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TECHNICAL NOTE

Evaluation of foliar-applied post-emergence corn–soybean herbicides on giant ragweed and waterhemp control in Wisconsin

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Abstract

Giant ragweed (*Ambrosia trifida L.*) and waterhemp (*Amaranthus tuberculatus [Moq.] J.D.Sauer*) are highly competitive and the most troublesome weeds in corn (*Zea mays L.*) and soybean (*Glycine max Merr.*) cropping systems in Wisconsin. Field experiments were conducted to evaluate the efficacy of multiple foliar-applied POST-emergence herbicides on giant ragweed at Janesville, WI (2020 and 2021), and on groups 2- and 9-resistant waterhemp at Brooklyn, WI (2019 and 2020), respectively. Several herbicides from site of action groups 2, 4, 5, 6, 9, 10, 14, and 27 were evaluated. Herbicide treatments were applied when giant ragweed and waterhemp reached ~10 cm in height. Herbicide efficacy (0-100% visual control) was evaluated 14 days after treatment (DAT). Group 2 herbicides provided poor (<45%) control of giant ragweed and waterhemp 14 DAT. Several herbicides encompassing different sites of action provided >90% giant ragweed control. Certain herbicides from groups 4, 10, 14, and 27 provided the best control (74-87%) of waterhemp, but no herbicide evaluated in this study provided = 90% waterhemp control. Weed management programs containing multiple effective herbicide sites of action PRE- and POST-emergence accompanied by non-chemical strategies are recommended to extend the spectrum of chemical control and reduce the risk of selection of further herbicide-resistant biotypes for both giant ragweed and waterhemp in Wisconsin and beyond.

Giant ragweed (*Ambrosia trifida* L.) and waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer) are highly competitive weeds in corn (*Zea mays* L.*)* and soybean (*Glycine max* Merr.) cropping systems (Ganie & Jhala, 2017; Wu & Owen, 2014). There are 22 (groups 2 and 9) unique cases of giant ragweed and 62 (groups 2, 4, 5, 9, 14, and 27) unique cases of waterhemp accessions with either single or multiple herbicide resistance reported in the United States (Heap, 2022). A survey of Wisconsin growers from 54 counties documented these two species as the most troublesome agricultural weeds across the state (Werle & Oliveira, 2018). A broad range of herbicides from different herbicide site of action groups are labeled for foliar-applied post-emergence (POST) giant ragweed and waterhemp control in corn and soybean. Field evaluations of various single active ingredient POST herbicides for control of these two troublesome weed species can help corn and soybean growers design more effective chemical weed control programs.

Thus, field experiments were conducted to evaluate POST efficacy of multiple herbicides on giant ragweed at Janesville, WI (2020 and 2021), and on groups 2- and 9-resistant waterhemp at Brooklyn, WI (2019 and 2020), respectively

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(Table 1). Bareground field experiments were conducted in a randomized complete block design with four replications. Herbicide treatments were applied when giant ragweed and waterhemp reached 10 cm in height. Herbicide control efficacy on established weeds (0%–100% visual control) was evaluated 14 days after treatment application (i.e., standard time for visual control data collection following application of POST herbicides in field experiments; Frene et al., 2018; Rao & Ratnam, 2010). For data analyses, POST herbicide treatments (Table 2) and experimental year were treated as fixed effects and replication as random. Analysis of variance was conducted using R statistical software version 4.0.2 (R Core Team, 2020).

In both experiments (giant ragweed and waterhemp), the interaction between herbicide treatment and experimental year and the main effect of experimental year were not significant ($p > 0.05$); thus, data between years were pooled. The effect of POST herbicide treatment on control of giant ragweed and waterhemp was significant ($p < 0.001$ for both species). Several herbicides encompassing different sites of action provided >90% giant ragweed control, but group 2 herbicides provided poor control (37%–47%; Figure 1). Given the poor control by group 2 herbicides, we suspect the giant ragweed population at Janesville to be resistant to this site of action. Although giant ragweed resistance to herbicide groups 2 and 9 have been reported in Wisconsin and beyond (Heap, 2022), this population needs to be evaluated. The giant ragweed population at Janesville was well controlled by glyphosate (95%). The current study showcases that for giant ragweed, several effective herbicide options remain available for POST control in corn and soybean. To postpone further resistance, growers should deploy effective herbicides strategically and use them as part of integrated weed management programs (Norsworthy et al., 2012).

Core Ideas

- Acetolactate synthase inhibitor herbicides (group 2) provided poor (<50%) control of giant ragweed and waterhemp.
- A wide range of herbicides provided effective (≥90%) post-emergence control of giant ragweed.
- None of the herbicides evaluated herein provided effective (≥90%) post-emergence control of waterhemp.
- Selected herbicides from groups 4, 10, 14, and 27 provided the best control (74−87%) of waterhemp.
- Single active ingredient post-emergence herbicides could not provide effective waterhemp control demonstrating the need of integrated weed management programs.

Surprisingly and unfortunately, none of the POST herbicide treatments provided effective (≥90%) waterhemp control 14 DAT (Figure 2). The best control of waterhemp was observed with fomesafen (87%) and lactofen (85%), followed by 2,4-D (83%), mesotrione (82%), tembotrione (82%), glufosinate (79%), dicamba (77%), and isoxaflutole (74%) (Figure 2). Herbicides within groups 4, 14, and 27 provided varying levels of waterhemp control; for instance, clopyralid provided poor control (4%), whereas 2,4-D and dicamba provided ≥77% control (these three herbicides belong to group 4). Herbicide groups 2 and 6 provided poor (<10%) control of waterhemp. We suspect that besides resistant to groups 2 and 9, the waterhemp population at the Brooklyn, WI research site is segregating for target site and non-target site resistance to multiple herbicide groups and that is currently under investigation. Results of the current study indicate that no single

TABLE 1 Site description and meteorological condition during herbicide application

						Soil conditions			
Site and year	Average weed density m^{-2}	Herbicides application date	Air temperature (°C)	RH (%)	Wind speed (kph)/ direction	Texture	Organic matter (%)	pH	Temperature (°C)
Brooklyn 2019[a]	160	June 27	28	58	3–6/NE	Kengonsa silt loam	2.0	7.1	22
Brooklyn 2020[a]	30	June 17	28	40	2–6/S	Kengonsa silt loam	2.0	7.1	22
Janesville 2020[b]	240	May 27	29	56	3–5/SE	Plano silt loam	3.5	6.4	25
Janesville 2021[b]	630	May 26	23	58	8–17/WNW	Plano silt loam	3.3	6.7	20

Abbreviation: RH, relative humidity.

[a]GPS coordinates = 42.8776 N; 89.3988 W. Groups 2- and 9-resistant waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer).

[b]GPS coordinates = 42.7253 N; 89.0196 W. Giant ragweed (*Ambrosia trifida* L.).

TABLE 2 Foliar-applied post-emergence herbicides evaluated in the field experiments

Active ingredient	Herbicide name	Product rate	Adjuvants	Active ingredient (ai)/acid equivalent (ae) per hectare	Labeled for post-emergence in:	Site of action group [a]
Chlorimuron	Classic	52.5 g ha^{-1}	COC (1% v/v) + AMS (2.24 kg/ha)	13.1	Soybean	2
Cloransulam	FirstRate	21.0 g ha^{-1}	COC (1.2% v/v) + AMS (2.24 kg/ha)	17.7	Soybean	2
Imazethapyr	Pursuit	292.0 ml ha^{-1}	COC (1.25% v/v) + AMS (2.24 kg/ha)	70.0	Imidazolinone-resistant corn and soybean	2
Flumetsulam	Python	70.0 g ha^{-1}	COC (1% v/v) + AMS (2.24 kg/ha)	56.0	Corn and soybean	2
2,4-D[b]	Enlist One	1755.0 or 2340.0 ml ha^{-1}	AMS (2.24 kg/ha)	802.5 or 1070.0	Corn and Enlist soybean	4
Clopyralid	Stinger	440.0 ml ha^{-1}	–	158.0	Corn	4
Dicamba	XtendiMax	1600.0 ml ha^{-1}	Class Act Ridion (1% v/v)	557.0	Xtend soybean	4
Atrazine[c]	Aatrex	2340.0 ml ha^{-1}	COC (2.34 L ha^{-1})	1120.0	Corn	5
Bentazon	Basagran 5L	1870.0 ml ha^{-1}	COC (1% v/v) + AMS (2.24 kg ha^{-1})	1120.0	Corn and soybean	6
Bromoxynil	Buctril	1750.0 ml ha^{-1}	–	420.90	Corn	6
Glyphosate	Roundup PowerMAX	2340.0 ml ha^{-1}	AMS (2.24 kg ha^{-1})	1260.0	Roundup Ready corn and soybean	9
Glufosinate	Liberty	2340.0 ml ha^{-1}	AMS (2.24 kg ha^{-1})	656.0	Liberty Link corn and soybean	10
Fluthiacet-methyl	Cadet	66.0 ml ha^{-1}	COC (1% v/v) + AMS (2.24 kg ha^{-1})	7.2	Corn and soybean	14
Lactofen	Cobra	910.0 ml ha^{-1}	COC (3.351 kg ha^{-1}) + AMS (2 lb/a)	220.3	Soybean	14
Fomesafen	Flexstar	1170.0 ml ha^{-1}	MSO (1% v/v) + AMS (2.24 kg ha^{-1})	263.1	Soybean	14
Flumiclorac	Resource	585.0 ml ha^{-1}	COC (1 qt/a) + AMS (2.24 kg ha^{-1})	60.0	Corn and soybean	14
Topramezone	Armezon	55.0 ml ha^{-1}	MSO (1% v/v) + AMS (2.24 kg ha^{-1})	18.2	Corn	27
Isoxaflutole	Balance Flexx	635.0 ml ha^{-1}	MSO (1% v/v) + AMS (2.24 kg ha^{-1})	87.7	Corn	27
Mesotrione	Callisto	220.0 ml ha^{-1}	COC (1% v/v) + AMS (2.24 kg ha^{-1})	105.9	Corn	27
Tembotrione	Laudis	220.0 ml ha^{-1}	MSO (1% v/v) + AMS (2.24 kg ha^{-1})	91.9	Corn	27

Abbreviations: AMS, spray grade ammonium sulfate; COC, crop oil concentrate; MSO, methylated seed oil.

[a]Site of action; group 2 = acetolactate synthase inhibitors; group 4 = synthetic auxins inhibitors; group 5 = photosystem II inhibitors, 264 binder; group 6 = photosystem II inhibitors, histidine 215 binders; group 9 = enolpyruvyl shikimate-3-phosphate (EPSP) synthase inhibitors; group 10 = glutamine synthetase inhibitors; group 14 = protoporphyrinogen oxidase (PPO) inhibitors; group 27 = 4-hydroxyphenylpyruate dioxygenase (HPPD) inhibitors.

[b]Enlist One at 1755 ml ha^{-1} was used in the 2019 waterhemp experiment. Enlist One at 2340 ml ha^{-1} was used in the 2020 and 2021 giant ragweed experiments and in the 2020 waterhemp experiment. Enlist One should be sprayed at 2340 ml ha^{-1} for control of giant ragweed and waterhemp.

[c]AAtrex was only used at the Janesville, WI location. Brooklyn, WI, is in an atrazine prohibition area; thus, AAtrex could not be evaluated. Turbo TeeJet 110015 nozzles were used to spray all herbicide treatments, except XtendiMax and Enlist One which were sprayed with Turbo TeeJet Induction 110015 nozzles. The carrier rate for all herbicide applications was 15 GPA.

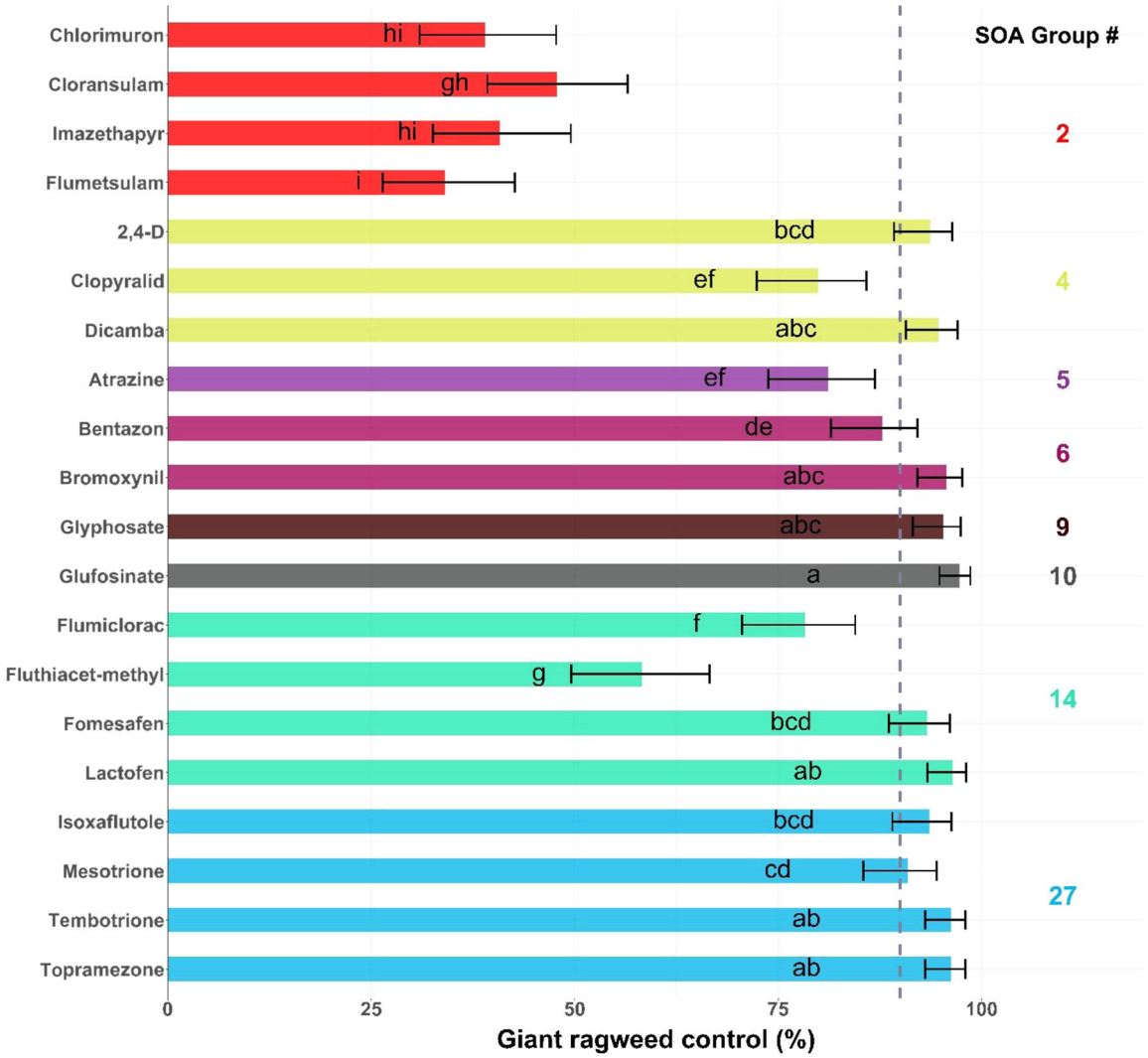


FIGURE 1 Efficacy (% visual control) of common foliar-applied post-emergence corn and/or soybean herbicides on control of established giant ragweed plants 14 days after application. Treatments with the same letter(s) are not different from each other (LSD, $\alpha = 0.05$). Bars indicate the standard deviation of eight replications (data pooled between 2 experimental years). The dashed line indicates 90% visual control. Commercial name and active ingredient rate of all treatments are displayed in Table 2. SOA, site of action

active ingredient POST herbicide provided complete control of established waterhemp plants at Brooklyn, WI. Our previous research demonstrated that herbicides with soil residual activity are effective tools for waterhemp and can provide additional sites of action toward more effective chemical weed management programs (Arneson et al., 2019; Ribeiro et al., 2022). Weed management programs containing multiple effective herbicide sites of action pre- and post-emergence (Hydrick & Shaw, 1994; Kumar et al., 2021) accompanied by non-chemical strategies (i.e., cover crops, narrow row spacing, harvest weed seed control) are recommended to extend the spectrum of chemical weed control and reduce the risk of selection of further herbicide-resistant biotypes for both giant ragweed and waterhemp in Wisconsin and beyond.

AUTHOR CONTRIBUTIONS

Rodrigo P. Werle: Conceptualization; investigation; methodology; project administration; supervision; validation; writing-review and editing. **Ryan DeWerff**: Conceptualization; investigation; methodology; project administration; supervision; validation; writing-review and editing. **Ahmadreza Mobli**: Writing-original draft; formal analysis; visualization. **Nicholas J. Arneson**: Investigation; project administration; supervision; writing-review and editing.

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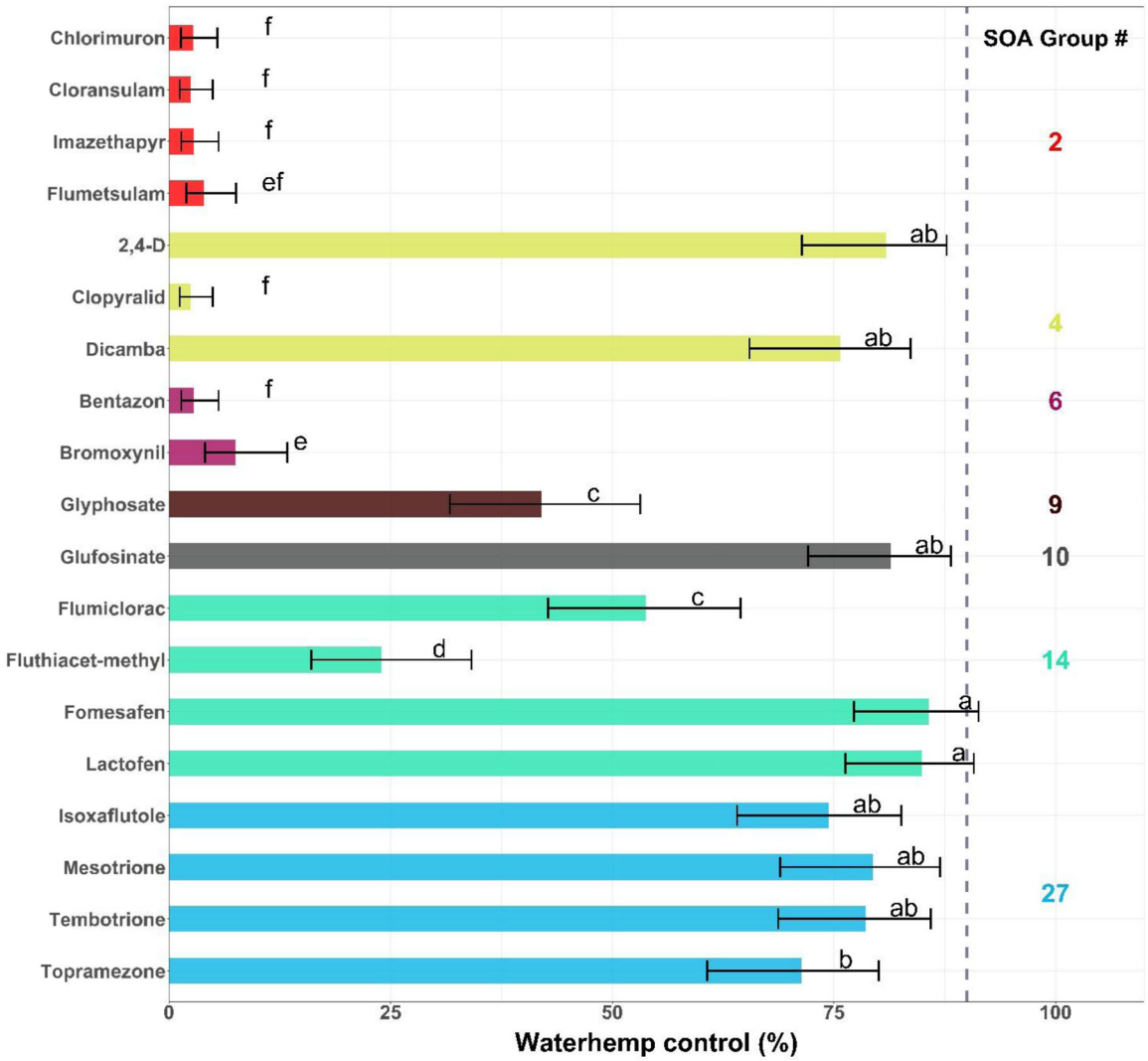


FIGURE 2 Efficacy (% visual control) of common foliar-applied post-emergence corn and/or soybean herbicides on control of established waterhemp plants 14 days after application. Treatments with the same letter(s) are not different from each other (LSD, $\alpha = 0.05$). Bars indicate the standard deviation of eight replications (data pooled between 2 experimental years). The dashed line indicates 90% visual control. Commercial name and active ingredient rate of all treatments are displayed in Table 2. SOA, site of action

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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