HERBICIDE-RESISTANT PIGWEEDS (*AMARANTHUS SPP.*) ARE IN WISCONSIN, HOW SERIOUS IS IT? [1/]

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Introduction

Pigweeds, specifically common waterhemp (*Amaranthus rudis Sauer*) and Palmer amaranth (*Amaranthus palmeri S. Wats.*), are an increasing threat to current agricultural production systems. Common waterhemp and Palmer amaranth are dioecious, small seeded, broadleaf weed species' known for their prolific growth characteristics and high competitive ability. Exceedingly plastic in nature, common waterhemp and Palmer amaranth can grow at rates of 0.16 and 0.21 cm per growing degree day, respectively (Horak and Loughin, 2000). Furthermore, both species can produce over 250,000 seeds per female plant (Sellers et al., 2003). This intensifies the likelihood and speed that herbicide-resistant biotypes can increase in a population and transfer from one location to another through seed dispersal. Moreover, common waterhemp and Palmer amaranth cause significant yield loss in corn (74 and 91%, respectively) and soybean (56 and 79%, respectively) when left unmanaged (Bensch et al., 2003; Massinga et al., 2001; Steckel and Sprague, 2004).

Control of common waterhemp and Palmer amaranth has become increasingly difficult due to their ability of evolving resistance to numerous herbicide sites-of-action. These two weed species have developed herbicide resistance to more than five different sites-of-action, with resistance to at least one site-of-action occurring in 32 states (Heap, 2014). Wisconsin currently has one confirmed ALS-resistant biotype of common waterhemp, but there are indications of further resistance problems throughout the state. In 2012, the *Late-Season Weed Escape Survey in Wisconsin Corn and Soybean Fields* was initiated. A main objective of this research was to identify herbicide-resistant weed species in Wisconsin and begin proactively educating growers about herbicide resistance management.

Materials and Methods

The survey identified fields containing potential herbicide-resistant weeds through grower communication, field history, and in-field sampling. Five, ten, and six separate common waterhemp populations were identified for herbicide resistance screening in 2012, 2013, and 2014, respectively. Moreover, these surveys identified the first confirmed case of Palmer amaranth occurrence in Wisconsin (Dane County) in 2013 (Davis and Recker, 2014), and a second Palmer amaranth occurrence (Iowa County) was identified in 2014. To confirm herbicide resistance, seed heads from at least 30 mature plants were collected in situ, dried, and threshed for use in whole plant herbicide dose response bioassays. Twelve common waterhemp populations were screened for glyphosate resistance, one Palmer amaranth population was screened for glyphosate resistance, and one Palmer amaranth population was screened for both glyphosate resistance and tembotrione resistance. Progeny were grown; and seven to ten plants per herbicide

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rate plus the appropriate adjuvants were sprayed when they reached four inches tall. Glyphosate (Roundup PowerMAX®) rates used for common waterhemp populations were 0, 0.22 (5.5), 0.43 (11), 0.87 (22), 1.74 (44), 3.48 (88), and 6.96 (176) kg ae ha^{-1} (fl. oz. ac^{-1}). Glyphosate rates used for Palmer amaranth populations were 0, 0.0087 (0.22), 0.087 (2.2), 0.87 (22), and 8.7 (220) kg ae ha^{-1} (fl. oz. ac^{-1}). Tembotrione (Laudis®) rates used were 0, 0.023 (0.75), 0.046 (1.5), 0.092 (3), 0.184 (6), 0.368 (12), and 0.736 (24) kg ai ha^{-1} (fl. oz. ac^{-1}). Plant dry biomass data were collected 28 days after application and analyzed using the dose response model package in R statistical software. Comparisons between our putative resistant and susceptible biotypes were determined by the effective herbicide dose needed to reduce plant dry biomass 90% (ED_{90}) and 50% (ED_{50}) for common waterhemp and Palmer amaranth, respectively (Knezevic et al., 2007). Two separate screenings were conducted for the common waterhemp populations to confirm resistance, and one initial screening was conducted for the Palmer amaranth populations.

Results and Discussion

Two Wisconsin common waterhemp populations from Eau Claire and Pierce Counties were confirmed glyphosate-resistant. The Eau Claire County plants sprayed at the 0.87 kg ae ha^{-1} (22 fl. oz. ac^{-1}) rate all survived and grew to an average of six times their spray date height. At the 1.74 kg ae ha^{-1} (44 fl. oz. ac^{-1}) rate, 95% survived and grew to an average of five times their spray date height. The glyphosate ED_{90} for the Eau Claire County and susceptible populations was 3.91 and 0.40 kg ae ha^{-1}, respectively (Figure 1). This indicates the Eau Claire County population is nearly 10-fold glyphosate-resistant.

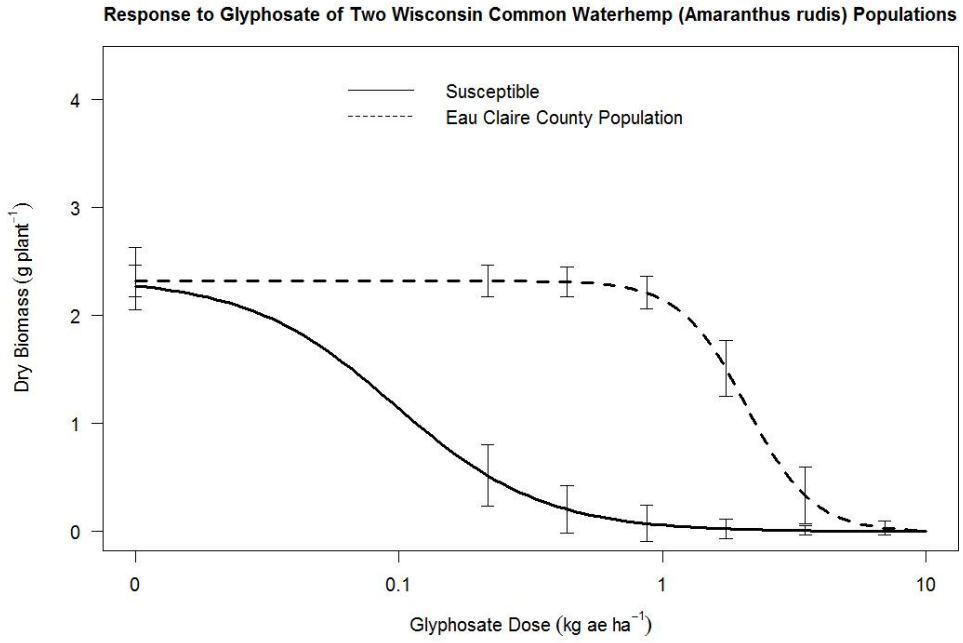

Figure 1. Glyphosate dose response models for two Wisconsin common waterhemp (*Amaranthus rudis*) populations. A three parameter log logistic function was used for analysis.

The Pierce County plants sprayed at the 0.87 kg ae ha^{-1} (22 fl. oz. ac^{-1}) rate all survived and grew to an average of six times their spray date height. At the 1.74 kg ae ha^{-1} (44 fl. oz. ac^{-1}) rate, 85% survived and grew to an average of four times their spray date height. The glyphosate ED_{90} for the Pierce County and susceptible populations was 5.15 and 0.40 kg ae ha^{-1}, respectively (Figure 2). This indicates the Pierce County population is nearly 13-fold glyphosate-resistant.

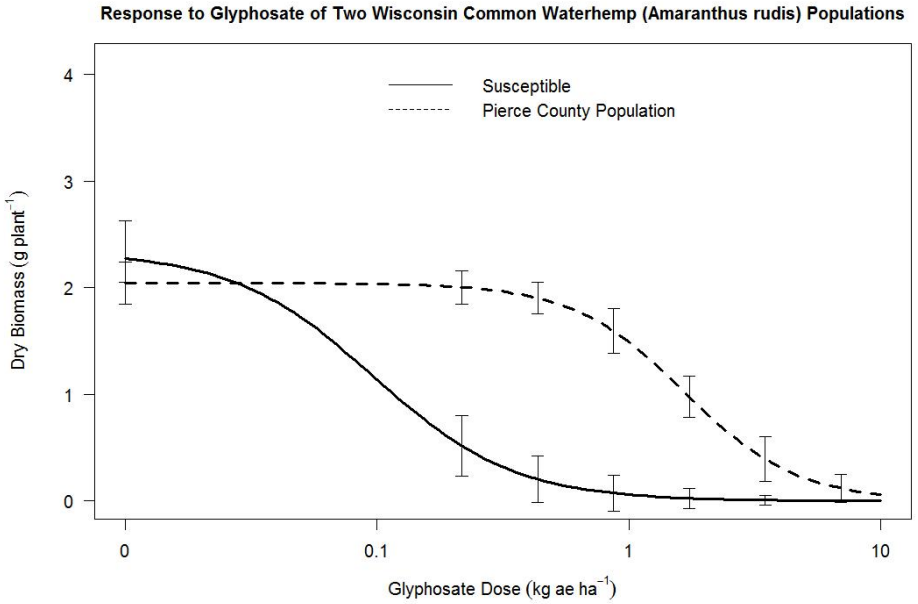

Figure 2. Glyphosate dose response models for two Wisconsin common waterhemp (*Amaranthus rudis*) populations. A three parameter log logistic function was used for analysis.

The Dane County Palmer amaranth population was confirmed glyphosate-resistant. Leaf tissue samples were sent to Dr. Patrick Tranel at the University of Illinois where a polymerase chain reaction (PCR) technique detected a 3- to 20-fold amplification of the EPSPS gene indicating high likelihood of glyphosate resistance. To confirm these results, the whole plant glyphosate dose response bioassay was conducted. Dane County plants sprayed at the 0.87 kg ae ha^{-1} (22 fl. oz. ac^{-1}) rate all survived and grew to an average of two times their spray date height. Due to high variance in biomass production of individual plants, dry plant biomass averages were used to compare putative resistant and susceptible ED_{50} estimates (Figure 3). This demonstrated nearly an 18-fold level of glyphosate resistance validating previous results from the PCR technique. Furthermore, ANOVA showed significant differences in plant dry biomass between the Dane County and susceptible populations at the 0.087 and 0.87 kg ae ha^{-1} rates (Table 1).

Table 1. Comparison of plant dry biomass 28 days after application between the Dane County and susceptible Palmer amaranth populations at each glyphosate rate.

	Glyphosate Rate (kg ae ha^{-1})				
	0	0.0087	0.087	0.87	8.7
Significance	NS	NS	**	**	NS

*Significant at the *P*=0.05 probability level.
**Significant at the *P*=0.01 probability level.
***Significant at the *P*=0.001 probability level.

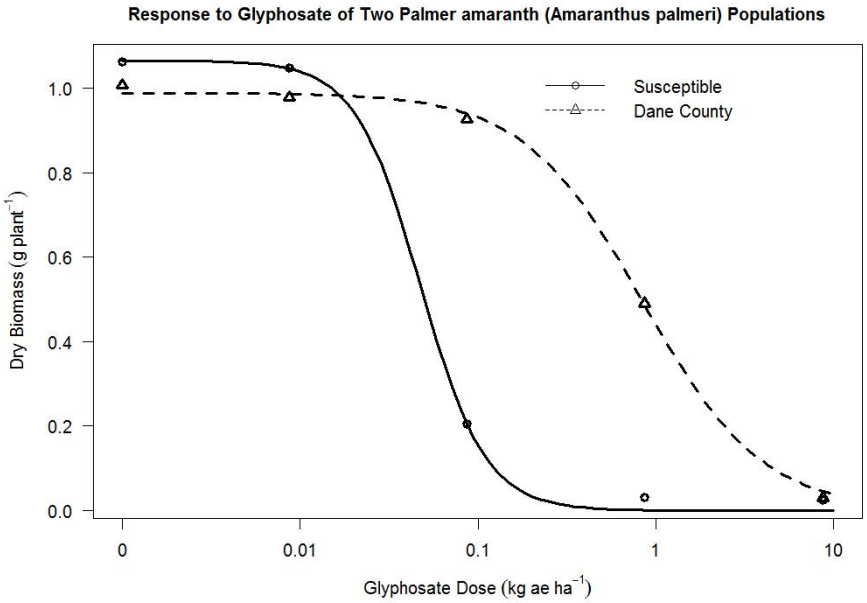

Figure 3. Glyphosate dose response models for two Palmer amaranth (*Amaranthus palmeri*) populations. A three parameter log logistic function was used for analysis.

Preliminary results indicate tembotrione controlled the Iowa County Palmer amaranth population less than the susceptible population. The Iowa County plants sprayed at the 0.046 kg ai ha^{-1} (1.5 fl. oz. ac^{-1}) rate had a 90% survival rate and grew to an average of two times their spray date height. At the 0.092 kg ai ha^{-1} (3 fl. oz. ac^{-1}) rate, 40% survived. The tembotrione ED_{50} for the Iowa County and susceptible populations was 0.034 and 0.023 kg ai ha^{-1}, respectively (Figure 4). This indicates the Iowa County population is nearly 1.5-fold more tolerant to tembotrione than the susceptible population.

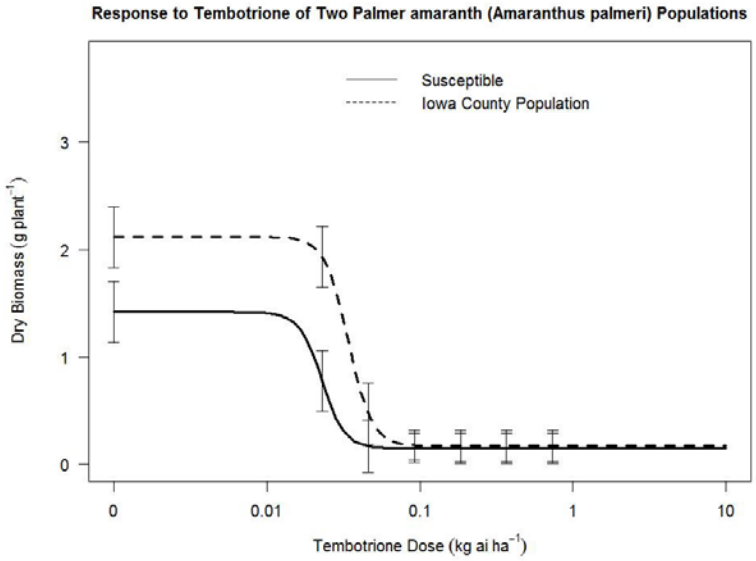

Figure 4. Tembotrione dose response models for two Palmer amaranth (*Amaranthus palmeri*) populations. A four parameter log logistic function was used for analysis.

Conclusions

Two Wisconsin common waterhemp populations from Eau Claire and Pierce Counties were confirmed glyphosate-resistant with 10- and 13-fold levels of resistance, respectively. The first confirmed case of Palmer amaranth occurrence in Wisconsin was discovered in Dane County in 2013 and was confirmed glyphosate-resistant. Preliminary results indicate a second Wisconsin Palmer amaranth population from Iowa County is not adequately controlled by tembotrione. Further screenings will be conducted on the Iowa County Palmer amaranth population to confirm tembotrione resistance.

There are several key components to an effective control strategy to combat herbicide-resistant weeds. The use of alternative herbicide sites-of-action and tank-mixing multiple herbicide sites-of-action will improve glyphosate-resistant weed control. An early planting date and the use of a preemergence residual herbicide will allow crops to gain a competitive advantage over weeds. Herbicide applications should be made at the correct timing when weeds are small and actively growing to ensure the greatest efficacy of the herbicide based on label recommendations. Furthermore, special care should be taken to clean tillage and harvest equipment thoroughly as they can quickly spread weed seed among fields. The focus of these best management practices is to diversify weed control measures, reduce weed seed additions to the soil seedbank, and utilize control measures in the most effective method possible.

For updates on Wisconsin weeds please visit the Wisconsin Crop Weed Science website at http://wcws.cals.wisc.edu/. Further information on controlling common waterhemp, Palmer amaranth, or other herbicide-resistant weeds can be found at: http://takeactiononweeds.com/. Finally, if you believe you may be facing herbicide-resistant weeds in your fields, contact your local county extension agent and/or Dr. Vince Davis at vmdavis@wisc.edu or (608) 262-1392.

References

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

Davis VM, Recker RA (2014) Palmer amaranth identified through the late-season weed escape survey. Accessed February 4, 2014, 2014

Heap I (2014) The International Survey of Herbicide Resistant Weeds: Web page. http://www.weedscience.com/Summary/home.aspx. Accessed Nov. 1, 2014.

Horak MJ, Loughin TM (2000) Growth Analysis of Four Amaranthus Species. Weed Science 48:347-355

Knezevic SZ, Streibig JC, Ritz C (2007) Utilizing R Software Package for Dose-Response Studies: The Concept and Data Analysis. Weed Technology 21:840-848

Massinga RA, Currie RS, Horak MJ, Boyer J, Jr. (2001) Interference of Palmer Amaranth in Corn. Weed Science 49:202-208

Sellers BA, Smeda RJ, Johnson WG, Kendig JA, Ellersieck MR (2003) Comparative Growth of Six Amaranthus Species in Missouri. Weed Science 51:329-333

Steckel LE, Sprague CL (2004) Common waterhemp (Amaranthus rudis) interference in corn. Weed Science 52:359-364