The Glyphosate, Weeds, and Crops Series

Biology and Management of Waterhemp

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Biology and Management of Waterhemp

Waterhemp is one of the most common weeds with which Midwest farmers must contend. A number of factors — reduced tillage systems, herbicide-resistant biotypes, and simplified weed management systems — contributed to the rise of waterhemp problems in the late 1980s and early 1990s. The 1996 introduction of Roundup Ready® soybean helped many farmers regain control of waterhemp; however, this weed possesses many traits that continue to make it a formidable foe in any management system.

This publication first will provide an overview of the biological characteristics that make waterhemp difficult to manage in agronomic crops. Second, it will provide management strategies to help growers better manage this weed and slow the selection of glyphosate-resistant biotypes.

Identification

Waterhemp is most common in the Midwest, but is found from Texas to Maine. As the name implies, waterhemp thrives in wet areas of fields, but is adapted to a variety of conditions. Previously, two waterhemp species were recognized: tall waterhemp (*Amaranthus tuberculatus*) and common waterhemp (*Amaranthus rudis*), which are both native to the Midwest. However, due to the high degree of genetic similarity and frequent hybridization between the two waterhemps, many botanists now group them into one "waterhemp" species, *Amaranthus tuberculatus* (Pratt and Clark 2001).

Waterhemp is a member of the pigweed (or Amaranth) family, which includes crops (grain amaranths) as well as several weedy species including Palmer amaranth, redroot pigweed, and smooth pigweed. Distinguishing the different pigweed species from one another is challenging, especially in the seedling stages.

However, there are a few key differences:

- Waterhemp cotyledons are often more egg-shaped than the long, linear cotyledons of other pigweed species (Figure 1).
- Waterhemp's first true leaves are generally longer and more lance-shaped than other pigweeds.
- Waterhemp seedlings are hairless with waxy- or glossy-looking leaves.
- Waterhemp and Palmer amaranth stems are hairless, whereas other pigweeds have hairy stems.

Figure 1. *(Clockwise from top left) Seedlings of waterhemp, Palmer amaranth, redroot pigweed, and smooth pigweed.*

As waterhemp matures, it becomes easier to distinguish from the other pigweeds.

Waterhemp can range from 4 inches to 12 feet tall, but generally grows to about 4 or 5 feet in most agronomic settings. Mature plant leaves are elongated, lance-shaped, and often appear waxy or glossy. Stem and leaf color tend to be shades of green, but within a population, some plants often have distinctly red stems or leaves.

Waterhemp is dioecious, meaning that its male and female flowers are on separate plants. The simplest way to distinguish between male and female plants is to rub the mature flowers between your fingers and look for the shiny, black seeds found only on female plants.

Palmer amaranth also is dioecious; whereas redroot and smooth pigweeds are monoecious (that is, the same plant has male and female flowers). Redroot and smooth pigweeds have denser, more compact seedheads than waterhemp, and Palmer amaranth has long, mostly unbranched, prickly seedheads (Figure 2).

Figure 2. *(Clockwise from top left) The seedheads of male waterhemp, female waterhemp, redroot pigweed, and smooth pigweed.*

Emergence Pattern

Waterhemp plants emerge throughout the growing season, and a higher percentage of plants emerge later in the season than most other summer annual weeds (Figure 3). These discontinuous emergence patterns can make waterhemp control a challenge. Later-emerging waterhemp usually does not affect crop yields; however, seed from uncontrolled plants can contribute a significant amount of seed to the soil seedbank.

Like most weeds, waterhemp seeds remain viable in the soil for several years. Under controlled seed bank studies, Buhler and Hartzler (2001) found that 12% of the waterhemp seed still persisted after 4 years of burial. Steckel et al. (2007) reported 10% survival after 3 years and a rapid decline to less than 1% after 4 years.

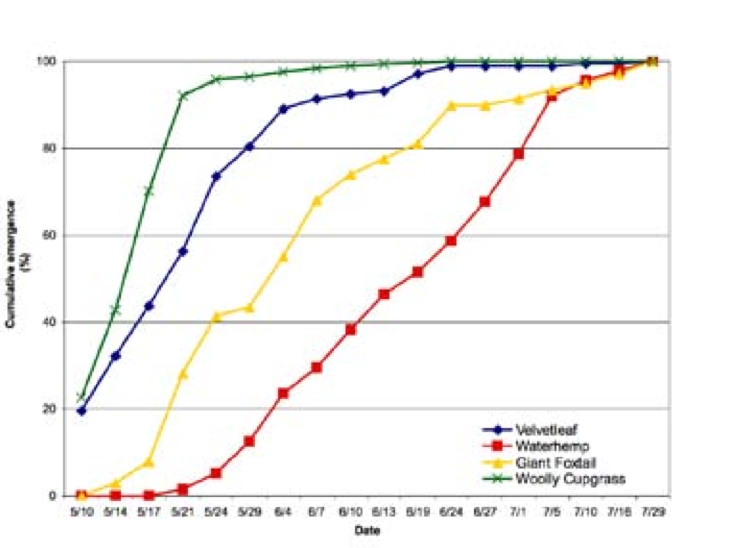

Figure 3. *Emergence of four annual weed species. Adapted from Hartzler et al., 1999.*

Growth, Development, and Seed Production

Waterhemp plants compensate for small seed size by having higher relative growth rates than most weeds or crops — based on research by Siebert and Pearce (1993) and Horak and Loughin (2000). That rate can be almost 1 inch per day during the growing season.

Without competition, waterhemp plants may produce more than 1 million seeds per plant. Such seed production is much greater than with most other weeds. One study found that waterhemp produced more than 1.5 times more seed than other pigweed species of the same size (Sellers et al., 2003). A crop canopy places waterhemp at a competitive disadvantage by reducing waterhemp biomass and seed production, and increasing seedling mortality compared to plants growing in sunlight (Hartzler et al., 2004; Horak and Loughlin, 2000; Nordby and Hartzler, 2004; Steckel and Sprague, 2004).

Waterhemp that emerges after crop establishment produces significantly less seed than plants emerging with the crop, but these late-emerging plants still can sustain or increase the number of waterhemp seed in the soil.

Interference and Competition

Although several summer annual weeds are more competitive on a plant-for-plant basis, waterhemp gains a competitive advantage through the sheer number of plants infesting an area (Figure 4). Seasonlong competition by waterhemp (more than 20 plants per square foot) reduced soybean yields 44% in 30-inch rows and 37% in 7.5-inch rows (Steckel and Sprague, 2004b). Waterhemp that emerged as late as the V5 soybean growth stage reduced yields up to 10%.

Figure 4. *Waterhemp gains a competitive advantage over other plants because of high densities.*

Waterhemp can have a similar effect on corn yields. Early-season competition from a heavy waterhemp infestation (more than 30 plants per square foot) reduced corn yields 15% by the time the waterhemp was 6 inches tall. With lower waterhemp densities (less than 10 plants per square foot), yields were reduced by only 1% when waterhemp was controlled at 6 inches (Cordes et al., 2004).

Reasons for Increased Prevalence

Factors that have likely contributed to waterhemp's increased prevalance include:

- Changes in agronomic and weed management practices during the past 20 to 30 years, including reduced tillage and less use of residual herbicides.
- Diversity within the waterhemp population.

Changing Production Practices

Waterhemp produces small seed that can emerge only from shallow depths. Thus, increased no-tillage and reduced tillage practices favor waterhemp since most of the seed remains near the soil surface in these systems. Reduced between-row cultivation also favors waterhemp since this practice controlled many late-emerging plants.

Herbicide programs also have changed. In the 1970s and early 1980s, farmers relied primarily on soil-applied herbicides with long residual activity. The late 1980s and 1990s brought widespread use of ALS-inhibiting herbicides — followed by the development of ALS-resistant waterhemp. Today, weed management systems heavily rely on postemergence herbicides with little or no residual activity. The epitome of this change is the total postemergence glyphosate programs used in Roundup Ready® crops.

Genetic Diversity and Resistance

Because waterhemp is dioecious, two plants always mix genes when the plant reproduces. This increases a given population's genetic diversity and increases the potential for spreading herbicide resistance and other traits that favor survival in agronomic systems.

Pollen movement can transfer herbicide resistance traits across long distances, allowing resistance to quickly jump fences and beyond. Based on the relative sizes of corn and waterhemp pollen and their release heights, waterhemp pollen could travel a half mile or farther from the host plant under windy conditions (Costea et al., 2005).

Currently, waterhemp populations resistant to ALS-inhibitors, triazines, diphenylethers (PPO-inhibitors), and glyphosate have been identified.

ALS-inhibiting herbicides (Pursuit®, Accent®, and many others) were introduced in the mid-1980s and widely used in corn and soybean. After only a few years of use, ALS-resistant waterhemp biotypes were reported throughout the Midwest. This problem grew to such an extent that these herbicides are considered obsolete for waterhemp control.

Prior to the introduction of Roundup Ready® soybean, the primary alternative to ALS-inhibiting herbicides for postemergence waterhemp control in soybean were PPO-inhibiting herbicides (Reflex®, Ultra Blazer®, Cobra®, and others). At present, PPO-resistant waterhemp populations are limited but have been found in several states.

Glyphosate-resistant waterhemp populations have been identified in Missouri in fields where Roundup Ready® soybean had been grown continuously for as many as 7 or 8 years and glyphosate was used exclusively. In most of these fields, there were at least two glyphosate applications per growing season. Such cropping and herbicide-use histories placed tremendous selection pressure on waterhemp and other weeds, increasing the likelihood of selecting glyphosate-resistant weeds.

Waterhemp was among the first U.S. weeds identified with multiple herbicide resistance. In 1998, a waterhemp population was confirmed resistant to ALS and PSII-inhibiting herbicides (atrazine, etc.). More recently, waterhemp garnered the distinction of being the first U.S. weed to develop three-way multiple resistance — these combinations include resistance to ALS-, PSII-, and PPO-inhibiting herbicides; and glyphosate, ALS-, and PPO-inhibiting herbicides (Figure 5).

Figure 5. *The waterhemp plants shown here developed three-way multiple herbicide resistance — to glyphosate, ALS-, and PPO-inhibitors.*

Control

Timely scouting, proper herbicide application timing, and using herbicides with multiple modes-of-action are key components of a successful waterhemp management program. In addition, cultural practices that enhance the competitiveness of the crop (row spacing, planting rate, etc.) will improve the consistency of herbicide programs.

Research has shown that management programs that use soil-applied herbicides followed by postemergence herbicides have less variability in weed control, crop yield, and net return compared with total postemergence programs.

It is important to account for any herbicide-resistant waterhemp biotypes that are present in the target field. Almost all waterhemp populations are resistant to ALS-inhibiting herbicides, so growers should not rely on this class of herbicides for waterhemp control. Waterhemp populations resistant to other herbicide classes are relatively uncommon at this time, so most farmers will be able to rely on triazine and PPO-inhibiting herbicides and glyphosate in their management systems. However, growers should closely monitor the performance of all products to stay abreast of any changes in the sensitivity of specific populations in all fields.

Field Corn

Under ideal conditions, preemergence programs may provide full-season waterhemp control. This will require applying a combination of products at full-label rates to extend control until the crop canopy fully develops. At that point, the crop should be able to shade out most waterhemp. Combining preemergence herbicides with postemergence herbicides or cultivation will often provide more consistent weed control and protect crop yields better than one-pass preemergence or total-postemergence programs.

A large number of preemergence herbicides have good activity on waterhemp, including the chloroacetamide herbicides (metolachlor, acetochlor, etc.), atrazine, Callisto®, and Balance Pro® (Table 1). Many of these herbicides are combined in packaged mixes that provide broader spectrum and more consistent control.

Application timing is critical to achieve the desired control with postemergence herbicides. Generally, waterhemp tolerance to postemergence herbicides increases with plant height and product labels often specify the maximum plant height at application for acceptable control.

Soybean

Growers may use soil-applied herbicides, cultivation, postemergence herbicides, or a combination of these tactics to control waterhemp in soybean (Table 2).

Glyphosate is the primary herbicide used to control waterhemp in glyphosate-resistant soybean and provides excellent control in most situations. Two postemergence applications typically are required to achieve full-season control and protect yields. Using soil-applied herbicides in glyphosate-resistant soybean will often improve the consistency of control and reduce early-season weed competition that can lead to crop yield loss. This practice also introduces an herbicide with an alternative mode of action, reducing the selection pressure for glyphosate-resistant waterhemp.

Table 1. *Waterhemp response to herbicides in corn.*

Herbicide[1]	Active ingredient(s)	Crop Response[2]	Waterhemp response[3]
Preplant Incorporated or Preemergence			
Prowl®/others	pendimethalin	0	8
Preemergence			
atrazine	atrazine	0	8
Balance Pro® (*Radius*®)	isoxaflutole	2	9
Callisto® (*Camix*®, *Lexar*®, *Lumax*®)	mesotrione	1	9
Dual II Magnum®[4]	*S*-metolachlor	1	8
Harness®/Degree®/ Surpass®/TopNotch®[4]	acetochlor	1+	8+
Micro-Tech®[4]	alachlor	1+	8
Outlook®	dimethenamid	1	8
Princep®	simazine	0	7
Postemergence			
Aim®	carfentrazone	2+	8
atrazine	atrazine	0	9
Banvel®/Clarity®/ Status® (*Marksman*®, *Celebrity Plus*®, *NorthStar*®, *Yukon*®)	dicamba	1+	8
Buctril® + atrazine	bromoxynil + atrazine	2	8
Callisto®	mesotrione	1	9
Celebrity Plus®	nicosulfuron + diflufenzopyr + dicamba	1+	8
Impact®	topramezone	1	9
Liberty-Link® Corn			
Liberty® (*Liberty*® + *atrazine*)	glufosinate	0	8
Roundup Ready® Corn			
Roundup®/others	glyphosate	0	9

[1] ***Products in italics are premixes that include the primary product.***

[2] ***Crop Response:***
0 = no response
1-2 = some injury possible, but not enough to affect yield
3 = injury is probable, yield may be affected

[3] ***Waterhemp Response:***
8-10-good
6-7=fair (partial control/suppression)

[4] ***These products are available in packaged mixes with atrazine, refer to label.***
Product performance may vary due to weather and other factors.

Table 2. *Waterhemp response to herbicides in soybeans.*

Herbicide	Active ingredient(s)	Crop response[1]	Waterhemp response[2]
Preplant Incorporated			
Sonalan®	ethalfluralin	1	8
Treflan®	trifluralin	0	8
Preplant Incorporated or Preemergence			
Authority First®/ Sonic®	sulfentrazone + cloransulam	2	9
Dual II Magnum®	*S*-metolachlor	0	8
IntRRo®/ Micro-Tech®	alachlor	1	8
Outlook®	dimethenamid-P	0	8
Prefix®	*S*-metolachlor + fomesafen	1	8
Prowl®/others	pendimethalin	0	8
Sencor®	metribuzin	2	8
Preemergence			
Gangster®	flumioxazin + cloransulam	2	8
Lorox®/Linex®	linuron	1	7
Valor®/Valor XLT®	flumioxazin	2	9
Postemergence			
Aim®	carfentrazone	2+	6
Blazer®	acifluorfen	1	7
Cobra®	lactofen	2	8
Reflex®/Flexstar®	fomesafen	1	8
Resource®	flumiclorac	1	6
Roundup Ready® Soybean			
Roundup®/others	glyphosate	0	9

[1] ***Crop Response:***
0 = no response
1-2 = some injury possible, but not enough to affect yield

[2] ***Waterhemp Response:***
8-10-good
6-7=fair (partial control/suppression)
less than 6=poor

Product performance may vary due to weather and other factors.

Conclusions

Waterhemp is a genetically diverse weed that has proven to be very responsive to current weed management practices. Therefore, waterhemp is not likely to go away in the near future. For serious waterhemp infestations, diversifying weed management practices can, over a period of 3 or 4 years, deplete the weed seedbank density. These practices include: promoting rapid crop canopy development, using soil-applied herbicides, using cultivation practices, and using postemergence herbicides. Although waterhemp will not go away, developing integrated management systems will result in economically viable weed management strategies.

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