FIELD FACTS

Management of Glyphosate-Resistant Waterhemp and Palmer Amaranth

by Mark Jeschke, Agronomy Research Manager

Introduction

Amaranthus is the scientific name of a genus of plants more commonly known as pigweeds. The name is derived from the Greek *amarantos*, meaning unfading or unwithering, and the amaranth has long symbolized immortality in poetry and literature. Currently, two *Amaranthus* species, common waterhemp (*A. rudis*) and palmer amaranth (*A. palmeri*), are becoming seemingly immortal in corn and soybean fields due to the development of populations resistant to glyphosate.

Neither waterhemp nor palmer amaranth is new to the world of herbicide resistance. Both have extensive histories of populations developing resistance to commonly used herbicides (See Tables 1 and 4). This propensity for resistance is troublesome when faced with glyphosate-resistant populations because it means that many alternative herbicide options may already be off the table. It also means that an alternative herbicide that does provide effective control may lose that effectiveness if used repeatedly.

Waterhemp and palmer amaranth have several characteristics that make them particularly troublesome weeds. Like corn and sorghum, pigweeds are C_4 plants, making them very efficient at fixing carbon and well-adapted to high temperatures and intense sunlight. Pigweeds are capable of producing greater than 500,000 seeds per plant and tend to germinate throughout the summer, making them difficult to manage in crops. In contrast to other pigweed species, waterhemp and palmer amaranth are dioecious (separate male and female plants). The resulting cross-pollination between plants can increase the genetic diversity of a population which may favor development of herbicide resistance. Both species can be very competitive with crops. Palmer amaranth is generally considered the most aggressive of the pigweeds.

Identification

Plant shape, leaf shape, and color of common waterhemp plants can be highly variable, making proper identification a challenge. Waterhemp can be distinguished from other pigweed species such as redroot pigweed and smooth pigweed by its smooth, hairless stem. Leaves of waterhemp plants are often longer and narrower than other pigweeds.

Some taxonomic references recognize two waterhemp species, tall waterhemp and common waterhemp. This distinction is based on a difference in the female flowers.

Figure 1. Waterhemp (left) next to palmer amaranth (right) in a soybean field.

From a management standpoint, the two species are indistinguishable. Consequently, many agricultural references refer to them collectively as common waterhemp or waterhemp.

Palmer amaranth plants tend to have diamond-shaped leaves and are distinguished by their long petioles (branches connecting the leaves to the stem). They also can be characterized by a smooth, hairless stem and a poinsettia-like leaf arrangement when viewed from above.

Management of Resistant Populations

The simplest means of managing glyphosate-resistant waterhemp or palmer amaranth is to use an alternative herbicide, either in place of or in addition to glyphosate. With any herbicide applied post-emergence, including glyphosate, it is important to treat weeds at the size specified by the label. This is especially crucial when switching from glyphosate to another herbicide. Growers that have become accustomed to delaying post-emergence applications with glyphosate may need to treat earlier to get good results with a different herbicide.

A sequential weed management program consisting of a pre-emergence and post-emergence treatment will provide the most consistent management of waterhemp or palmer amaranth in both corn and soybean. Consult your local weed specialist for specific management recommendations.

Glyphosate-Resistant Waterhemp

The list of alternative herbicide options for glyphosate-resistant waterhemp may be reduced if populations are resistant to other herbicide modes of action in addition to glyphosate. For example, waterhemp resistant to ALS-inhibitors is widespread, particularly in Illinois and Missouri (Table 1). Therefore, in many cases, ALS-inhibitors will not be a viable option for control of glyphosate-resistant waterhemp.

Table 1. Confirmed cases of herbicide-resistant waterhemp populations in the U.S. and Canada (Heap 2012).

Mode of Action	State/Province
ALS Inhibitors	Illinois, Missouri, Kansas, Iowa, Ohio, Wisconsin, Oklahoma, Tennessee, Michigan, Indiana, Ontario
Photosystem II Inhibitors	Kansas, Missouri, Nebraska, Iowa, Illinois
PPO Inhibitors	Iowa
Synthetic Auxins	Nebraska
4-HPPD Inhibitors	Nebraska
Glyphosate	Kansas, Minnesota, Iowa, Indiana, Mississippi, Oklahoma, North Dakota, South Dakota, Tennessee
ALS Inhibitors + Photosystem II Inhibitors	Illinois, Ontario
ALS Inhibitors + **Glyphosate**	Illinois
ALS Inhibitors + PPO Inhibitors	Kansas
ALS Inhibitors + Photosystem II Inhibitors + PPO Inhibitors	Illinois
ALS Inhibitors + PPO Inhibitors + **Glyphosate**	Missouri
ALS Inhibitors + Photosystem II Inhibitors + 4-HPPD Inhibitors	Iowa, Illinois
ALS Inhibitors + 4-HPPD Inhibitors + **Glyphosate**	Iowa

Resistance to PPO-inhibitor herbicides is less common. In a survey of 88 Missouri waterhemp populations conducted in 2008, over half were found to be glyphosate resistant, whereas only one was PPO resistant (Bradley 2009). Waterhemp populations with multiple resistance to glyphosate, ALS-inhibitors, and PPO-inhibitors have been confirmed in Missouri, however, and are suspected in Illinois.

Be sure to follow label guidelines when tankmixing glyphosate with other herbicides. Tank-mixing glyphosate with some herbicides is not recommended due to the potential for antagonism. The label of the glyphosate herbicide will list products that may be used as tankmix partners.

Management in Corn

Several pre-emergence herbicide options are available for controlling glyphosate-resistant waterhemp in corn. Pre-emergence corn herbicides containing alachlor, acetochlor, metolachlor, dimethenamid, isoxaflutole, and mesotrione will provide control of waterhemp.

Post-emergence options for waterhemp control include herbicides containing atrazine, 2,4-D, or dicamba. Growers planting hybrids with the LibertyLink® trait also have the option of using glufosinate for post-emergence waterhemp control. All hybrids with Herculex® I, Herculex RW, or Herculex XTRA insect protection also contain the LibertyLink trait.

Figure 2. Waterhemp plants that survived an application of glyphosate.

Management in Soybean

Fewer alternatives for controlling glyphosate-resistant waterhemp are available in soybean than in corn. Options for post-emergence control are very limited. When managing glyphosate-resistant waterhemp in soybean, the best place to start is with an effective pre-emergence treatment. Not only will this provide more herbicide options for waterhemp control, research has shown that a pre-emergence followed by post-emergence herbicide program provides much better control of waterhemp than a post-emergence program alone.

Waterhemp has a long emergence window, so it is unlikely that a pre-emergence treatment alone will provide complete control. A post-emergence treatment will likely be necessary to manage late-emerging individuals. PPO-inhibitors are generally the only herbicide option available for post-emergence control of glyphosate-resisant waterhemp in soybean. Multiple resistance of waterhemp to glyphosate and PPO-inhibitors is still relatively rare, so post-emergence application of a PPO herbicide is a viable option for waterhemp control in most cases.

In cases with resistance to ALS-inhibitors, PPO-inhibitors, and glyphosate, the only other effective post-emergence herbicide option is glufosinate, however this may only be used in soybean with the LibertyLink® trait. Tables 2 and 3 show the response of resistant waterhemp to several pre-emergence and post-emergence herbicides in University of Missouri research.

Table 2. Efficacy of pre-emergence herbicides for management of resistant waterhemp in soybean (Bradley et al. 2008).

Herbicide	Active Ingredient	Resistance	
		ALS Gly	ALS Gly PPO
Authority® Assist	sulfentrazone + imazethapyr	E	E
Authority™ First/ Sonic™	sulfentrazone + cloransulam	E	E
Authority MTZ®	sulfentrazone + metribuzin	E	E
Boundary®	*S*-metolachlor + metribuzin	E	E
Canopy®	chlorimuron + metribuzin	F	F
Dual II Magnum®	*S*-metolachlor	G/E	G/E
Envive™	flumioxazin + chlorimuron + thifensulfuron	G	G
Gangster®	flumioxazin + cloransulam	G	G
Intrro®/Micro-Tech®	alachlor	F/G	F/G
Outlook®	dimethenamid	G	G
Prefix™	S-metolachlor + fomesafen	E	E
Prowl® H2O	pendimethalin	F/G	F/G
Sencor®	metribuzin	F	F
Treflan®	trifluralin	F/G	F/G
Valor®	flumioxazin	G	G
Valor® XLT	flumioxazin + chlorimuron	G	G

Table 3. Efficacy of post-emergence herbicides for management of resistant waterhemp in soybean (Bradley et al. 2008).

Herbicide	Active Ingredient	Resistance	
		ALS Gly	ALS Gly PPO
Aim®	carfentrazone	F	F
Butyrac®	2,4-DB	P/F	P/F
Cobra®/Phoenix®	lactofen	G/E	P
Flexstar®/Reflex®	fomesafen	G/E	P
Resource®	flumiclorac	F	F
Ultra Blazer®	acifluorfen	G/E	P
Ignite®*	glufosinate	G	G

*For use only on soybean with the LibertyLink trait.

(E=Excellent >90% control, G=Good 75-89% control, F=Fair 60-74% control, P=Poor <60% control. Herbicides rated poor for both resistance profiles not shown)

University of Illinois Recommendations for Glyphosate-Resistant Waterhemp Management in Soybean

1. Apply a full rate of a soil residual herbicide no more than 7 days before planting.
2. Apply post-emergence glyphosate treatment when waterhemp plants are 3 to 5 inches tall.
3. Scout the field 7 days after glyphosate treatment. If waterhemp control is inadequate, consider applying a full labeled rate of a PPO-inhibiting herbicide.
4. Rescout the field 10 to 14 days later. Rogue any surviving plants before they reach reproductive growth stage.

Glyphosate-Resistant Palmer Amaranth

Glyphosate-resistant palmer amaranth is most prevalent and has presented the greatest challenge in cotton production in southern states, where cotton is often grown in a continuous monoculture with glyphosate applied every year. Multiple resistance to glyphosate plus other herbicide modes of action is less prevalent in palmer amaranth than in waterhemp (Table 4), which permits a greater range of options for controlling glyphosate-resistant populations in corn and soybean. PPO-inhibiting herbicides are good option for Palmer amaranth control in soybean as resistance to these herbicides has not yet occurred. However, there are concerns that over-reliance on this single mode of action will yield resistant palmer amaranth populations in a short time.

Table 4. Confirmed cases of herbicide-resistant palmer amaranth populations in the U.S. and Canada (Heap 2012).

Mode of Action	State/Province
ALS Inhibitors	Tennessee, Kansas, Arkansas, North Carolina, Florida, Georgia, South Carolina
Photosystem II Inhibitors	Texas, Kansas, Georgia
Dinitroanilines	South Carolina, Tennessee
Glyphosate	Tennessee, Georgia, Missouri, North Carolina, Alabama, Arkansas, New Mexico, Louisiana, Illinois, Michigan, Virginia, California
ALS Inhibitors + **Glyphosate**	Mississippi, Georgia, Tennessee

Herbicide options for pre-emergence and post-emergence control of glyphosate-resistant palmer amaranth in corn and pre-emergence control in soybean are similar to those for waterhemp. Herbicides containing a PPO-inhibitor such as lactofen, fomesafen, and acifluorfen will provide post-emergence control of glyphosate-resistant palmer amaranth in soybean (Holshouser et al. 2008). Several ALS-inhibitor herbicides are also labeled for control of palmer amaranth, but the prevalence of ALS-resistant populations limits their usefulness.

Preventing the Development of Herbicide Resistant Weeds

The Weed Science Society of America has outlined the following management guidelines for preventing weed resistance to herbicides:

- Scout fields prior to the application of any herbicide to determine the species and if economic levels justify an herbicide application.
- Use alternative weed management practices, such as mechanical cultivation, delayed planting and weed-free crop seeds.
- Rotate crops with an accompanying rotation of herbicides to avoid using herbicides with the same site of action on the same field.
- Limit the number of applications of a single herbicide or herbicides with the same site of action in a single growing season.
- Use mixtures or sequential treatments of the herbicides that each control the weeds in question, but have a different site of action.
- Scout fields after application to detect weed escapes or shifts. If a potentially resistant weed or weed population has been detected, use available control methods to avoid seed deposition in the field.
- Clean equipment before leaving fields suspected to have resistant weeds.

Herbicide Resistance Prevention

It is important to remember that herbicide resistance is a numbers game; the more plants that are exposed to a herbicide, the greater the likelihood of selecting a resistant individual which will then proliferate and result in a resistant population. Resistance to glyphosate in several weed species originated in continuous monoculture systems where glyphosate was a primary weed management tool every year. Management practices such as crop rotation and herbicide rotation can reduce the selection pressure exerted by a given herbicide and prolong its usefulness.

Sources

Anonymous. 2008. Recommendations for Management of Glyphosate-Resistant Waterhemp in Illinois Soybean. Univ. of Illinois Extension. http://weeds.cropsci.illinois.edu/extension/factsheets/whempsoy.pdf

Bradley, K. 2009. Resistance Run Amok. Integrated Pest & Crop Management. Vol. 19, No. 16. Univ. of Missouri. http://ppp.missouri.edu/newsletters/ipcm/archives/v19n16/a1.pdf

Bradley, K., R. Smeda, and R. Massey. 2008. Management of Glyphosate-Resistant Waterhemp in Corn and Soybean. IPM 1030. Univ. of Missouri Extension. http://extension.missouri.edu/publications/DisplayPub.aspx?P=IPM1030

Hager, A., and C. Sprague. 2001. Waterhemp—Biology, Identification, and Management Considerations. The Bulletin. Univ. of Illinois Extension. http://ipm.illinois.edu/bulletin/pastpest/articles/200105l.html

Heap, I. The International Survey of Herbicide Resistant Weeds. October 12, 2012. http://ww.weedscience.com

Holshouser, D., H. Wilson, and S. Hagood. 2008. Prevention and Control of Palmer Amaranth in Soybean. Virginia Cooperative Extension. http://pubs.ext.vt.edu/2808/2808-1006/2808-1006.pdf

Steckel, L. 2004. Pigweeds in Tennessee. W068. Univ. of Tennessee Extension. http://www.utextension.utk.edu/publications/wfiles/W068.pdf