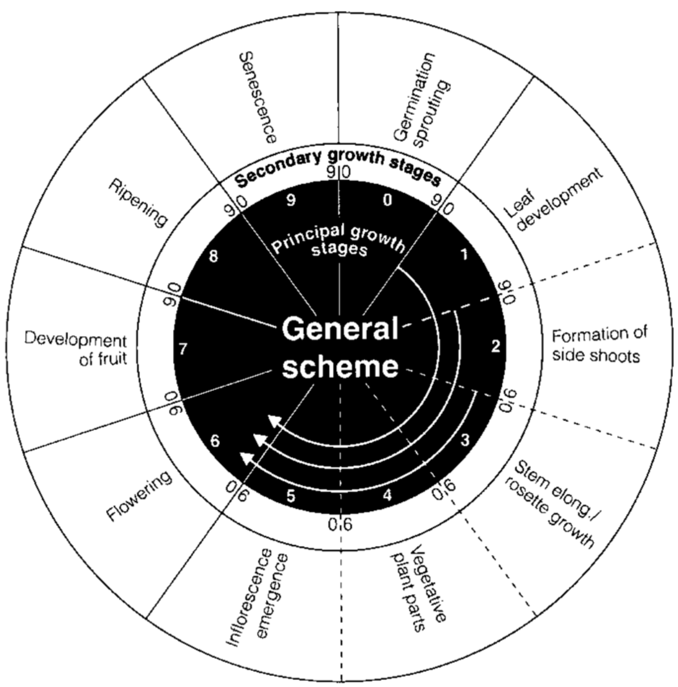
Hop exportation considerations for maximum residue levels

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	Vegetative Growth	Reproductive Growth	Reproductive Growth	Preparation for Dormancy
	sprouting	leaf development; elongation of bines	side shoots; elongation of bines	burr stage; flowering	cone development	maturity of cones



Hop Rossbauer et al., 1995

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

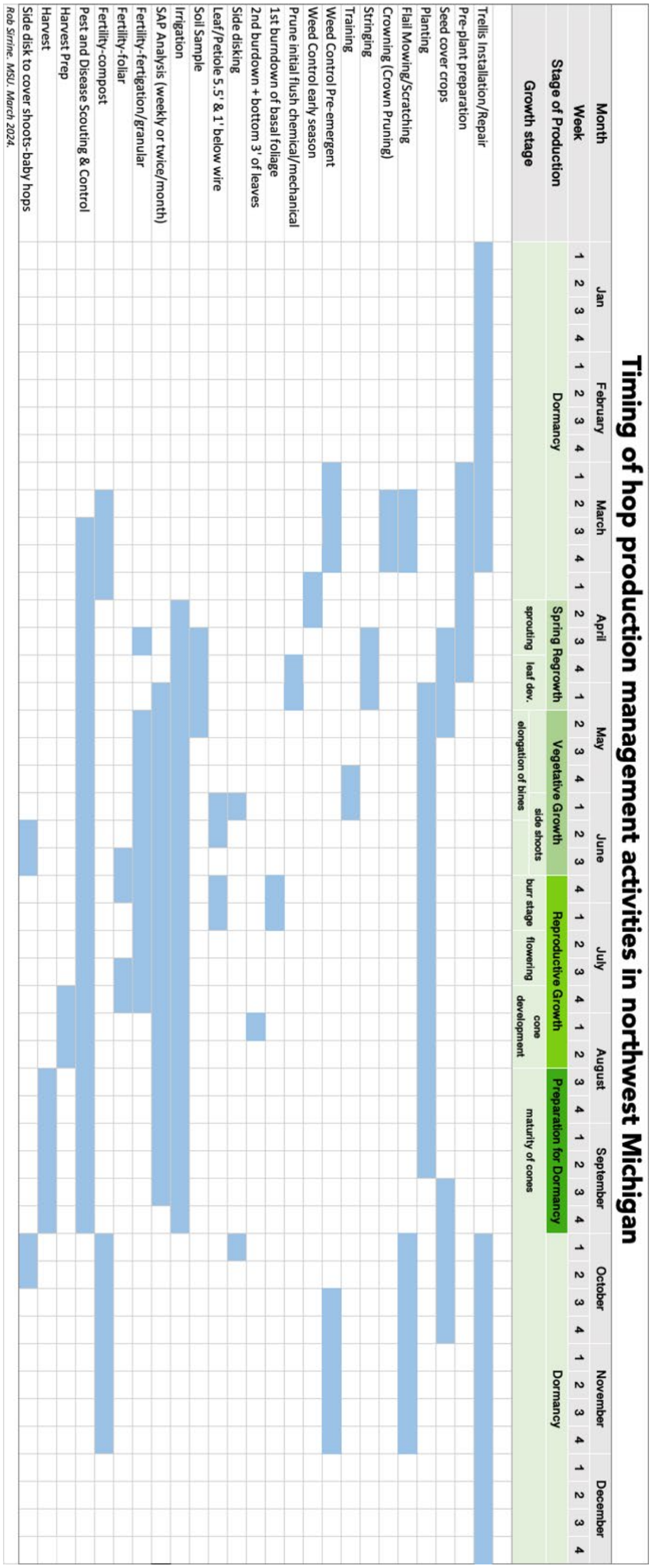
Code	Description
Principal growth stage 0: Sprouting	
00	Dormancy: rootstock without shoots (uncut)
01	Dormancy: rootstock without shoots (cut)
07	Rootstock with shoots (uncut)
08	Beginning of shoot-growth (rootstock cut)
09	Emergence: first shoots emerge at the soil surface
Principal growth stage 1: 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

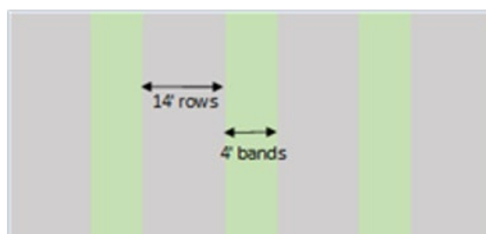
APPLYING BANDED APPLICATIONS

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 acres. 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.

glyphosate are examples of herbicides that must be used very carefully and at the appropriate time to avoid injury.



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, 2025

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 (3)	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.

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, 2026

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Pre- emergent	Annual grasses/ broadleaf	trifluralin (3)	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.
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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, 2026

	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)	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)	Badge X2, Certis Kocide 2000-0[O], Champ DP Dry Prill, ChampION++, Champ Formula 2 Flowable, Champ WG[O], Kentan DF, Kocide 50 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, 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, 2026

	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	see label/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	DM, PM	until dry/5d
	mineral oil	BioCover MLT, Damoil Dormant, Glacial Spray Fluid, PureSpray Green, SuffOil-X, Ultra-Pure Oil	PM	see label
	paraffinic oil	Organic JMS Stylet oil[O], JMS Stylet Oil	PM	4h/0d
	potassium bicarbonate	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

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Michigan hop disease management options

Michigan hops are susceptible to several fungal diseases that favor the region's temperate and moist climate conditions. Hop downy mildew (Pseudoperonospora humuli), halo blight (*Diaporthe humulicola*) and powdery mildew (*Podosphaera macularis*) account for the bulk of disease-related crop loss in Michigan hops. Managing these diseases requires a multifaceted approach that includes starting with clean plant material, monitoring the crop carefully, implementing horticultural and sanitation practices to reduce disease pressure and utilizing a targeted and preventative fungicide program. This article will summarize current information regarding fungicide efficacy and timings, but growers should familiarize themselves with each pathogen and the non-chemical management strategies clarified in the pest management section of the MSU Hop Pest Management Webpage.

The following table is a summary of the relative performance of certain fungicides for the control of hop diseases at various growth stages. These recommendations are primarily based on research of MSU scientists over several years. These ratings can help growers determine which fungicides are likely to be most effective at disease suppression and take into account pesticide use patterns like the preharvest interval. These ratings may not accurately reflect the performance of these fungicides in all situations. Fungicide efficacy can be impacted by fungicide use history, application equipment, environmental conditions and hop variety.

In general, most fungicides provide around 10-14 days of efficacy, but rainfall can impact longevity. It should also be noted that fungicidal modes of action should be tank mixed or rotated to prevent resistance development over time.

Michigan hop disease fungicide management options

Stage 1. Sprouting

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), Ridomil Gold SL (4), Ultra Flourish (4), MetaStar 2E (4), Metalaxyl 2E Ag (4), ReCon 4F (4), Xyler FC Fungicide (4), Orondis Ultra (40/49), Orondis Gold (49/4), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Sulfur (M2), Flint (11), Rhyme (3), Procure 480 SC (3) or Unicorn DF (3/M2)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Notes: Ridomil Gold SL and Ultra Flourish have a 135 day preharvest interval for drench applications and a 45 day interval for foliar applications. Orondis Gold has a 45 day preharvest interval.

Stage 1. Leaf development

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), Ridomil Gold SL (4), Ultra Flourish (4), MetaStar 2E (4), Metalaxyl 2E Ag (4), ReCon 4F (4), Xyler FC Fungicide (4), Orondis Ultra (40/49), Orondis Gold (49/4), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Sulfur (M2), Flint (11), Rhyme (3), Procure 480 SC (3) or Unicorn DF (3/M2)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Notes: Ridomil Gold SL and Ultra Flourish have a 135 day preharvest interval for drench applications and a 45 day interval for foliar applications. Orondis Gold has a 45 day preharvest interval.

Michigan hop disease fungicide management options

Stage 2. Side shoot formation

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), MetaStar 2E (4), Metalaxyl 2E Ag (4), ReCon 4F (4), Xyler FC Fungicide (4), Orondis Ultra (40/49), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Sulfur (M2), Flint (11), Rhyme (3), Procure 480 SC (3) or Unicorn DF (3/M2)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Stage 3. Bine elongation

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), MetaStar 2E (4), Metalaxyl 2E Ag (4), ReCon 4F (4), Xyler FC Fungicide (4), Orondis Ultra (40/49), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Rhyme (3), Procure 480 SC (3), Luna Experience (7 + 3), Vivando (50), Gatten (U13) and Torino (U6)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Stage 4. Flower development

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), MetaStar 2E (4), Metalaxyl 2E Ag (4), ReCon 4F (4), Xyler FC Fungicide (4), Orondis Ultra (40/49), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Rhyme (3), Procure 480 SC (3), Luna Experience (7 + 3), Vivando (50), Gatten (U13) and Torino (U6)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Stage 5. Bloom

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40), Revus (40), Orondis Ultra (40/49), Presidio (43), Ranman 400 SC (21), RenaZ SC (21), Zampro (45/40), Curzate 60DF (27), Tanos (11/27)
Powdery mildew	Quintec (13), Pristine (11/7), Luna Sensation (7/11), Vivando (50), Gatten (U13) and Torino (U6)
Halo blight	Flint Extra (11), Rhyme (3), Luna Experience (7/3)

Michigan hop disease fungicide management options

Stage 6. Cone development

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40, 7-day preharvest interval), Revus (40, 7-day preharvest interval), Orondis Ultra (40/49, 7-day preharvest interval), Presidio (43, 24-day preharvest interval), Ranman 400 SC (21, 3-day preharvest interval), RenaZ SC (21, 3-day preharvest interval), Zampro (45/40, 7-day preharvest interval), Curzate 60DF (27, 7-day preharvest interval), Tanos (11/27, 7-day preharvest interval)
Powdery mildew	Quintec (13, 21-day preharvest interval), Pristine (11/7, 14-day preharvest interval), Luna Sensation (7/ 11, 14-day preharvest interval), Vivando (50, 14-day preharvest interval), Gatten (U13, 7 day preharvest inteval) and Torino (U6, 6 day preharvest interval)
Halo blight	Flint Extra (11, 14-day preharvest interval), Rhyme (3, 14-day preharvest interval), Luna Experience (7/3, 14-day preharvest interval)

Notes: Pay close attention to the preharvest interval as harvest approaches.

Stage 7. Cone maturity

DISEASES	EFFECTIVE FUNGICIDE CHOICES (FRAC CODE)
Downy mildew	Forum (40, 7-day preharvest interval), Revus (40, 7-day preharvest interval), Orondis Ultra (40/49, 7-day preharvest interval), Ranman 400 SC (21, 3-day preharvest interval), RenaZ SC (21, 3-day preharvest interval), Zampro (45/40, 7-day preharvest interval), Curzate 60DF (27, 7-day preharvest interval), Tanos (11/27, 7-day preharvest interval)
Powdery mildew	Pristine (11/7, 14-day preharvest interval), Luna Sensation (7/ 11, 14-day preharvest interval), Vivando (50, 14-day preharvest interval), Gatten (U13, 7 day preharvest inteval) and Torino (U6, 6 day preharvest interval)
Halo blight	Flint Extra (11, 14-day preharvest interval), Rhyme (3, 14-day preharvest interval), Luna Experience (7/3, 14-day preharvest interval)

Notes: Pay close attention to the preharvest interval as harvest approaches.

Stage 8. Senescence

After the first killing frost, the focus should be on good sanitation including the removal of any residual bine and crop debris. Materials removed from the yard should be actively composted, burned or burried as they can harbor spores.

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.

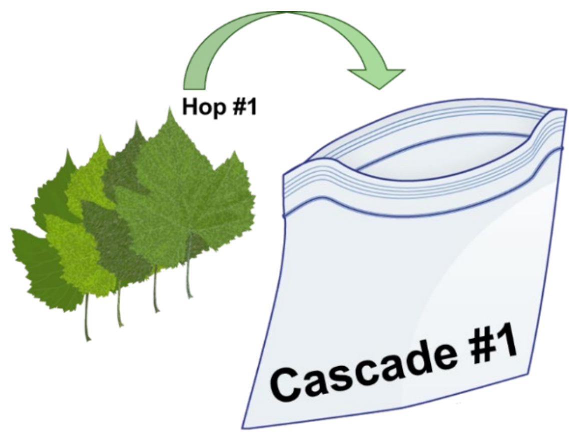
- Use only new, clean, resealable plastic bags and place the sample immediately into the bag.

- **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.

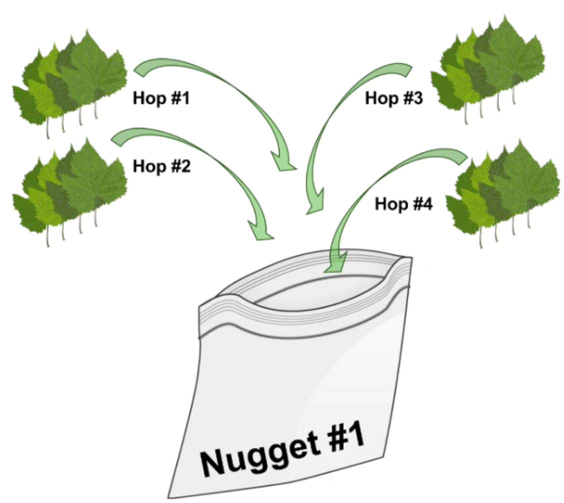
- Reach for a full-size living leaf and pull it backwards until the petiole snaps off.
- Collect a total of 4 leaves from different bines and in different positions (for example, front and back) on the suspect hop plant. You can restrict the sampling to those leaves that are easiest to reach. Include 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, 2026

Chemical Class (IRAC group[1])	Active Ingredient (IRAC group[1])	Products labeled	Pesticide Efficacy[2] Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	REI/PHI[3]
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)	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	12h/0d
	petroleum oil	Biocover MLT, Glacial Spray, 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 SL, 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, 2026

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	
Neonicitinoids (4A)	imidacloprid	Acronyx 2 Flowable, Acronyx 4F, Admire Pro, Advise Four, Admire Pro Systemic Protectant, Alias 4F, Avenger S3, Brigadier, Imidashot DF, Macho 2.0 FL, Macho 4.0, 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, Provoke, Sherpa, Skyraider, Swagger, Tigris Imida 4 F, Viloprid FC 1.7, Widow, 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, UPL Acramite 50 WS, Banter WDG, Enervate 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, 2026

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	Moltile	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	Initiate sprays at early leaf stage. Discontinue sprays at burr development.	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	Initiate sprays at early leaf stage. Discontinue sprays at burr development.	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 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)	Motile	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)	Motile	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)	Motile	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, Enervate 4SC, Enervate 50WSB,	bifenazate (20D)	Motile	Provides quick knockdown, good coverage is key. Best positioned as soon as mites become active.	6-8 wks.	14d	1
Nealta Miticide	cyflumetofen (25)	Motile	Requires a supplemental label.	6-8 wks.	14d	1
Magister SC[R]	fenazaquin (21)	Motile	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.

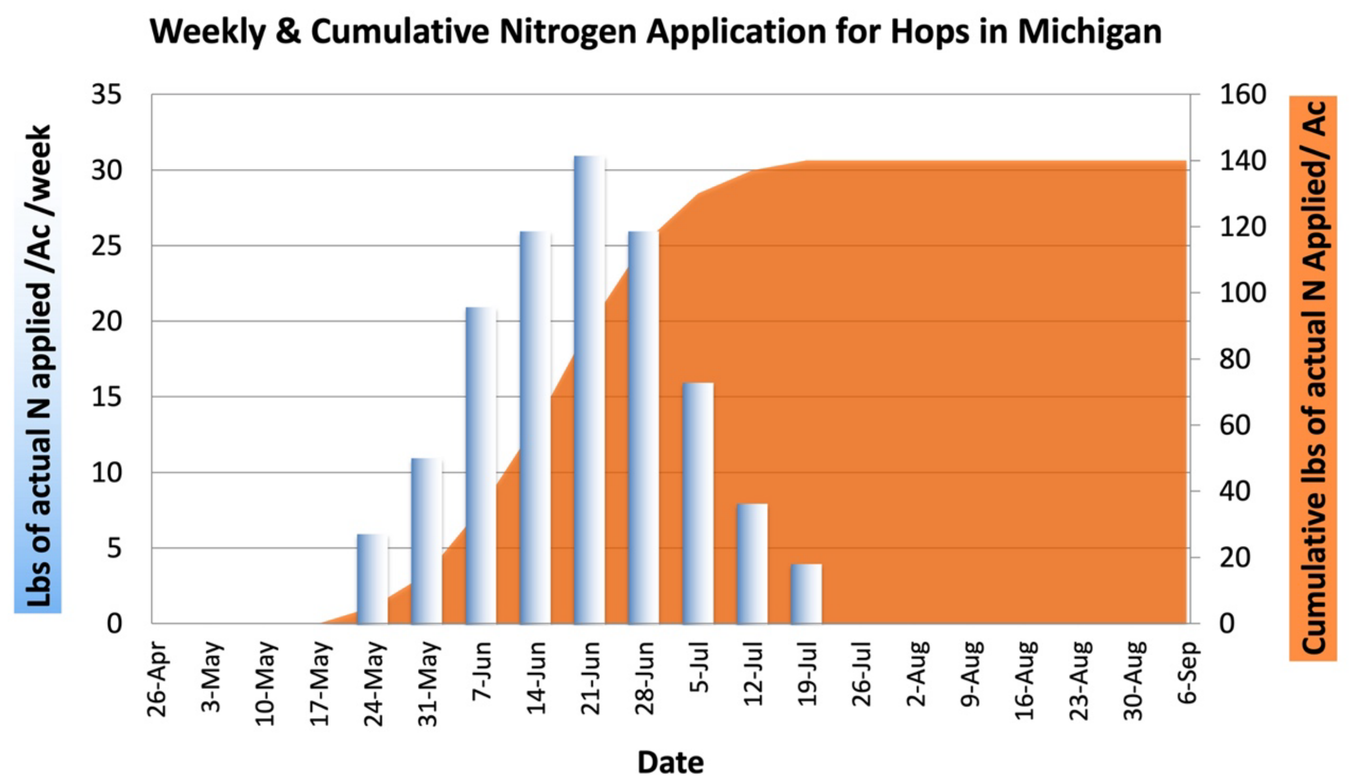
[R] Products containing these active ingredients are classified as a restricted use pesticides and require the applicator to retain a pesticide applicator license.

[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,

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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

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 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 apply ~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, which 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 3rd-4th 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

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[3] Neve. R.A. 1991. Hops. London: Chapman and Hall.
[4] Gingrich, G., J. Hart, and N. Christensen. 2000. Fertilizer Guide: Hops. FG 79. Oregon State University, Corvallis, OR.

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.

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.

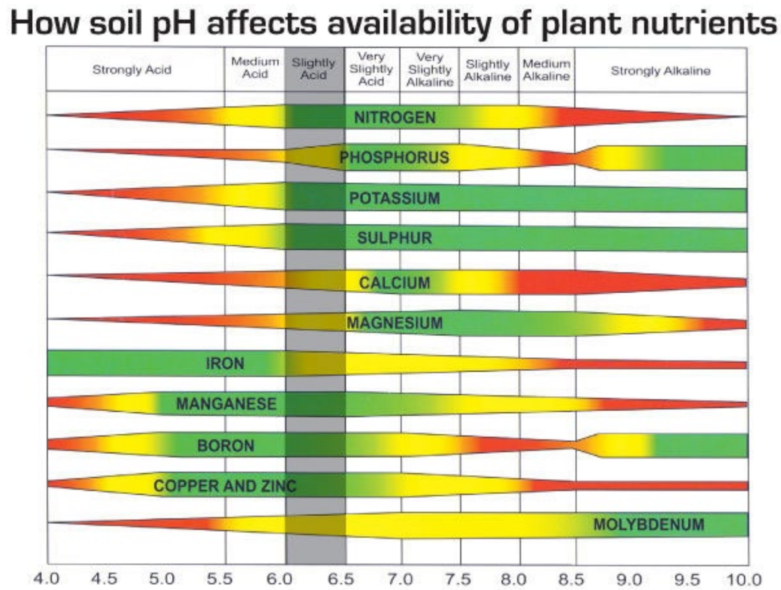
Sodium (Na) Though non-essential, Sodium is important for metabolic processes and chlorophyll synthesis. Excessive Na can lead to toxicity, generally demonstrated by leaf margin and tip necrosis. Soil Sodium levels should be <225 ppm.

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

[5] Taberna, J. 2018. Hop nutrient needs for maximum production and quality. Western Labs Inc.

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)	

[6] 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 Lab

Visit www.pestID.msu.edu for additional information and submittal forms. The following are just some selected services of interest, please note the lab provides many additional services.

Services Provided by MSU Plant & Pest Diagnostics

1. Plant Health Analysis

Basic Sample Submission

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.

Add-on Testing Services

In-house serological test

The lab has limited availability of serological test kits for viruses and bacterial pathogens. This allows for rapid and sensitive testing for specific pathogens. Contact us to learn more about the available tests.

Bacterial identification (BIOLOG®)

Upon request and based on culture results, a BIOLOG® metabolic analysis can be conducted.

Molecular pathogen identification

Upon request and depending on the available barcodes, identification to genus or species (when possible) level can be conducted.

Molecular pathogen detection (PCR/qPCR)

Upon request and/or based on culture results, detection of specific bacteria, fungi, and oomycetes can be conducted.

List of relevant molecular tests:

- Fungal and oomycete diseases
  - Downy mildew (*Pseudoperonospora humuli*)
  - Fusarium canker of hop (*Fusarium sambucinum*)
  - Halo blight (*Diaporthe humulicola*)
  - Phytophthora root/crown rot (*Phytophthora* spp.)
  - Verticillium wilt (*Verticillium dahliae*)
- Viral diseases
  - 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)

2. Plant/Weed Identification

Plant ID

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.

3. Herbicide Resistance in Weeds

Herbicide resistance screening

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

4. Nematode Analysis

Basic nematode analysis

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

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

Nematode trophic composition

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 into functional or trophic groups, such as bacterial-feeding, fungal-feeding, and predatory.

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

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

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 www.canr.msu.edu/psep/

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