

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 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

The efficacies of products listed have not 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.

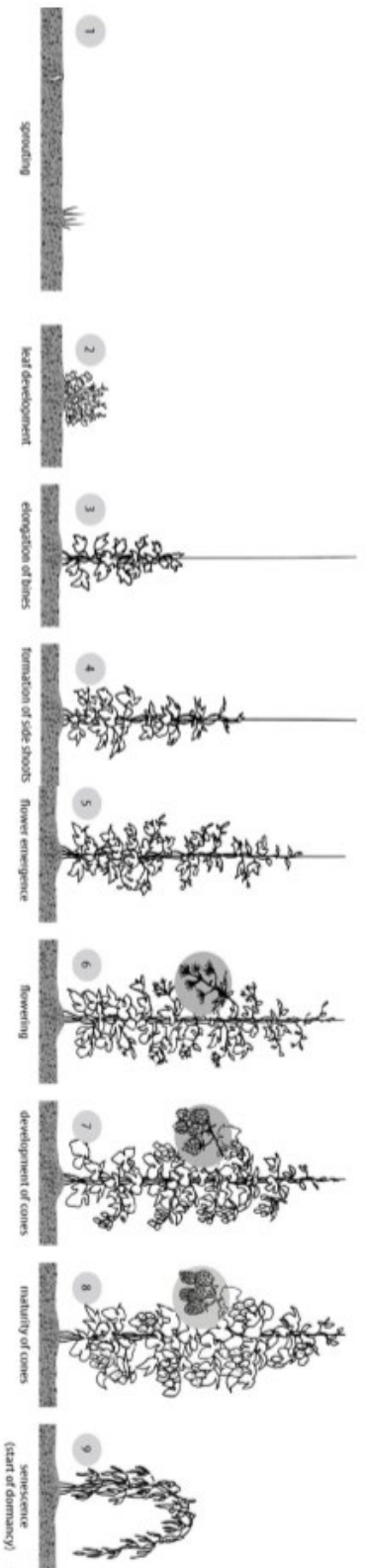
Hop exportation

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>.

Average Michigan hop growth stages based on date.

	March				April				May				June				July				August				September							
Dormancy	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
					Spring Regrowth				Vegetative Growth				Reproductive Growth				Preparation for Dormancy															
					sprouting				leaf development				side shoots				burr stage				cone development				maturity of cones							



Botanical drawings courtesy of Dodds, Kevin. 2017. Hops, a guide for new growers. NSW Department of Primary Industries.

Management activities guide

Month Week	Jan				February				March				April				May				June				July				August				September				October				November				December			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4				
Stage of Production	Dormancy																																															
Growth stage	sprouting																																															
Trailis installation/repair	[Blue bar]																																															
Pre-plant preparation	[Blue bar]																																															
Seed cover crops	[Blue bar]																																															
Planting	[Blue bar]																																															
Crowning (Crown Pruning)	[Blue bar]																																															
Striking	[Blue bar]																																															
Training	[Blue bar]																																															
Weed Control pre-season	[Blue bar]																																															
Pruning-chemical/pruning	[Blue bar]																																															
Burnback/Stripping	[Blue bar]																																															
Side dishing	[Blue bar]																																															
Leaf/Periole 5, 5' & 1' below wire	[Blue bar]																																															
Soil Sample	[Blue bar]																																															
Irrigation	[Blue bar]																																															
SAP Analysis (weekly or twice/month)	[Blue bar]																																															
Fertility-fertilization/granular	[Blue bar]																																															
Fertility-foliar	[Blue bar]																																															
Fertility-compost	[Blue bar]																																															
Pest and Disease Scouting & Control	[Blue bar]																																															
Harvest Prep	[Blue bar]																																															
Harvest	[Blue bar]																																															
Side disk to cover shoots-baby hops	[Blue bar]																																															

Ref. Source: MSU, March 2022.

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 inrow 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, 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 ($43,560 \div 14$). 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 ($3,111 \times 4$), 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 (30×0.28). 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. $43,560/14 = 3,111\text{ft}$
2. Multiply the feet of row by the band width to get the area to be treated. $3,111' \times 4' = 12,444 \text{ sq. ft.}$
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 determine in step 3.
 $1 \text{ lb.} \times 0.28 = 0.28 \text{ pounds}$
5. Multiply the recommended volume of water for an acre by the percentage of an acre as determined in step 3.
 $30 \text{ gallons} \times 0.28 = 8.4 \text{ gallons.}$



Registered herbicides

Registered herbicides for use on hops in Michigan, 2022

Application timing ¹	Broadleaf or grasses	Active ingredient (WSSA code ²)	Products labeled	REI/PHI ³	Notes
Post-emergent	Both	glyphosate (9)	Abundit Extra, Abundit Edge, Buccaneer, Buccaneer Plus, Cornerstone Plus, Credit 41, 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, 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	ammonium nonanoate	Axxe*	4h/0d	OMRI listed.
	Both	pelargonic acid (27)	Scythe	12h/see label	Uses prior to crop emergence, dormant or post harvest spray.
	Both	caprylic + capric acid	HomePlate 80L*	24h/	Avoid contact with crop stem and foliage. OMRI listed.
	Broadleaf	pyraflufen-ethyl (14)	Venue ⁵	12h/30d	For the management of suckers and broadleaf weeds. Avoid contact with desirable growth.
	Broadleaf	carfentrazone (14)	Aim EC ⁴	12h/7d	Use with shielded or hooded sprayers to control small broadleaf weeds and hop suckers and lower
	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.
	Broadleaf	clopyralid (4)	Spur	12h/30d	Controls Canada thistle. Some activity on hosenettle at high rate.
	Grasses	clethodim (1)	Arrow 2EC, Avatar, Avatar S2, Cleanse, Cleanse 2EC, Clethodim 2E, Clethodim 2EC, Dakota, Intensity One, Intensity Post-Emergence, Omni Brand Clethodim 2 EC, Opti-Amine, Section Three, Select Max with Inside Technology, Select 2EC, Shadow, Shadow 3EC, Tapout, Tide USA Clethodim 2EC, Vaquero, Volunteer, Wildwood Clethodim 2 EC	see label	Controls annual and perennial grasses.
Pre-emergent	Annual grasses/broadleaf	trifluralin (3)	Cornbelt Trifluralin EC, Treflan 4EC, 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 applications prior to emergence. Product is water activated.
	Both	flumioxazin (14)	Chateau SW, Chateau EZ, Flumi 51 WDG, Flumi SX Herbicide, Flumioxazin 51% WDG, Tuscany, Tuscany SC, Varsity, Venue	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.

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.

Disease management

Hop Disease Scouting Calendar								
	Dormancy	Sprouting	Leaf expansion	Bine elongation and sidearm formation	Flowering	Cone development	Cone maturity	Senescence
Diseases								
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								

Registered fungicides

Fungicides registered for use on hop in Michigan, 2022

	Active ingredient (FRAC code ¹)	Products labeled	Diseases listed on label ²	REI/PHI ³
Single site	cyazofamid (21)	Ranman 400 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 ⁴	DM	12h/24d
	fluopyram (7)	Luna Privilege ⁵ , Velum Prime ⁵	PM	12h/7d
	flutianil (U13)	Gatten ⁴	PM	12h/7d
	flutriafol (3)	Rhyme ⁵	PM	12h/14d
	mandipropamid (40)	Revus	DM	4h/7d
	mefenoxam (4)	Ridomil Gold SL, Ultra Flourish	DM	see label
	metalaxyl (4)	MetaStar 2E, Metalaxyl 2E Ag, ReCon 4F, Xylar FC Fungicide	DM	see label
	metrafenone (50)	Vivando	PM	12h/3d
	quinoxifen (13)	Quintec	PM	12h/21d
	tebuconazole (3) ⁵	Buzz Ultra DF, Monsoon, Onset 3.6 L, Orius 3.6 F, Tebu-Crop 3.6 F, Tebustar 3.6 L, Toledo 3.6 Ag Fungicide	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)	Agristar Basic Copper 53*, C-O-C-S WDG, Cuprofix Ultra 40 Disperss, Mastercop*	DM	see label
	copper hydroxide (M1)	Champ DP Dry Prill, ChampION++, Champ Formula 2 Flowable, Champ WG*, Kentan DF, Kocide 2000, Kocide 2000-O, Kocide 3000-O, Nu-Cop HB, Nu-Cop 3L, Nu-Cop 50 DF*, Nu Cop 50 WP*, Nu-Cop 30 HB, Nu-Cop XLR, Previsto	DM	48h/14d
	copper octanoate (M1)	Cueva*	Anthraco-nose, DM, PM	4h/0d
	copper oxychloride (M1)	COC DF		48h/label
	copper oxychloride + copper hydroxide (M1)	Badge SC, Badge X2*	DM	48h/14d
	folpet (M4)	Folpan 80 WDG	DM	24h/14d
	sulfur (M2)	Auron DF*, Cosavet DF Edge*, Microfine, Microthiol Disperss, Sulfur*, Sulfur DF*, Thiolutx*	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 is 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.

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Fungicides registered for use on hop in Michigan, 2022

	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)	Orodnis Ultra	DM	4h/7d
	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
	tebuconazole (3) + sulfur (M2)	Unicorn DF ⁵	PM	12h/14d
Plant defense inducers	fosetyl-Al (33)	Aliette WDG, Linebacker WDG	DM	12h/24d
	phosphorous acid, mono & di-potassium salts (33)	Agri-Fos, Confine Extra, OxiPhos, Phiticide, Phostrol, Reliant	DM	4h/0d
	potassium phosphite (33)	Fosphite Fungicide, Fungi-Phite, Helena Prophyt, Prophyt, Rampart	DM	4h/0d
Biopesticide	<i>Bacillus amyloliquefaciens</i> strain D747 (44)	Double Nickel 55*, Double Nickel LC*, Serifel*	PM	4h/0d
	<i>Bacillus pumilus</i> strain QST 2808 (44)	Sonata*	DM, PM	4h/0d
	<i>Bacillus subtilis</i> (44)	Serenade Max*, Serenade ASO*	PM	4h/0d
	extract of neem oil	Trilogy*	DM, PM	4h/0d
	hydrogen dioxide/peroxyacetic acid	Oxidate 2.0, StorOx 2.0	DM, PM	until dry/5d
	mineral oil	Damoil Dormant, 440 Superior Spray Oil, Omni Supreme Spray, PureSpray Green, SuffOil-X, Ultra-Pure Oil, and Summer Spray Oil	PM	see label
	paraffinic oil	Organic JMS Stylet oil*, JMS Stylet Oil	PM	4h/0d
	potassium bicarbonate	Carb-O-Nator, Kaligreen*, Milstop*, Milstop SP*	PM, DM, anthracnose	see label
	<i>Reynoutria sachalinensis</i> extract (P5)	Regalia*	DM, PM	4h/0d
	<i>Streptomyces lydicus</i> WYEC 108	Actinovate AG*, Actinovate STP*	Verticillium wilt, DM, PM	4h/0d
	tea tree oil (F7)	Timorex Gold	DM, PM	12h/48h

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. 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.

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Hop downy mildew management

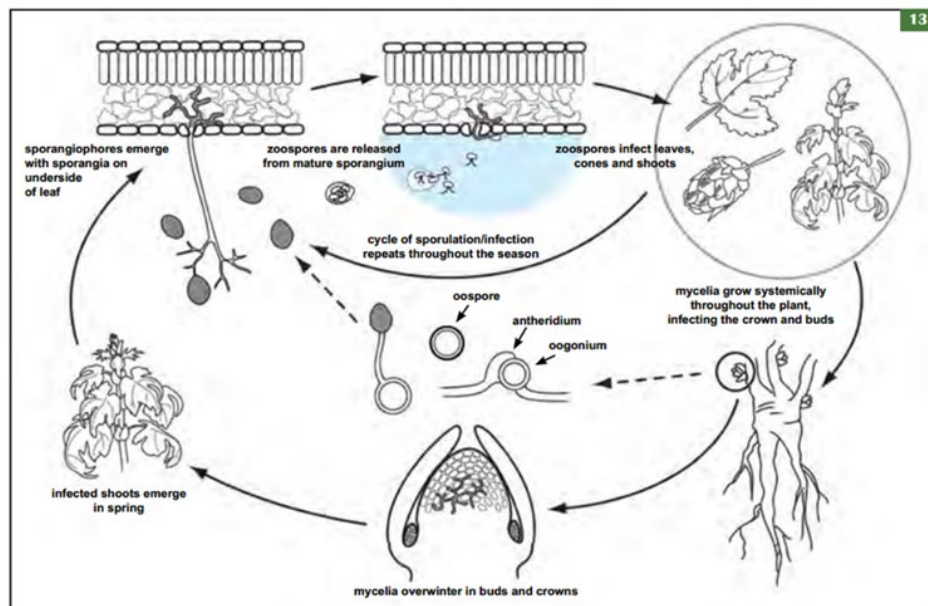
Downy mildew is caused by the fungal-like organism *Pseudoperonospora humuli* and is a significant disease of hop in Michigan, potentially causing substantial yield and quality losses. This disease affects cones, and foliage and can become systemic; in extreme cases the crown may die. Cool and damp weather during the spring provide 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 also 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.



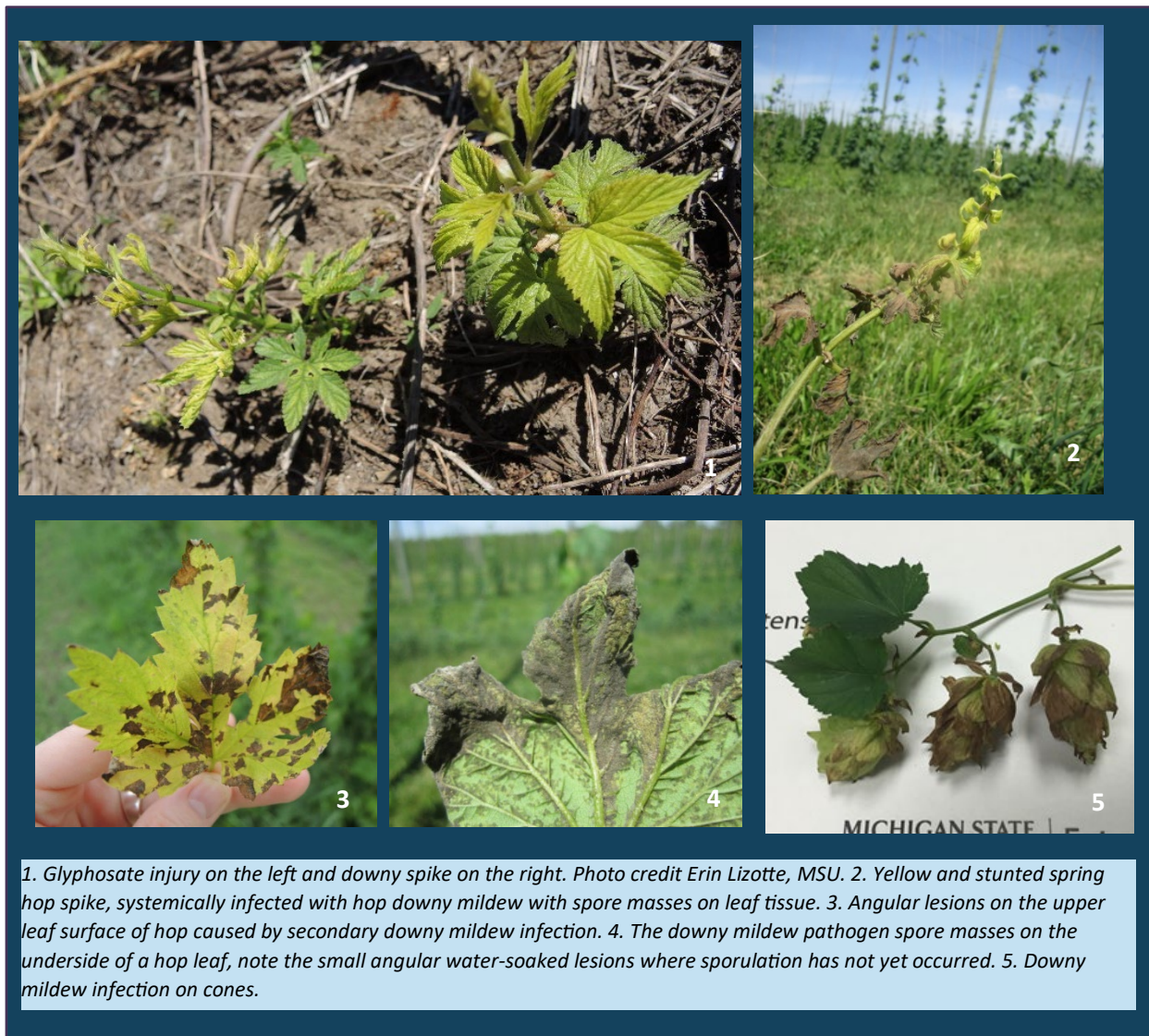
Life cycle of *Pseudoperonospora humuli* on hop. Prepared by V. Brewster, *Compendium of Hop Diseases and Pests*.

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 as a result 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.



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, as well as 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 hotspots 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 numbers 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 (8-10'), 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 Aim herbicide or concentrated nitrogen fertilizer solutions. Aim will also control smaller weeds within the row. The use of Aim, 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 up. Covering young,

developing bracts before cones close up 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 are 1 day or less, at this time we have no data on the efficacy of these products.

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	metalaxyl (4)	E	See label
Orondis Ultra	mandipropamid (40), oxathiapiroline (49)	E	4h/7d
Presidio ⁵	fluopicolide (43)	E	12h/24d
Ranman 400 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
AgriStar Basic Copper 53*, C-O-C-S WDG, Cuprofix-Ultra 40 Disperss, Mastercop*	basic copper sulfate (M1)	P/F	see label
Cueva*	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 WG*, Kentan DF, Kocide 2000-O, Kocide 3000-O, Nu-Cop 3L, Nu-Cop 50 DF*, Nu COP 50 WP*, Nu-Cop 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
Agri-Fos, Confine Extra, OxiPhos, Phiticide, Phostrol, Reliant	phosphorous acid, mono & di-potassium salts (33)	P/F	4h/0d
Fosphite, Fungi-Phite, Prophyt, 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*, Actinovate STP*	<i>Streptomyces lydicus</i> WYEC 108	0	
Folpan 80 WDG	folpet (M4)	U	24h/14d
Sonata*	<i>Bacillus pumilus</i> strain QST 2808 (44)	U	4h/0d
Trilogy*	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*, Milstop*	potassium bicarbonate	U	see label
Regalia*	<i>Reynoutria sachalinensis</i> extract (P5)	U	see label

1. FRAC - Fungicide Resistance Action Committee (FRAC) codes are used to distinguish the fungicide groups for resistance

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

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.

* 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.

Insect pest management

Hop Insect Pest Scouting Calendar								
	Dormancy	Sprouting	Leaf expansion	Bine elongation and sidearm formation	Flowering	Cone development	Cone maturity	Senescence
Insects								
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								

Registered insecticides

Registered insecticides for use on hops in Michigan, 2022

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

1. Insecticide Resistance Action Committee (IRAC) codes are used to distinguish the insecticide modes of action for resistance management purposes. **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.

* OMRI approved for organic production.** 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, 2022

Chemical Class (IRAC group ¹)	Active Ingredient	Products labeled	Pesticide Efficacy ²				REI/PHI ³
			Potato leafhopper	Rose chafer	Japanese beetle	Two- spotted spider mite	
Neonicotinoids (4A)	imidacloprid	Admire Pro, Advise Four, Alsias 4F, Imidashot DF, Imidacloprid 4F, Imidacloprid 4SC, Macho 2.0 FL, Macho 4.0, Malice 2F, Malice 75 WSP, Montana 2F, Montana 4F, Midash 2SC, Midash Forte Insecticide, Nuprid 2F, Nuprid 2SC, Nuprid 4.6F Pro, Nuprid 4F Max, Prey 1.6, Provoke, Sherpa, Widow, Willowood Imidacloprid 4 SC, Wrangler	G	G	G	N	see label
	thiamethoxam	Platinum, Platinum 75SG	G	G	G	N	12h/65d
Pyrethroids (3)	bifenthrin**	Athena, Avenger S3, Battallion 2EC, Bi-Dash 2E, Bifen 2AG Gold, Bifender FC, Bifenthrin 2EC, Bifenture 10DF, Bifenture EC, Brigade WSB, Brigade 2EC, Discipline 2EC, Fanfare ES, Fanfare EC, Reveal, Reveal Endurx, Sniper, Sniper Helios, Sniper LFR, Tundra EC	G	U	E	U	see label, many are 12h/14d
	cyfluthrin**	Tombstone, Tombstone Helios	U	N	U	N	12h/7d
	pyrethrins	EverGreen Crop Protection EC 60-6, Pyganic EC 1.4 II*, Pyganic EC 5.0 II*, Pyganic Specialty, Tersus	U	F	F	U	12h/0d
	beta-cyfluthrin**	Baythroid XL, Sultrus	E	G	G	U	12h/7d
Pyridine azomethine derivatives (9)	pymetrozine	Fulfill	N	N	N	N	12h/14d
Spinosyns (5)	spinosad	Entrust*, Entrust SC*, GF-120 NF*, SpinTor 2SC*	N	N	N	U	4h/1d
	spinetoram	Delegate WG	N	G	N	N	4h/1d
Tetramic acids (23)	spirotetramat	Movento	N	N	N	U	24h/7d
	spirodiclofen	Envidor 2SC	N	N	N	E	12h/14d
Premixed products	beta-cyfluthrin(3)** + imidacloprid(4A)	Leverage 360	U	G	G	N	12h/28d
	bifenthrin(3)** + imidacloprid(4A)	Avenger S3, Brigadier, Skyraider, Swagger, Tempest	N	U	U	U	12h/28d
	abamectin(6) + bifenthrin(3)	Athena	U	U	U	U	12h/28d
	azadirachtin + pyrethrin(3)	Azera	U	U	U	U	12h/0d
Bifenazate (20D)	bifenazate	Acramite 50WS, Acramite 4 SC, Banter WDG, Bizate 4 SC, Bizate 50 WDG, Vigilant 4 SC	N	N	N	E	12h/14d

1. Insecticide Resistance Action Committee (IRAC) codes are used to distinguish the insecticide modes of action for resistance management purposes. **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.

* OMRI approved for organic production. ** Products containing these active ingredients are classified as a restricted use pesticides and require the applicator to retain a pesticide applicator license.

Registered miticides

Registered miticides for use on hops in Michigan, 2022						
Products labeled (IRAC Code)	Active ingredient	Affected stage ¹	Considerations	Residual control ²	Preharvest interval	Impact on predatory mites ³
JMS Stylet-Oil, Organic JMS Stylet-Oil	paraffinic oil	Eggs/larvae	Apply to dormant trees in the spring when temperatures are forecast to be above freezing.	2-6 weeks	see label	unknown
BioCover MLT, Damoil Dormant & Summer Spray Oil, Glacial Spray Fluid, PureSpray Green, SuffOil-X, Ultra-Pure Oil	mineral oil	Eggs/larvae	Apply to dormant trees in the spring when temperatures are forecast to be above freezing.	2-6 weeks	see label	unknown
Hexamite, Onager, Savey DF (10A)	hexythiazox	Egg/larvae	Apply before burr formation and before adult build up. Savey will not control adults. Use higher rate for moderate to heavy mite pressure, for large plants or longer residual control.	6-12 weeks	see label	1
Abacus, Abacus V, Abba 0.15 EC, Abba Ultra Miticide, Abamex, Agri-Mek SC, Averland FC, Reaper 0.15 EC, Reaper Clearform, Reaper Advance, Tide Timectin 0.15 EC Ag Insecticide/Miticide (6)	abamectin**	Motiles	Apply at threshold and with required adjuvant. Application rate is based on bine height.	6-12 weeks	28d	3
Zeal (10B)	etoxazole	Egg/larvae	For best results apply when mite populations are low, at or prior to threshold.	6-10 weeks	7d	2
Endomite (12C)	propargite**	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 (21)	fenpyroximate	Motiles	For best results, apply before mite populations exceed 5 mites/leaf. Not recommended when temperature exceed 90F.	6-8 weeks	15d	1
Acramite 50 WS, Acramite 4SC, Banter WDG, Bizate 4SC, Bizate 50WDG, Enervate 4SC, Enervate 50WSB, Vigilant 4 SC (20D)	bifenazate	Motiles	Provides quick knockdown, good coverage is key. Best positioned as soon as mites become active. Use low rates at early infestation and increased rates under higher mite pressure.	6-8 weeks	14d	1
Appollo SC Ovicide/Miticide (10A)	clofentezine	Eggs	Requires a supplemental label.	8-10 weeks	21d	1
Nealta Miticide (25)	cyflumetofen	Motiles	Requires a supplemental label.	6-8 weeks	14d	1
Magister SC (21)	fenazaquin**	Motiles	Provides quick knowdown. Has some activity against powdery mildew. One application per year.	3-5 weeks	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.

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

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

Nutrient Management Considerations

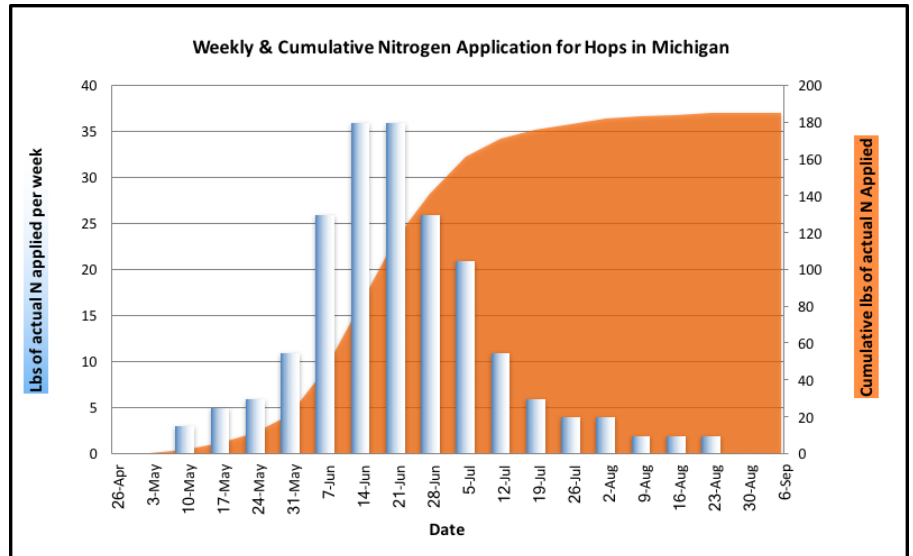
As hops reach technical maturity in August and September prior to dormancy, more carbohydrates are produced than are needed for growth; excess carbohydrates are directed toward the rootstock in preparation for the following growing season. As hops break dormancy, they rely solely on carbohydrate reserves until photosynthesis commences with the period of vegetation. For optimum production, supplemental nutrition is necessary at this time¹. 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.

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.

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/ac². 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 percent³. This suggests that roughly thirty-five 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 be applying ~170 lbs of actual N/ac/yr. This does not account for additional N inputs such as compost, plant residue, or N-fixing leguminous cover crops, which should be added to 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.

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 150-185 lbs of actual N/acre/yr to mature hop plants (See Figure 2, which shows 185 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 130-150 lbs. by the end of June when plants begin to transition from vegetative to reproductive growth. If the early summer has been overly wet and growers have not had the opportunity to fertigate this amount, granular N should be band applied and lightly tilled.



Weekly and cumulative nitrogen application in Michigan hops. Rob Serrine, MSU

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.

Nitrogen needs may differ depending upon cultivar vigor and disease susceptibility. Vigorous cultivars may need less N, while weaker cultivars may need more N over the course of 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, feathermeal, 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/ac⁴. 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.

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.

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.

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.

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.

Copper (Cu)

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.

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 result 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.

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.

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).

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.

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.

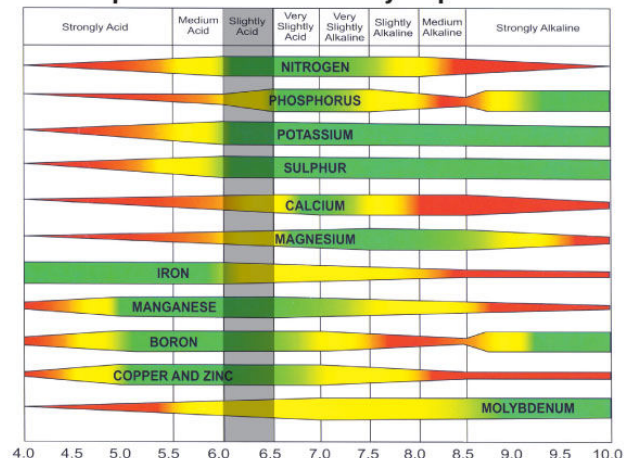
*Ratios amongst certain nutrients can be very important and should be discussed with your soil test laboratory.

pH

Soil pH is a measure of the 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.

How soil pH affects availability of plant nutrients



⁶ <https://www.superior.net.nz>

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 and 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)	

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				

¹Del Moro, S. 2014. Great Lakes Hop and Barley Conference. John I Haas.

²Plant Analysis Handbook IV. 2015. Bryson and Mills (eds). P. 301

³Taberna, J. 2017. Leaf + Petiole collected at 5.5' when plant is 8' and from 1' below wire when plant reaches wire

⁴CSIRO. 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 that is 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 are able to 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 need to be collected in the morning, ideally before 9am, at the same time throughout the season. Samples should also be consistently collected from the same side of the plant (eg. 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 (Eg. \$70 for 10 sets).

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/>



Client: Example Contact
Acct #: Example Contact
Data Reported To: Example Contact
Collected By: Example Contact
Sample Location: Example Hops Field
Date/Time Sampled: 03-16-2022
Sample Name: New: HOPS SAMPLE - OLD
Date/Time Received: 03-16-2022 00:00
NAL Sample ID: New: t004064 Old: t004063
Plant Type: Hops
Variety: Centennial
Growth Stage: Vegetative Growth

Parameter	Units	OLs	Result		Low	Optimal	High
Sugars, Total*	%	High: 1.5 Low: 0.5	0.27 0.38	New Old			
Brix*	-	High: 16 Low: 8	3.6 2.6	New Old			
pH*	-	High: 6.3 Low: 5.8	6.6 6.4	New Old			
EC*	ms/cm ms/cm	High: 10 Low: 6	14 13	New Old			
Anions							
Chloride (Cl-)*	ppm	High: 1000 Low: 200	1800 980	New Old			
Sulfur (S)	ppm	High: 400 Low: 100	180 130	New Old			
Phosphorus (P)	ppm	High: 300 Low: 125	210 240	New Old			
Cations							
Calcium (Ca)	ppm	High: 1500 Low: 600	1500 960	New Old			
Potassium (K)	ppm	High: 7500 Low: 5000	3900 3900	New Old			
K/Ca Ratio			2.6 4.06	New Old			
Magnesium (Mg)	ppm	High: 900 Low: 400	1200 570	New Old			
Sodium (Na)	ppm	High: 50 Low: 15	30 18	New Old			
Trace Elements							
Aluminum (Al)	ppm	High: Low:	0.06 0.2	New Old			
Boron (B)	ppm	High: 8 Low: 2	4.2 2.8	New Old			
Cobalt (Co)	ppm	High: Low:	0.02 0.02	New Old			
Copper (Cu)	ppm	High: 8 Low: 1.5	0.39 0.31	New Old			
Iron (Fe)	ppm	High: 15 Low: 4	0.81 1.2	New Old			
Manganese (Mn)	ppm	High: 10 Low: 1.5	4.8 2.7	New Old			
Molybdenum (Mo)	ppm	High: 3 Low: 1	0.04 < 0.01	New Old			
Nickel (Ni)	ppm	High: Low:	< 0.01 0.01	New Old			
Selenium (Se)	ppm	High: Low:	< 0.01 < 0.01	New Old			
Silica (Si)	ppm	High: 90 Low: 50	65 74	New Old			
Zinc (Zn)	ppm	High: 10 Low: 3	14 4.8	New Old			
Nitrogen Parameters							
Nitrogen from Ammonium (NH4)*	ppm	High: Low:	120 180	New Old			
Nitrogen from Nitrate (NO3)	ppm	High: Low:	78 190	New Old			
Nitrogen (N), Total*	ppm	High: 3500 Low: 1500	1700 2000	New Old			
Nitrogen Conversion Efficiency	%		88.4 81.5	New Old			

- NAL holds certification under ISO 17025:2017 and meets the AOAC International Guidelines for Laboratories Performing Microbiological and Chemical Analyses of Food Standards
 - The results reported apply only to the two (2) samples listed
 - This report may not be reproduced except in full without written permission of NEW AGE Laboratories
DISCLAIMER: Results are based on analysis of the samples as received. Because of the variability of sampling procedures and environmental conditions, the company does not accept liability for lack of performance based on these recommendations. Recommendations are made based on the sample and information received.

Scott D. Wall
 President/Technical
 Manager

Example SAP analysis laboratory report. Source: New Age Labs.

Guidelines for safe use of pesticides

Karen Renner, Julianna Wilson, Meghan Milbrath

Pesticides are important tools for managing pests of orchard crops, but they need to be handled with care and responsibility. In this section we cover several important topics with respect to pesticide safety: worker safety, emergency preparedness, pesticide handling, storage and disposal, protecting water, protecting pollinators and other beneficial insects, and important legal considerations.

Worker Safety

Agricultural operations that apply restricted-use pesticides are required by Federal law to follow certain worker protection safety rules (for more information on WPS rules, visit your county MSU Extension office). It is good practice to protect workers from potential exposure to all pesticides being used – whether they are derived from synthetic or organic origins. Following are a basic set of good practices to protect workers from exposure:

- Provide employees with annual training in worker safety, if they are not already certified as pesticide applicators.
- Use a Central Notification Board to provide access to information about pesticide safety and the pesticides that are being used in the operation.
- Post pesticide safety posters to remind workers about how to be safe around pesticide use.
- Provide access to pesticide labels and MSDS sheets.
- Post what and where pesticide treatments were made and include when it is safe to enter the treated area based on the pesticide's restricted entry interval (REI).
- Protect workers from exposure to pesticides.
- Prohibit handlers from applying pesticides in any way that will expose workers or others. Monitor the health of handlers who apply highly toxic pesticides.
- Workers not applying pesticides must be excluded from areas being treated with pesticides and adhere to the REI on the pesticide label.
- Early-entry workers must be protected while they are doing permitted tasks in an area under REI and provided instruction for use of personal protective equipment.
- Mitigate exposure: Provide decontamination sites for washing up in the field.
- Provide emergency assistance to make transportation available to a medical facility in the event of a pesticide-related injury or illness.

Emergency Preparedness

At the time that the pesticide is purchased, ask the chemical dealer for a complete specimen label of the product you bought. This label and labeling information packet is an exact duplicate of the label information that is affixed to and/or must accompany the pesticide container. Use the specimen label material as a reference during any pesticide emergency. Bring the label along with any person who has become poisoned and needs medical attention.

Closely follow all the warning statements outlined in the Precautionary Statements section of the pesticide label. Be certain that you use all protective clothing and equipment as specified by the label. Make certain all persons involved in the operation of the farm know and can carry out the information in the Statement of Practical Treatment. (See also the section on SARA Title III.)

Pesticide Handling, Storage and Disposal

This section is not meant to be exhaustive or to take the place of labeled instructions for the product being used. ALWAYS READ AND FOLLOW THE LABEL for whatever product you are using.

Transporting pesticides

Have pesticides delivered by your dealer directly to your pesticide storage facility, if possible. Transporting pesticides, especially large quantities, can involve a high degree of assumed liability by the grower. Department of Transportation shipping rules must be followed for transporting large quantities of pesticides, including proper placarding of the vehicle, liability insurance, special handling requirements, etc.

Storing pesticides

Pesticides must be stored in a facility that will protect them from temperature extremes, high humidity and direct sunlight. The storage facility should be heated, dry and well-ventilated. It should be designed for easy containment and cleanup of pesticide spills and made of materials that will not absorb any pesticide material that leaks out of a container. Store only pesticides in such a facility, and always store them in their original containers.

Do not store any feed, seed, food or fertilizer with pesticides. Do not store any protective clothing or equipment in the pesticide storage facility. Store herbicides separately from insecticides and fungicides to avoid contamination of one material by another and accidental misuse.

Keep the facility locked at all times when not in use to prevent animals, children and irresponsible adults from entering and becoming poisoned. Post the facility as a Pesticide Storage Facility to warn others that the area is off-limits. Maintain an accurate inventory of the pesticides stored in the facility at all times in case of emergency.

Always read and follow the Storage and Disposal section of pesticide labels for specific storage and handling instructions. For additional information on pesticide storage, refer to Midwest Plan Service bulletin 37, Designing Facilities for Pesticide and Fertilizer Containment, and MSU Bulletin E-2335, On-Farm Agrichemical Storage and Handling. Handling and mixing pesticides. Always wear protective clothing and equipment when handling, mixing and applying pesticides, and during cleanup of application equipment. Always wear what is required on the label.

Handling and mixing pesticides

Always wear protective clothing and equipment when handling, mixing and applying pesticides, and during cleanup of application equipment. Always wear what is required on the label.

Mix pesticides downwind and below eye level. Avoid excessive splashing and sloshing. If pesticides are spilled on you, wash them off immediately with lots of water and change clothing. Resume spraying only after cleaning up any spills. Try to use closed handling/mixing systems when appropriate.

Mix only what is required for the area to be sprayed according to label directions. Do not mix excessive amounts. Otherwise, hazardous waste will be created that is difficult and expensive to dispose of. Keep unauthorized persons out of the area when you handle pesticides.

Applying pesticides

Prior to any application, the equipment used must be thoroughly checked for sound operation and accurately calibrated. Poor maintenance and calibration practices lead to excessive residues on the crop and could harm humans, animals, crops and other parts of the environment. Inspect the equipment during use to prevent the unintentional misapplication of chemicals. If equipment needs repair, stop spraying and fix the problem immediately.

Do not spray when the wind is greater than 10 miles per hour and/or weather conditions (e.g., inversions) are conducive to pesticide drift away from the target area. Make every effort to AVOID PESTICIDES MOVING OFF TARGET!

Handling and disposing of pesticide containers

Pesticide containers are considered hazardous waste unless they are triple rinsed or pressure rinsed and the rinsate is used as additional dilution in the spray mixture. After triple or pressure rinsing all emptied pesticide containers, perforate both ends so that the container cannot be reused. All metal and plastic triple-rinsed containers should be offered for recycling. If this option is not available, dispose of them in a state-licensed sanitary land fill. Dispose of all paper containers in a sanitary land fill or a municipal waste incinerator. Do not bury or burn any pesticide containers. Do not reuse any empty pesticide containers for any purpose.

Cleaning pesticide application equipment

Follow all specific label directions for cleaning application equipment. If such instructions are not given on the pesticide label, then triple rinse the entire inside of the application equipment, spraying the rinsate on a labeled site not exceeding labeled rates. Wash off the outside of the equipment in the target area. Only after rinsing out the equipment with fresh water should you clean the spray system with an appropriate cleaning solution. Do not spray any cleaning solution onto any crop; dispose of the cleaning solution as you would any municipal waste. Follow the equipment manufacturer's guidelines for routine and year-end cleaning and maintenance.

Disposing of unused and unwanted pesticides Unused and unwanted pesticides are considered hazardous waste by both federal and state regulations. To be exempt from the stringent requirements for the disposal of hazardous pesticide waste, make every effort to purchase the exact amount of pesticides that will be needed during the growing season. Take extreme care in the calibration and application of any pesticide so that leftovers are not generated at the end of the job. Use any pesticide-containing rinsates and unused pesticides exactly according to labeled use directions. Unused and unwanted pesticides can be disposed of at Michigan Clean Sweep sites located throughout the state. Contact the MDARD (800-292-3939) for the site nearest you.

If these procedures cannot be met, contact the Michigan Department of Environmental Quality Hazardous Waste Management Division for instructions on the legal disposal of pesticide waste.

Protecting Water

The key to preventing pesticides in groundwater and surface waters is identification of the source and route to the water. Point source contamination refers to situations where movement of a pesticide into water can be traced to a specific site. Nonpoint sources occur over a wide area, and most pesticides detected in groundwater and surface water are from nonpoint sources. This type of pollution generally results from land runoff, precipitation, acid rain or percolation rather than from a discharge at a specific, single location (such as a single pipe or well head).

Fate and transport of pesticides

Several processes determine the fate of pesticides and whether they will end up in ground or surface waters.

- Adsorption is the binding of chemicals to soil particles. The amount and persistence of pesticide adsorption vary with pesticide properties, soil moisture, soil pH and soil texture. Soils high in organic matter or clay are the most adsorptive; coarse, sandy soils are much less adsorptive. A soil-adsorbed pesticide is less likely to volatilize, leach or be degraded by microorganisms, but it is also less available for uptake by plants.
- Volatilization occurs when a solid or liquid turns into a gas. Pesticide volatilization increases with higher air temperature and air movement, higher temperature at the treated surface (soil, plant, etc.), and low relative humidity, and when spray droplets are small. Pesticides also volatilize more readily from coarse-textured soils and from medium- to fine-textured soils with high moisture content. A pesticide in a gaseous state is invisible and carried away from a treated area by air currents. The movement of pesticide vapors in the atmosphere is called vapor drift. Unlike the drift of sprays and dusts that can sometimes be seen during an application, vapor drift is invisible.

- Runoff is the movement of pesticides in water across the soil surface. It occurs as water moves over a sloping surface, carrying pesticides either mixed in the water or bound to eroding soil. The amount of pesticide runoff depends on the grade or slope of an area, the erodibility and texture of the soil, the soil moisture content, the amount and timing of irrigation or rainfall, and properties of the pesticide. Pesticide losses from runoff are greatest when heavy rainfall occurs shortly after a pesticide application.
- Leaching also moves pesticides in water. In contrast to runoff, leaching occurs as water moves downward through the soil. Factors that influence leaching include whether the pesticide dissolves easily in water, soil structure and texture, and the amount and persistence of pesticide adsorption to soil particles.
- Absorption is the process by which chemicals are taken up by plants. Once absorbed, most pesticides are degraded within plants. However, some residues may persist inside the plant and be released back into the environment as the plant tissues decay.
- Crop removal can transfer pesticides. When treated crops are harvested, the pesticide residues are removed with them and transferred to a new location.
- Microbial degradation occurs when microorganisms such as fungi and bacteria use a pesticide as a food source. Conditions that favor microbial growth include warm temperatures, favorable pH levels, adequate soil moisture, aeration (oxygen) and fertility. Adsorbed pesticides are more slowly degraded because they are less available to some microorganisms.
- Chemical degradation is the breakdown of a pesticide by processes not involving a living organism. The adsorption of pesticides to the soil, soil pH levels, soil temperature and moisture all influence the rate and type of chemical reactions that occur. Many pesticides, especially the organophosphate insecticides, are susceptible to degradation by hydrolysis in high pH (alkaline) soils or spray mixes.
- Photodegradation is the breakdown of pesticides by sun-light. A pesticide that is not volatilized, absorbed by plants, bound to soil or broken down can potentially move through the soil to groundwater. The movement of groundwater is often slow and difficult to predict. Substances that enter groundwater in one location can turn up years later in other locations. A major difficulty in dealing with groundwater contaminants is that the sources of pollution are not easily recognizable. The problem is occurring underground, out of sight.

Groundwater is the water beneath the earth's surface occupying the saturated zone (the area where all the pores in the rock or soil are filled with water). It is stored in geological formations known as aquifers. Groundwater moves through aquifers and can be obtained at points of natural discharge such as springs or streams, or by drilling a well into the aquifer. The upper level of the saturated zone in the ground is called the water table. The water table depth below the soil surface fluctuates throughout the year, depending on the amount of water removed from the ground and the amount of water added by recharge and connected surface waters. Recharge is water that seeps through the soil from rain, melting snow or irrigation.

Many people who live in rural Michigan get their drinking water from wells. Well water is groundwater, so it is easy to see why you should be concerned about keeping pesticides out of groundwater. Surface waters are visible bodies of water such as lakes, rivers and oceans. Surface water contamination is a major concern associated with the runoff of pesticides from treated fields, mixing and rinsing sites, waste disposal areas and manufacturing facilities. In the 1988 inventory of water quality, pesticides were ranked sixth as river and stream pollutants, behind siltation, nutrients, pathogens, organic enrichment and metals.

Surface waters are home to many different organisms including fish and other wildlife. Fish can be harmed directly or indirectly from pesticides. Direct effects such as kills can result from water polluted by a pesticide (usually insecticides). Indirect effects include loss of food when aquatic insects that they eat are harmed or killed. Pesticides can enter water via drift, surface runoff, soil erosion and leaching. Take the precautions outlined below to protect surface waters.

Keeping pesticides out of groundwater and surface water

It is very difficult to clean contaminated groundwater or surface water. The best solution is to prevent contamination in the first place. The following pesticide use practices can reduce the potential for surface and groundwater contamination.

- Use integrated pest management programs – Keep pesticide use to a minimum by combining chemical control with other pest management practices.
- Reduce compaction – Surface water runoff increases when soils are compacted.
- Utilize conservation practices that reduce erosion and surface runoff – These practices include but are not limited to planting grassed waterways to retard soil and water runoff and keeping buffer strips to protect surface water boundaries. These reduce pesticide runoff by trapping sediment and slowing water runoff so that pesticides can interact with the vegetation and soil.
- Consider the geology of your area – Be aware of the water table depth and the permeability of the geological layers between the surface soil and groundwater. Sinkholes can be especially troublesome because they allow surface water to quickly reach groundwater.
- Consider soil and field characteristics – Determine the susceptibility of the soil or field site to leaching or runoff. Soil texture and organic matter content influence chemical movement into groundwater and the slope of the field influences surface runoff. Surface grading, drainage ditches and dikes can help reduce the amount and control the movement of runoff waters.
- Select pesticides carefully – Pesticides that are highly soluble, relatively stable and not readily adsorbed to soil tend to be the most likely to leach. Read labels carefully and consult a specialist from MSU Extension office or your chemical dealer if necessary. The tables in this bulletin will also help you choose the best pesticide for your use.
- Follow label directions – The label carries crucial information about the proper rate, timing and placement of the pesticide.
- Calibrate accurately – Calibrate equipment carefully and often to avoid over- and underapplication.
- Measure accurately – Carefully measure concentrates before they are placed into the spray tank. Do not “add a little extra” to ensure that the pesticide will do a better job.
- Avoid back-siphoning – The end of the fill hose should remain above the water level in the spray tank at all times to prevent back-siphoning of chemical into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond or stream.
- Consider weather and irrigation – If heavy rainfall is expected, delay applying pesticides. Control the quantity of irrigation to minimize potential pesticide leaching and runoff.
- Avoid spills – When spills do occur, contain and clean them up quickly with an absorbent material such as cat litter.
- Change the location of mixing areas – Mix and load pesticides on an impervious pad, if possible, where spills can be contained and cleaned up.

- Dispose of wastes properly – Obey laws regulating the disposal of pesticide wastes. Follow the label instructions for rinsing containers. Pour the rinsewater into the spray tank and use for treating the site or the crop.
- Store and mix pesticides away from water sources such as wells, ponds and springs – Locate pesticide mix-ing and storage sites a safe distance away to avoid contaminat-ing water sources through accidental spills and leaks.
- Dispose of post-harvest rinse water properly – After harvest, many agricultural commodities are washed or processed, and this can remove or degrade much of the remaining residue. However, the wash water may now be contaminated and should be disposed of as a potential contaminant.

The Michigan Groundwater Stewardship Program

The Michigan Groundwater Stewardship Program (MGSP) is a co-operative effort between the Michigan Department of Agriculture and Rural Development (MDARD), Michigan State University Extension, Conservation Districts and the USDA Natural Resources Conserva-tion Service. The program is funded through fees assessed on sales of pesticides and nitrogen fertilizers. MGSP-sponsored education, technical assistance and cost-share programs help individuals reduce the risk of groundwater contamination associated with pesticide and nitrogen fertilizer use.

Producers who complete the environmental risk assessments for their farmstead and cropping systems (Farm*A*Syst and Crop*A*Syst) will be able to determine what structural, management and record-keeping changes (if any) will be needed for their farming systems to be in conformance with Michigan Right-to-Farm guide- lines and state and federal environmental laws.

The Michigan Agriculture Environmental Assurance Program (MAEAP) is a voluntary program that assists growers in developing and implementing a plan to address the risks indicated by environmental assessments associated with farming practices. Many farms are becoming MAEAP-verified and as a result are eligible for various incentives. For more information about MAEAP and these incentives, contact MDARD.

Protecting Bees and Other Beneficial Insects

Pesticides can cause harm to pollinating bees and other non-pest insects. Be aware of how your pesticide use could potentially put these organisms at risk. The best thing you can do is to reduce potential exposure, since pesticide labels do not always reflect poten-tial hazards, and the health risks of all pesticides for every group of beneficial insects may not be well-studied. The following precautions may help reduce the chance of exposure:

- Avoid pesticide applications on flowers.
- If possible, do not apply pesticides if the site contains a crop or weeds in bloom.
- Pay attention to the orchard or vineyard floor and the spaces between rows: mow cover crops and weeds to remove blooms before spraying.
- Target your pest.
- Select pesticides that are most specific to the target pest.
- Apply only when models or scouting indicate the need.
- Reduce drift during application.
- Calibrate your sprayer early and often to ensure that the applica-tion is staying on target.
- Use drift control materials whenever possible – target nozzles where they are meant to spray; adapt or modify sprayers to recapture over-spray.
- Do not apply pesticides when wind speeds exceed 10 miles per hour.
- Time pesticide applications carefully.
- Bees are most active during midday – if possible, spray at dusk or at night.
- Honey bees are inactive when temperatures go below 55 F – if possible, spray when temperatures are below this threshold.

- Be aware of exposures through standing water.
- Do not let puddles of spray or rinsate accumulate on the ground, honey bees are attracted to standing water and use it to drink or bring back to cool the hive.
- If you rely on honey bee pollination, communication with your beekeeper is essential.
- Work with the beekeeper to choose a safe site for the hives; remember that honey bees can fly far and do not need to be directly in the crop to provide good pollination.
- Coordinate dates and times with the beekeeper for when hives will be delivered and then removed after bloom.
- Discuss your planned spray schedule and the materials you plan to use, so that the beekeeper can adjust if necessary.

Important Legal Considerations

Pesticide Labels

Always thoroughly read the label and the supplemental labeling material for any pesticide that you may consider using. Understand the label instructions and limitations. Use the pesticide only for the purposes listed and in the manner directed on the label. Select only pesticides labeled for the crop you wish to use them on and the pest(s) you wish to control. To do otherwise will cost you in effective and economical product performance and may lead to an unacceptable risk to humans, the crop and the surrounding environment, and later disposal problems of illegal material.

Record Keeping

The 1990 Farm Bill requires that all applicators who apply restricted use pesticides (RUP) keep records and maintain them for two years. The State of Michigan requires RUP records be kept and maintained for three years. Records to be kept include:

- Brand name or product name and the EPA registration number.
- Total amount of the product used.
- Size of the area treated.
- Crop, commodity, stored product or site to which the pesticide was applied.
- Location of the application.
- Month, day and year of the application.
- Name and certification number of the applicator or the applicator's supervisor.

The spray record sheet at the end of this publication or any re-cord form is acceptable as long as the required data are included. Penalties are up to \$500 for the first violation and up to \$1,000 for subsequent violations. Provisions for protecting the identity of the individual producers are included in the law. Commercial applicators must furnish a copy of the required records to the customer of the RUP application.

Endangered Species Act

To minimize the adverse impact of pesticides on endangered species, the EPA initiated the Endangered Species Act. The Michigan Department of Natural Resources (MDNR) administers the Michigan Endangered Species Act and maintains the federal and state endangered species lists in the state. Pesticide applications are a potential problem, particularly affecting birds, butterflies and moths. Alteration of the farm landscape can also negatively affect resident endangered species.

The Environmental Protection Agency (EPA) has determined threshold pesticide application rates that may affect listed species. This information is or will be included on pesticide labels. Counties with vulnerable endangered or threatened species will be identified on pesticide labels. Farmers must take the initiative and consult with the MDNR and the Fish and Wildlife Service (FWS) to be sure there are no endangered species in their area. The Nature Conservancy, a private

land and habitat conservation organization, is working with the MDNR and the FWS and is conducting a landowner contact program to work with landowners who own property important for endangered species protection.

SARA Title III Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Law, under SARA Title III, requires farmers to notify the Michigan SARA Title III Program and the Local Emergency Planning Committee (LEPC) if they store extremely hazardous materials, along with the name and telephone number of the facility representative. Check Extension bulletin E-2575 for a list of EPA-classified “extremely hazardous substances” and their threshold planning quantities. The LEPC may request maps of your storage facility and detailed lists of materials you store. This law also requires that, in the event of a spill, the state SARA Title III Program, the LEPC and the National Response Commission be notified.

Right to Farm

Farmers in Michigan are protected from nuisance lawsuits under the Right-to-Farm Act if they follow specific acceptable management practices. The generally accepted agricultural and management practices (GAAMPs) for pesticide utilization and pest control, nutrient utilization, irrigation and manure management have been completed and are revised annually. The current right-to-farm GAAMPs are posted on the MDARD website: www.michigan.gov/mdard.

Federal Worker Protection Standard

Changes to Federal worker protection rules for worker protection went into effect as of the 2018 field season. The Worker Protection Standard (WPS) covers pesticides that are used in the production of agricultural plants on farms and in forests, nurseries and greenhouses. Details for compliance with the Worker Protection Standard as well as other regulations affecting worker safety can be obtained at the county MSU Extension office.

Additional hop resources

[Hops.msu.edu](https://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 Online Course

[Enviroweather.msu.edu](https://enviroweather.msu.edu)

[Usahops.org](https://usahops.org)



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