Lack of Effective Control of a Wisconsin Waterhemp (*Amaranthus tuberculatus*) Accession with Soil-applied PPO-inhibitor Herbicides

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INTRODUCTION

- Waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] herbicide resistance in Wisconsin has been confirmed to inhibitors of ALS (imazethapyr), auxin mimics (2,4-D and dicamba), PSII (atrazine), EPSPS (glyphosate), and PPO (fomesafen and lactofen)[1].
- In 2021, a putative PPO-resistant waterhemp accession (A92) was identified in southern Wisconsin after established plants were observed following a labeled rate of sulfentrazone PRE

OBJECTIVE AND HYPOTHESIS

Objective: confirm soil-applied PPO-inhibitor resistance in the A92 accession using dose-response greenhouse experiments.

Hypothesis: soil-applied PPO-inhibitor herbicides are ineffective for controlling the A92 accession.

MATERIAL AND METHODS

- **Dose-Response Greenhouse Experiment**:
  - The response of the putative-resistant (A92) and a known PPO-susceptible accession (A66) were evaluated in an CRD, with four replications per treatment, and two experimental runs.
  - Doses were 0x, 0.125x, 0.25x, 0.5x, 1x, 2x, 4x, and 8x the labeled rate of sulfentrazone (1x: 280 g ai ha^{-1}) and fomesafen (1x: 263 g ai ha^{-1}) (Table 1).
  - Experimental units consisted of approximately 190 seeds (measured by volume) planted 1.5 cm deep in 360 ml pot filled with non-sterilized field soil (silt clay loam, 6.4 pH, 3.0% OM, 18% sand, 53% silt, 30% clay by weight).
  - Pots were watered immediately before herbicide application to promote herbicide adsorption into soil and seed germination. After application, pots were watered daily.
  - Herbicide treatments were applied using a single-nozzle research track spray chamber, equipped with DG9502EVS nozzle, and a carrier volume of 140 L ha^{-1} (Figure 1).
  - At 28 DAT, plant density per experimental unit was accessed.
- **Statistical Analyses**:
  - A log-logistic three- or four-parameter model was fitted to the plant density using the "*drc*" package in "*R*"[2-5].
  - Student`s t-test ($\alpha = 0.05$) was used to determine whether model parameters differed between accessions.

Table 1. Soil-applied herbicide treatments.

Active Ingredient	Trade Name	WSSA SOA (#)	Herbicide Rate 1x
			g ai ha^{-1}
Sulfentrazone	Spartan 4F®	PPO (14)	280
Fomesafen	Flexstar®		263

Figure 1. Experimental units placed inside the single-nozzle spray chamber ready to be sprayed.

RESULTS

Sulfentrazone

Table 2. Dose-response log-logistic three-parameter model output comparing plant density of the putative-resistant (A92) and the susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied sulfentrazone. Standard errors are shown in parentheses.

Accession	ED_{50}[a]	RI[b]
	g ai ha^{-1}	
A92	87.6 (±18.1)[A]	2.7 (±1.1)
A66	32.8 (±11.3)[B]	

[a] ED_{50}: rate of sulfentrazone that decreased plant density by 50% to the non-treated control.
[b] RI: resistance index ED_{50} A92 / ED_{50} A66
Estimates followed by the same capital letter within a column did not differ by Student`s t-test ($\alpha = 0.05$).

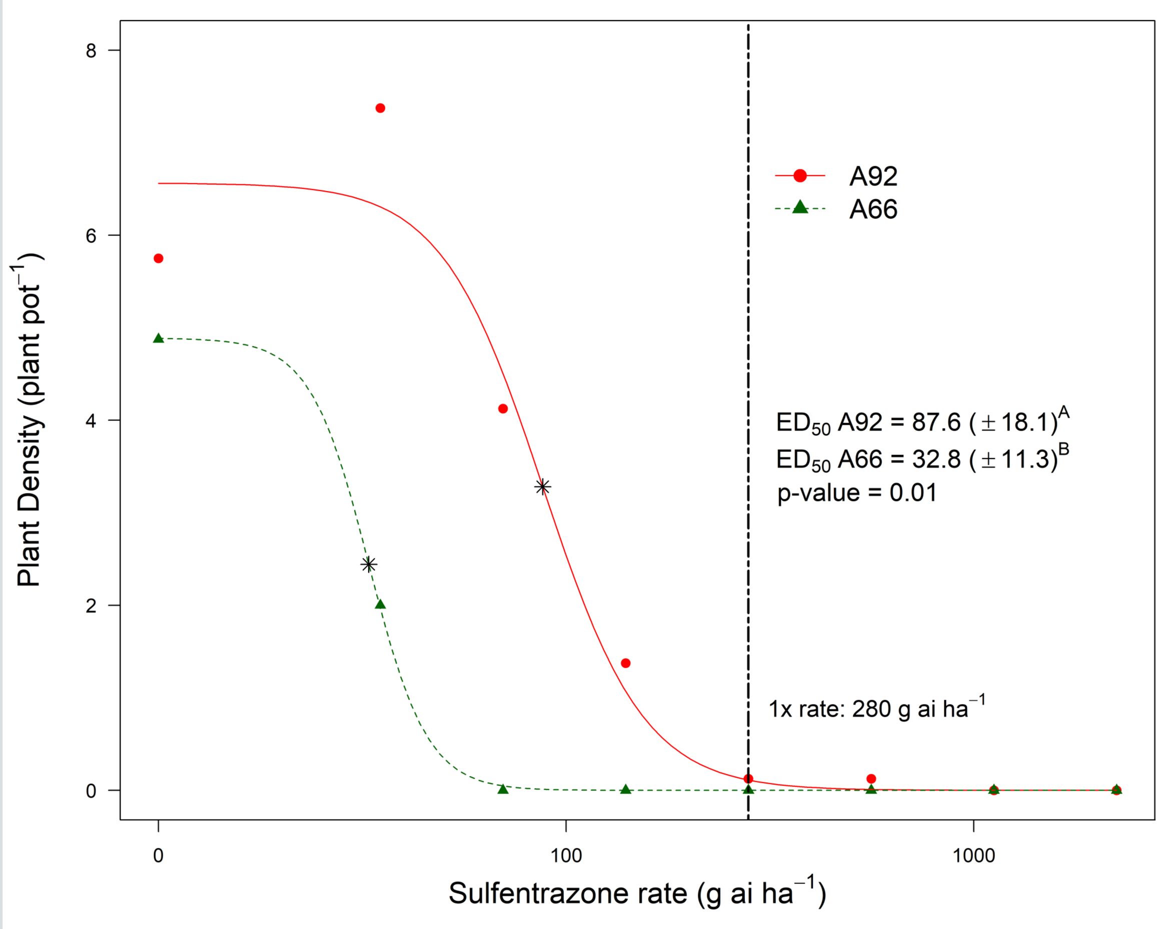

Figure 2. Dose-response log-logistic three-parameter curve comparing plant density of the putative-resistant (A92) and the susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied sulfentrazone. Estimates followed by the same capital did not differ by Student`s t-test ($\alpha = 0.05$).

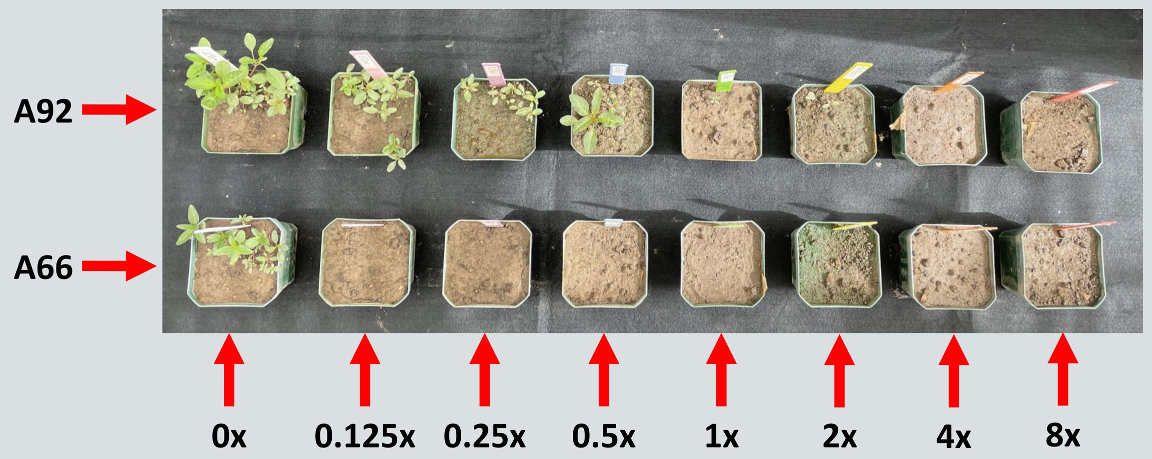

Figure 4. The putative-resistant (A92) and susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied sulfentrazone at 0x, 0.125x, 0.25x, 0.5x, 1x, 2x, 4x, and 8x the labeled rate.

Fomesafen

Table 3. Dose-response log-logistic four-parameter model output comparing plant density of the putative-resistant (A92) and the susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied fomesafen. Standard errors are shown in parentheses.

Accession	ED_{50}[a]	RI[b]
	g ai ha^{-1}	
A92	132.0 (±37.3)[A]	9.8 (±18.1)
A66	13.5 (±24.6)[B]	

[a] ED_{50}: rate of fomesafen that decreased plant density by 50% to the non-treated control.
[b] RI: resistance index ED_{50} A92 / ED_{50} A66
Estimates followed by the same capital letter within a column did not differ by Student`s t-test ($\alpha = 0.05$).

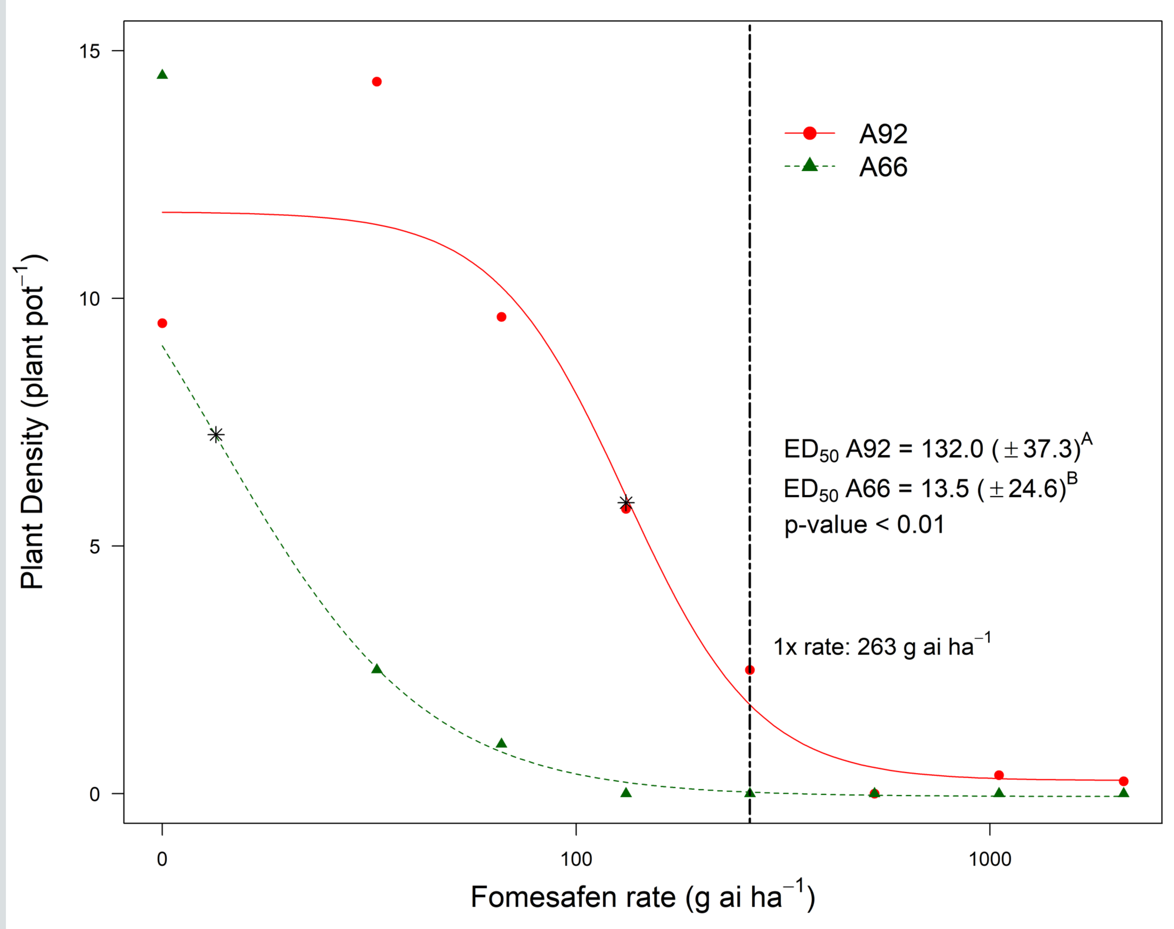

Figure 3. Dose-response log-logistic four-parameter curve comparing plant density of the putative-resistant (A92) and the susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied fomesafen. Estimates followed by the same capital did not differ by Student`s t-test ($\alpha = 0.05$).

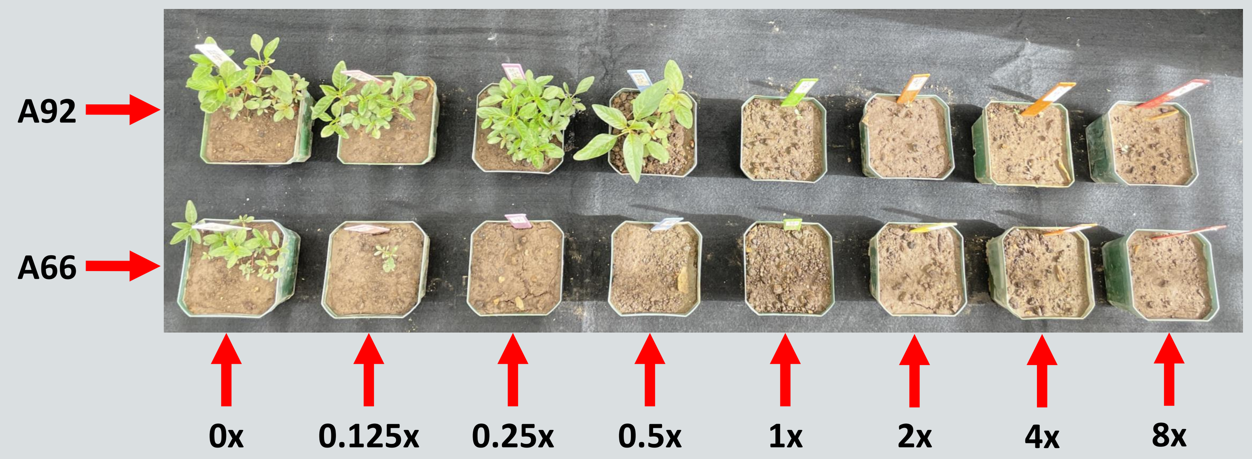

Figure 5. The putative-resistant (A92) and susceptible (A66) waterhemp accessions from WI 28 DAT with soil-applied fomesafen at 0x, 0.125x, 0.25x, 0.5x, 1x, 2x, 4x, and 8x the labeled rate.

- The effective dose of **sulfentrazone** that decreased plant density by 50% relative to non-treated control **(ED_{50}) for A92 and A66 were 87.6 (± 18.1) and 32.8 (± 11.3) g ai ha^{-1}, respectively**, with **RI = 2.7 (±1.1) and p-value = 0.01** (Figure 2).
- For **fomesafen**, the **ED_{50} for A92 and A66 were 132.0 (± 37.3) and 13.5 (± 24.6) g ai ha^{-1}, respectively**, with **RI = 9.8 (±18.1) and p-value < 0.01** (Figure 3).

CONCLUSIONS

- Our results indicate that the A92 accession is resistant to soil-applied sulfentrazone and fomesafen. From our knowledge, this is the first documented case of waterhemp resistance to sulfentrazone and fomesafen applied PRE in Wisconsin.
- These results are very concerning given the importance of these two herbicides for waterhemp control in Wisconsin soybean production, particularly because of the shorter residual control period.
- Proactive resistance management, including the diversified use of effective herbicides and integrated weed management, will be of paramount importance for long-term sustainable weed management in Wisconsin and beyond.

FUTURE RESEARCH

- Future research will investigate the A92 accession response to PPO-inhibitors fomesafen and lactofen applied POST, and the mechanism of resistance.

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