Palmer amaranth: ID, biology and management

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Palmer amaranth is native to the Southwestern United States, but its range has expanded over the past 50 years. The first documented occurrence in Iowa was this year, although with these infestations it is clear that the weed was initially introduced to the state prior to 2013. It has been a serious problem in the south, and gained national notoriety after developing resistance to glyphosate and devastating the cotton industry in the Southeast. This paper will review why the weed has garnered such attention and access the threat it poses to Iowa.

Identification

Our heavy reliance on glyphosate has led to complacency in weed identification. However, the ability to identify Palmer amaranth is critical since Iowa is at the initial stages of invasion (Figure 1). The best way to minimize the impact of Palmer amaranth is to identify new infestations quickly and initiate steps to prevent its establishment and spread.

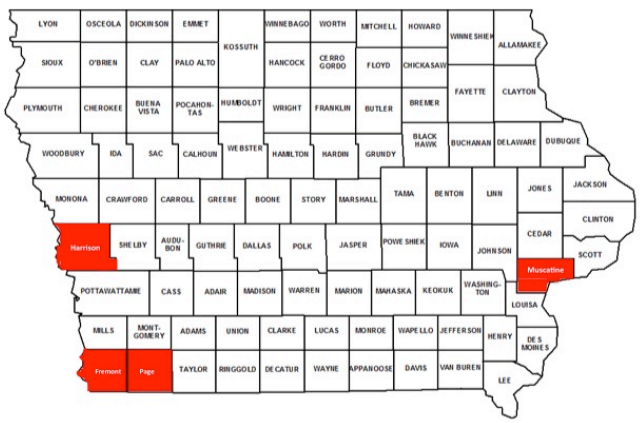

Figure 1. Known infestations of Palmer amaranth (Nov. 2013).

Palmer amaranth is one of several weedy pigweed (*Amaranthus)* species found across Iowa. Prior to the 1980's redroot pigweed and smooth pigweed were our most common pigweed species, but since the late 1980's, waterhemp has been our number one pigweed. Less common weedy pigweeds of Iowa fields include Powell amaranth and spiny pigweed. At casual glance there are many similarities among the weedy pigweeds, but knowledge of what specifically to look for simplifies differentiating Palmer amaranth from the other pigweeds.

Upon encountering an unknown pigweed, the first trait to look for is hairs on the stem. Redroot pigweed, smooth pigweed and Powell amaranth have hairy (pubescent) stems; the hairs are most prominent on young branches. Palmer amaranth, waterhemp and spiny amaranth have hairless (glabrous) stems. Spiny amaranth can be differentiated from Palmer amaranth and waterhemp due to the presence of sharp spines at the point where leaves attach to the stem. These spines are up to ½ inch in length.

This leaves Palmer amaranth and waterhemp, and until the plants are flowering, it can be difficult to differentiate the two species. With experience it may be possible to differentiate vegetative Palmer amaranth and waterhemp, but the diversity within both species makes this difficult. Vegetative traits used to differentiate the two species are listed in Table 1. Keep in mind that that there are significant overlaps in these traits among individual plants of the two species.

Table 1. Vegetative characteristics of Palmer amaranth (PA) and waterhemp (WH).

Leaf shape	WH leaves tend to be long and narrow, whereas PA leaves are wider and ovate to diamond shaped.
Leaf petiole	Petioles on PA leaves are often longer than the leaf blade.
Leaf watermark	Some PA plants have a silverish watermark on the leaves, but this trait occasionally is found on WH.
Canopy shape	PA tend to have a relatively dense canopy compared to the open canopy of WH. PA often have a tight cluster of leaves that has been compared to a poinsettia at the apical meristem.
Leaf tip hair	A hair on the tip of PA leaves has been promoted as a reliable trait, but this hair is often present on WH.
Seedlings	The cotyledon stage of all of the *Amaranthus* species are difficult, if not impossible, to distinguish from each other.

It is much easier to distinguish Palmer amaranth from waterhemp once the plants have initiated flowering. Both species are dioecious, having separate male and female plants. Female plants can be easily identified by rubbing the inflorescences (seedheads) and looking for the presence of small, black seed. As with vegetative traits, the inflorescences of both species are highly variable. Palmer amaranth inflorescences tend to be thicker (up to 1" in diameter) than those of waterhemp (Figure 2), and terminal branches of Palmer amaranth are long, sometimes exceeding three feet in length. Male waterhemp plants sometimes have thick inflorescences that may be mistaken for Palmer amaranth.

Figure 2. Inflorescences of female Palmer amaranth (L) and waterhemp (R).

The flowers of the two species provide the most reliable way of differentiating Palmer amaranth and waterhemp. Many weeds, including the pigweeds, have very small flowers that are difficult for novices to find the flower parts used to identify a species. Fortunately, the flower parts used to separate Palmer amaranth from waterhemp are easy to locate and sufficiently different to eliminate subjectivity. There are differences in the male and female flowers of the species; female plants are easier to differentiate. Female flowers of pigweeds have three major components – bracts, tepals and the seed capsule. Bracts are modified leaves found at the base of flowers. Tepal is a term used to describe flower petals when the petals and sepals of the flower are indistinguishable. The seed capsule contains the seed. Male flowers have bracts, tepals and anthers (male component that produce pollen). The anthers are relatively short-lived and fall from the male flowers when completed shedding pollen.

The distinguishing feature of Palmer amaranth is the large bract on female flowers (Figure 3). The bracts are green, up to ¼ inch in length, and extend well beyond the tepals and seed capsule. As the bracts mature they become sharp and make the seedheads painful to handle. There are five translucent tepals that surround the seed capsule, each with a dark green midrib. The bract on female waterhemp plants is less than 1/8 inch in length and there is one or no tepals. The seed capsule in waterhemp flowers extends beyond the bract and petal. While the flowers of Palmer amaranth are much larger than those of waterhemp, the seeds are only slightly larger.


Figure 3. Female flowers of Palmer amaranth (L) and waterhemp (R).

Male Palmer amaranth flowers have five tepals that are nearly as long as the bract, the bract is slightly shorter than those on females. Male waterhemp flowers have five tepals that extend well beyond the bract.

The bracts on redroot pigweed, smooth pigweed and Powell amaranth are as long as those on Palmer amaranth. These bracts also become sharp as they mature, but are not as sharp as those of Palmer amaranth. There are two simple ways to distinguish redroot, smooth pigweed and Powell amaranth from Palmer amaranth. First, these three species are monoecious, meaning that all plants will produce seed. Second, and most important, the hairy stems of these monoecious species easily distinguishes them from Palmer amaranth.

Biology

Like most weeds of our cropping system, Palmer amaranth is an annual that initiates growth each spring from seed present in the seedbank (Figure 4). Understanding factors that influence the fate of the weed at different phases of the life cycle is the key to developing successful weed management strategies.

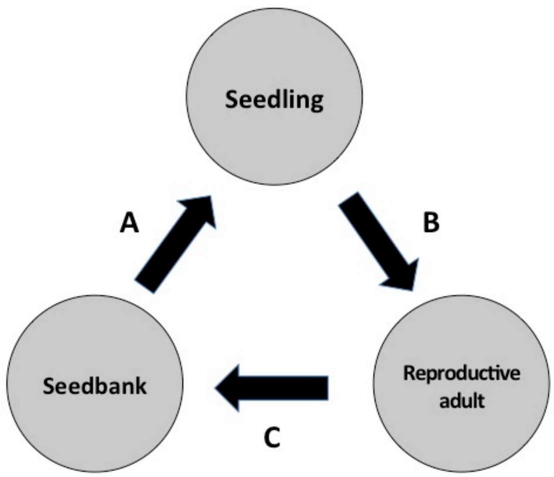

Figure 4. Stages of the annual life cycle.

Seedbank (A)

Seeds of Palmer amaranth possess dormancy and are relatively persistent in the seedbank. Once the weed gets established in a field management becomes a long-term problem. Scientists in Georgia reported the persistence of Palmer amaranth seed was directly related to depth of burial (Table 2) (Sosnoskie et al. 2013). Twelve percent of seed remained viable three years after burial at a one inch depth. The longevity of Palmer amaranth seed in Georgia was slightly less than waterhemp seed in Iowa. After 3 and 4 years of burial in the upper 2 inches of soil, viability of waterhemp seed was 28 and 12%, respectably (Buhler and Hartzler, 2001). The differences in persistence could be due to inherent differences between the two species, or differences in environment and soils of the two states. The shorter growing season in Iowa likely enhances seed persistence.

Table 2. Viability of Palmer amaranth seed at different burial depths.

Months after burial	Burial depth (inches)		
	0.4	1.0	4.0
	% Viable		
0	96	96	96
12	44	48	53
36	9	12	15

Emergence patterns of weeds strongly influence the types of problems they present. Researchers in Kansas (Guo and Al-Khatib, 2003) evaluated the influence of fluctuating soil temperature on germination of Palmer amaranth, waterhemp and redroot pigweed. Palmer amaranth and redroot pigweed had higher optimum temperature for emergence than did waterhemp. In California field studies, Palmer amaranth emergence was observed at average soil temperatures as low as 65 F, but emergence rates were much higher and rapid at higher temperatures. At optimum soil temperatures, emergence of Palmer amaranth was much more rapid than that of waterhemp (Steckel et al. 2004). Like waterhemp, Palmer amaranth emerges throughout the growing season, complicating weed management. Observations at the current Iowa infestations suggest that there is more Palmer amaranth emergence late in the season than occurs with waterhemp. This can be both advantageous and detrimental for a weed since late-emerging weeds often escape early season control tactics, but very late-emerging plants are not competitive with the crop and may not be successful at producing seed.

Growth and competitiveness (B)

Palmer amaranth has gained recognition for two reasons: 1) its propensity for herbicide resistance, and 2) its rapid growth and competiveness. There is no evidence suggesting that it is any more adept at evolving herbicide resistance than waterhemp; however, it is clear that uncontrolled Palmer amaranth is more damaging to crop yields than other weedy pigweeds due to differences in growth habits (Table 3) (Horak and Loughin, 2000; Bensch et al. 2003).

Table 3. Growth analysis of three weedy *Amaranthus* species.

	Growth rate (Height)	Relative growth rate	End of season biomass	Soybean yield loss (8 plants/m row)
	cm/GDD	g/g/day	g/plant	%
P. amaranth	0.20	0.32	115	79
Waterhemp	0.14	0.31	55	56
RR pigweed	0.10	0.30	40	38

One frequently cited characteristic of Palmer amaranth is its rapid growth rate, with reports of plants growing more than three inches in a single day. In Kansas State University research Palmer amaranth height increased at twice the rate as redroot pigweed and more than 42% faster than waterhemp. This rapid growth results in a narrower application window for postemergence herbicide applications, one of the factors complicating Palmer amaranth management. It is important to keep this rapid growth rate in perspective – seedling Palmer amaranth do not grow three inches in a day. These rapid growth rates occur when the plants are already at least four or five inches in height, well after the optimum application window for postemergence herbicides.

Palmer amaranth had a higher relative growth rate than the other pigweed species, and accumulated more than twice the biomass (Table 3). The greater growth rate of Palmer amaranth is largely due to how it allocates resources compared to the other species. Palmer amaranth puts more dry matter into leaves than the other species, resulting in a higher photosynthetic capacity. The dense canopy architecture of Palmer amaranth that facilitates its rapid growth is easily visible in many individual plants. The rapid growth and large biomass of

Palmer amaranth make it much more damaging to crop yields than waterhemp or redroot pigweed. Palmer amaranth that emerged within a week of soybean planting reduced yields by 79% compared to 56% for waterhemp (Table 3). In this research, Palmer amaranth that emerged 3 to 4 weeks after soybean planting did not impact yields. While late-emerging plants may not impact yields, they do contribute seed to the seedbank.

Seed production (C)
A primary weedy trait of pigweed species is prolific seed production. In Iowa, a single waterhemp plant can produce over 2 million seeds. This is accomplished by producing small seed. Since plants have a limited supply of resources, the smaller the seed the more seeds that can be produced. While seedlings of small seeded species are more vulnerable to stresses (e.g. tillage, herbicides) than those of large seeded species (e.g. velvetleaf, cocklebur), their high numbers increase the probability that some individuals will survive.

While Palmer amaranth produces more biomass per individual plant, researchers in Missouri reported no difference in the number of seed produced by individual waterhemp and Palmer amaranth plants (Sellers et al. 2003). Waterhemp overcame the lower biomass compared to Palmer amaranth by converting a higher percentage of biomass to seed and producing slightly smaller seeds.

Palmer amaranth management
If there is a bright side to the threat posed by Palmer amaranth, it is that everyone involved in weed management in Iowa should be experienced at managing waterhemp. The basic tactics used to control waterhemp also are effective against Palmer amaranth. The primary differences when managing these two species are 1) the rapid growth rate of Palmer amaranth creates narrower application windows for postemergence control tactics, and 2) control failures with Palmer amaranth carry a much larger yield penalty.

Both Palmer amaranth and waterhemp are prone to evolving herbicide resistance when herbicides are used in ways that result in significant selection pressure (Table 4). A Palmer amaranth population in Kansas was recently documented to be resistant to three Herbicide Groups: 3, 5 and 27. The resistance profiles of the Palmer amaranth biotypes present in Iowa are unknown at this time. As selection pressure from herbicides continues, more types and combinations of multiple herbicide resistant populations will evolve.

Table 4. Documented herbicide resistances in Palmer amaranth and waterhemp.

Herbicide		Palmer amaranth	Waterhemp
Group Number	Examples		
2	Classic, Pursuit	x	x
3	Treflan, Prowl	x	
4	2,4-D; dicamba		x
5	atrazine	x	x
9	glyphosate	x	x
14	Valor, Reflex		x

27	Callisto, Laudis	**x**	**x**

Steps for effective Palmer amaranth management

1) Prevention. It is unlikely that Palmer amaranth will be stopped from spreading in Iowa; however, the rate that it moves into new fields can be limited. This requires improved weed identification skills and better scouting. When new infestations are identified steps should be implemented to prevent seed production (e.g. hand weeding, etc.) and limit movement of seed from infested areas to clean fields. Control Palmer amaranth growing in fencelines, roadsides and other crop areas. At current Iowa infestations there was more Palmer amaranth present in non-crop areas than in the adjacent crop fields. Combines are the most efficient seed disseminator ever developed; whenever possible harvest infested fields last to limit spread of seed.

2) Start clean. Make sure all Palmer amaranth is killed before planting the crop. It is probably safe to assume that most Palmer amaranth found in Iowa will be resistant to glyphosate, so use alternative herbicides (e.g. 2,4-D; Liberty, etc.) in burndown applications for no-till fields. In tilled fields, ensure that the preplant tillage completely kills all established weeds.

3. Full rates of effective preemergence herbicides. Due to the rapid growth rate of Palmer amaranth, effective preemergence herbicides are essential to effective management. Herbicide Group 3 (dinitroanilines), 5 (triazines), 15 (amides) and 27 (HPPD inhibitors) herbicides provide the crop a head start on Palmer amaranth. This allows postemergence herbicides to be applied later in the season when the crop canopy will be able to reduce weed establishment following the application.

4) Timely postemergence applications. Timing is everything. Applying postemergence herbicides to too large of waterhemp is probably the number one cause of control failures of this weed. Due to the rapid growth of Palmer amaranth, this is an even greater problem with Palmer amaranth. Applications should be targeted for weeds that are less than three inches in height.

5) Include residual herbicides with postemergence applications. The prolonged emergence pattern of Palmer amaranth allows significant establishment of plants after postemergence applications. While these late-emerging weeds may not impact yields, they increase the size of the seedbank. Several residual herbicides are registered for postemergence use in corn and soybean and provide an effective management option for late-emerging Palmer amaranth.

6) Use a diversity of herbicide groups. Relying on a single herbicide program repeatedly will result in rapid selection of new herbicide resistant biotypes. Use multiple herbicide groups that are effective against pigweed species and rotate groups over time.

7) Use cultural and mechanical practices. Relying only on herbicides, regardless of how well they are managed, will eventually result in the selection of resistant biotypes. Consider all practices that enhance the competitiveness of the crop (row spacing, planting population, planting date, etc.) and use mechanical practices where feasible.

Summary

It is unclear how big an impact Palmer amaranth will have in Iowa, but we know it is a formidable foe and the threat should be taken seriously. The impact of Palmer amaranth on the cotton industry is well documented, but there is no reason why the weed should cause such damage here due to our inherent advantages. A greater diversity of herbicides is available for use in corn and soybean than for cotton. By taking advantage of this broader selection the speed that weeds adapt to herbicides is reduced. In addition, Iowa has some of the most productive soils in the world. Good soils provide a highly competitive crop that greatly enhances the effectiveness of all control tactics. It is interesting that all but one of the current Palmer amaranth infestations in Iowa are located on sands or other atypical soils for Iowa. This suggests that perhaps Palmer amaranth is not yet well adapted to competing on our more productive soils. Increasing vigilance to identify new infestations, taking appropriate actions to minimize the establishment and spread of these infestations, and implementing diversified weed management programs will minimize the impact that Palmer amaranth has on corn and soybean production in Iowa.

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