Multiple herbicide-resistant waterhemp & Palmer amaranth in Michigan

Keys to management in soybean, corn and alfalfa

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Waterhemp (*Amaranthus tuberculatus*) and to a lesser extent Palmer amaranth (*A. palmeri*) are pigweed species that have become prevalent in Michigan agronomic fields. Both species pose management challenges for Michigan growers with herbicide resistance being the greatest threat. In Michigan, waterhemp and Palmer amaranth range from being resistant only to glyphosate (Group 9) or ALS-inhibiting herbicides (Group 2) (i.e, Classic, Raptor) to many of these populations being **resistant to multiple herbicides**, including Group 2 and Group 9 or Group 2 herbicides and atrazine (Group 5). In fact, in Michigan we have populations of waterhemp and Palmer amaranth that are resistant to **three** different herbicide sites of action. More recently, resistance to PPO-inhibiting herbicides (Group 14) (i.e., Flexstar, Cobra) have also been confirmed. 2,4-D (Group 4) resistance has also been found in a few waterhemp populations. Many of these populations are also resistant to an additional one or two more herbicide sites of action. In other states, these pigweed species have evolved resistance to a combined eight different herbicide sites of action, including Groups 2, 3, 4, 5, 9, 14, 15 and 27. This leaves very few herbicide options available for management. The ability of these species to emerge throughout the growing season, rapid growth rates, prolific seed production, and ability to evolve resistance quickly makes these weeds difficult 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

Multiple herbicide-resistant waterhemp & Palmer amaranth

Keys to successful management in soybean

Soybean varieties with different herbicide-resistant traits provide additional options for management of herbicide-resistant waterhemp and Palmer amaranth. Following the six steps outlined below helps ensure successful management of these weeds, regardless of soybean trait.

Consider planting LibertyLink, LibertyLink GT27, Enlist E3, or XtendFlex soybean

Due to the limited postemergence (POST) herbicide options available, label restrictions, and lack of consistency observed with postemergence herbicides control of multiple-resistant waterhemp and Palmer amaranth is a challenge in Roundup Ready soybean. With LibertyLink, LibertyLink GT27, Enlist E3, and XtendFlex soybean there is more flexibility in use rates and the number of *glufosinate* (Liberty Ultra, others) applications that can be made. Information on *glufosinate* use for POST waterhemp and Palmer amaranth control is outlined in Step 3.

Michigan soybean field infested with waterhemp

Enlist E3 soybean:

In addition to glufosinate resistance, Enlist E3 soybean are also resistant to the choline salt of 2,4-D and glyphosate. The use of Enlist One (2,4-D choline) or Enlist Duo (2,4-D choline + glyphosate) in Enlist E3 soybean provides additional POST options for waterhemp and Palmer amaranth control (see Step 3), unless 2,4-D resistance is confirmed. Additional information and ***guidelines*** on the use of Enlist One and Enlist Duo in Enlist E3 soybean are outlined in Table 2G of the MSU Weed Control Guide (E0434).

Steps for Successful Management:

Step 1: Start clean!!

Make sure that all waterhemp or Palmer amaranth plants are controlled with tillage or an effective burndown herbicide, i.e., Gramoxone or Liberty Ultra 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. Fierce, Fierce XLT, and Fierce MTZ/Kyber Pro have been the most consistent control options. Valor (*flumioxazin*) and other Valor-based products: Dimetric Charged, Envive, Surveil, Trivence, Valor XLT, and Zone Defense also provide good control. Premixes that contain Spartan (*sulfentrazone*); Authority Assist/Edge/Elite/First/ Supreme/XL, BroadAxe XC, Sonic, and Sonic Boom have also shown 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 or applying premixtures that contain these products may provide additional residual control. Remember, higher rates of these herbicides also increase the likelihood for soybean injury. The Group 15 herbicides (i.e., Dual II Magnum, Warrant/Enversa, Outlook, or Zidua) also provide good waterhemp and Palmer amaranth control. Adding *metribuzin* to one of the Group 15 herbicides or applying premixtures of these products (i.e., Boundary, Tendovo) can also provide additional residual control. However, in many cases the Group 15 herbicides are best used as a residual tank-mixture with the postemergence herbicide application. Step 4 outlines how these residual herbicides can be used.

Keys to successful management in soybean (continued)

Step 3: Timely postemergence herbicide applications.

Proper timing is everything!! Postemergence herbicides must be applied before waterhemp and Palmer amaranth are 3-inches tall. 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 many of the postemergence herbicides is substantially reduced.

- **Roundup Ready, Roundup Ready 2 Xtend, 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. These herbicides will not control Group 14 resistant waterhemp or Palmer amaranth. The use of a methylated seed oil (MSO) with these herbicides may also improve control.
- **LibertyLink, LibertyLink GT27, or XtendFlex soybean:** Use 24-34 oz/A of Liberty Ultra 1.76SL. Ammonium sulfate (AMS) should always be included. Use the higher glufosinate rate to control taller plants or plants that have escaped initial control. *One POST application of glufosinate will not effectively provide season-long control.*
- **Enlist E3 soybean:** Enlist One (32 oz/A), Enlist Duo (4.75 pt/A), Liberty Ultra (24-34 oz/A) can be applied POST prior to plants exceeding 4-inches in height. Under high waterhemp populations the combination of Enlist One + Liberty Ultra provides the most consistent control. Only approved spray additives and herbicides can be tank mixed with these products. The list of these approved products are found at **EnlistTankmix.com.**

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

A residual herbicide (i.e., Dual II Magnum, Warrant/Enversa, Outlook, or Zidua) should be tank-mixed with the postemergence herbicide application. It is essential for the postemergence herbicide Flexstar, Cobra, Ultra Blazer, Liberty Ultra (LibertyLink, LibertyLink GT27, Enlist E3, XtendFlex soybean only), or Enlist One, Enlist Duo (Enlist E3 soybean only) to have effective control of waterhemp and Palmer amaranth, 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.

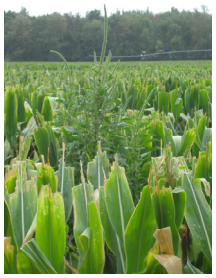
Follow-up postemergence herbicide applications may be needed. Make these applications when plants are 4-inches or less. If Flexstar was used in the first postemergence application, Cobra or Ultra Blazer are the only Group 14 herbicide options remaining. If plants are larger than 3-inches you will have 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, LibertyLink GT27, Enlist E3, or XtendFlex soybean, Liberty Ultra should be applied at rates ranging from 24 to 34 oz/A, depending on weed height. In Enlist E3 soybean, Enlist One or Enlist Duo can be applied if applications occur not later than R2 soybean.

Step 6: Additional measures to stop seed production.

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

Financial support for this research was provided by the Michigan Soybean Committee.

Multiple herbicide-resistant waterhemp & Palmer amaranth



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 waterhemp and Palmer amaranth. However, this can also be difficult since there are populations of these species 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 waterhemp and Palmer amaranth'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, Laudis, or Sheildex will quickly lead to additional resistances. The following steps should be followed to manage multiple-resistant waterhemp and Palmer amaranth 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 waterhemp and Palmer amaranth, planting a Roundup Ready/LibertyLink stack provides one more additional site of action, Liberty Ultra, that can be used to help control resistant waterhemp and Palmer amaranth.

Step 2: Plant into a clean seedbed.

Control all emerged waterhemp and Palmer amaranth 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.

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

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

Table 1. Effective herbicides for management of glyphosate/ALS-resistant waterhemp and Palmer amaranth. 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, DiFlexx, (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
Shieldex	tolpyralate	27	POST

* Consult the 2026 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 waterhemp or Palmer amaranth are 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.

Corn Marketing Program of Michigan

Multiple herbicide-resistant waterhemp & Palmer amaranth

Table 2. Example sequential corn herbicide programs and their effectiveness for management of glyphosate/ALS-resistant waterhemp and Palmer amaranth. 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 Ultra ***(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 Ultra+ Warrant/ Enversa ***(LibertyLink corn)***	5+15+27 fb. 10+15	Good - Excellent
7	atrazine + Group 15 (i.e., Harness Xtra, Bicep II Magnum)	Liberty Ultra ***(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