

2021

Michigan Chestnut Management Guide



MICHIGAN STATE UNIVERSITY | **Extension**



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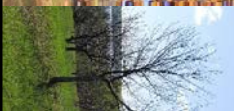
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Information presented here does not supersede the label directions.

The information presented here is intended as a guide for Michigan chestnut growers in selecting pesticides and is for educational purposes only. The efficacies of products listed have not been evaluated on chestnuts in Michigan. Reference to commercial products or trade names does not imply endorsement by Michigan State University Extension or bias against those not mentioned. 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. Labels can and do change—greenbook.net, cdms.com, and agrian.com are free online databases for looking up label and MSDS information.

Questions? Visit www.chestnuts.msu.edu or contact Erin Lizotte at taylo548@msu.edu or 231-944-6504.

Approximate timing of chestnut production management activities in Michigan													
Approximate Date	Jan-Mar	April	May	June	July	Aug-Sep	Sep-Oct	October	Nov-Dec				
Crop Stage	Dormancy												
	Pruning												
	Irrigation repair												
	Adjust tree stakes*												
	Remove tree guards*												
	Seed cover crops												
	Early season weed control												
	Soil sampling												
	Spring tree planting*												
	Apply needed fertilizer/amendments												
	Scout for pests												
	Tissue testing for nutrients								Late July				
Crop estimate								After nonviable bur shed					
Fall tree planting*													
Prepare for harvest													
Harvest													
Install mouse guards*													
Paint trunks													
Winterize irrigation system													

* Applicable only in immature orchards.

Chestnut Pest Scouting Calendar

	Dormancy	Bud swell	Bud break	Leaf expansion	Shoot elongation and catkin initials	Catkin maturity and pollen shed	Bur formation and catkin senescence	Kernel development	Bur splitting	Nut drop	Leaf senescence	Dormancy
Insects												
Asian chestnut gall wasp	+	+	+	+	+	+	+	+	+	+	+	+
Potato leafhopper		+	+	+	+	+	+	+	+	+	+	
Chestnut weevil			+	+	+	+	+	+	+	+		
European rose chafer				+	+	+	+					
Japanese beetle							+	+	+			
European red mite	+	+	+	+	+	+	+	+	+	+	+	+
Lecanium Scale	+	+	+	+	+	+	+	+	+	+	+	+
Disease												
Chestnut blight	+	+	+	+	+	+	+	+	+	+	+	+

High risk, monitoring and control may be required

Less risk, monitoring or control may be required

+ Potential pest activity or visibility, monitoring should occur

Chestnut Nutrient Management Considerations

Nutrient management in chestnut trees is unique among perennial tree crops. A complete fertilization program based on soil testing, annual leaf analysis and observation of tree growth will maximize the establishment and development of chestnut trees. Many soils in Michigan provide nutrients in sufficient levels for chestnut production. However, before planting it is recommended that growers do a soil test. A soil test provides you with valuable information on soil pH, texture and nutrient status. Chestnut trees require well drained soils and a pH of 5.0-6.5. Even though optimum nutrient levels for phosphorus, potassium, calcium and magnesium are not known for chestnuts, a soil test can provide you with information to base your nutrient and sulfur or lime addition decisions.

Nitrogen Management

Nitrogen is an essential nutrient and plays an essential role in many plant functions and fertilizer application is a necessary part of your orchard maintenance as the nitrogen status of a tree can have a profound effect on health and vigor. When considering how much nitrogen to use, more is not necessarily better. Excessive nitrogen fertilization will over-invigorate vegetative growth on bearing trees, which will result in reduced flower bud formation and reduced fruit yield. It is important to provide enough nitrogen to maintain healthy nutritional status, but to not oversupply nitrogen. Fertilizer use during the first year is not recommended and may cause damage to roots. Fertilizer recommendations for years 2-5 are based off better-studied systems, including apple. After the fifth year, tree vigor and health as well as trunk diameter are used to determine fertilizer rates.

Fertilizer timing and placement

There are several standard ways available to apply nitrogen and other nutrients to your trees in your orchard and probably dozens of less than standard ways that work. The guidelines below are based on soil application of the nitrogen. While some people may apply it to the leaves, there is no precedent for foliar applications on chestnut.

Timing of nitrogen fertilizer applications to the soil surface influences the type of response that trees are likely to exhibit. With most tree crops, early season growth potential and strength of flower buds are largely determined by the nitrogen reserves that the buds contain when growth begins that season. This is a standard statement used for most fruit trees. However, most fruit trees flower in the spring. Chestnut flowers in the very late spring or early summer. We may be able to have some influence with our spring nitrogen application on the strength of the flower bud with spring application of nitrogen.

With most tree crops, nitrogen fertilizers applied during the dormant season as soon as the snow clears will stimulate vegetative growth and generally do not influence the nitrogen status or strength of current season flower buds or fruit set. This may be true for chestnut, too.

Applications during the summer, particularly after current season shoot growth has been completed, are more likely to result in improved nitrogen status of the buds for the next season. However, applications of nitrogen late in the summer may delay or reduce fruit development, increase the pre-harvest fruit drop, delay maturation of buds and woody tissues and/or stimulate late season growth, thus increasing susceptibility of woody tissues and buds to cold injury. In regions where cold injury is of concern, summer applications of nitrogen must be carefully managed to ensure the tree properly shuts down in preparation for winter. Fall applications of nitrogen may delay hardening of buds and woody tissues and increase the potential for desiccation during the winter, particularly if made before trees have become completely dormant.

For most efficient use, nitrogen fertilizers should be spread over the area where the herbicide treatment eliminated the weeds (weed-free zone) or along the cultivated tree-row strips where the majority of the active tree roots are located. Application to weeds or grasses will act to fertilize the weeds and the tree roots will get the leftovers. For this reason, broadcasting over the entire orchard floor is less efficient, requires considerably greater rates of application, and is more likely to benefit ground covers than the trees.

Soil testing

Soil testing is an important diagnostic tool in evaluating nutrient imbalances and in understanding plant growth problems. Soil test results help growers adjust fertilizer application to provide nutrients that are lacking in the trees. Also, soil testing helps growers maintain soil pH within an optimum range (5.5-6.5 for chestnut), which keeps nutrients available for plant uptake. The soil test section is usually placed with the fertilizer section of a report like this, but we place it here to inform you that it should be used before you even plant your orchard. The soil test report includes soil pH, lime index, available phosphorus, potassium, calcium, and magnesium, liming and /or fertilizer recommendations based on the crop to be grown and soil test results. Michigan State University recommendations are given in “pound of nutrients needed,” not pounds of commercial fertilizer to be applied. You can pick up soil testing kits at your local county Extension office or buy a soil test online at the Bookstore.

Nitrogen recommendations, 0-5 years

Using this table, you can select the fertilizer of your choice based on availability and specific needs. Note the difference between actual nitrogen, ‘Amount of nitrogen per tree’ and product amount as indicated in the ‘Urea’, ‘Ammonium Nitrate’, and ‘Ammonium Sulfate’ columns. These recommendations are based on standard fruit and nut tree nutrient management from Europe. A given site may require depending on soil and leaf analysis. Visual observation of leaf color can also be a useful indicator of tree health. Leaf yellowing may be an indicator that the soil pH is too high at those locations which prohibits the tree from efficiently utilizing the macro and micronutrients you have made available. Growers should be evaluating and adjusting pH via soil testing and visual observation.

Annual nitrogen recommendations for chestnut trees from planting through year five.						
Field age	Amount of nitrogen per tree (oz.)	Urea, 48% N	Ammonium sulfate, 21% N	Triple 19, 19% N	Triple 16, 16% N	Triple 12 12% N
0	None	0	0	0	0	0
1	2	5 oz	10 oz	11 oz	13 oz	1
2	4	8 oz	1 lb 3 oz	1 lb 5 oz	1 lb 10 oz	2
3	6	13 oz	1 lb 11 oz	2 lb	2 lb 6 oz	3
4	8	1 lb 2 oz	2 lb 5 oz	2 lb 13 oz	3 lb 3 oz	4
5	12	1 lb 10 oz	3 lb 6 oz	4 lb	4 lb 13 oz	6

Nitrogen recommendations, older than 5 years

Fertilizer rates for bearing chestnut trees are determined by tree size and vigor. The diameter of the trunk is multiplied by the nitrogen rate based on the average length of last year’s terminal branch growth. See next page for table.

- Low vigor: If tree growth is considered low (under 8 inches per year) then a multiplier rate of 1/6 lb. (2.7 oz.) nitrogen per inch of trunk diameter is used.
- Normal vigor: If tree growth is considered normal (8 to 12 inches per year) then a multiplier rate of 1/8 lb. (2 oz.) nitrogen per inch of trunk diameter is used.
- Excessive vigor: If growth is more vigorous (greater than 12 inches on average) then a multiplier rate of 1/10 lb. (1.6 oz.) nitrogen per inch of trunk diameter

Note: Regardless of the outcome of the nitrogen calculation above, no more than 1 lb. (16 oz.) of actual nitrogen should be applied per tree annually.

Example calculation:

How much ammonium sulfate do you have to apply to get the correct amount of nitrogen for a tree with a 5” trunk diameter, 5” terminal growth average last year and utilizing Ammonium sulfate (21-0-0)?

Answer: Your average terminal growth last year was 5 inches, indicating a low vigor which means that you would need 1/6 lb. (2.7 oz.) nitrogen per inch of trunk diameter.

5-inch trunk diameter × 2.7 oz. N = 13.5 oz. actual N needed per tree

Ammonium sulfate is only 21% nitrogen, so to determine the rate of product needed, use the following formula:

Actual nitrogen (oz.) ÷ by nitrogen in product (%) = product needed (oz.)

13.5 oz. actual N / 0.21 % N in ammonium sulfate = 64.3 oz. of ammonium sulfate per tree

Annual nitrogen recommendations for bearing chestnut trees 6 years or older.						
Trunk diameter (in.)	Vigor	Terminal growth (in)	Nitrogen (lb.)	Actual N per tree (lb.)*	Urea (46% N)	Ammonium sulfate (21% N)
3	Low	<8	0.17	0.5	1.1	2.4
3	Normal	8-12	0.13	0.4	0.8	1.8
3	High	>12	0.10	0.3	0.7	1.4
4	Low	<8	0.17	0.7	1.4	3.2
4	Normal	8-12	0.13	0.5	1.1	2.4
4	High	>12	0.10	0.4	0.9	1.9
5	Low	<8	0.17	0.8	1.8	4.0
5	Normal	8-12	0.13	0.6	1.4	3.0
5	High	>12	0.10	0.5	1.1	2.4
6	Low	<8	0.17	1.0	2.2	4.8
6	Normal	8-12	0.13	0.8	1.6	3.6
6	High	>12	0.10	0.6	1.3	2.9
7	Low	<8	0.17	1.0	2.2	4.8
7	Normal	8-12	0.13	0.9	1.9	4.2
7	High	>12	0.10	0.7	1.5	3.3
8	Low	<8	0.17	1.0	2.2	4.8
8	Normal	8-12	0.13	1.0	2.2	4.8
8	High	>12	0.10	0.8	1.7	3.8
9	Low	<8	0.17	1.0	2.2	4.8
9	Normal	8-12	0.13	1.0	2.2	4.8
9	High	>12	0.10	0.9	2.0	4.3
10	Low	<8	0.17	1.0	2.2	4.8
10	Normal	8-12	0.13	1.0	2.2	4.8
10	High	>12	0.10	1.0	2.2	4.8
11	Low	<8	0.17	1.0	2.2	4.8
11	Normal	8-12	0.13	1.0	2.2	4.8
11	High	>12	0.10	1.0	2.2	4.8
12	Low	<8	0.17	1.0	2.2	4.8
12	Normal	8-12	0.13	1.0	2.2	4.8
12	High	>12	0.10	1.0	2.2	4.8
13	Low	<8	0.17	1.0	2.2	4.8
13	Normal	8-12	0.13	1.0	2.2	4.8
13	High	>12	0.10	1.0	2.2	4.8
14	Low	<8	0.17	1.0	2.2	4.8
14	Normal	8-12	0.13	1.0	2.2	4.8
14	High	>12	0.10	1.0	2.2	4.8
15	Low	<8	0.17	1.0	2.2	4.8
15	Normal	8-12	0.13	1.0	2.2	4.8
15	High	>12	0.10	1.0	2.2	4.8
16	Low	<8	0.17	1.0	2.2	4.8
16	Normal	8-12	0.13	1.0	2.2	4.8
16	High	>12	0.10	1.0	2.2	4.8
17	Low	<8	0.17	1.0	2.2	4.8
17	Normal	8-12	0.13	1.0	2.2	4.8
17	High	>12	0.10	1.0	2.2	4.8
18	Low	<8	0.17	1.0	2.2	4.8
18	Normal	8-12	0.13	1.0	2.2	4.8
18	High	>12	0.10	1.0	2.2	4.8

* Based on tree uptake, nitrogen applications should never exceed 1 lb actual nitrogen per tree annually.

Registered Insecticides/Miticides on edible chestnuts on Michigan, 2021

Chemical Class (IRAC Insecticide group)	Active Ingredient	Products Labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes
			Potato leafhopper	Rose chaffer	Japanese beetle	Two-spotted spider mite	European red mite	Bees	Mite predators	Insect predators	
Pyridine azinomethine derivatives (9B)	Pyrifluquinazon	POZ Insecticide	U	U	U	U	U	U	U	U	
Multisite, Organophosphates (1B)	Malathion	Chemnova Malathion 57%, Fyfanon 57% EC, Malathion 5 EC, Malathion 57 EC, Malathion 8 Aquanail	N	F-G	F-G	U	U	T	M	M	Malathion is an organophosphate insecticide, it has relatively short residual activity. It is active on a wide range of insect pests, and has lower human toxicity than many other organophosphates.
	Phosmet	Imidan 70W	G-E	G	E	N	N	T	S	M	Imidan is an organophosphate insecticide and provides good broad-spectrum control of many pests in Michigan. To prevent premature product breakdown from alkaline hydrolysis, spray-tank water should be buffered to a pH of 5.0–5.5.
Avermectins (6)	Emamectin benzoate**	Proclaim	N	N	N	F	U	T	S	S	Primarily for lepidopteran pests (leafrollers, leafminers, moths).
Carbamates (1A)	Carbaryl	Carbaryl 4L, Sevin XLR Plus, Sevin SL	E	G	G	U	U	T	T	T	Its residual effectiveness varies from 3 to 10 days, depending on the target pest to control. Sevin is toxic to bees as well as mite predators and should be used carefully to prevent flaring mite populations. It is compatible with most other pesticides.
Diamides (2B)	Chlorantraniliprole	Altacor	N	N	G	N	N	S	S	S	Altacor works on the insect by activating ryanodine receptors, thus preventing muscle contraction. Exirel is registered for control of a range of pests including moths, weevils, leafhopper and Japanese beetle.
	Cyrantraniliprole	Exirel, Exirel Insect Control	G	N	G	N	N	M	S	S	

1. Pesticide efficacy ratings; E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. 2. Beneficial insect toxicity; S-safe, M-moderate, T-toxic, U-unknown * 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. Pesticide efficacy and beneficial insect toxicity is based on trials in fruit crops with products containing the same active ingredient, as reported in the E154 Fruit Management Guide, Michigan State University Extension.

Insecticides

Registered Insecticides/Miticides on edible chestnuts on Michigan, 2021

Chemical Class (IRAC Insecticide group)	Active Ingredient	Products Labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes	
			Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	European red mite	Bees predators	Mite predators	Insect predators		
Pyrethroids (3)	Alpha-cypermethrin	Fastac EC, Fastac CS Insecticide Batallion 2 EC, Bi-Dash 2E, Bifenxure 10DF, Bifenxure EC, Bifen 2AG Gold, Brigade WSB, Brigade 2EC, Bifenthrin 2EC, Insecticide, Discipline 2EC, Fanfare EC, Fanfare ES, Fanfare 2 EC, Hero EW, Sniper-Hellos, Sniper, Sniper LFR						T	U	U		
	Bifenthrin**		G	U	E	U	U	T	T	T	Bifenthrin controls a range of pests including mites, leafhoppers, plant bugs, stink bugs. These products are toxic to predatory mites and other beneficials.	
	Beta-cyfluthrin**	Baythroid XL, Sultirus	E	G	G	U	U	T	T	T	Beta-cyfluthrin controls of a broad spectrum of insect pests. This material is highly toxic to mite predators and should be used carefully to prevent mite population buildup.	
	Cyfluthrin**	Tombstone, Tombstone Helios	U	N	U	N	N	T	T	T	Gamma-cyhalothrin controls a broad spectrum of sucking and chewing pests, including leafrollers, leafhoppers, curculios and scarab beetles. Highly toxic to mite predators and should be used carefully to prevent mite population buildup.	
	Gamma-cyhalothrin**	Declare, Proaxis	U	G	G	U	N	T	T	T	Lambda cyhalothrin is labeled for control of a broad spectrum of sucking and chewing pests, including leafrollers, leafhoppers, curculio, and scarab beetles. This material is also highly toxic to mite predators and should be used carefully to prevent mite population buildup.	
		Grizzly Too, Kendo, Kendo 22.8 CS, Lambda T, Lambda-CY 1EC, Lambda-CY AG, Lambda-CY EC LambdaStar, LambdaStar 1CS, LambdaStar Plus Insecticide, Lamcap II, L-C Insecticide, Nufarm Lambda-Cyhalothrin 1EC, Paradigm VC, Province, Province II, Ravage, Silence, Warrior II with Zeon, Willowood Lambda 1EC		U	G	G	U	N	T	T	T	
		Pyrethrin EverGreen EC60-6*, Pyganic EC1.4*, Pyganic EC 1.4 II *, Pyganic EC 5.0 II *, Tersus Insecticide		U	F	F	U	U	M	S	S	Pyrethrin is a botanical insecticide, low in acute toxicity to humans and other vertebrate animals, is non-carcinogenic, causes no adverse reproductive effects and is non-mutagenic.
		Deltamethrin** Delta Gold		U	N	U	N	N	T	T	T	Zeta-cypermethrin controls cutworms, plant bugs, leafhoppers, leafrollers and beetle. This material is highly toxic to bees and is disruptive to natural enemies.
		Zeta-cypermethrin Mustang Insecticide, Mustang Maxx		G	G	G	U	U	T	T	T	Fenpropathrin controls plant bugs, leafhoppers, leafrollers, and beetles. This material is highly toxic to bees and is disruptive to natural enemies.
		Fenpropathrin** Danitol 2.4EC Spray		G	U	G	U	G	T	T	T	

1. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. 2. Beneficial insect toxicity: S-safe, M-moderate, T-toxic, U-unknown * 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. Pesticide efficacy and beneficial insect toxicity is based on trials in fruit crops with products containing the same active ingredient, as reported in the E154 Fruit Management Guide, Michigan State University Extension.

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Chemical Class (IRAC Insecticide group)	Active Ingredient	Products labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes
			Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	European red mite	Bees	Mite predators	Insect predators	
Neonicotinoids (4)	Imidacloprid(4A)	Admirer Pro, Advise Four, Advise ZFL, Alias 4F, Imidashot DF Insecticide, Macho 2.0 FL, Macho 4.0, Malice ZF, Marathon 60 WP, Mana Alias 4F, Midash 2 SC Ag Insecticide, Midash Forte Insecticide, Montana ZF, Montana 4F, Nuprid ZSC, Nuprid 4.6F Pro, Nuprid 4F Max, Provoke, Sherpa, Widow, Willowood Imidacloprid 45C, Wrangler	G	G	G	N	N	T	S	M	Imidacloprid may be applied as a foliar or soil-applied insecticide depending on the specific product. As a foliar spray it is labeled for control of aphids, leafhoppers, scale insects and Japanese beetles. With soil application it is labeled for control of leafhoppers, mealybug and the white grub complex.
			E	G	G	N	N	M	S	M	Acetamiprid targets aphids, leafhoppers, leafminers, Japanese beetle, plum curculio, as well as some lepidopteran pests. This material has a long residual inside the plant but is relatively safe for beneficials.
	Clothianidin(4A)	Belay	E	G	G	N	N	M	S	Belay targets aphids, leafhoppers, leafminers, curculio, Japanese beetle and lepidopteran pests. As a foliar spray Belay is a transliniar and has long residual activity.	
	Flupyradifurone (4P)	Altus, Sivanto 200 SL, Sivanto Prime	N	N	N	N	N	S	S	S	Flupyradifurone controls sap-feeding insects, including aphids, leafhoppers. It displays transliniar movement when applied to foliage and is xylem mobile. It has been shown to be relatively safe on many beneficials, including honey bees.
Spinosyns (5)	Sulfoxaflor(4G)	Closer SC, Transform WG	G	U	U	U	U	T	U	U	Spinosad targets lepidopteran pests and provides 7-14 days of control, depending on the target pest. Good coverage is important. The use of a penetrating or silicone surfactant can enhance coverage and penetration.
	Spinosad	Entrust*, Entrust SC*, GF-120 NF*, Seduce*, Spintor ZSC*,	N	N	N	U	N	M	S	M	Spinetoram controls lepidopteran pests. The primary route of entry into the target insects is through ingestion, although the product is also absorbed through the cuticle. Delegate provides up to 14 days of control. Good coverage is important. Delegate is safe for some beneficials but is highly toxic to bees.
	Spinetoram	Delegate WG	N	G	N	N	N	M	S	M	

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Registered Insecticides/Miticides on edible chestnuts on Michigan, 2021

Chemical Class (IRAC insecticide group)	Active Ingredient	Products Labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes	
			Potato leafhopper	Rose chafer	Japanese beetle	Two-spotted spider mite	European red mite	Bees predators	Mite predators	Insect predators		
Tetramic acid derivatives (23)	Spirotetramat	Kontos, Movento	N	N	N	U	U	M	S	S	Spirotetramat belongs to the tetramic acid derivatives, which work on the insect by inhibiting lipid biosynthesis. Movento Z5C is used to control aphids and scale insects. Movento Z5C has a unique two-way systemic movement in the plant (phloem and xylem), with foliar applications it is transported to young leaf tissue and also down to the root tips. It is not recommended to include Movento Z5C in a tank mix and/or sequential treatment with oil. Flonicamid targets plant bugs and aphids and is an antifeedant.	
			N	N	N	N	N	M	S	M		
Biopesticides	Flonicamid (9C)	Beleaf 505G	N	N	N	N	N	M	S	M	Flonicamid targets plant bugs and aphids and is an antifeedant.	
			<i>Bacillus thuringiensis</i> (11A)	BT Now*, Dipel DF*, Leprotec*, Xentari*	N,U	N,U	N,U	N,U	S	S		S
			<i>Chromobacterium subsysgae</i>	Grandevo*, Grandevo CG*, Grandevo WDG*	U	N	N	U	U	S		S
Biopesticides	Kaolin	Surround WP	U	N	N	U	U	U	S	S	Surround is a kaolin clay product used to create a film that acts as a protective barrier between the plant and the pest. In addition, if picked up onto body parts of the insect or mite, the abrasive nature of the material can cause significant irritation leading to repellency or even mortality of the pest.	
			Extract of <i>Chenopodium ambrosioides</i>	Requiem EC	U	N	N	U	U	S		S

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Insect growth regulators	Pyriproxyfen(7C)	Esteem 0.86EC, Esteem 35WP, Pich 35WP, Terva 35 WP	N	F,U	N	N	N	S	S	S	Intrepid is an insect growth regulator for the control of lepidopterous insect pests. Confirm is an insect growth regulator for the control of lepidopterous insect pests. Intrepid is an insect growth regulator for the control of lepidopterous insect pests. It must be ingested by the larvae and may take several days to cause mortality. The addition of an agricultural adjuvant is recommended. Dimilin disrupts the generation of chitin in the insect exoskeleton, preventing normal development of larval instars and suppressing embryogenesis. Dimilin has no direct activity on adult insects. Dimilin will control leaf miners.
	Methoxyfenozide (18)	Inspirato 2F, Intrepid 2F, Invertid 2F, Troubadour 2F insecticide, Vexer, Zyl'o insecticide	N	N	N	N	N	S	S	S	
	Tebufenozide (18)	Confirm 2F	U	U	U	U	U	S	S	S	
Insect growth regulators	Diffubenzuron(15)	Dimilin 2L, Durant 2 LIGR, Unforgiven	N	N	N	N	N	T	T	T	Azadirachtin compounds control insects in the larval, pupal and nymphal stages by interfering with metabolism and preventing development. It also works as a repellent and feeding deterrent on the adult stage of many insect pests. Because of its short residual life, it may need to be reapplied every 5 to 10 days if pest populations persist. This pesticide is toxic to bees exposed to direct treatment or residues on blooming crops or weeds.
	Azadirachtin (IGR)	Aza-Direct* Azaguard, Azarol EC Insecticide, Ecozin Plus 1.2% ME*, Molt-X, Neemix 4.5*	U	F	F	U	U	S	S	S	

1. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. 2. Beneficial insect toxicity: S-safe, M-moderate, T-toxic, U-unknown * 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. Pesticide efficacy and beneficial insect toxicity is based on trials in fruit crops with products containing the same active ingredient, as reported in the E154 Fruit Management Guide, Michigan State University Extension.

Registered Insecticides/Miticides on edible chestnuts on Michigan, 2021

Chemical Class (IRAC Insecticide group)	Active Ingredient	Products Labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes
			Potato leafhopper	Rose chaffer	Japanese beetle	Two-spotted spider mite	European red mite	Bees predators	Mite predators	Insect predators	
Premixed products	Azadirachtin + Pyrethrin (3)	Azera	U	U	U	U	U	T	T	T	
	Chlorantraniliprole(28) + Lambda-cyhalothrin(3)**	Voliam Xpress**	G	G	G	N	N	T	T	T	
	Abamectin (6)**+ Cyantilaniloprole (28)	Mifecto Pro**	U	U	U	E	E	T	S	S	Mifecto Pro combines two active ingredients as a pre-mix formulated compound. It targets mites, leafminers, leafrollers, and curculio.
	Imidacloprid (4) + Beta- cyfluthrin (3)**	Leverage 360**	E	G	G	U	U	T	S	M	Leverage 360 combines two active ingredients as a pre-mix formulated product. It targets lepidopteran, aphids, leafhoppers, leafminers, and curculio.
	Methoxyfenozide (18) + Spinetoram (5)	Intrepid Edge	U	U	U	U	U	M	M	M	Intrepid Edge is an insecticide that combines two active ingredients as a pre-mix formulated com-pound. It targets lepidopteran pests such as leafrollers.
	Bifenthrin(3)** + Zeta- cypermethrin(3)**	Hero EW, Steed**	E	E	G	U	N	T	T	T	Bifenthrin + zeta-cypermethrin products are pre-mix synthetic pyrethroids for the control of many insect and mite pests, including leafrollers, leafhoppers, plant bugs, beetles, and spider mites.
	Zeta-cypermethrin(3)**+ Avermectin(6)**	Gladiator**	E	G	G	E	E	T	T	T	Gladiator is an insecticide/miticide that combines two active ingredients as a pre-mix formulated compound. It targets mites, leafhoppers, leafminers, leafrollers, curculio and Japanese beetle. The application of this product is recommende d with the addition of a non-ionic surfactant.
	Lambda-cyhalothrin(3)**, Thiamethoxan(4A)	Endigo ZC**	E	E	G	E	N	T	T	T	Endigo ZC is an insecticide that combines two active ingredients as a pre-mix formulated com-pound. Endigo targets aphids, leafhoppers, leafminers, curculio, leafrollers and Scarab beetle.
	Bifenthrin(3)**+ Imidacloprid(4A)	Avenge r**, Brigadier Insecticide**, Skyraider**, Swagger**, Tempest**	E	E	G	U	U	T	T	T	Imidacloprid + bifenthrin pesticide combinations target cutworms, lepidopteran, Japanese beetle and leafhoppers.
	Lambda-cyhalothrin(3)**+ Imidacloprid(4A)	Kilte r**	U	U	U	U	N	T	T	T	

1. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. 2. Beneficial insect toxicity: S-safe, M-moderate, T-toxic, U-unknown * 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. Pesticide efficacy and beneficial insect toxicity is based on trials in fruit crops with products containing the same active ingredient, as reported in the E154 Fruit Management Guide, Michigan State University Extension.

Registered Insecticides/Miticides on edible chestnuts on Michigan, 2021											
Chemical Class (IRAC Insecticide group)	Active Ingredient	Products Labeled	Pesticide Efficacy ¹					Beneficial Insect Toxicity ²			Notes
			Potato leafhopper	Rose chaffer	Japanese beetle	Two-spotted spider mite	European red mite	Bees predators	Mite predators	Insect predators	
Miticides	Acequinocyl (20)	Kanemite 15SC	N	N	N	G	G	S	S	S	Kanemite controls spider mites and red mites, providing control from 6 to 8 weeks depending on mite pressure, the extent of vegetative growth and predator mite populations.
	Hexythiazox (10A)	Hexamite, Onager, Onager Optek, Savey 50 DF	N	N	N	E	R	S	S	S	Hexythiazox controls European red mites and two-spotted spider mites. It is an active mite ovicide and larvicide, providing 10+ weeks of control, depending on mite pressure.
	Fenazaquin (21)	Magister SC, Magus Miticide	U	U	U	E	E	T	M	S	Magister is registered for spider mite control and provides up to 3-5 weeks of control.
	Fenpyroximate (21)	Portal XLO, Portal Miticide/Insecticide	G	N	N	G	E	M	M	M	Portal provides good knockdown and residual control of mites and leafhoppers. It should be applied when pest pressure is low.
	Tofenpyrad (21A)	Apta	U	U	U	U	U	M	S	S	Apta controls a range of pests including leafrollers, leafhoppers, and cutworm.
	Pyridaben (21)	Nexter, Nexter SC Miticide/Insecticide	N	N	N	G	E	M	M	M	Pyridaben provides knockdown and residual control of mite and leafhopper and should be applied when pest populations are beginning to build. Requires thorough coverage.
	Spirodiclofen (23)	Envidor 25C	N	N	N	E	E	M	S	M	Spirodiclofen has activity against European red mite and twospotted spider mite and it is active by contact to all life stages.
	Cyflumetofen (25)	Nealta	N	N	N	E	E	S	S	S	Nealta provides knock-down and residual control of European red mites and two-spotted spider mites. Controls all life stages.
	Etoxazole (10)	Eschaton 5 WDG, Zeal Miticide 1	N	N	N	E	E	S	S	S	Zeal is active against spider mite and red mite eggs and larvae, providing control ranging from 8 weeks to full-season. Activity may not be observable for several days.
	Abamectin** (6)	Abacus Miticide/Insecticide, Averland FC, Abacus, Abacus V, Abamex Miticide/Insecticide, Abba Ultra Miticide/Insecticide, Abamectin 0.15EC, Abba Ultra, Agri-Mek SC, Reaper 0.15 EC, Reaper Clearform, Reaper Advance, Willowood Abamectin 0.15 EC, Willowood Abamectin 1.5 LV	U	G	N	E	E	T	S	S	Abamectin targets mites, leafhopper and leafminer. It is locally systemic and it has long residual inside the foliage. For best mite control apply when mites first appear.
Bifenazate (20D)	Acramite 50 WS, Acramite 45C, Banter WDG, Bizate 45C, Bizate 50WDG, Enervate 45C, Enervate 50WSB, Vigilant 45C, Willowood Bifenazate 50WDG	N	N	N	E	G	M	S	S	Bifenazate is primarily active against mottle stages of European red mite and twospotted spider mite but also nymphal stages that hatch after application. For best performance, maintain spray tank water at or near pH 7.0.	

1. Pesticide efficacy ratings: E-excellent, G-good, F-fair, P-poor, U-unknown, N-pest not included on label. 2. Beneficial insect toxicity: S-safe, M-moderate, T-toxic, U-unknown * 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. Pesticide efficacy and beneficial insect toxicity is based on trials in fruit crops with products containing the same active ingredient, as reported in the E154 Fruit Management Guide, Michigan State University Extension.

Registered Fungicides

Fungicides labeled for use on edible chestnuts in Michigan, 2021		
Activity	Active Ingredient (FRAC fungicide group)	Products Labeled
Single site	Fluopyram (7)	Luna Privilege
	Propiconazole (3)	Bumper 41.8 EC, Fitness, Marazo, Omni Brand Propiconazole 41.8% EC, Propi-Star EC, Propicure 3.6F, Propimax EC, Shar-Shield PPZ, Slant, Tilt, Topaz, Willowood Propicon 3.6 EC
	Mefentrifluconazole (3)	Cevya Fungicide
	Flutriafol (3)	Topguard Fungicide
	Trifloxystrobin (11)	Flint Extra, Gem 500 SC
	Tebuconazole (3)	Buzz Ultra DF, Miresa, Toledo 45 WP, Willowood Teb 45 DF
	Azoxystrobin (11)	Abound, Acadia 2SC, Aframe, Arius 250, AzoxyStar, Azoxyzone Fungicide, Azteroid FC, AZteroid FC 3.3, Dexter SC, Heritage Fungicide, Mazolin, Satori Fungicide, Tetraban, Trevo
Multisite	Copper hydroxide + Copper Oxychloride (M01)	Badge SC, Badge X2
Premixes	Sulfur (M2); Tebuconazole (3)	Helmstar Plus SC, Unicorn DF
	Azoxystrobin (11) + Difenconazole (3)	Quadris Top
	Azoxystrobin (11) + Flutriafol (3)	Topguard EQ Fungicide
	Azoxystrobin (11) + Propiconazole (3)	Aframe Plus, Avaris 2XS, Cover XL, Propaz, Trevo P, Willowood AzoxyProp Xtra, Quilt Xcel, Xiphosin
	Boscalid (7) + Pyraclostrobin (11)	Pristine
	Fluaxpyroxad (7) + Pyraclostrobin (11)	Merivon Xemium Fungicide
	Cyprodinil (9) + Difenconazole (3)	Inspire Super
	Fluopyram (7) + Tebuconazole (3)	Luna Experience
	Fluopyram (7) + Trifloxystrobin (11)	Luna Sensation
Potassium based defense inducers	Phosphorous acid, mono and dibasic sodium, potassium, and ammonium salts (33, P07)	Alude Fungicide, Fungi-Phite Fungicide, K-Phite 7LP Systemic Fungicide Bactericide, Phiticide, Phostrolm
	Potassium phosphite (P07)	Fosphite, Rampart, Confine Extra
Biopesticides	Neem oil (NC ¹)	Trilogy*
	Streptomyces lydicus	Actinovate AG
	Trichoderma biopesticides (NA ²)	Bio-Tam 2.0*, RootShield WP Biological Fungicide, RootShield Granules*, RootShield Plus Granules*, RootShield Plus WP*
	Bacillus biopesticides (44)	Aviv*, Double Nickel 55*, Double Nickel LC*, Serifel Biofungicide*, Serenade ASO*, Serenade Max*, Sonota*, Serenade Opti
	Extract of Reynoutria sachalinensis (P5)	Regalia* Regalia CG*

1. Not classified as belonging to a particular mode of action. 2. Not listed or classified by the Fungicide Resistance Action Committee. *OMRI approved for organic production.

Registered Herbicides

Herbicides registered for use on edible chestnuts in Michigan, 2021				
Application timing ¹	Active ingredient (WSSA group number ²)	Trade Name	Notes	Preharvest Interval ³
Pre-emergent	Flumioxazin (14)	Chateau SW, Flumi 51 WDG, Tuscany SC Herbicide, Tuscany, Warfox	Controls most broadleaves and grasses. Fall application is most effective. Apply to trees established at least 1 year. Weak on horseweed. Apply before bud swell.	60 days
	Indaziflam (29)	Alion Herbicide	Controls annual grasses and broadleaf weeds. Orchards must be at least one year old. See label for application restrictions and instructions.	14 days
	Rimsulfuron (2)	Grapple, Hinge, Matrix FNV, Matrix SG Pruvin Herbicide, Solida Herbicide,	Apply to trees that have been established for one year or more. Controls grasses and broadleaves.	14 days
	Pendimethalin (3)	Prowl H2O, Pin-Dee 3.3 EC, Satellite Flex, Satellite HydroCap Herbicide, Stealth Herbicide	Non-bearing only. Controls annual grasses and some broadleaves. Apply before bud swell or only in non-bearing trees. Do not apply to newly transplanted trees until ground has settled and no cracks are present.	Non bearing, see label
	Oryzalin (3)	Surflan AS	Controls annual grasses and some broadleaves for 4-6 weeks. Apply in spring before weeds emerge. Needs rainfall to activate.	see label
	Isoxaben (21)	Trellis or Trellis SC	Controls broadleaves for 4-6 weeks. Apply to established bearing and non-bearing trees. Needs rainfall of 0.5 inch to activate. Note 60-day preharvest interval.	60 days
Post-emergent	Ammonium nonanoate	Axxe	OMRI approved. Broad spectrum, non selective burn down of broadleaf and grass weeds. Do not allow to contact desirable plants. Do not apply when weeds are wet from rain, dew, or irrigation. Do not irrigate within 2 hours of application. Do not apply if rainfall is expected within two hours.	see label
	Clethodim (1)	Arrow 2 EC, Cleanse, Clethodim 2E, Dakota, Intensity Post- Emergence Grass Herbicide, Intensity One Post-Emergence Grass Herbicide, Omni Brand Clethodim 2 EC, Section Three Herbicide, Select Max Herbicide with Inside Technology, Shadow Herbicide, Shadow 3EC, Tide USA Clethodim 2EC, Volunteer Herbicide, Willowood Clethodim 2EC	Selective, postemergence for annual and perennial grasses. Non bearing trees only. Shadow Herbicide requires a supplemental label.	Not applicable
	Glyphosate (9)	Abundit Extra, Buccaneer, Buccaneer 5, Buccaneer 5 Extra, Buccaneer Plus, Cornerstone Plus, Cornerstone 5 Plus, Credit 41, Credit 41 Extra, Credit 5.4 Extra, Duramax Herbicide, Durango DMA Herbicide, Envy, Envy Intense, Four Power Plus, Gly Star Original, Gly Start Plus, Glyphogan Plus Herbicide, Glyphosate 4 Plus, Honcho K6 Herbicide, Mad Dog, Makaze Herbicide, Roundup PowerMAX, Roundup WeatherMAX, Showdown Herbicide, Wynca USA Sunphosate 41% Herbicide, and more.	Controls annual and perennial weeds. Avoid contact with trees.	3 days
	Oryzalin (3)	Fugitive, Surflan Flex	Surface applied to control many annual grasses and broadleaf weeds.	see label
	Glufosinate-ammonium (10)	Cheetah Herbicide, Fever, Glufosinate 280SL, Inflame 280 SL, Interline Herbicide, Scout Herbicide, Willowood Glufosinate 280SL	Controls broadleaf and grassy weeds. Avoid crop contact.	14 days
	Paraquat (22)	Devour, Gramoxone SL 2.0, Gramoxone SL 3.0, Helmquat 3SL, Paraquat Concentrate, Para-Shot 3.0, Parazone 3SL, Quik-Quat, Purgatory 3 SL, Willowood Paraquat 3SL	Restricted use pesticide. Desiccates green foliage.	see label
	Mesotrione (27)	Broadworks, Meso Star, Mesotrione 45C, MesoTryOne 4L, Motif Herbicide	Systemic herbicide for the control of broadleaf weeds. Note 30-day preharvest interval. Only apply to vigorous orchards, one year or older.	30 days
	Carfentrazone (14)	Aim EC ²	Controls small broadleaf weeds. Include NIS in tank mix.	3 days
	Pyraflufen (14)	Venue	Use with other post-emergent herbicides to improve broadleaf weed desiccation. Include non-ionic surfactant.	0 days
	Pelagronic acid	Scythe Herbicide	Broadspectrum burndown for site prep and spot treatments, and as shielded application.	see label
	Sethoxydim (1)	Poast	Kills grasses. Use high rate for perennial grasses. Use with non-ionic surfactant. See label for application restrictions and instructions.	15 days
	2, 4-D (4)	De-Amine 4, Embed, Formula 40, Orchard Clean, Orchard Star, Rugged Herbicide, Saber, Savage Dry Soluble, Shredder Amine 4, Weed Rhap A-4d, WeeDestroy AM-40 Amine Salt, Weedar 64	Controls most annual and perennial broadleaf weeds. Note 60-day preharvest interval.	60 days
	Pre/Post Emergent	Sulfentrazone (14)	Sulfin 45C	Controls select grasses, sedges and broadleaf weeds. Trees must be healthy and 1 year or older. Avoid contact with tree.
Oxyfluorfen (14)		Galigan 2E, GoalTender Herbicide, Goal 2XL, Willowood OxyFlo 2EC, Willowood OxyFlo 45C	Some grasses and broadleaf weed control. Apply while trees are dormant (do not apply between budswell and final harvest).	Dormant only
Halosulfuron (2)		Sandea 75DF, Stadia	Controls nutsedge and broadleaf weeds. Apply to nut trees that have been established 1 year or more.	1 day

1. Pre-emergent herbicides should be applied to control weeds before germination takes place. Post-emergent herbicides may be applied to actively growing weeds.

2. WSSA (Weed Science Society of America) herbicide group numbers are based on the site of action and can assist in making resistance management decisions.

3. The preharvest interval is the minimum number of days between application and harvest.

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 are 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.

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.

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.

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 always remain above the water level in the spray tank 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 mixing and storage sites a safe distance away to avoid contaminating 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 Conservation 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 potential 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 application 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 if 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.

Spray Adjuvants for Fruit Crops

Bill Shane and Annemiek Schilder, MSU Extension and Department of Plant, Soil and Microbial Sciences

Spray adjuvants are products added to a spray tank to improve the performance of the treatment. Improper use of an adjuvant may result in poorer performance and possible phytotoxicity as well as increasing the cost of the treatment. An adjuvant may not be needed in some cases. Many agrichemical products are formulated with adjuvants and may not need an additional one. Check the agrichemical label to see what type of adjuvant, if any, is recommended or is prohibited. Check the adjuvant label to be sure that the target crop and the intended use are listed.

Avoid use of adjuvants with penetrating action with potentially phytotoxic fungicides. For example, do not use an adjuvant with strong penetrating action with copper compounds, Captan or Syllit. Be aware that soluble fertilizers and oils may also have penetrant activity and can help move the copper or Captan into the plant tissue. Be careful when using adjuvants with penetrating action with herbicides that may come in contact with young tree trunks, vines and canes.

Emulsifiable concentrate agrichemicals contain oil and special adjuvants to allow them to mix with water. These emulsifiable concentrates will sometimes help other normally non-systemic agrichemicals to penetrate plant tissue.

Systemic fungicides and insecticides are designed to move into plant tissue. With such agrichemicals it is best not to use an adjuvant with aggressive “sticking” action that would impede movement into plant tissue.

Avoid adjuvants with strong sticking action early in the growing season when redistribution of fungicides and insecticides by rain is desirable to extend protection to newly emerged green tissue. However, sticker action may be desirable under extended rain and cool conditions.

General terminology

Spreader: Also called surfactants, wetting agents, surface-active agents. An adjuvant with spreader activity helps to decrease water surface tension, encouraging spray droplets to land and spread over hard-to-wet surfaces such as waxy and/or hairy plants. A detergent can act as a spreader to prevent beading. Too much spreader can result in increased spray treatment dripping off treated surfaces.

Non-ionic spreader: A surfactant with spreading action and relatively neutral charge. For general use, non-ionic spreaders are usually preferred to negatively charged (anion) and positively charged (cation) spreaders because non-ionic types are least likely to inactivate the chemicals being applied.

Penetrant: An adjuvant that enhances the movement of the agrichemical into the plant tissue. Penetrants may also help penetrate the cuticles of arthropods. Penetrants are used with many herbicides and defoliants and certain fungicides and insecticides. Many penetrants also act as spreaders and surfactants. Use penetrants with caution — they can cause phytotoxicity by helping to move non-systemic materials such as copper and Captan inside the plant cuticle. Penetrants should not be used with materials that should stay on the surface. Penetrants are not recommended on certain crops, such as grapes, where they may increase risk of damage to tender skin. Common penetrants include oils and methylated or ethylated oils, ethylenes, alcohols and aliphatic acids.

Sticker: Also called bonder. It is an adjuvant that enhances the adherence of agrichemicals to the target surface. Sticker activity is generally more useful for non-systemic agrichemicals than for systemic agrichemicals that work best inside plant tissue. Stickers are helpful for fungicide or insecticide products that are prone to wash-off, including biocontrol products. High rates of some stickers can immobilize agrichemicals, result in excess foaming or develop a tenacious film on equipment. Latex-based stickers usually need to dry on plant surfaces before they provide protection. Terpene-based stickers (Nu-Film products) need sunlight to set the film. Stickers are not needed for emulsifiable concentrate (EC) formulations of spray materials that incorporate into plant cuticles.

pH modification agents and buffers: An acidifier helps to reduce water pH. A buffer helps the spray solution to be stable at a specific pH, usually acidic. Buffers and acidifiers help guard against unwanted agrichemical breakdown, clumping and other effects that may occur because groundwater sources are often alkaline (high pH) in Michigan. Most agrichemicals are most stable at slightly less than neutral pH (below 7). Materials with a significantly shorter life at high pH include Captan and Imidan.

Drift retardant: An adjuvant that helps to inhibit the production of fine droplets by spray nozzles. It's usually used to help prevent off-target movement of herbicides or other potentially damaging agrichemicals.

Water conditioner: An adjuvant providing some benefit such as protecting against negative effects of some water sources. An example is ammonium sulfate, which helps to prevent inactivation of glyphosate by tying up calcium, magnesium and iron in hard water that would otherwise bind to the herbicide. Ammonium sulfate replacements are available from several companies.

Foam retardant: This is commonly a dimethylpolysiloxane product that helps to suppress excess foam in the spray tank that results from agitation of other materials and water. It works better if added to the spray tank before excessive foaming occurs rather than afterward.

Compatibility agent: This is useful when pesticides are combined with liquid fertilizers to help avoid breakdown of the pesticide by the salt solution from the fertilizer. Some troublesome combinations of products can be stabilized with a compatibility agent.

Silicon-based adjuvant: Reduces surface tension (aids wetting). Higher rates result in more penetration. Recommended for use with water-soluble pesticides only. This class of adjuvant contains some of the more aggressive penetrants.

Crop oil concentrate: An adjuvant that is a combination of surfactants (15 to 20 percent) and non-phytotoxic oil, either petroleum or vegetable-based. Crop oil concentrates are used to increase effectiveness of herbicides by increasing wetting, spreading and penetration. Methylated seed oils tend to work better than petroleum-based oils as adjuvants for weed control where weeds are under environmental stress.

pH Modifiers*

Product	Source	Acidifier	Buffer	Notes
Aero Dyne-Amic	Helena	X		
Buffer Xtra Strength	Helena		X	Includes conditioning agent
Buffer P.S.	Helena		X	
Choice Weather Master	Loveland		X	Hard water conditioner
Combine	Riverside		X	
Denali	Wilbur-Ellis	X	X	NPE free
Induce pH	Helena	X	X	Low foam, non-ionic surfactant
LI700	Loveland	X		
Sorba-Spray MG	Leffingwell	X		
Spray Aide	Miller	X		
Tri-Fol	Wilbur-Ellis	X	X	Not for use with copper fungicides
Vinegar, muriatic acid, citric acid	Various	X		No buffering action
Weather Gard Complete	Loveland	X	X	Hard water conditioner

* Do not acidify solutions containing copper, phosphorous acid, Bordeaux mixtures

Foam Retardants

Product	Source	Note
Anti Foam Agent	Kalo	
Compadre	Loveland	Non-ionic, anti-drift
Defoamer	Kalo, Riverside	Also listed for Van Diest Supply
Foam Buster	Helena	
Foam Fighter	Miller	
No Foam	Wilbur-Ellis	
Unfoamer	Loveland	
Weather Gard Complete	Loveland	Includes hard water conditioner, antifoaming, and penetrant agents

Drift Retardants

Product	Source	Note
Brace	Riverside	
Drift Retardant	Loveland	Non-ionic, anti-foam
Drop Zone DC	Helena	
Drop Zone LC	Helena	
In-Place	Wilbur-Ellis	Includes cationic wetting agent
Reign	Loveland	
LI700	Loveland	
Placement	Agriliance	Includes cationic wetting agent
Strike Zone DC	Setre	
Weather Gard Complete	Loveland	Includes hard water conditioner antifoaming, and penetrant agents
Windbrake	Riverside	
Windcheck	Riverside	

Compatibility Agents

Product	Source	Note
Blendex VHC	Setre	
Complex	Kalo	
Convert	Precision Labs	
E-Z Mix	Loveland	Increases mixability of pesticide and liquid fertilizer
Spray-Aide	Miller	
Combine	Riverside	
Setre FA-1	Setre	

Credits:

Paul Domoto, Dept. of Horticulture, Iowa State University, Crop Data Management System
Special thanks to Crop Protection Services for their help in updating this table.

Common adjuvants used for fruit and their properties.

Product	Source	Type ^a	Use ^b	Spreader	Sticker ^c	Penetrant	Other ^d
Activator 90	Loveland	NIS	I,F,H,G	X		(X)	O
Antero-EA	Wilbur-Elis	NIS	I,F,H	X	X		NPE free
Bond Max	Loveland	LBS	I,F	X	X		
Chem-Stik LpH	Precision Lab	NIS		X	X		8
Cohere	Helena	NIS	I,F,H	X	X		Wax soluble
Denali-EA	Wilbur-Elis	NIS	I,F,H,G	X			A,B, NPE free ^g
Dyne-Amic	Helena	OSI	I,F,H	X		X	
Franchise	Loveland	NIS	I,F,H	X	X	X	
Freeway	Loveland	OSI	I,F,H	X			D
Hasten-EA	Wilbur-Elis	ESO	I,F,H	X		X	
Hyper-Active	Helena	NIS	I,F	X		(X)	
Induce	Helena	NIS	I,F,H	X			O
Induce pH	Helena	NIS		X	X		O,B
Kinetic	Helena	OSI, NIS	I,F,H	X		X	S
LI-700	Loveland	NIS	I,F,H,G	X		X	A,D
Liberate	Loveland	NIS	I,F,H	X		X	Neutral pH, not for grapes
No Foam A	CMR	NIS	I,F,H,G	X	X		O
Nu-Film 17 ^e	Miller	TBS	I,F,H	X	XX	(X)	
Nu-Film P	Miller	TBS	I,F,H	X	XX		NPF free ^g , U
Preference	Agrilience	NIS	I,F,H	X			S
Protyx	Precision Lab	NIS	I,F,G				C
R-11 Spreader Activator	Wilbur-Elis	NIS	I,F,H	X		X	
R-56 Spreader Sticker	Wilbur-Elis	NIS	I,F,H	X	X		
Rainier-EA	Wilbur-Elis	NIS	I,F,H	X		X	NPE free ^g
Regulaid	Kalo	NIS	G	X		X	S
Silken	Agrilience	OSI	I,F	X		X	
Super Spread 90	Wilbur-Elis	NIS	I,F,H	X			
Sustain	Miller	TBS	I,F		XX		U
Syl-Tac-EA	Wilbur-Elis	OSI + modified veg oil	I,F,H	X	X	X	NPE free ^g
Tactic	Loveland	OSI + LBS	I,F	X	X	X	
Vertex	Precision Lab	NIS		X		X	
Weather Gard Complete	Loveland	OSI	I,F,H			X	A,D,O
Widespread Max, formerly Silwet L-77	Loveland	OSI	I,F,H,G	X		X	
Yucca Ag-Aide ^f	Desert King	NIS	I, F, H	X			

^a ESO = ethylated seed oil, NIS = non-ionic surfactant, NPE = nonylphenol ethoxylate, Note: NPE has been implicated as an endocrine disruptor, OSI = organo-silicone surfactant, TBS = terpene-based, non-ionic surfactant, LBS = latex-based sticker.

^b I = insecticide, F = fungicide, H = herbicide (contact type), G = growth regulator.

^c XX = tenacious sticker.

^d O = foam retardant, A = acidifier, B = buffer, C = activator, D = drift retardant, S = slows drying, U = UV protection.

^e 30-day PHI for pesticides other than tolerance-exempt products because it can significantly extend pesticide residues to the point that MRL's may be exceeded.

^f Yucca Ag-Aide is a natural extract of the Mohave Yucca Plant and is OMRI-listed.

^g Nonylphenol Ethoxylates (NPEs) have many uses, but they are primarily used as surfactants in cleaning chemical formulations, as wetting agents and as dispersants or emulsifiers in some pesticide formulations.

Effect of Water pH on the Stability of Pesticides

Annemiek Schilder, Department of Plant, Soil and Microbial Sciences

Most pesticides are sold in concentrated form and have to be dissolved or suspended in water before they can be applied to crops. This water can come from various sources, such as wells, ponds, rivers or municipal water supplies. Water naturally varies in the amounts of dissolved minerals and organic matter and pH, depending on its source. The pH is a measure of the acidity or alkalinity of water, which refers to the number of hydrogen (H⁺) and hydroxyl (OH⁻) ions in a solution. The scale for measuring pH runs from 0 to 14. The lower the pH, the more acidic the solution; a higher pH indicates that the solution is more alkaline. Water at pH 7 is neutral — meaning that there are equal numbers of hydrogen and hydroxyl ions in the solution. Many areas in Michigan have alkaline water with high mineral/iron content. In addition, the pH of water from natural sources can vary throughout the season.

The pH of water can negatively affect the stability of some pesticides. Under alkaline conditions, alkaline hydrolysis occurs, which degrades the pesticide to non-toxic (inactive) forms. In general, insecticides (particularly organophosphates and carbamates) are more susceptible to alkaline hydrolysis than are fungicides, herbicides or growth regulators. The result is less active ingredient applied and poor pesticide performance. The degradation of a pesticide can be measured in terms of its half-life. For example, if a product has a half-life of 1 hour, its effectiveness is reduced to 50% in 1 hour, to 25% in the next hour, to 12.5% in the next hour, etc. Eventually, the pesticide becomes virtually ineffective. The effect of pH on pesticides varies from product to product and is also moderated by buffering solutions contained in the pesticide formulation. Tank mixing multiple pesticides can modify the pH of the tank mix.

The table below shows the half-lives of several pesticide products as well as the optimum pH (where known). As you can see from the table, most pesticides are most stable when the spray solution has a pH of about 5. Many water sources are more alkaline than this, so it may be necessary to adjust the pH of the spray solution. There are important exceptions to the rule that spray solutions should be acidified. For instance, in the case of copper-based fungicides, copper becomes more soluble at a lower pH and may become phytotoxic to crops. In addition, phosphorous acid and other acid-based fungicides already have a low pH and lowering it even more can cause them to injure crops. On the other hand, acidifying carbonate salt fungicides, such as Armicarb, may render them ineffective.

Check the pH of the water used for spraying pesticides frequently throughout the season. If you know that your water has a pH of 7.5 or greater, consider lowering the pH, especially if you are applying a pesticide that is sensitive to high pH. The fastest way to determine the pH level of water is to test it with a pH meter or test paper. Paper test strips are less expensive, but they can be unreliable — results can vary by as much as 2 pH points. A pH meter will provide more reliable and consistent readings. Meters are available commercially for \$50 to \$400.

Adjust the water pH by using a commercially available acidifying/buffering agent before adding the pesticide. Buffering agents will stabilize a spray solution at a predetermined pH and keep it at that level. Examples are Buffer-X and LI 700 Acidiphactant. Granulated food-grade citric acid may be the most convenient and inexpensive acidifying material. Two ounces per 100 gallons has been shown to reduce the pH of tap water from 8.3 to 5.4. Convenient granulated food-grade citric acid measures are:

per 100 gal: 1/4 cup, slightly rounded

per 300 gal: 3/4 cup, rounded

per 500 gal: 1 1/3 cups

However, citric acid does not have built-in buffering capacity like commercial products. Granulated food-grade citric acid is available in 50-lb bags from suppliers that handle food-grade chemicals. Even though a pH of 5 may be optimal, a pH of 6 is usually satisfactory for many pesticides, especially if they will be sprayed out immediately after mixing. Some buffering agents, such as pHase5 or PHT Indicate 5, contain a color indicator to show when the correct pH is achieved. Growers can add this product into the water until it reaches the color that indicates a given pH. For example, 5 = pink or red; 6 = orange; etc. Read and closely follow the directions on the label of the buffering agent, and make sure that the solution is stirred well before taking a pH measurement.

When tank mixing multiple pesticides and/or foliar fertilizers, check the pH after the products have been thoroughly mixed and adjust the pH as needed. Not all pesticides react the same to the pH of the spray water solution, and some products should not be used with buffering agents. Always read the label for any precautions with respect to pH and potential product incompatibility issues. Apply pesticides soon after mixing and avoid leaving pesticide tank mixes in the spray tank overnight.

Product	Active Ingredient	Optimum pH	Half-life (time until 50% hydrolysis*)
Insecticides/Miticides			
Admire	imidacloprid	7.5	Greater than 31 days at pH 5-9
Agri-Mek	avermectin		Stable at pH 5-9
Apollo	clofentezine		pH 7 = 34 hrs; pH 9.2 = 4.8 hrs
Assail	acetamiprid	5 - 6	Unstable at pH below 4 and above 7
Avaunt	indoxacarb		Stable for 3 days at pH 5-10
Carzol	formetanate hydrochloride	5	Not stable in alkaline water; use within 4 hrs of mixing.
Cygon/Lagon	dimethoate	5	pH 4 = 20 hrs; pH 6 = 12 hrs; pH 9 = 48 min
Cymbush	cypermethrin		pH 9 = 39 hours
Diazinon	phosphorothioate	7	pH 5 = 2 wks; pH 7 = 10 wks; pH 8 = 3 wks; pH 9 = 29 days
Dipel/Foray	<i>Bacillus thuringiensis</i>	6	Unstable at pH above 8
Dylox	trichlorfon		pH 6 = 3.7 days; pH 7 = 6.5 hrs; pH 8 = 63 min
Endosulfan	endosulfan		70% loss after 7 days at pH 7.3-8
Furadan	carbofuran		pH 6 = 8 days; pH 9 = 78 hrs
Imidan	phosmet	5	pH 5 = 7 days; pH 7 < 12 hrs; pH 8 = 4 hrs
Kelthane	dicofof	5.5	pH 5 = 20 days; pH 7 = 5 days; pH 9 = 1hr
Lannate	methomyl		Stable at pH below 7
Lorsban	chlorpyrifos		pH 5 = 63 days; pH 7 = 35 days; pH 8 = 1.5 days
Malathion	dimethyl dithiophosphate	5	pH 6 = 8 days; pH 7 = 3 days; pH 8 = 19 hrs; pH 9 = 5 hrs
Matador	lambda-cyhalothrin	6.5	Stable at pH 5-9
Mavrik	tau-fluvalinate		pH 6 = 30 days; pH 9 = 1-2 days
Mitac	amitraz	5	pH 5 = 35 hrs; pH 7 = 15 hrs; pH 9 = 1.5 hrs
Omite	propargite		Effectiveness reduced at pH above 7
Orthene	acephate		pH 5 = 55 days; pH 7 = 17 days; pH 9 = 3 days
Pounce	permethrin	6	pH 5.7 to 7.7 is optimal
Pyramite	pyridaben		Stable at pH 4-9
Sevin XLR	carbaryl	7	pH 6 = 100 days; pH 7 = 24 days; pH 8 = 2.5 days; pH 9 = 1 day
SpinTor	spinosad	6	Stable at pH 5-7; pH 9 = 200 days
Zolone	phosalone	6	Stable at pH 5-7; pH 9 = 9 days
Fungicides			
Alette	fosetyl-al	6	Stable at pH 4.0 to 8.0
Benlate	benomyl	5	pH 5 = 80 hrs; pH 6 = 7 hrs; pH 7 = 1 hr; pH 9 = 45 min
Bravo	chlorothalonil	7	Stable over a wide range of pH values
Captan	captan	5	pH 5 = 32 hrs; pH 7 = 8 hrs; pH 8 = 10 min
Dithane	mancozeb	6	pH 5 = 20 days; pH 7 = 17 hrs; pH 9 = 34 hrs
Quash	metconazole		Stable over a wide range of pH values
Rally	myclobutanil		Not affected by pH
Ridomil	mefenoxam		pH 5-9 = more than 4 weeks
Rovral	iprodione	5 - 7	Chemical breakdown could take place at high pH
Tilt	propiconazole		Stable at pH 5-9
Herbicides			
Barvel	dicamba		Stable at pH 5-6
Fusilade	fluazifop-p		pH 4.5 = 455 days; pH 7 = 147 days; pH 9 = 17 days
Gramoxone	paraquat		Not stable at pH above 7
Poast	sethoxydim	7	Stable at pH 4.0 to 10
Princep	simazine		pH 4.5 = 20 days; pH 5 = 96 days; pH 9 = 24 days
Prowl	pendimethalin		Stable over a wide range of pH values
Rely	glufosinate-ammonium	5.5	
Roundup	glyphosate	5 - 6	
Touchdown	glyphosate	5 - 6	
Treflan	trifluralin		Very stable over a wide range of pH values
Weedar	2,4-d		Stable at pH 4.5 to 7

*The half-life is the period of time it takes for one half of the amount of pesticide in the water to degrade. Other factors than the pH can affect the rate of hydrolysis, including temperature, solubility, concentration, type of agitation, humidity, and other pesticides and adjuvants in the mixture.

This article is based on the following online articles: "Pesticide wise" by the Government of British Columbia Ministry of Agriculture and Lands; "Effects of Water pH on the Stability of Pesticides" by F. Fishel, Department of Agronomy, University of Missouri; "Effects of pH on Pesticides and Growth Regulators" by T. Smith, Dept. of Plant, Soil and Insect Sciences, University of Massachusetts; "Effect of water pH on the chemical stability of pesticides" by H. M. Deer and R. Beard, Utah State University Extension; and "The Wonderful World of Roses: pH and Pesticides" by R. B. Martin, Jr., Pasadena, Calif.; Midwest Commercial Small Fruit and Grape Spray Guide, 2009. B. Bordelon, M. Ellis and R. Weinzierl (eds.).



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