Cropping Systems Weed Science
UNIVERSITY OF WISCONSIN–MADISON

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Evaluating Efficacy of Preemergence Soybean Herbicides Using Field Treated Soil in Greenhouse Bioassays[1]

Take Home Message

- PRE-emergence (PRE) herbicides are important tools for control of small-seeded weed species such as Palmer amaranth and giant foxtail.
- Sulfentrazone, pyroxasulfone, flumioxazin, and S-metolachlor were the most efficacious herbicides on Palmer amaranth while pyroxasulfone, S-metolachlor, and sulfentrazone were the most efficacious on giant foxtail.
- Fall-seeded cover crops can be an additional tool as part of an integrated weed management program.
- Overall, radish was less affected by PRE herbicides than cereal rye at 900 growing degree days (GDD; approx. 48-59 days after PRE application).
- Most PRE herbicides evaluated would likely not affect radish and cereal rye established in the fall after soybean harvest.

Introduction

PRE-emergence (PRE) herbicides are recommended in soybean production systems for management of weed species with extended emergence window. Additionally, the use of PRE herbicides is considered a crucial component for management of glyphosate-resistant (GR) weeds. Due to the widespread prevalence of GR weeds and limited effective POST herbicide options in soybean, the use of PRE herbicides has become a standard recommendation for weed management in the US (Norsworthy et al., 2012). Even though extended soil residual efficacy from PRE herbicides during the growing season is desirable for weed control, certain residual herbicides can persist (carryover) in the soil and negatively affect growth of subsequent crops, including cover crops (Curran 2016). The planting of cover crops after cash crop harvest for soil conservation and weed suppression purposes has increased in the United States, but successful cover crop establishment in corn-soybean rotations where PRE herbicides are used remains a concern (Cornelius and Bradley 2017; Oliveira et al. 2019; Whalen et al. 2019). The use of plants as bioindicator organisms of herbicide residue in soil (i.e., soil bioassays) has been widely adopted as an alternative technique to chemical extraction analytical methods (e.g., liquid chromatography, gas chromatography, mass spectrometry, capillary electrophoresis, and immunoassays; Geisel et al. 2008; Horowitz 1976; Mehdizadeh et al. 2017; Streibig 1988; Wang and Freemark 1995).

Experiment Overview

In 2018 and 2019 the UW-Madison Cropping Systems Weed Science Lab conducted greenhouse bioassay experiments evaluating the efficacy of 11 commonly used PRE-emergence herbicides on two weeds (Palmer amaranth and Giant foxtail) and two cover crops (Radish and Cereal Rye).

Objective

- Evaluate the length of soil residual weed control from PRE soybean herbicides and the impact of these herbicides on cover crop and weed species using field treated soil in greenhouse bioassays

Table 1: Herbicide treatment information for the greenhouse bioassay experiments conducted at the University of Wisconsin-Madison Walnut Street Greenhouse in Madison, WI in 2018 and 2019.

Herbicide	Trade Name	Company	Group (SOA)[a]	Half-life[b]	Field Rate
chlorimuron-ethyl	Classic®	Corteva	ALS (2)	40	3.0 oz ac^{-1}
cloransulam-methyl	FirstRate®	Corteva	ALS (2)	8-10	0.6 oz ac^{-1}
imazethapyr	Pursuit®	BASF	ALS (2)	60-90	4.0 fl oz ac^{-1}
metribuzin	Tricor® DF	UPL	PSII (5)	30-60	0.67 lb ac^{-1}
flumioxazin	Valor® SX	Valent	PPO (14)	12-18	3.0 oz ac^{-1}
saflufenacil	Sharpen®	BASF	PPO (14)	15-29	1.0 fl oz ac^{-1}
sulfentrazone	Spartan®	FMC	PPO (14)	121-302	8.0 fl oz ac^{-1}
acetochlor	Warrant®	Bayer	VLCFA (15)	90	1.5 qt ac^{-1}
dimethenamid-P	Outlook®	BASF	VLCFA (15)	35-42	18 fl oz ac^{-1}
pyroxasulfone	Zidua®	BASF	VLCFA (15)	16-26	3.0 oz ac^{-1}
S-metolachlor	Dual II Magnum®	Syngenta	VLCFA (15)	112-124	1.67 pt ac^{-1}

[a] Site of action (SOA), Acetolactate synthase (ALS)-, photosystem II (PSII)-, protoporphyrinogen oxidase (PPO)-, and very-long-chain fatty acid (VLCFA)-inhibiting herbicides.

[b] Half-life values (average days) were obtained from the WSSA Herbicide Handbook (10th ed; Shaner 2014) other than saflufenacil and acetochlor which were obtained from Camargo et al. (2013) and Jablonkai (2000), respectively.

[1]Access the journal publication: https://doi.org/10.1017/wet.2021.22

Materials and Methods (Technical Description)

Greenhouse bioassay experiments were conducted in 2018 and 2019 at the Walnut Street Greenhouse, University of Wisconsin-Madison, in Madison, WI. Soil samples used in these experiments were collected during the 2018 and 2019 growing seasons from field experimental plots that received the respective PRE herbicide treatment application. Herbicides in the field experiments were applied within 3 d after soybean planting using a CO2-pressurized backpack sprayer equipped with four XR11002 (Teejet, Springfield, IL) nozzles on 20 in spacing calibrated to deliver 15 gal ac^{-1}. **Herbicide treatments are provided in Table 1.** Soil samples were collected from 0-4 in depth at 0, 10, 20, 30, 40 and 50 days after treatment (DAT) using a 2.5 in diameter handeld soil sampler (Fiskars®, Middleton, WI).

Greenhouse bioassay experiments consisted of four site-year replications from experiments located at the UW-Madison Arlington and Lancaster Agricultural Research Stations (Arlington-18, Arlington-19, Lancaster-18, and Lancaster-19). Soil from each field experiment was either a silt loam or silty clay loam (Arlington-18), pH ranged from 6.5-7.0, and organic matter ranged from 2.5-4.1 %. The experimental unit consisted of one cell within a 4-cell seed tray filled with soil from the field experiments (Figure 1). Composite soil samples within a site-year were thawed and combined across replications from the same PRE herbicide by sampling time, thoroughly mixed, and then split into the bioassay experimental units. Four bioindicator species were used: two small-seeded weed species, Palmer amaranth and giant foxtail (collected in 2017 in Keith Co, NE and in 2018 in Columbia Co, WI, respectively); and two cover crops, radish ('Tillage Radish'®; La Crosse Seed, La Crosse, WI) and cereal rye ('Guardian'® WInter Rye; La Crosse Seed). To maintain consistent seeding rates for the weed species, the same volume of seeds was planted, which averaged 60 and 20 seeds of Palmer amaranth and giant foxtail, respectively. Five seeds of each cover crop species were planted. Each species was grown in a separate cell of the 4-cell seed tray (Figure 1). Experimental units were watered daily for the duration of the experiment. The greenhouse bioassay experiment was conducted in a randomized complete block design with four replications and replicated twice over time (14 days apart).

Plant biomass was collected at 28 d after planting (DAP). Biomass samples were cut at the soil surface, placed in paper bags, and dried (160 F) until constant weight. The biomass of plants grown in soil treated with herbicides from each sampling time were compared with that of the average nontreated control from each sampling time for each site-year and expressed as percent biomass compared to the nontreated control using the following equation (1):

$$Z = (B/C) \times 100 \tag{1}$$

where Z is percent biomass compared to that of the nontreated control (the closer to 100% the lower the herbicide impacted plant growth), B is the observed biomass for the respective experimental unit (g), and C is the average biomass of the nontreated control (g). Accumulated growing degree day (GDD) units at the field soil sampling times were estimated and used as the explanatory variable to standardize the differences in planting dates and growing conditions across site-years. GDD was estimated based on recorded field soil temperature (0 to 1 in) collected with a Watchdog 1650 Micro Station (Spectrum Technologies, Aurora, IL). Daily soil GDD was calculated according to the equation (2) described by McMaster and Wilhelm (1997):

$$GDD = \sum[Tmax + Tmin)/2] - Tbase \tag{2}$$

where Tmax is the daily maximum soil temperature (F), Tmin is the daily minimum soil temperature, Tbase is the base temperature (41 F, which indicates the minimum temperature necessary for herbicide degradation in soil; Cupples et al. 2000). The first soil sampling at each site-year occurred immediately after PRE herbicide application thus representing the onset of GDD accumulation (0 DAT = 0 GDD).

Statistical analysis – R 4.0.2 Linear regression models were fitted to the percent biomass compared to the nontreated control (Z; response variable) and regressed against GDD (explanatory variable) using the lm function of the LM4 package (Bates et al. 2015). To enable stronger inferences, models were fitted to the data pooled across site-years for each PRE herbicide by bioindicator species combination. The percent biomass at 100, 500, and 900 accumulated GDD (GDD accumulation range representative of the soil sampling interval across site-years; 0 to 50 DAT) was estimated for each bioindicator species from the linear regression models using the predict function of the LM4 package (Bates et al. 2015) to aid in the interpretation of the residual efficacy through the season.

Results and Discussion

Sulfentrazone, pyroxasulfone, flumioxazin, and S-metolachlor were the most efficacious herbicides in the bioassay in terms of Palmer amaranth biomass production whereas pyroxasulfone, S-metolachlor, and sulfentrazone presented the highest residual impact on giant foxtail biomass (Figure 2). Thus, growers and practitioners should be able to use these results to support their selection of PRE herbicide(s) based on their weed infestations and benefit from a range of effective herbicide SOAs to include during multiyear crop rotations. Moreover, the results regarding Palmer amaranth are applicable to waterhemp management in Wisconsin soybean production systems as these two species are have similar biological characteristics and are both small-seeded weeds. Overall, these results showed that radish was less affected by PRE herbicides than cereal rye at 900 GDD (Figure 2). Most PRE herbicides evaluated herein would likely not affect radish and cereal rye established in the fall after soybean harvest under environmental conditions across southern Wisconsin. Additionally, these findings showcase the value of bioassays as a strategy to evaluate the biological residual efficacy of herbicides in soil using plant species of interest (e.g., weed and/or crops from a control and/or carryover perspective, respectively). The use of greenhouse bioassays can also reduce the impact of confounding environmental factors under field settings that may lead to uneven seedling establishment.

Recommendation for Soybean Growers

Results of these bioassay experiments can be of value to growers and applicators considering herbicide options for enhanced control of small-seeded weed species such as Palmer amaranth and giant foxtail and reduced impact on establishment of subsequent cover crops such as radish and cereal rye. With caution, these results can guide growers and applicators with proper selection of herbicides to be used as part of a layered residual approach (i.e., inclusion of soil-residual herbicide with the POST program) in systems where a radish or cereal rye cover crop may be seeded after such applications.

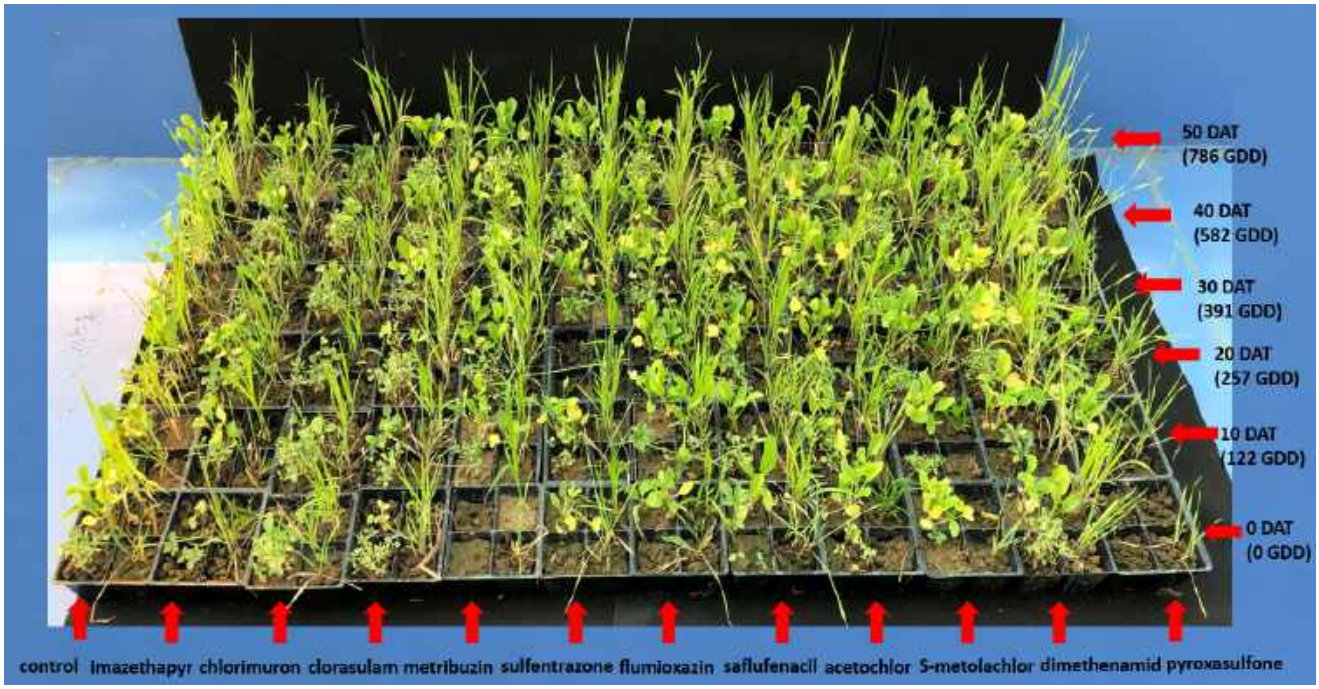

Figure 1. Complete set of experimental units for a single site-year (Lancaster-19) replication of the greenhouse bioassay experiment. PRE herbicide treatments are listed from left to right while soil sampling dates (0, 10, 20, 30, 40, and 50 DAT) are listed chronologically from bottom of the photo to the top. Each set of 4-cell seed trays consists of the four bioindicator species: Palmer amaranth, giant foxtail, radish, and cereal rye.

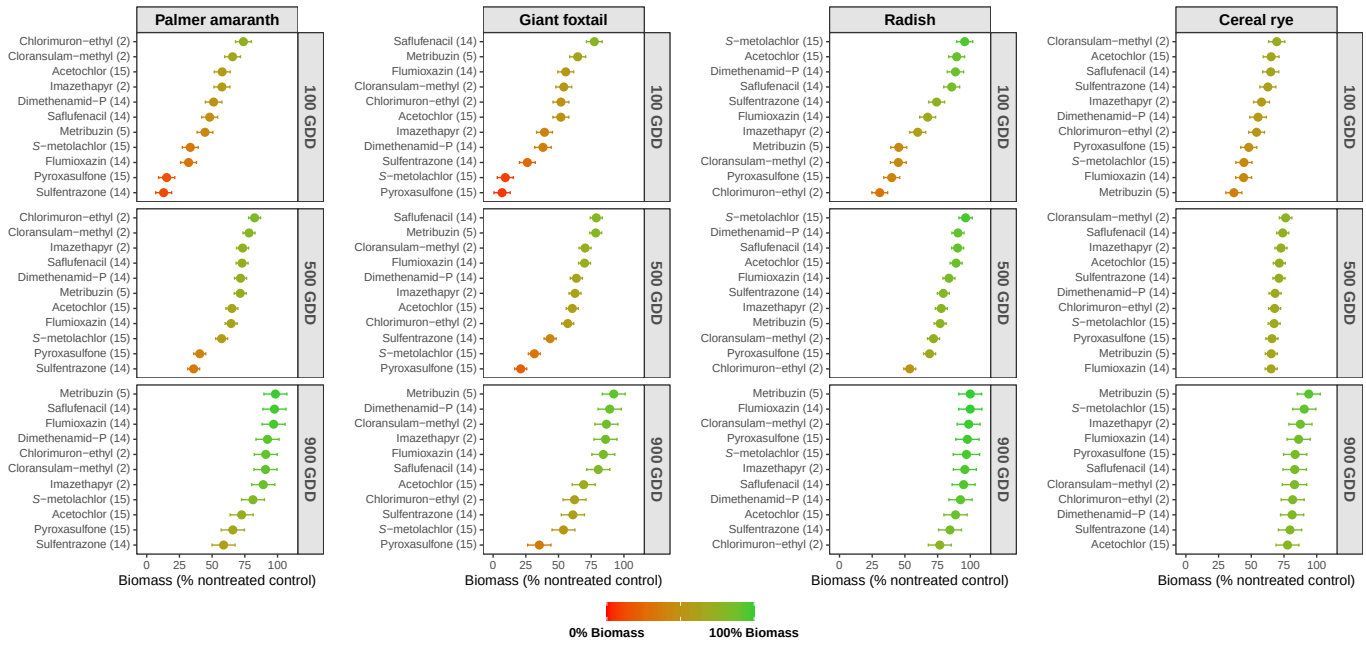

Figure 2. Estimated biomass (% biomass compared with the nontreated control) of each bioindicator species by PRE herbicide at 100, 500, and 900 growing degree days (GDD) across 4 site-years in southern WI. The days after PRE herbicide application that represent 100, 500, and 900 GDD were 5, 27, and 48 at Arlington-18; 11, 38, and 59 at Arlington-19; 5, 32, and 53 at Lancaster-18; and 8, 36, and 55 at Lancaster-19. Dots represent the means and dashes represent the 95 % confidence intervals. PRE herbicides are ranked within each subfigure (bioindicator species by GDD combination) according to their impact on bioindicator biomass accumulation from least (100% biomass; light green = no control) to highest (0% biomass; dark red = 100 % control).

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Additional Resources

- Residual Control of Waterhemp with PRE-emergence Herbicides in Soybean.
- Herbicide Comparison for Residual Waterhemp Control in Corn.
- Cereal Rye Cover Crop Termination Timing and its Impact on Weed Suppression and Soybean Yield.
- 2019 Wisconsin Weed Science Research Report.
- 2020 Wisconsin Weed Science Research Report.
- Herbicide Rotational Restrictions for Cover and Forage Cropping Systems (tips on conducting a bioassay).

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