Palmer amaranth: It's here, now what?

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Palmer amaranth and waterhemp are two dioecious pigweed species native to North America. Waterhemp's original range was the western Corn Belt, including Iowa, whereas Palmer amaranth originally inhabited the southwestern United States. Palmer amaranth began to spread to the southeastern United States early in the 20th century but was not listed among the most troublesome weeds of the Southeast until the late 1980s. Interestingly, this is the same time frame that waterhemp emerged as a serious management issue in Iowa and surrounding states. This paper will review the history of Palmer amaranth in Iowa, factors that contribute to its weediness, and management considerations.

History in Iowa

The first report of Palmer amaranth in Iowa was in Harrison County in August 2013. The infested field had been in fallow for several years and used to spread sludge from a fermentation plant in Nebraska. It is believed the Palmer amaranth was introduced on vehicles used for sludge transport. Based on the heavy infestation in this and adjacent areas we concluded the Palmer amaranth must have been present at this location for at least two or three years prior to discovery.

The second report of Palmer amaranth was in September 2013 in Muscatine County. The weed was found on a farm near swine facilities and it is believed the Palmer amaranth may have been introduced in feed or transport of materials used in the swine operation. In October of 2013 Palmer amaranth was found in Page and Fremont counties. These sites were adjacent to commercial grain storage facilities. Palmer amaranth was found at two separate locations in Lee County in 2014, one site was involved in corn and soybean seed production, while the other was a dairy farm that imported cotton seed for feed.

We entered 2016 with Palmer amaranth infestations in the five counties described above, although we suspected it was present in additional counties. At the end of October 2016, Palmer amaranth had been confirmed in at least 46 counties, and again we believe it is present in many more counties (Figure 1). We were surprised by both the dramatic increase in Palmer amaranth infestations in Iowa and the primary means of introduction. Six of the 2016 discoveries were associated with traditional agricultural practices; several of the new infestations were located on dairy or cattle operations that imported feed or bedding from southern states, one site was in an area where farming equipment used in regions with known Palmer amaranth infestations was stored. By far, the most important source of Palmer amaranth was the planting of native seed mixes used for conservation plantings that were contaminated with Palmer amaranth seed.

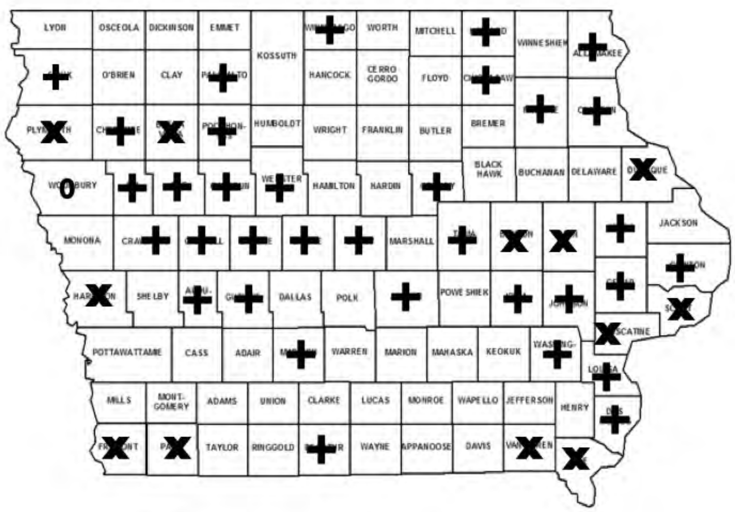

Figure 1. Counties with confirmed Palmer amaranth infestations, Oct. 2016. 'X' indicates first detection via conventional agricultural practices, '+' indicates first detection via conservation planting. Several counties are known to have both means of introduction. Woodbury County infestation was found on a railroad siding.

Palmer amaranth in conservation plantings

In 2016 there was a tremendous increase in planting of native seed mixes across Iowa due to government programs like the Conservation Reserve Program (CRP). Pollinator habitat (CP 42) was one of the more popular programs due to cost share for establishment, signing incentives, and annual rental payments competitive with cash rent rates. Other programs such as wildlife food plots, native grass and forb plantings, and permanent wildlife habitat also encouraged planting of native seed mixes. In Iowa over 100,000 acres were planted with native seeds in 2016, and many counties had between 100 and 200 fields entered into these programs.

In mid-July, we received the first two reports of Palmer amaranth discoveries in new conservation plantings. One of these sites was wildlife habitat (CP33) whereas the other was pollinator habitat. Due to the expertise of the two landowners and the random distribution of Palmer amaranth within the fields, we were confident the Palmer amaranth was not present in the fields prior to establishment of the new conservation planting in the spring of 2016. Since publicizing the concern over Palmer amaranth infesting conservation plantings, Palmer amaranth has been found in conservation plantings in 35 counties across Iowa.

The primary means of introduction of Palmer amaranth in conservation plantings has been use of native seed mixes contaminated with Palmer amaranth seed. We have obtained samples of several of the seed mixes used in fields with Palmer amaranth infestations, isolated *Amaranthus* spp. seed in the seed mix, and confirmed the seed as Palmer amaranth.

We have visited the largest Iowa producer of native seeds, inspected their production fields, and were unable to find Palmer amaranth. The huge increase in demand for seed of native prairie plants in 2016 resulted in local seed producers being unable to meet this demand. Most Iowa producers purchased seed of several species from outside vendors. The producers believe that these imported seed were the source of the Palmer amaranth.

Introduction of Palmer amaranth via contaminated native seed has occurred in other states as well. Ohio documented contaminated seed native seed mixes as a problem in 2014; the native seed contaminated with Palmer amaranth was imported from Texas. Both Illinois and Minnesota identified new conservation plantings this summer where Palmer amaranth was introduced, but the number of new introductions in those states appear to be a fraction of that in Iowa during 2016.

Biology

Like most weeds of our cropping system, Palmer amaranth is an annual that initiates growth each spring from seed present in the seedbank. 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.

Seedbank

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. Sosnoskie et al. (2013) reported the persistence of Palmer amaranth seed in Georgia was directly related to depth of burial (Table 2). 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 three and four years of burial in the upper two 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.

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

Emergence patterns strongly influence the types of problems weeds 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 more 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. We have observed that Palmer amaranth seed germinates much more rapidly than waterhemp in the greenhouse, and Palmer amaranth has a much lower percentage of dormant seeds.

Growth and competitiveness

Palmer amaranth has gained recognition for two reasons: 1) its propensity for herbicide resistance, and 2) its rapid growth and competitiveness. 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, 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, 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 most 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 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

A primary weedy trait of pigweed species is prolific seed production. In Iowa, a single waterhemp plant can produce over two 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.

Threat to Iowa agriculture

The widespread introduction of Palmer amaranth during 2016 in conservation plantings was an unfortunate situation, and its long-term impact on the spread of Palmer amaranth in the state is uncertain. Palmer amaranth, like most annual weeds, is unlikely to persist in perennial plantings. However, during the initial years of establishment the Palmer amaranth in these fields will produce significant quantities of seed. Our concern is that some of these seed are likely to be transported outside of the conservation planting into nearby crop fields where the weed is better adapted for survival.

While the aggressive nature of Palmer amaranth is well documented, it is unlikely to overwhelm Iowa crop fields in a few years. The typical increase in area infested by a weed introduced into a new region is shown in Figure 2. The initial rate of spread is relatively slow for 20 to 30 years (lag phase), and then the weed spreads rapidly until it occupies nearly all suitable habitats. We feel it is safe to state that for most Iowa farmers, waterhemp will be their number one pigweed foe for at least the next decade.

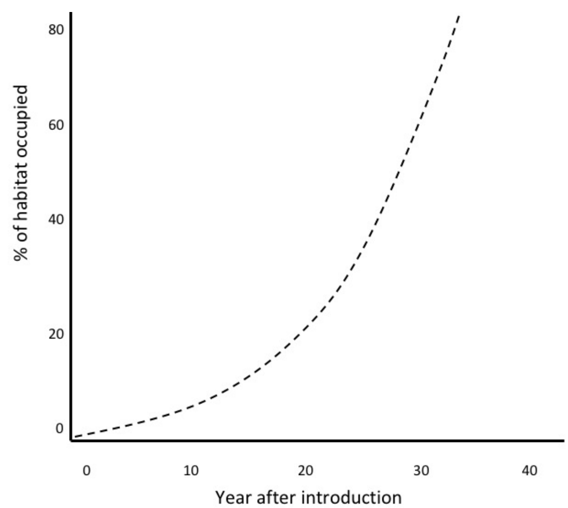

Figure 2. Increase in area infested by an invading weed. Adapted from Cousens and Mortimer, 1995.

Several factors are likely to limit the rate that Palmer amaranth initially spreads across the Iowa landscape. First, nearly all crop acres are treated with a herbicide program targeting waterhemp. This will make it difficult for the few Palmer amaranth seed that are introduced into crop fields to survive and produce new seed. Waterhemp is able to overcome these management programs since most fields have millions of waterhemp seed in their seed bank.

The second is based on our belief that Palmer amaranth is not yet adapted to Iowa's climate and soils. While there is no doubt that Palmer amaranth can survive in Iowa, observations of the first Iowa infested fields suggest it is 'not ready for prime time' in the state. Several of the fields where Palmer amaranth was first found have atypical soils for Iowa crop fields (e.g. sand, silty clay). We have casually followed the infestations in Harrison, Page and Fremont counties since 2013 by visiting the fields in early fall. While Palmer amaranth is still present in all fields, the populations in most fields have declined over time, and there is no evidence that it is spreading rapidly in the immediate area. We should state that there have not been any systematic scouting programs designed to detect the spread of Palmer amaranth in these areas.

The other observation that suggests it is not yet adapted to Iowa is the germination behavior of Palmer amaranth. One of the traits that makes waterhemp difficult to manage is a prolonged emergence pattern. Waterhemp typically begins emerging in early May and emergence continues until mid-July. Very few waterhemp seeds germinate after this time. When we have visited Palmer amaranth infested fields in September, there have always been significant numbers of newly emerged seedlings (assuming recent rains provided sufficient soil moisture). These seedlings are unlikely to complete their life cycle prior to the first frost, thus these very late emerging plants are depleting the seedbank rather than producing reproductive plants.

We are not suggesting agronomists be complacent about Palmer amaranth moving into Iowa. One trait of weeds is their ability to adapt, and Palmer amaranth is likely to acclimate to Iowa conditions over time. Rather than simply accepting the movement of Palmer amaranth into Iowa, we feel it is critical to take advantage of this 'grace period' and use every reasonable measure to prevent spreading the weed, and to eradicate new infestations before they establish a permanent seed bank.

Palmer amaranth identification

Early detection is the key to minimizing the impact of Palmer amaranth. It is difficult distinguishing Palmer amaranth and waterhemp when they are in the vegetative stage, but long petioles and dense clusters of leaves at ends of stems on Palmer amaranth are probably the most consistent vegetative traits. The large, sharp bracts on female Palmer amaranth plants are the simplest characteristic to differentiate the two species. Iowa State University Extension and Outreach developed a new handout to help identify Palmer amaranth. (see *Palmer amaranth identification* on page 83.)

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, a close relative of Palmer amaranth. The tactics used to control waterhemp 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 a manner that results in significant selection pressure (Table 4). Both species also rapidly accumulate multiple resistances. 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			
Group Number	Examples	Palmer amaranth	Waterhemp
2	Classic, Pursuit	X	X
3	Treflan, Prowl	X	
4	2,4-D; dicamba		X
5	atrazine	X	X
9	glyphosate	X	X
10	glufosinate		
14	Valor, Reflex	X	X
27	Callisto, Laudis	X	X

International Survey of Herbicide Resistant Weeds. www.weedscience.com

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 fence lines, roadsides and other crop areas. Combines are the most efficient seed disseminator ever developed; whenever possible harvest infested fields last to limit spread of seed.

The Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) are providing very little flexibility in managing Palmer amaranth in conservation plantings. Mowing and hand rogueing are the two options available, and experience with mowing in 2016 suggests it will not kill Palmer amaranth, but can reduce seed production. Taking steps to prevent seed movement from these fields is critical. Limit traffic in these fields, especially late in the season when seed is present on plants.

2) Start clean. Make sure all Palmer amaranth is killed before planting the crop.

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), 14 (PPO inhibitors), 15 (amides) and 27 (HPPD inhibitors) herbicides provide the crop a head start on Palmer amaranth. Full rates are important in order to extend control later in the season and reduce the potential for selecting resistant biotypes. This allows postemergence herbicides to be applied later in the season when the crop canopy may reduce weed establishment following the application.

4) Timely postemergence herbicide 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 than waterhemp. Applications should be targeted for weeds that are less than three inches in height.

5) Include residual herbicides with postemergence herbicide applications. The prolonged emergence pattern of Palmer amaranth allows significant establishment of plants after postemergence herbicide 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

Palmer amaranth is undoubtedly a permanent component of the Iowa flora. The key to minimizing the impact of this aggressive weed will be for everyone involved in production agriculture to learn how to differentiate Palmer amaranth from waterhemp and other pigweeds. Because of the ubiquitous presence of waterhemp across the Iowa landscape, it is easy to 'tune out' when encountering another *Amaranthus* infested field. Some Palmer amaranth plants are distinct enough in the reproductive stage to make long distance identification simple, but many plants require close up examination to confirm their identification.

New conservation plantings where Palmer amaranth was introduced during 2016 will serve as a source of Palmer amaranth seed production for several years. The time needed for the perennial vegetation to smother the Palmer amaranth will vary, depending primarily on the density and competitiveness of the native plants. Care must be taken to minimize moving seed out of these fields into crop fields where Palmer amaranth is better adapted to long-term survival.

Palmer amaranth will adapt to Iowa conditions over time. When it does, its presence in fields will result in farmers needing to adopt more aggressive management tactics or accept greater yield losses than they have incurred with waterhemp. Early detection and eradication is the mantra for managing invasive species of natural areas, it is time that agronomists adopt this strategy in order to minimize the cost associated with the introduction of Palmer amaranth to Iowa.

References

Bensch, C.N., M.J. Horak and D. Peterson. 2003. Interference of redroot pigweed (*Amaranthus retroflexus*), Palmer amaranth (*A. palmeri*), and common waterhemp (*A. rudis*) in soybean. Weed Sci. 51:37-43.

Buhler, D.D. and R.G. Hartzler. 2001. Emergence and persistence of seed of velvetleaf, common waterhemp, woolly cupgrass, and giant foxtail. Weed Sci. 49:230-235.

Cousens, R. and M. Mortimer. 1995. Dynamics of weed populations. University of Cambridge. 332 pp.

Guo, P. and K. Al-Khatib. 2003. Temperature effects on germination and growth of redroot pigweed (*Amaranthus retroflexus*), Palmer amaranth (*A. palmeri*), and common waterhemp (*A. rudis*). Weed Sci. 51:869-875.

Horak, M.J. and T.M. Loughin. 2000. Growth analysis of four *Amaranthus* species. Weed Sci. 48:347-355.

Keeley, P.E., C.H. Carter and R.J. Thullen. 1987. Influence of planting date on growth of Palmer amaranth (*Amaranthus palmeri*). Weed Sci.: 35: 199-204.

Sellers, B.A., R.J. Smeda, W. G. Johnson, J. A. Kendig and M.R. Ellesieck. 2003. Comparative growth of six *Amaranthus* species in Missouri. Weed Sci. 51:329-333.

Sosnoskie, L.M., T.M. Webster and S. Culpepper. 2013. Glyphosate resistance does not affect Palmer amaranth seedbank longevity. Weed Sci. 61:283-288.

Steckel, L.E., C.L. Sprague, E.W. Stoller and L.M. Wax. 2004. Temperature effects on germination of nine *Amaranthus* species. Weed Sci. 52:217-221.

Palmer amaranth identification

Recent Palmer amaranth (*Amaranthus palmeri*) discoveries in fields planted to native seed mixes (e.g. pollinator and wildlife habitat) have land owners on high alert. Newly-seeded fields should be scouted for Palmer amaranth and steps be taken to preferably eliminate the newly introduced weed, or at minimum reduce seed production.

Palmer amaranth is a serious concern due to its fast growth, high competitiveness, prolific seed production, and resistance to multiple herbicides. Currently, Palmer amaranth has a very limited distribution across Iowa. Seed production within fields planted to conservation plantings may provide this weed an opportunity to move into Iowa crop fields.

Palmer amaranth inflorescences: female (L); male (R). The large, sharp bracts on female plants are the definitive trait to tell Palmer amaranth apart from waterhemp.

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Palmer amaranth is closely related to waterhemp (*Amaranthus tuberculatus*); to the untrained eye the two species look very similar. Fields in which Palmer amaranth has been introduced are likely to contain both species. The following traits can distinguish these two species, and other weedy pigweeds.

1. Both Palmer amaranth and waterhemp have hairless stems.
2. Palmer amaranth usually has a much denser canopy than waterhemp.
3. Palmer amaranth will have some leaves with petioles longer than the leaf blade.
4. Seedheads of Palmer amaranth are usually longer and thicker than those of waterhemp.
5. Female Palmer amaranth flowers have large, sharp bracts that are painful to touch when mature.

A petiole longer than the leaf blade is the most reliable vegetative trait to distinguish the two pigweeds. Not all leaves on a Palmer amaranth will have this trait.

Dense canopy of Palmer amaranth. The ends of stems often have a rosette appearance due to tightly clustered leaves.

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