Multiple herbicide-resistant Palmer amaranth & waterhemp in Michigan

Keys to management in soybean, corn and alfalfa

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Palmer amaranth (*Amaranthus palmeri*) and common waterhemp (*A. rudis*) are pigweed species that are becoming more prevalent in Michigan agronomic fields. Both species pose severe management challenges for Michigan growers with herbicide resistance being the greatest of these challenges. Palmer amaranth and waterhemp populations in Michigan range from being resistant only to glyphosate or ALS-inhibiting herbicides to many of these populations being **resistant to multiple herbicides** including **glyphosate** and **ALS-inhibitors**. In fact, we have a Palmer amaranth population in Michigan that is resistant to three herbicide sites of action, including glyphosate (Group 9), ALS-inhibiting herbicides (Group 2), and atrazine (Group 5). In other states, Palmer amaranth and waterhemp have evolved resistance to a combined seven different herbicide sites of action, including Groups 2, 3, 4, 5, 9, 14 and 27. This leaves very few herbicide options available for management. The ability of these species to emerge throughout the growing season, their rapid growth rates, prolific seed production, and their ability to evolve herbicide resistance quickly makes these species two of the more difficult weeds to manage.

Identifying characteristics:

Palmer amaranth and common waterhemp are dioecious, having separate male and female plants. The stem and leaf surfaces of both of these species are smooth and due to genetic variability within each species there are several variations in stem and flower structure color.

Palmer amaranth	Waterhemp
• Rounded leaves	• Long narrow leaves
• Leaves are in a symmetrical arrangement	• Open canopy
• Petioles are as long or longer than the leaf	• Leaves appear shiny or waxy
• Spiny bracts are at leaf axils on female plants	• No spiny bracts
• Flowering structures are thick, unbranched, and 1 to 2 feet long	• Flowering structures are slender, unbranched, and usually only 6 inches long

Long leaf petiole

Female plant spiny bracts

Flowering structure Palmer amaranth

Long narrow leaves

Flowering structure waterhemp

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Keys to successful management in soybean

Consider planting LibertyLink or LibertyLink GT27 soybean

Due to the limited postemergence herbicide options available, label restrictions, and lack of consistency observed with postemergence herbicides control of multiple-resistant Palmer amaranth and waterhemp is a challenge in Roundup Ready soybean. With LibertyLink soybean there is more flexibility in use rates and the number of *glufosinate* (Liberty, Interline, others) applications that can be made.

What about Roundup Ready 2 Xtend soybean?

The use of registered dicamba products in Roundup Ready 2 Xtend (dicamba-resistant) soybean provides growers with another option for postemergence control of multiple-resistant Palmer amaranth and waterhemp. However, due to label restrictions growers should weigh the risks associated with POST dicamba applications prior to using this technology. If Xtend soybeans are used XtendiMax, FeXapan (22 oz), or Engenia (12.8 oz) may be applied as the POST herbicide option in Step 3 outlined below. All other steps need to be followed. ***Restrictions*** and ***additional precautions*** for use of dicamba in Xtend soybean are outlined in Table 2H of the MSU Weed Control Guide (E0434) and the label must be followed.

Step 1: Start clean!!

Make sure that all Palmer amaranth or common waterhemp plants are controlled with tillage or an effective burndown herbicide, i.e., Gramoxone or Liberty, prior to planting soybean.

Step 2: Effective soil-applied (PRE) herbicides are essential.

Apply the ***full-rate*** of an effective soil-residual herbicide, prior to or soon after soybean planting. Valor and Fierce have been the most consistent control options. Valor XLT, Envive, Surveil and Trivence are also Valor (*flumioxazin*)-based products that have provided good control. Premixes that contain Spartan (*sulfentrazone*); Authority MTZ, Authority Assist/Elite/First/MAXX/Supreme/XL, and Sonic have also shown some positive results. However, rates need to be equivalent to 8 oz/A of Spartan (0.25 lb ai/A of *sulfentrazone*). Adding *metribuzin* to Valor or Authority products (where allowed) may provide additional residual control of Palmer amaranth and waterhemp. Remember, higher rates of these herbicides also increase the likelihood for soybean injury.

Step 3: Timely postemergence herbicide applications.

Proper timing is everything!! Postemergence herbicides must be applied before Palmer amaranth and waterhemp are 3-inches tall. In Roundup Ready or non-GMO soybean, Flexstar, Cobra, or Ultra Blazer should be used. Flexstar has been the most consistent of these herbicides for Palmer amaranth control. In LibertyLink soybean, use 32-43 oz/A of Liberty. In Roundup Ready 2 Xtend soybean, XtendiMax, FeXapan (22 oz), or Engenia (12.8 oz) may be applied. Spray coverage is essential with any of these herbicides, so a minimum of 15 gallons per acre of spray solution should be used. Once plants exceed 3-inches tall, control with any of these postemergence herbicides is substantially reduced.

Step 4: Residual product tank-mixtures with postemergence herbicides.

A residual herbicide (i.e., Dual II Magnum, Warrant, Outlook, or Zidua) should be tank-mixed with the postemergence herbicide application. It is essential for the postemergence herbicide Flexstar, Cobra, Ultra Blazer, Liberty (LibertyLink soybean only) or registered dicamba products (Xtend soybean only) to have effective control of herbicide-resistant Palmer amaranth and waterhemp, since the residual herbicides will not control emerged plants. Several premixes (i.e., Prefix and Warrant Ultra) contain an effective POST with a residual herbicide.

Step 5: Additional postemergence herbicide applications if needed.

Follow-up postemergence herbicide applications may be needed. Make these applications when plants are 3-inches or less. If Flexstar was used in the first postemergence application, Cobra or Ultra Blazer are the only Group 14 herbicide options remaining. If plants are larger than 3-inches you will have to use 12.5 oz/A of Cobra. The use of a methylated seed oil (MSO) with these mixes may also improve control. In LibertyLink soybean, Liberty should be applied at rates ranging from 32 to 43 oz/A, depending on weed height.

Step 6: Additional measures to stop seed production.

Additional cultural control measures, such as hand-weeding, should be implemented to prevent any remaining resistant Palmer amaranth and waterhemp plants from going to seed in the field, around field edges, or along ditch banks.

Michigan Soybean Promotion Committee
The Soybean Checkoff
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Multiple herbicide-resistant Palmer amaranth & waterhemp

Multiple herbicide -resistant Palmer amaranth in a MI seed corn field

Keys to successful management in corn

Corn provides the best opportunity for management of Palmer amaranth and waterhemp. However, this can also be difficult since there are Palmer amaranth populations in Michigan that are not only resistant to glyphosate and ALS-inhibiting herbicides, but also to atrazine. In order for management strategies to be effective, careful planning is needed. In addition, due to Palmer amaranth and waterhemp's propensity to evolve herbicide resistance, it is important not to rely solely on one herbicide site of action for management. In fields with three-way resistance only relying on one herbicide site of action such as the HPPD-inhibiting (Group 27) herbicides like Callisto, Impact, or Laudis will quickly lead to additional resistances. The following steps should be followed to manage multiple-resistant Palmer amaranth and waterhemp in corn.

Step 1: Consider planting a Roundup Ready/LibertyLink stacked corn hybrid.

While there are several postemergence herbicides available in corn that have some activity on Palmer amaranth and waterhemp, planting a Roundup Ready/LibertyLink stack provides one more additional site of action, Liberty, that can be used to help control resistant Palmer amaranth and waterhemp.

Step 2: Plant into a clean seedbed.

Control all emerged Palmer amaranth and waterhemp plants prior to planting corn.

Step 3: Two-pass (sequential) herbicide programs are needed.

- ***PRE:*** Full-labeled rates of a minimum of **two effective herbicide sites of action** (Table 1) are required for initial control (i.e., Zidua + AAtrex).
- ***POST:*** Must be applied before plants are 3-inches tall and requires the use of at least **two effective POST herbicide sites of action** (Table 1). A Group 15 herbicide may also be tank-mixed for additional residual control.

"CORN PROVIDES THE BEST OPPORTUNITY FOR MANAGEMENT OF MULTIPLE-RESISTANT PALMER AMARANTH AND WATERHEMP."

Step 4: Hand-weed to eliminate any remaining resistant plants

Table 1. Effective herbicides for management of glyphosate/ALS-resistant Palmer amaranth and waterhemp. No single herbicide active ingredient is 100% effective and a minimum of two effective herbicides are needed PRE and POST.

Trade names*	Active ingredient	Group #	Application timing
AAtrex, others**	atrazine	5	PRE/POST
2,4-D amine, several	2,4-D amine	4	POST
Clarity, (Status)	dicamba (+ difluenzopyr)	4 (+19)	POST
Liberty **(LibertyLink corn)**	glufosinate	10	POST
Dual II Magnum, Cinch	*s*-metolachlor	15	PRE
Harness	acetochlor	15	PRE
Zidua	pyroxasulfone	15	PRE
Balance Flexx	isoxaflutole	27	PRE
Callisto	mesotrione	27	PRE/POST
Impact, Armezon	topramezone	27	POST
Laudis	tembotrione	27	POST

* Consult the 2019 Weed Control Guide for Field Crops (E-434) for premixtures of these herbicide active ingredients and product restrictions. DO NOT apply more than a maximum of 2 lb ai/A per application or 2.5 lb ai/A total of atrazine for all applications per season.

** If Palmer amaranth is resistant to atrazine, herbicides with other **effective** sites of action are required.

Financial support for corn research was provided by the Michigan Corn Marketing Program.

Multiple herbicide-resistant Palmer amaranth & waterhemp

Table 2. Example sequential corn herbicide programs and their effectiveness for management of glyphosate/ALS-resistant Palmer amaranth and waterhemp. In populations where atrazine resistance is present, the inclusion of atrazine POST with a Group 27 herbicide has improved Palmer amaranth control.

	Premergence	Postemergence	Group #	Effectiveness
1	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Callisto Xtra	5+15 fb. 27+5	Good - Excellent
2	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Armezon/Impact + atrazine	5+15 fb. 27+5	Good - Excellent
3	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Laudis + Liberty ***(LibertyLink corn)***	5+15 fb. 27+10	Good - Excellent
4	Verdict	Laudis + Status	14+15 fb. 27+4	Good - Excellent
5	Lexar EZ/Lumax EZ/Acuron	Laudis + atrazine	5+15+27 fb. 27+5	Good - Excellent
6	Lexar EZ/Lumax EZ/Acuron	Liberty + Warrant ***(LibertyLink corn)***	5+15+27 fb. 10+15	Good - Excellent
7	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Liberty ***(LibertyLink corn)***	5+15 fb. 10	Fair
8	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Roundup PowerMax ***(RR corn)***	5+15 fb. 9	Poor

Keys to successful Palmer amaranth management in alfalfa

If not properly managed in alfalfa, Palmer amaranth can produce viable seed that can perpetuate the spread of this devastating weed. Seed heads of Palmer amaranth generally appear after the last cutting of alfalfa. In 2013, we were able to reduce the number of mature seed producing Palmer amaranth plants with the following.

Between-cutting applications:

- Apply Gramoxone 2.0 SL (paraquat) at 1 pt/A + surfactant at 0.25% v/v
- Application should be made within 5 days after cutting
- Best results occurred after the 3rd or 4th alfalfa harvest
- DO NOT cut or harvest within 30 days of application

Multiple herbicide-resistant Palmer amaranth in alfalfa