Palmer Amaranth Biology, Identification, and Management

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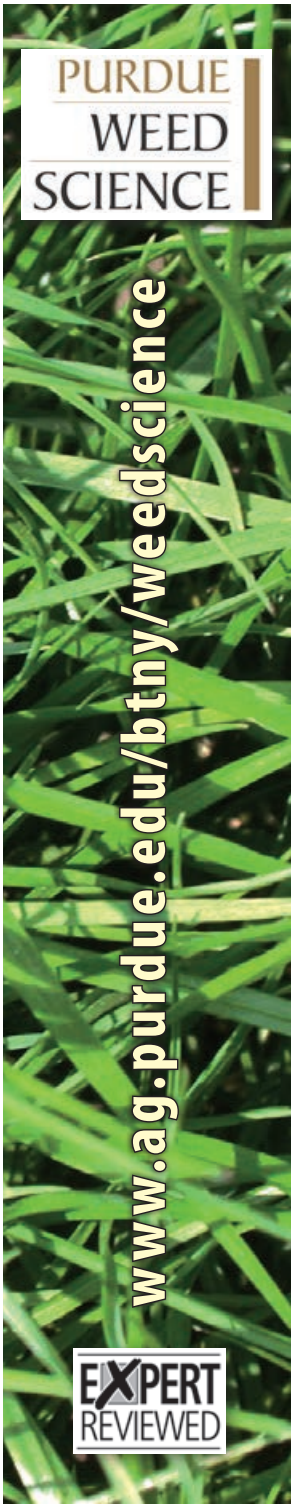


Palmer amaranth (*Amaranthus palmeri*) is an aggressive, invasive weed native to the desert regions of the southwest United States and northern Mexico. It slowly infiltrated the southeast United States and has become one of the most significant weed pests of cotton and soybean producers. What makes Palmer amaranth such a problem is that most populations are resistant to glyphosate and ALS herbicides.

Recently, Palmer amaranth has been confirmed in Indiana (particularly in the northwest), Michigan, Ohio, and Illinois. This means Palmer amaranth could potentially become a major agronomic weed in Indiana and the Midwest.

This publication indicates where Palmer amaranth has been found in Indiana, describes the plant's biology, provides ways to properly identify it, and offers management strategies.

Palmer Amaranth in Indiana

In Indiana, Palmer amaranth was first confirmed in the river bottoms of Posey and Vanderburgh counties. Purdue University researchers collected Palmer amaranth seed from one of the river bottom fields. In greenhouse settings, the plants from this seed survived applications of 20 lbs. ae/acre glyphosate (equivalent of 7 gallons/acre of generic glyphosate).

In the fall of 2012, 51 fields across five northwest Indiana counties were confirmed to have Palmer amaranth plant populations that were not controlled by management tactics used during that growing season. The majority of fields (and the heaviest infestations) were confirmed in Jasper County. Many of the observed fields received multiple applications of glyphosate and attempted rescue applications of PPO-inhibiting herbicides (Flexstar®, Cobra®, Ultra Blazer®, etc.).

Researchers believe Palmer amaranth was introduced to northern Indiana in dairy or beef manure from animals that were fed cotton seed hulls that came from the South that were contaminated with Palmer seed. The exact timing of the initial event is unknown, but is estimated to have happened at least two or three years ago due to the severity of infestation in multiple fields.

Farm equipment, specifically combines, has and will spread Palmer amaranth seed. Wildlife can also spread the seed into new, previously uninfested fields. It is likely

Photos by Travis Legleiter, except Figures 7 and 8 by Tom Sinnot, Superior Ag Resources.

that more Palmer amaranth populations exist in northwest Indiana and other regions, but these areas have yet to be properly identified.

Biology and Impact

Palmer amaranth is adaptable and invasive. Evidence of its adaptability is the success of populations in Michigan and northern Indiana where average temperatures are below the preferred temperatures of native Palmer populations.

The biological distinctions that highlight Palmer amaranth's success as a weed are described below.

Adapts Quickly

Palmer amaranth has dioecious reproduction, so individual plants are either male or female, which forces outcrossing and genetic diversity. This gives Palmer amaranth the ability to adapt and quickly spread herbicide resistance genes when selection pressure is applied (as when producers repeatedly apply single mode of action herbicides).

Produces Lots of Seed

Palmer amaranth is a prolific seed producer. Each plant can produce at least 100,000 seeds when they compete with a crop. In noncompetitive scenarios they can produce nearly a half million seeds.

Distributes Small Seed

Palmer amaranth seeds are rather small and thrive in no-till or minimum tillage fields. In those situations, seeds are allowed to stay in their ideal emergence zone: the top inch of soil. Humans easily transport the small seeds through grain, seed, or feed contamination; or on equipment such as combines.

Competes Aggressively

Palmer exhibits aggressive growth and competitiveness with crops. Under ideal conditions, Palmer amaranth plants can grow 2 or 3 inches per day. When allowed to compete throughout the growing season, Palmer amaranth can create yield losses of 11 to 91 percent in corn and 17 to 79 percent in soybean.

Herbicide Resistance

Palmer populations have evolved resistance to multiple herbicide modes of action, including ALS inhibitors, triazines, HPPD inhibitors, dinitroanilines, and glyphosate. The majority of populations in the South are ALS-inhibitor- and glyphosate-resistant.

Amaranth Identification

The first, and often critical, step to managing Palmer amaranth (or any weed) is to scout and identify the species that exist in each agronomic field. It is easy to misidentify Palmer amaranth because it looks similar to three other common amaranth species: redroot pigweed (*Amaranthus retroflexus*), smooth pigweed (*Amaranthus hybridus*), and common waterhemp (*Amaranthus rudis*). The resemblance is especially strong during the seedling stages of growth.

All too often, the amaranths are all called "pigweed" and not identified properly by species. The populations in northwest Indiana were misidentified as waterhemp for at least the last couple of years and were not managed as aggressively as the situation demanded.

There are several characteristics that differentiate the three amaranth species:

- The presence of hair
- Leaf shape
- Petiole length
- Apical meristem growth pattern
- Seed head structures
- Leaf blade watermark

Understanding these characteristics will help producers correctly identify amaranth species, and then determine the proper management strategies.

Presence of Hair

Only redroot and smooth pigweeds have hairs (pubescence) on their stems and leaf surfaces (Figure 1). The fine hairs will be most noticeable on the stems towards the newest growth. Palmer amaranth and common waterhemp do not have hair on any surface. Looking for pubescence is a quick and easy way to differentiate redroot and smooth pigweeds from the other two amaranths.

Figure 1. Redroot and smooth pigweeds have hairs on their stems and leaf surfaces. These hairs distinguish them from common waterhemp and Palmer amaranth.

Leaf Shape

The leaf shapes of amaranths can vary quite a bit within a single species; however, there are general shapes that distinguish the species (Figures 2-5).

Common waterhemp leaves are generally long, linear, and lanceolate.

Palmer amaranth leaves are wider and ovate to diamond-shaped.

Redroot and smooth pigweed leaves are similar to Palmer leaves and have a round to ovate shape — redroot and smooth pigweed leaves, however, have hairs while Palmer and common waterhemp leaves do not.

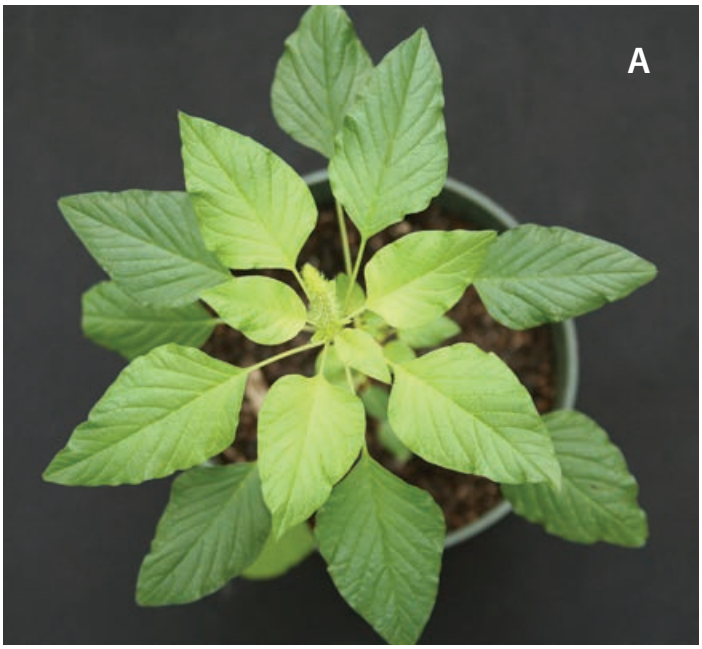
Plants that have been sprayed and survived multiple herbicide applications (especially PPO-inhibitors) can exhibit variable leaf shapes that may not correctly represent the species.

Figure 2. A Palmer amaranth leaf blade with extended petiole.

Figure 3. A Palmer amaranth petiole bent back over the leaf blade, demonstrating the length of its petiole.

Figure 4. The linear, lance-shaped leaf blade and short petiole characteristic of common waterhemp.

Figure 5. A common waterhemp petiole bent back over the leaf blade, illustrating the length of its petiole.



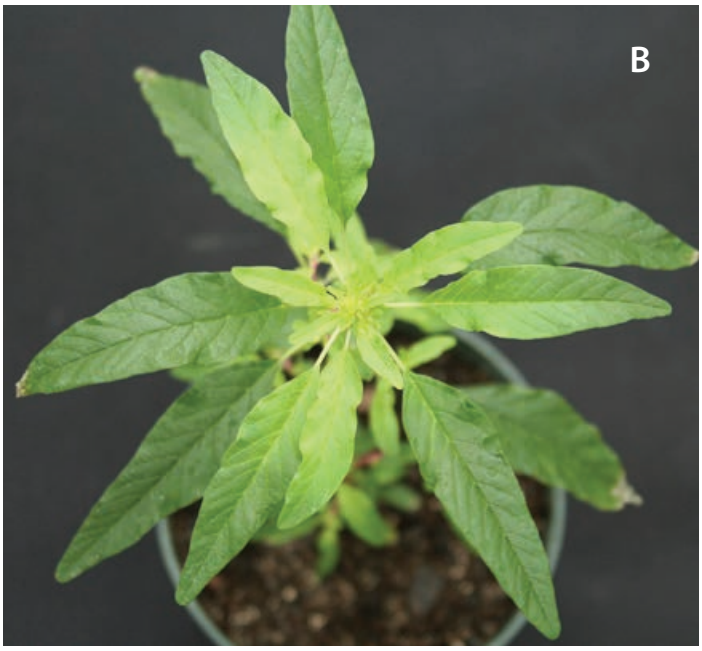


Figure 6. These photos show the leaf shapes and apical meristem growth patterns of Palmer amaranth (A) and common waterhemp (B).

Petiole Length

The petiole is the stem-like structure that connects the leaf blade to the main stem. In Palmer amaranth the petioles (especially on older leaves) will be as long (or longer) than the leaf blade itself (Figure 2). The petioles of waterhemp, on the other hand, will be shorter than their long, lance-shaped leaves (Figure 4).

A quick way to determine the petiole length is to simply pull a leaf and petiole off a plant and bend the petiole back over the leaf blade to compare the petiole and leaf blade lengths (Figures 3 and 5).

Apical Meristem Growth Pattern

Palmer amaranth's leaf shape and petiole lengths are the result of the growth pattern of the apical meristem, which grows to capture as much light as possible. This results in a rosette-like appearance as you look directly down from the top of the plant (Figure 6A). This growth pattern and rosette appearance is often compared to that of a poinsettia.

The short petioles and long linear leaves of common waterhemp form a less patterned rosette appearance when observed from above (Figure 6B).

Seed Head Structures

Although one should identify weeds before the plants reach reproductive stage, it can be useful to look at seed head structures of escaped weeds to help identify the species.

Palmer amaranth females have a long main terminal seed head that can reach up to 3 feet long (Figures 7 and 8). Palmer amaranth female seed heads also have stiff, sharp bracts that give the seed heads a prickly feeling when touched.

Figure 7. A Palmer amaranth plant growing in soybean with multiple terminal seed heads.

Common waterhemp has multiple branched seed heads that are similar in length and lack the stiff, prickly bracts.

Figure 8. A Palmer amaranth seed head measuring close to 30 inches long.

Leaf Blade Watermark

The leaves of some (but not all) Palmer amaranth plants have a white watermark shaped like a chevron or V (Figure 9). This mark is not present on common waterhemp, but use this mark only to verify an identification of Palmer amaranth since not all Palmer plants will express this characteristic.

Figure 9. Some Palmer amaranth leaves have white chevron or V-shaped watermarks.

Spiny Amaranth: A Common Misidentification

The presence of stiff, pointy bracts on the female seed head and leaf axils can lead to confusing Palmer amaranth with spiny amaranth or spiny pigweed (*Amaranthus spinosus*). Spiny amaranth is predominantly a weed of pastures, livestock holding pens, and feeding areas; it is rare in agronomic fields. Spiny amaranth has a bushy growth pattern and exhibits the spiny bracts throughout its life cycle, whereas Palmer amaranth exhibits the bracts only at maturity and during reproductive stages.

Palmer Amaranth Management

Once Palmer amaranth has been properly identified in a field, the next step is to develop a proactive management plan. The main management goals should be to prevent the plants from producing seed and to avoid spreading the weed to other areas.

Indiana producers who encounter Palmer amaranth should treat the population as if it is ALS- and glyphosate-resistant — that's because the original transplanted seed likely came from the South, where the majority of Palmer populations *are* resistant to these herbicides. Again, the most crucial step is to scout fields dilligently and properly identify Palmer amaranth when it first appears.

Palmer amaranth has only recently been confirmed in Indiana. Therefore, Purdue Weed Science has yet to establish research and collect data on its management. The recommendations provided here are based on the research and recommendations from researchers in the South and Michigan.

Consider combining cultural practices and herbicide programs for the most effective Palmer amaranth management. Palmer is a very aggressive and adaptive weed, and management programs that rely on a single mode of action (such as glyphosate as the only post herbicide) will typically be ineffective at completely controlling the weed.

Cultural Practices

Rotate Crops

Although it's not a new concept to rotate corn and soybean, rotating fields to corn allows producers to use herbicides with additional modes of action that will control Palmer amaranth. Rotation also helps slow further resistance issues and preserves current herbicide tools. In highly infested fields, consider growing corn for at least two years to maximize Palmer control. Although, as noted below, exercise caution to prevent resistance to corn herbicides.

Practice Deep Tillage

Deep tillage (moldboard plow) will bury the small Palmer amaranth seed below its preferred emergence depth. Deep tillage will not provide complete control, but will reduce the number of seeds that can emerge from the top 1 inch of soil. Use this method in extreme cases because one pass of a moldboard plow will essentially delete the benefits of years of no-till or minimum tillage practices.

Plant a Cereal Rye Cover Crop

A properly managed and crimped cereal rye cover crop can provide a mulch that will suppress Palmer amaranth emergence. The majority of research on crimped cereal rye cover crop suppression on Palmer amaranth has been combined with deep tillage; hence, the cover crop is used for its weed suppression capabilities and not the soil health benefits that cover crop advocates often promote. No other cover crops have been extensively studied for use to suppress Palmer amaranth.

Hand Weed

In severe infestations in southern U.S. cotton fields, producers have resorted to hiring hand weeding crews to remove Palmer amaranth. The hope is that Indiana producers will be able to control Palmer amaranth through other practices before going to these extremes. Still, producers should be willing to scout for late-season escapes and pull these plants to avoid spreading seed or pollen.

Monitor Ditches and Borders

Take care to control Palmer amaranth plants in ditches and field edges. In fall 2012, Purdue weed scientists identified Palmer amaranth scattered along multiple roadside ditches in northwest Indiana. Although these plants did not compete with field crops, they still help spread of the population through pollen and seed.

Herbicide Control in Corn

There are a number of herbicides available in corn that effectively control Palmer amaranth and offer alternate modes of action to incorporate into your herbicide rotations. In highly infested fields, growing corn for multiple years can be effective in reducing Palmer populations. However, when growing corn for multiple years, take care to not rely heavily on single modes of action because atrazine- and HPPD-resistant Palmer amaranth populations have previously been confirmed.

Tables 1 and 2 outline the products available for pre-emergence and post-emergence use in corn. The tables also provide the active ingredients and sites of action for these products. Use these tables (along with knowledge of other weeds present) to formulate an effective herbicide program that maximizes the number of sites of action to delay resistance. Also, be aware that a maximum application of atrazine is 2 lbs./acre of active ingredient (ai) and the total of all applications cannot exceed 2.5 lbs. ai/acre.

Table 1. Herbicides that provide pre-emergence control of Palmer amaranth in corn.

Trade Name(s)	Active Ingredient	Site of Action	Site of Action Group #[a]
Aatrex® and others[b]	atrazine	PSII-Inhibitor	5
Balance Flexx®	isoxaflutole	HPPD-Inhibitor	27
Bicep II Magnum®, Brawl II ATZ®, and Cinch ATZ®	atrazine	PSII-Inhibitor	5
	S-metolachlor	Long chain fatty acid-Inhibitor	15
Bullet® and Lariat®	atrazine	PSII-Inhibitor	5
	alachlor	Long chain fatty acid-Inhibitor	15
Corvus®	isoxaflutole	HPPD-Inhibitor	27
	thiencarbazone	ALS-Inhibitor	2
Dual II Magnum® and Cinch®	S-metolachlor	Long chain fatty acid-Inhibitor	15
Fierce®	pyroxasulfone	Long chain fatty acid-Inhibitor	15
	flumioxazin	PPO-Inhibitor	14
Guardsman Max® and G-Max Lite®	atrazine	PSII-Inhibitor	5
	dimethenamid-P	Long chain fatty acid-Inhibitor	15
Outlook®	dimethenamid-P	Long chain fatty acid-Inhibitor	15
Lexar and Lumax®	atrazine	PSII-Inhibitor	5
	S-metolachlor	Long chain fatty acid-Inhibitor	15
	mesotrione	HPPD-Inhibitor	27
Verdict®	saflufenacil	PPO-Inhibitor	14
	dimethenamid-P	Long chain fatty acid-Inhibitor	15
Zidua®	pyroxasulfone	Long chain fatty acid-Inhibitor	15

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]Maximum of 2 lbs. ai/A per application and 2.5 lbs. ai/A total for all applications per season.

Table 2. Corn herbicides that provide post-emergence control of Palmer amaranth.

Trade Name(s)	Active Ingredient	Site of Action	Site of Action Group #[a]
various	2,4-D	Growth Regulator	4
Aatrex® and others[b]	atrazine	PSII-Inhibitor	5
Callisto®	mesotrione	HPPD-Inhibitor	27
Banvel®, Clarity®, Sterling Blue®, and others	dicamba	Growth Regulator	4
Callisto Xtra®	atrazine	PSII-Inhibitor	5
	mesotrione	HPPD-Inhibitor	27
Capreno®	tembotrione	HPPD-Inhibitor	27
	thiencarbazone-methyl	ALS-Inhibitor	2
Expert®[c]	glyphosate	EPSPS-Inhibitor	9
	S-metolachlor	Long chain fatty acid-Inhibitor	15
	atrazine	PSII-Inhibitor	5
Halex GT®[c]	glyphosate	EPSPS-Inhibitor	9
	S-metolachlor	Long chain fatty acid-Inhibitor	15
	mesotrione	HPPD-Inhibitor	27
Impact® and Armezon®	topramezone	HPPD-Inhibitor	27
Laudis®	tembotrione	HPPD-Inhibitor	27
Liberty®[d]	glufosinate	Glutamine Synthesis Inhibitor	10
Status®	dicamba	Growth Regulator	4
	diflufenzopyr	Auxin Transport	19

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]Maximum of 2 lbs. ai/A per application and 2.5 lbs. ai/A total for all applications per season.
[c]Roundup Ready® corn hybrids only.
[d]Liberty Link® corn hybrids only.

Herbicide Control in Soybean

In soybean the number of herbicides available to replace glyphosate for Palmer amaranth control is limited. Furthermore, the herbicides must be applied at appropriate weed sizes for consistent control. The major herbicide limitation occurs with post-emergence products, so producers must take advantage of the available burndown and residual products.

Start With a Clean Field

Start with a clean field (either with tillage or an herbicide burndown) as the first key to successful Palmer amaranth management in soybean (see Table 3). Burndown treatments of glyphosate + 2,4-D or glyphosate + dicamba can be inconsistent on Palmer larger than four inches. Researchers in Tennessee have found that gramoxone + metribuzin is the most consistent burndown, even on large Palmer plants. Producers may have to consider a two-pass burndown because gramoxone + metribuzin can be weak on winter annuals that may also exist in the field.

Table 3. Herbicide products and tank mixes for burndown of Palmer amaranth prior to soybean planting.

Trade Name(s) or Tank Mix	Active Ingredient	Site of Action	Site of Action Group #[a]
glyphosate + 2,4-D[b,c,d]	glyphosate	EPSPS-Inhibitor	9
	2,4-D	Growth Regulator	4
glyphosate + Clarity®[b,c,d]	glyphosate	EPSPS-Inhibitor	9
	dicamba	Growth Regulator	4
Gramoxone® + Dimetric®[b]	paraquat	PSI-Electron Diverter	22
	metribuzin	PSII-Inhibitor	5
Liberty®[d]	glufosinate	Glutamine Synthesis Inhibitor	10
Sharpen®/OpTill®/OpTill PRO®/Veridct +® glyphosate, Liberty®, Gramaxone®[d]	saflufenacil	PPO-Inhibitor	14
	glyphosate or glufosinate or paraquat	EPSPS-Inhibitor or Glutamine Synthesis Inhibitor or PSI-Electron Diverter	9 or 10 or 22

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]Specific trades names are used only for clarification. Multiple glyphosate, 2,4-D, dicamba, and metribuzin products are available for use and are equally effective on Palmer amaranth.
[c]Burndown applications containing 2,4-D or dicamba must be applied 7-28 days before planting depending on product and rate. Refer to labels for specific pre-plant intervals
[d]Must be applied to Palmer amaranth that is 4 inches tall or shorter to achieve maximum consistent control.

Residual Herbicides

Residual herbicides should be the foundation of all Palmer amaranth herbicide control programs in soybean (see Table 4). There are a variety of residual soybean herbicides that will control Palmer amaranth at its weakest point (emergence) and substantially reduce the number of plants requiring a post-emergence application. Using residual herbicides to manage Palmer will reduce the selection pressure of the few post-emergence herbicide options.

Post-emergence Herbicide Timing

Post-emergence herbicides in soybean are limited (see Table 5) to PPO-inhibiting herbicides and Liberty® (Liberty Link® beans only). The timing of these

Table 4. Herbicides that provide pre-emergence control of Palmer amaranth in soybean.

Trade Name(s)	Active Ingredient	Site of Action	Site of Action Group #[a]
Authority Assist®/XL®/First®, and Sonic®	sulfentrazone	PPO-Inhibitor	14
	various	ALS-Inhibitor	2
Authority MTZ®	sulfentrazone	PPO-Inhibitor	14
	metribuzin	PSII-Inhibitor	5
Boundary®	S-metolachlor	Long chain fatty acid-Inhibitor	15
	metribuzin	PSII-Inhibitor	5
Canopy®	chlorimuron	ALS-Inhibitor	2
	metribuzin	PSII-Inhibitor	5
Dual II Magnum® and Cinch®	S-metolachlor	Long chain fatty acid-Inhibitor	15
Dimetric®, TriCor®, and others	metribuzin	PSII-Inhibitor	5
Fierce®	pyroxasulfone	Long chain fatty acid-Inhibitor	15
	flumioxazin	PPO-Inhibitor	14
Intrro®, Lasso®, and Micro-Tech®	alachlor	Long chain fatty acid-Inhibitor	
Outlook®	dimethenamid-P	Long chain fatty acid-Inhibitor	15
Optill PRO®	dimethenamid-P	Long chain fatty acid-Inhibitor	15
	saflufenacil	PPO-Inhibitor	14
	imazethapyr	ALS-Inhibitor	2
Prefix®	S-metolachlor	Long chain fatty acid-Inhibitor	15
	fomesafen[b]	PPO-Inhibitor	14
Prowl®	pendimethalin	Microtubule Inhibitor	3
Valor®	flumioxazin	PPO-Inhibitor	14
Valor XLT®, Gangster®, and Envive®	flumioxazin	PPO-Inhibitor	14
	various	ALS-Inhibitor	2
Zidua®[c]	pyroxasulfone	Long chain fatty acid-Inhibitor	15

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]A total of 0.313 lb./A (north of I-70) or 0.375 lb./A (South of I-70) of fomesafen is allowed to be applied per season.
[c]Pending label approval for use in soybean expected early 2013. Check label to confirm status.

products is key for effective Palmer amaranth control. The consistency and overall control of the PPO-inhibitors and Liberty® is dramatically decreased once Palmer amaranth plants are taller than 4 inches. Soybean producers in the South often plow under and replant soybean once Palmer is taller than 4 inches without an effective post-emerge herbicide application.

Liberty Link® Considerations

In heavily infested fields consider planting Liberty Link® soybean because Liberty® offers consistent control of small Palmer amaranth and adds post-emergence options and another site of action to your rotation (thus reducing pressures on the PPO-inhibiting herbicides). Keep a pre-emergence residual as the foundation of all Palmer amaranth herbicide programs, even in Liberty Link® soybean.

Post-emergence Residuals

Although pre-emergence residuals are the foundation of Palmer amaranth herbicide programs, these products will not last the entire season — so Palmer plants will continue to emerge. Add a pre-emergence residual herbicide (such as Dual II Magnum®, Warrant®, or Outlook®) to your post-emergence application to add residual activity into the latter parts of the season (see Table 6). Remember, pre-emergence products do not control emerged plants and must be tank mixed with one of the post-emergence options mentioned above.

Multiple Applications and Sites of Action (SOA)

The days of one- and two-pass single mode of action soybean programs are gone. Producers should accept this fact when managing a Palmer amaranth-infested field. Producers will have to make multiple applications before and after planting. Producers should also avoid applying any single herbicide product or multiple products with the same mode of action more than twice in a growing season to avoid conferring resistance to the few remaining products left to control Palmer amaranth in soybean.

Tables 3-6 outline the products available for effective control of Palmer amaranth at burndown, pre-emergence, and post-emergence, and provide the sites of action of each product. Use these tables (and the information in this publication) to formulate a multiple-pass herbicide program for Palmer amaranth control that maximizes the number of herbicide sites of action to delay development of future resistance.

Table 5. Soybean herbicides that provide post-emergence control of Palmer amaranth that is 4 inches tall or less.

Trade Name(s)	Active Ingredient	Site of Action	Site of Action Group #[a]
Prefix®[b]	S-metolachlor	Long chain fatty acid-Inhibitor	15
	fomesafen[c]	PPO-Inhibitor	14
Reflex®/Dawn® and Flexstar®/Rhythm®	fomesafen[c]	PPO-Inhibitor	14
Flexstar GT®[d]	fomesafen[c]	PPO-Inhibitor	14
	glyphosate	EPSPS-Inhibitor	9
Cobra® and Phoenix®	lactofen	PPO-Inhibitor	14
Liberty[e]	glufosinate	Glutamine Synthesis Inhibitor	10

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]Prefix® has both post-emergence control and residual activity.
[c]A total of 0.313 lb./A (North of I-70) or 0.375 lb./A (South of I-70) of fomesafen is allowed per season.
[d]Roundup Ready® soybean varieties only.
[e]Liberty Link® soybean varieties only.

Table 6. Soybean herbicides that can be tank mixed with post-emergence the products listed in Table 5 for additional residual activity in the crop.

Trade Name(s)	Active Ingredient	Site of Action	Site of Action Group #[a]
Dual II Magnum®	S-metolachlor	Long chain fatty acid-Inhibitor	15
Outlook®	dimethenamid-P	Long chain fatty acid-Inhibitor	15
Warrant®	acetochlor	Long chain fatty acid-Inhibitor	15
Sequence®[b]	S-metolachlor	Long chain fatty acid-Inhibitor	15
	glyphosate	EPSPS-Inhibitor	9
Zidua®[c]	pyroxasulfone	Long chain fatty acid-Inhibitor	15

[a]Classification system using numbers for each specific site of action developed by the Weed Science Society of America.
[b]Roundup Ready® soybean varieties only.
[c]Pending label approval for use in soybean — expected in early 2013. Check label to confirm status.

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