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Early-planted soybean weed management as affected by herbicide application rate and timing

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Abstract

The opportunity to increase soybean yield has prompted Illinois farmers to plant soybean earlier than historical norms. Extending the growing season with an earlier planting date might alter the relationship between soybean growth and weed emergence timings, potentially altering the optimal herbicide application timings to minimize crop yield loss due to weed interference and ensure minimal weed seed production. The objective of this research was to examine various herbicide treatments applied at different timings and rates to assess the effect on weed control and yield in early-planted soybean. Field experiments were conducted in 2021 at three locations across central Illinois to determine effective chemical strategies for weed management in early-planted soybean. PRE treatments consisted of a *S*-metolachlor + metribuzin premix applied at planting or just prior to soybean emergence at 0.5X (883 + 210 g ai ha^{-1}) or 1X (1,766 + 420 g ai ha^{-1}) label-recommended rates. POST treatments were applied when weeds reached 10 cm tall and consisted of 1X rates of glufosinate (655 g ai ha^{-1}) + glyphosate (1,260 g ae ha^{-1}) + ammonium sulfate, without or with pyroxasulfone at a 0.5X (63 g ai ha^{-1}) or 1X (126 g ai ha^{-1}) rate. Treatments comprising both a full rate of PRE followed by a POST resulted in the greatest and most consistent weed control at the final evaluation timing. The addition of pyroxasulfone to POST treatments did not consistently reduce late-season weed emergence. The lack of a consistent effect by pyroxasulfone could be attributed to suppression of weeds by soybean canopy closure due to earlier soybean development. The full rate of PRE extended the timing of POST application 2 to 3 wk for all treatments at all locations except Urbana. Full-rate PRE treatments also reduced the time between the POST application and soybean canopy closure. Overall, a full-rate PRE reduced early-season weed interference and minimized soybean yield loss due to weed interference.

Introduction

Improvements in soybean genetics, seed treatments, and planting technology and equipment have combined to increase soybean yield and profitability over the last several decades. Concomitant with these advances has been a shift to earlier soybean planting. Early soybean planting has become an increasingly common practice with farmers across central Illinois and the U.S. Midwest (USDA-ESMIS 2024). The reason for earlier planting is to increase soybean growth prior to the summer solstice, which can lead to increased yield (Wilcox and Frankenberger 1987). Illinois, the leading soybean-producing state, alone accounted for 15.8% (4.53 million ha) of soybean planted in the United States in 2022 (USDA-NASS 2022, 2023). Considering the economic value and dominance of soybean as a cash crop in Illinois, evaluating weed management in an early-planted soybean environment is prudent.

There are concerns with planting soybean early, such as inadequate crop stands (Oplinger and Philbrook 1992) and increased disease incidence (Hamman et al. 2002). Weed control is another concern, and there are insufficient data to formulate recommendations for managing weeds in early-planted soybean, despite extensive research on weed control practices in soybean (especially chemical options).

PRE herbicides are valuable components of an integrated weed management program. PRE herbicides reduce early-season weed interference and often extend the time available to control weeds later in the growing season with a POST herbicide (Corrigan and Harvey 2000). The commercialization of glyphosate-resistant soybean in 1996 substantially reduced use of PRE herbicides (Shaner 2000). This greatly increased selection pressure on the weed communities with POST herbicides (including glyphosate), which led to the evolution of glyphosate resistance in weeds (Duke 2018). As a result, utilization of PRE herbicides in soybean has regained popularity to manage widespread resistance to many POST soybean herbicides.

In central Illinois, early soybean planting is generally considered to begin the first week of April, whereas historically, farmers waited to plant soybean until late April and May. Prior to 2020, Illinois farmers on average planted less than 10% of the soybean crop by April 30, whereas the average hectares planted early from 2020 to 2024 was 28% (USDA-ESMIS 2024). Weed control is crucial early in the growing season, as soybean are vulnerable to yield loss from weed interference (Cowan et al. 1998; Van Acker et al. 1993). Waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer], a summer annual weed common throughout U.S. soybean-growing regions, can reduce soybean yield up to 43% (Hager et al. 2002). However, the relative timing of crop and weed emergence may change with planting date, which might necessitate adjustment of herbicide application timing for early-planted soybean. Furthermore, the weed community might change with early-planted soybean, with increased prevalence of early-emerging summer annual species, such as common lambsquarters (*Chenopodium album* L.) and giant ragweed (*Ambrosia trifida* L.) (Werle et al. 2014).

Including herbicides with soil-residual activity with the POST herbicide can extend control of later-emerging weed species like waterhemp, thereby reducing soil seedbank replenishment and reducing selection pressure on future herbicide applications (Gonzini et al. 1999; Koger et al. 2007). Integrating a split PRE application in soybean may provide enhanced crop safety and extend residual weed control.

Owing to a lack of data on early-planted soybean, questions regarding the necessity of PRE and/or POST herbicides, along with questions about application rates, persist. The objectives of this research were to (1) evaluate the need for PRE and POST herbicides in early-planted soybean and (2) determine the appropriate application rates and timings for PRE and POST herbicides. The knowledge gained will allow weed management practitioners to formulate research-based weed management recommendations for early-planted soybean.

Materials and Methods

Site Selection

Field experiments were conducted in 2021 at three locations in central Illinois (Urbana, 40.079°N, 88.226°W; Seymour, 40.038°N, 88.394°W; and Athens, 39.945°N, 89.722°W). The field locations were selected owing to our cooperators' willingness to allow us to conduct research at each location. Access to available land and planting equipment were key factors in location selection. We selected multiple locations to reduce the risk of adverse weather and/or soil conditions that would preclude establishing experiments according to our objective. Additionally, each location was selected to ensure adequate weed pressure, but individual weed species present at each site was not a criterion of location selection.

The soils at Urbana and Seymour are a Drummer silty clay loam (fine-silty, mixed, superactive, mesic Typic Endoaquolls) with 5.5% organic matter and pH 6.7. Athens soils included an Ipava silt loam (fine, smectitic, mesic Aquic Argiudolls) and a Clarksdale silt loam (fine, smectitic, mesic Udollic Endoaqualfs). The Ipava silt loam had pH 5.8 with 4.3% organic matter, whereas the Clarksdale silt loam had pH 6.5 with 2.5% organic matter.

Table 1. Monthly total precipitation at Athens, Seymour, and Urbana, IL, in 2021.

	Monthly total precipitation		
Month	Athens	Seymour	Urbana
	cm		
Apr	7	5	5
May	14	9	8
Jun	12	17	17
Jul	12	10	9
Aug	13	6	7
Total	58	47	46

General Field Methods

Experiments in 2021 were initiated at Urbana on April 5 and at Athens and Seymour on April 6. Trials were established following secondary tillage. Either Xtendflex® (dicamba-, glufosinate-, and glyphosate-resistant) soybean (Asgrow® 33XF1, Bayer Crop Science, Creve Coeur, MO, USA; GH3442XF, Syngenta, Greensboro, NC, USA) or E3 (2,4-D-, glufosinate-, and glyphosate-resistant) soybean (XO3341E, BASF, Florham Park, NJ, USA; GH3442XF, Syngenta) was planted in rows spaced 76 cm apart at a seeding rate of 345,947 seeds ha^{-1} at all locations. Monthly precipitation totals for each location are presented in Table 1. Precipitation within 21 d after planting was 6, 3, and 3 cm at Athens, Seymour, and Urbana, respectively.

The experiment was arranged in a randomized complete block with four replicates of plots measuring 3 × 9 m. The treatment design was a 5 × 4 factorial of PRE and POST treatments. Treatment structure for each site included 0.5X or 1X PRE-only, POST-only, and 0.5X or 1X PRE followed by (fb) POST (Table 2). PRE treatments included a premix of *S*-metolachlor + metribuzin (Boundary®, Syngenta) applied at 0X, 0.5X, or 1X label-recommended rates either at planting or approximately 2 wk after planting and prior to soybean emergence. The POST treatments were applied when weeds reached 10 cm in height and included glyphosate (1,260 g ae ha^{-1}) (Roundup PowerMAX®, Bayer Crop Science) + glufosinate (655 g ai ha^{-1}) (Liberty®, BASF) + liquid ammonium sulfate (Amsol™, WinField Solutions, St. Paul, MN, USA) added at 3.4 kg ha^{-1} alone or with pyroxasulfone (63 or 126 g ai ha^{-1}) (Zidua®, BASF). The rationale for including pyroxasulfone was to assess the benefit of extended residual weed control later into the growing season relative to glyphosate + glufosinate alone. Dates of PRE and POST applications are presented in Table 2. All treatments, including application rates and timings, are presented in Table 3.

The premix of *S*-metolachlor + metribuzin was chosen as the PRE treatment because of the general lack of soybean injury and broad-spectrum weed control. A mixture of glyphosate + glufosinate was selected for POST treatments because both herbicides are nonselective and have no soil-residual activity. Moreover, volatility concerns of glyphosate and glufosinate are negligible compared to those of other POST herbicides in herbicide-resistant soybean (Duke and Powles 2008; Takano and Dayan 2020). Although glufosinate demonstrates minimal translocation, and efficacy is often environmentally dependent, resistant weed species are few (Heap 2024).

Herbicides were applied with a CO_2-pressurized backpack sprayer equipped with AI 110025VS nozzles for PRE applications and AIXR 110025 TeeJet® Air Induction XR nozzles (TeeJet® Technologies, Glendale Heights, IL, USA) for POST

Table 2. Herbicide application dates in early-planted soybean trials at Athens, Seymour, and Urbana, IL, in 2021[a].

Application timing	Athens	Seymour	Urbana
PRE	6 Apr	7 Apr	5 Apr
Delayed PRE	16 Apr	16 Apr	16 Apr
First POST[b]	3 Jun	27 May	27 May
Second POST[c]	10 Jun	11 Jun	4 Jun
Third POST[d]	17 Jun	17 Jun	—

[a]PRE application was made on the day of soybean planting. POST applications were made when weeds were 10 cm tall.
[b]Treatments that received herbicide application were POST-only across all sites, along with a half rate of PRE (HPRE) at Urbana.
[c]Treatments that received herbicide application were HPRE at Athens and Seymour and full rate of PRE (FPRE) at Urbana.
[d]Treatments that received herbicide application were FPRE at Athens and Seymour.

applications. Nozzles were spaced 50 cm apart and calibrated to deliver 187 L ha^{-1} at 5.6 km h^{-1} and 248 kPa.

Data Collection

Data collection included days until weed emergence in nontreated plots and all PRE treatments, days to crop emergence, and days to 10-cm-tall weeds. Weed species were combined for analysis because the scope of this project did not include evaluating the control of any individual species; rather, it aimed to evaluate the overall concept of weed control in an early-planted soybean environment. Visual evaluations of weed control and soybean injury were made on a scale ranging from 0% (no control or injury) to 100% (complete control) compared with the nontreated beginning at the POST application timing and again 14 and 28 d after each POST application (DAPO). A late-season visual assessment was also made 49 d after the final POST application (DAFPO). Weed density (plants m^{-2}) and biomass (g m^{-2}) were recorded from two 0.25-m^{-2} quadrats per plot at the POST application timing and again at the 28 DAPO weed control assessments. Each plot's two biomass samples were combined prior to drying at 65 C, and dry biomass was recorded. Soybean grain yield was determined at maturity using an ALMACO SPC40 combine with a 76-cm row head (ALMACO, Nevada, IA, USA) by harvesting the center two rows of each plot. Final yields were adjusted to 13% moisture.

Statistical Analysis

Weed control (at POST, 14 DAPO, 28 DAPO, and 49 DAFPO), weed biomass (at POST and 28 DAPO), weed density (at POST and 28 DAPO), days to 10-cm-tall weeds, and soybean yield were analyzed separately as linear mixed effect models using the LME4 package in R (Bates et al. 2014). PRE and POST treatments, as well as their interactions, were treated as fixed effects, while location and replication were treated as random effects in the models. Mean comparisons were made using Tukey's honestly significant difference test at $\alpha = 0.05$ with degrees of freedom calculated according to the Kenward–Roger method. Response variables demonstrating a significant PRE × POST interaction in Table 4 were included in Table 5 to compare all combinations of PRE and POST treatments.

Results and Discussion

Soybean Injury

Soybean injury did not exceed 5% for any PRE treatment regardless of application rate or timing (data not presented). Soybean injury from all POST treatments ≤10% at 7 DAPO and declined over time.

Weed Control

Overall, the full rate of PRE extended the timing of the POST application by 7 d compared to the half rate of PRE and 14 d compared to no PRE (Table 4). PRE herbicides are a valuable tool for delaying weed emergence and limiting weed interference with soybean (Knezevic et al. 2019).

Weed species rated across all sites included velvetleaf (*Abutilon theophrasti* Medik.), Palmer amaranth (*Amaranthus palmeri* S. Watson), waterhemp, common lambsquarters, large crabgrass [*Digitaria sanguinalis* (L.) Scop.], ivyleaf morningglory (*Ipomoea hederacea* Jacq.), fall panicum (*Panicum dichotomiflorum* Michx.), giant foxtail (*Setaria faberi* Herrm.), and common cocklebur (*Xanthium strumarium* L.). Weed control at the initial POST application was influenced by rate of the PRE herbicides whether applied at planting or delayed. Weed control with the full rate of PRE was at least 95% regardless of application timing, while control with the 0.5X rate of PRE was 88% to 91% (Table 4). In comparison, Ellis and Griffin (2002) observed no difference in weed control when using a half or full rate of pendimethalin + imazaquin, pendimethalin, metolachlor, dimethenamid + imazaquin, sulfentrazone + chlorimuron, and metribuzin + chlorimuron.

POST glyphosate + glufosinate was selected to control all weeds that had emerged through the PRE herbicide, thereby allowing the evaluation of any potential benefit of adding a soil-residual herbicide (pyroxasulfone) with the POST for control of later-emerging weeds. By 14 DAPO, control of all emerged weeds was at least 93% for treatments including a PRE (Table 4). Weed control from PRE-only treatments ranged from 83% to 89% across application rates and timings 14 DAPO (Table 5). In contrast, weed control with any PRE treatment followed by POST with or without pyroxasulfone ranged from 93% to 98% 14 DAPO. Incomplete weed control (90% to 93%) was observed in POST-only treatments with and without pyroxasulfone 14 DAPO. This would have occurred for two reasons. Weed density in POST-only treatments would have made it difficult to achieve adequate coverage with glufosinate, which is crucial for it to control weeds (Knoche 1994). Control of morningglory and waterhemp with glyphosate would have been insufficient alone. Second, species like velvetleaf, cocklebur, and morningglory emerged within 14 d after the POST application regardless of the inclusion of pyroxasulfone. A POST application too early could allow later-emerging weed seedlings to contribute to the soil seedbank. Waterhemp did as well, and this was expected, as it emerges in multiple flushes throughout the growing season, especially after a rainfall event (Hartzler et al. 1999).

By 28 DAPO, there were no differences in weed control among treatments regardless of PRE rate or timing (Table 4). Weed control ranged from 96% to 98%. At 28 DAPO, there was no improvement in weed control by including pyroxasulfone with the POST treatment. In contrast, Grey et al. (2013) reported improved weed control by including pyroxasulfone with the POST application of glyphosate + fomesafen. Weed control from treatments not receiving a POST was less compared with treatments with a POST (Table 4).

At 49 DAPO, neither PRE rate nor timing resulted in a difference in weed control among treatments; weed control ranged from 92% to 95%. PRE fb POST treatments provided 92% to 97%

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Table 3. Herbicide treatments applied in early-planted soybean trials at Athens, Seymour, and Urbana, IL, in 2021[a,b].

	PRE			POST	
	Treatment	Rate	Timing	Treatment	Rate
		g ai ha^{-1}			g ai ha^{-1}
1	Nontreated control	—	—	—	—
2	*S*-metolachlor + metribuzin	1,766 + 420	At planting	—	—
3	*S*-metolachlor + metribuzin	1,766 + 420	At planting	Glyphosate + glufosinate	1,260 + 655
4	*S*-metolachlor + metribuzin	1,766 + 420	At planting	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 63
5	*S*-metolachlor + metribuzin	1,766 + 420	At planting	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 126
6	*S*-metolachlor + metribuzin	883 + 210	At planting	—	—
7	*S*-metolachlor + metribuzin	883 + 210	At planting	Glyphosate + glufosinate	1,260 + 655
8	*S*-metolachlor + metribuzin	883 + 210	At planting	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 63
9	*S*-metolachlor + metribuzin	883 + 210	At planting	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 126
10	*S*-metolachlor + metribuzin	1,766 + 420	2 WAP	—	—
11	*S*-metolachlor + metribuzin	1,766 + 420	2 WAP	Glyphosate + glufosinate	1,260 + 655
12	*S*-metolachlor + metribuzin	1,766 + 420	2 WAP	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 63
13	*S*-metolachlor + metribuzin	1,766 + 420	2 WAP	Glyphosate + glufosinate + pyroxsulfone	1,260 + 655 + 126
14	*S*-metolachlor + metribuzin	883 + 210	2 WAP	—	—
15	*S*-metolachlor + metribuzin	883 + 210	2 WAP	Glyphosate + glufosinate	1,260 + 655
16	*S*-metolachlor + metribuzin	883 + 210	2 WAP	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 63
17	*S*-metolachlor + metribuzin	883 + 210	2 WAP	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 126
18	—	—	—	Glyphosate + glufosinate	1,260 + 655
19	—	—	—	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 63
20	—	—	—	Glyphosate + glufosinate + pyroxasulfone	1,260 + 655 + 126

[a]Abbreviations: WAP, weeks after planting.
[b]Rate for glyphosate expressed as g ae ha^{-1}.

Table 4. Summary of main effects and interactions for weed response and soybean yield in early-planted soybean trials at Athens, Seymour, and Urbana, IL, in 2021[a,b,c].

		Weed response								
Main effect	DAP until 10 cm tall	Control at POST[d]	Density at POST	Biomass at POST	Control 14 DAPO	Control 28 DAPO	Density 28 DAPO	Biomass 28 DAPO	Control 49 DAFPO	Soybean yield
			plants m^{-2}	g m^{-2}			plants m^{-2}	g m^{-2}		kg ha^{-1}
PRE treatment	*	*	*	*	*	*	*	*	*	ns
No PRE	54 c	0 d	68 a	12.4 a	67	95	36	43.6	95	4,828
At planting										
1X *S*-metolachlor + metribuzin	68 a	96 a	20 b	3.0 b	94	98	12	7.5	95	4,801
0.5X *S*-metolachlor + metribuzin	61 b	91 bc	19 b	2.0 b	93	96	15	13.3	93	4,613
2 WAP										
1X *S*-metolachlor + metribuzin	68 a	95 ab	20 b	2.4 b	95	97	13	8.1	94	5,030
0.5X *S*-metolachlor + metribuzin	61 b	88 c	20 b	1.9 b	94	96	21	16.1	92	4,983
POST treatment	NA	NA	NA	NA	*	*	*	*	*	*
No POST	—	—	—	—	69	90 b	39	56	84 b	4,257 b
Glyphosate + glufosinate	—	—	—	—	95	97 a	21	4.3	94 a	5,010 a
Glyphosate + glufosinate + 0.5X pyroxasulfone	—	—	—	—	95	97 a	10	3.9	97 a	5,010 a
Glyphosate + glufosinate + 1X pyroxasulfone	—	—	—	—	95	98 a	7	3	97 a	4,983 a
PRE × POST	NA	NA	NA	NA	*	ns	*	*	ns	ns

[a]Abbreviations: DAFPO, days after final POST; DAP, days after planting; DAPO, days after POST; NA, not applicable; ns, not significant; WAP, weeks after planting.
[b]Values shown are means. Main effect means among PRE or POST treatment within a column with no common letter are significantly different according to Tukey's HSD ($\alpha = 0.05$).
[c]An asterisk indicates significance at $P < 0.05$.
[d]Zero represents no control, and 100 represents complete control.

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Table 5. Weed control, density, and biomass in response to PRE and POST treatments at Athens, Seymour, and Urbana, IL, in 2021[a,b,c].

	POST treatment			
PRE treatment	No POST	Glyphosate + glufosinate	Glyphosate + glufosinate + 0.5X pyroxasulfone	Glyphosate + glufosinate + 1X pyroxasulfone
Weed control (%) 14 DAPO[d]				
No PRE	0 c	90 ab	90 ab	92 ab
At planting				
1X *S*-metolachlor + metribuzin	88 ab	96 a	96 a	96 a
0.5X *S*-metolachlor + metribuzin	83 b	96 a	96 a	93 ab
2 WAP				
1X *S*-metolachlor + metribuzin	88 ab	96 a	97 a	97 a
0.5X *S*-metolachlor + metribuzin	87 ab	95 a	96 a	96 a
Weed density (plants m^{-2}) 28 DAPO				
No PRE	79 a	26 bc	25 bc	14 bc
At planting				
1X *S*-metolachlor + metribuzin	24 bc	12 bc	7 bc	6 bc
0.5X *S*-metolachlor + metribuzin	28 bc	22 bc	6 bc	6 bc
2 WAP				
1X *S*-metolachlor + metribuzin	21 bc	23 bc	3 c	4 c
0.5X *S*-metolachlor + metribuzin	41 b	25 bc	8 bc	7 bc
Weed biomass (g m^{-2}) 28 DAPO				
No PRE	148.6 a	10.2 cd	10.6 b–d	4.5 cd
At planting				
1X *S*-metolachlor + metribuzin	26.7 b–d	0.8 d	1.6 d	0.9 d
0.5X *S*-metolachlor + metribuzin	42.9 bc	4.6 cd	3.3 cd	2.3 d
2 WAP				
1X *S*-metolachlor + metribuzin	29.1 b	1.5 d	0.5 d	1.1 d
0.5X *S*-metolachlor + metribuzin	50.7 a	4.2 cd	3.5 cd	5.8 cd

[a]Abbreviations: DAPO, days after POST; WAP, weeks after planting.
[b]Values shown are means. Means among PRE or POST treatments with no common letter are significantly different according to Tukey's HSD ($\alpha = 0.05$).
[c]An asterisk indicates significance at $P < 0.05$. Comparisons for each response variable can be made across PRE and POST treatments.
[d]Percent of nontreated, where 0 represents no control and 100 represents complete control.

weed control. Control with POST-only treatments was 94% to 97%, similar to PRE + POST treatments (Table 4). Weed control was less variable when herbicide treatments included PRE fb POST, although POST-only treatments provided similar levels of control.

Weed Density and Biomass

There were no differences among PRE rate or timing on weed density or weed biomass at the first POST. At 28 DAPO, weed densities in PRE-only treatments ranged from 21 to 41 weeds m^{-2}, while in POST-only treatments, they ranged from 14 to 26 weeds m^{-2} (Table 5). Weed density was lower 28 DAPO for PRE fb POST treatments relative to POST-only treatments, yet no statistical differences were apparent. Including pyroxasulfone with the POST did result in lower weed densities, but these were not significantly different compared to those of POST treatments without pyroxasulfone. Sarangi and Jhala (2019) did find a difference in Palmer amaranth density when they collectively analyzed POST versus POST with residual 28 DAPO; however, velvetleaf density was not different. When broken down by each treatment to evaluate Palmer amaranth density 28 DAPO, chloransulam-methyl + pyroxasulfone/fluthiacet-methyl was the only POST treatment with a residual herbicide to display differences, while no individual treatments had an effect on velvetleaf density.

Weed biomasses were comparable at the first POST regardless of PRE rate or timing, showing no difference and ranging from 2 to 3 g m^{-2}. At 28 DAPO, weed biomasses of PRE-only treatments ranged from 27 to 51 g m^{-2}. Weed biomasses of POST-only treatments were similar as well and ranged from 5 to 11 g m^{-2}. PRE fb POST treatments resulted in weed biomass of 1 to 6 g m^{-2} 28 DAPO (Table 5).

Soybean Canopy Closure/Weed Emergence

Despite the variability in soybean canopy closure timing at each site, other than Urbana, the only weeds noted to contribute to the weed seedbank were POST escapes in PRE fb POST treatments. Ivyleaf morningglory and common cocklebur were two weed species that emerged after the POST application and were not suppressed by the canopy in Urbana in 2021. Weed emergence was observed in treatments not receiving pyroxasulfone in the POST application at the other sites, but where common cocklebur was not present, these other weeds were suppressed by soybean canopy. Common cocklebur has shown the ability to tolerate reduced light levels under shaded conditions, which may explain why it was not suppressed by soybean (Regnier and Stoller 1989).

Early-planted soybean can achieve row closure sooner than later-planted soybean. Later-emerging weeds likely would be suppressed or have higher mortality rates in an early-planted soybean environment (Arsenijevic et al. 2022). Velvetleaf emerging later in the season experienced higher mortality levels when under a soybean canopy (Lindquist et al. 1995). However, later-emerging waterhemp has shown the ability to produce seed under shaded conditions in a standard soybean planting timing (Hartzler et al. 2004).

Soybean Yield

Soybean yields for POST-only and PRE fb POST treatments were similar (Table 4). Soybean yield was greater for treatments receiving a POST compared to treatments without a POST. Soybean yields have been similar between reduced and full labeled rates of PRE herbicides (Muyonga et al. 1996). Soybean yield may be most affected by the timing of weed emergence, with earlier-emerging weeds posing the greatest threat to yield loss

(Kropff et al. 1992). PRE herbicides minimize the duration of weed competition with the crop when it is most vulnerable. External stresses during seed fill reduce soybean yield, which PRE-only treatments would allow for, given greater weed interference during this reproductive period (Foroud et al. 1993).

Practical Implications

Applying a full rate of *S*-metolachlor + metribuzin extended the timing of the glyphosate + glufosinate application compared to a 0.5X rate or no PRE, although delaying *S*-metolachlor + metribuzin closer to soybean emergence offered no advantage in weed control or extending days to the POST application. Neither rate of pyroxasulfone when included with glyphosate + glufosinate significantly reduced weed density 28 DAPO. This may be explained by earlier soybean development in relation to weed emergence. A more developed soybean canopy would reduce the fluctuation of soil surface temperature and incident sunlight earlier in the season, reducing weed seedling emergence (Norsworthy and Oliveira 2007). PRE fb POST treatments provided the highest levels of weed control and soybean yield. The PRE-only treatments did not yield as high as the POST-only treatments, which were similar to PRE fb POST treatments. Klingaman and Oliver (1994) reported increased competitiveness of soybean with entireleaf morningglory (*Ipomoea hederacea* Jacq. var. *integriuscula* A. Gray) and sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby.] when planted in early May compared with early June. Planting soybean earlier should improve suppression of later-emerging weed species, yet this environment may be more conducive for earlier-emerging weed species (Werle et al. 2014), and soil disturbance may promote summer annual species to shift to earlier emergence. Current and future research on early-planted soybean in comparison to conventional soybean planting timing includes injury potential from various soil-residual herbicides, herbicide carryover potential, and POST timing efficacy with and without a soil-residual herbicide.

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