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Control of Glyphosate-Resistant Giant Ragweed (*Ambrosia trifida* L.) with 2,4-D Followed by Pre-Emergence or Post-Emergence Herbicides in Glyphosate-Resistant Soybean (*Glycine max* L.)

Amit J. Jhala[1*], Lowell D. Sandell[1], Greg R. Kruger[2]

[1]Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Lincoln, Nebraska, USA
[2]West Central Research and Extension Center, University of Nebraska-Lincoln, North Platte, Nebraska, USA
Email: *amit.jhala@unl.edu

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Abstract

Control of glyphosate-resistant giant ragweed is a challenge, particularly for soybean growers, because of limited effective post-emergence (POST) herbicide options. Many soybean growers in no-till production systems use 2,4-D in burndown application for control of broadleaf weeds, including giant ragweed. Field experiments were conducted at David City, NE, in 2012 and 2013 to evaluate 2,4-D followed by PRE or POST herbicide programs for control of glyphosate-resistant giant ragweed in glyphosate-resistant soybean. Results suggested that burndown application of 2,4-D or saflufenacil plus imazethapyr resulted in 89 to 99% control of giant ragweed at 21 days after treatment. Burndown-only treatments of S-metolachlor plus metribuzin or sulfentrazone plus cloransulam resulted in poor control (≤65%) of giant ragweed and reduced soybean yield (≤ 577 kg·ha^{-1}). Burndown application of 2,4-D followed by saflufenacil plus imazethapyr, S-metolachlor plus metribuzin, or sulfentrazone plus cloransulam applied pre-emergence (PRE) or cloransulam, chlorimuron, fomesafen, imazethapyr, or lactofen in tank-mixtures with acetochlor applied POST resulted in 87% to 99% giant ragweed control, reduced density to ≤7 plants m^{-2}, and resulted in soybean yield from 2519 to 3823 kg·ha^{-1}. There was no difference among and between 2,4-D followed by PRE or POST herbicides for giant ragweed control, density, or soybean yield, indicating all the two pass herbicide programs were effective. It is concluded that glypho-

*Corresponding author.

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sate-resistant giant ragweed can be effectively controlled in soybean by including 2,4-D in burndown program followed by PRE or POST herbicides tested in this study.

Keywords

Corn, Burndown, Giant Ragweed Biomass, Post-Emergence, Pre-Emergence, Resistance Management

1. Introduction

Soybean (*Glycine max* L.) is the most prevalent oilseed crop in the United States and it is the second most common field crop after corn [1]. In 2012, soybean was planted on 31.24 million ha in the United States [1]. Glyphosate-resistant soybean was first commercialized in 1996, and since then it has been rapidly accepted by soybean growers [2]. In 2012, the National Agriculture Statistics Service of the U.S. Department of Agriculture (USDA) reported that 91% of the soybean and 60% of corn ha were planted with glyphosate-resistant trait [3]. The success of glyphosate-resistant crop technology is due to broad-spectrum weed control that has facilitated adoption of conservation tillage [4]-[6]. However, over reliance and continuous use of glyphosate for last 15 years resulted in evolution of glyphosate-resistant weeds [7]. Currently, 25 weed species worldwide have evolved resistance to glyphosate including 14 in the United States [8].

Giant ragweed (*Ambrosia trifida* L.), a member of Asteraceae family, is an annual, broadleaf species that is native to the United States and it is found throughout North America and several other continents [9]. Giant ragweed has been common throughout the eastern United States, and in recent years the weed has become more problematic in Illinois, Iowa, Minnesota, and Nebraska [10]. It is a large-seeded broadleaf weed with a weight of an individual seed ranging from 27 to 45 mg [9]. Seed production in giant ragweed is in the range from 500 to 5000 seeds plant^{-1} [11], so if not controlled, it can establish an extensive weed seed bank in a few years.

The repeated use of herbicides with the same mode-of-action can impose selection pressure for resistance within or among weed species that have previously been susceptible [4] [12]. For example, a widespread and repeated use of the acetolactate synthase (ALS)-inhibiting herbicides resulted in the evolution of ALS inhibitor-resistant giant ragweed [13]. In 2005, a giant ragweed biotype in Ohio was reported to have reduced sensitivity to glyphosate [14]. In 2007, glyphosate-resistant giant ragweed was confirmed in Tennessee [15], and now it has been confirmed in several states including Arkansas, Indiana, Iowa, Kansas, Minnesota, Mississippi, Missouri, Nebraska, Ohio, and Wisconsin [8]. Therefore, management of glyphosate-resistant giant ragweed is not only a challenge in soybean fields in Nebraska, but also in several other states and crops.

Giant ragweed, one of the earliest emerging summer annual weeds found in Nebraska corn and soybean fields with emergence typically begins in the late March or early April (personal observation). Previous studies in Illinois reported that giant ragweed started emerging in the first week of March and continued through the second week of May [16] [17]. In contrast, research in Ohio and Tennessee indicated late emergence of giant ragweed until the second week of July [18] [19]. In Indiana, giant ragweed was one of the most common weeds that were found in soybean fields late in the season [20]. Therefore, the extended germination period of giant ragweed makes it difficult to control because late-emerging seedlings (late June through July) could escape POST herbicide application [18].

Early-spring emergence of giant ragweed intensifies the importance of applying an efficacious burndown herbicide prior to planting in no-tillage soybean production systems to prevent existing weeds from interfering with soybean growth. Saflufenacil, a pyrimidinedione herbicide, has been registered for burndown and/or PRE control of broadleaf weeds in several crops including soybean [21]. Saflufenacil controlled glyphosate-resistant horseweed [*Conyza canadensis* (L.) Cronq.] 94% up to 7 d before planting cotton (*Gossypium hirsutum* L.) without causing significant crop injury [22]. Saflufenacil has also been premixed with imazethapyr for use in corn, soybean, and field pea (*Pisum sativum* L.) [23]. Because of the activity on broadleaf weeds, low cost, and a few number of weeds having evolved resistance, 2,4-D is an option for soybean growers as burndown treatment [24]. Therefore, burndown application of 2,4-D and saflufenacil plus imazethapyr should be evaluated for control of glyphosate-resistant giant ragweed.

Several PRE and POST herbicides and their combinations have been evaluated for control of giant ragweed in soybean before commercialization of herbicide-resistant crops [25]-[27]. Prior to evolution of glyphosate-resistant giant ragweed, most no-till soybean growers were applying glyphosate before planting to control the existing population followed by an early-POST application for control of newly emerged giant ragweed plants. The protoporphyrinogen oxidase (PPO)-inhibiting herbicides such as fomesafen, lactofen, saflufenacil, and sulfentrazone are labeled in soybean and frequently used for control of glyphosate-resistant weeds [15] [22]. Another study reported 90% control of seedling giant ragweed with fomesafen [25]. Similarly, giant ragweed was controlled 95% when fomesafen was applied at the three-node stage [26] [27], compared to <66% at six-node stage [15]. Therefore, herbicides with different modes-of-action are needed for effective control of glyphosate-resistant giant ragweed.

The objectives of this study were to evaluate herbicide programs with 2,4-D as burndown followed by PRE or POST herbicides for control of glyphosate-resistant giant ragweed and their effect on soybean injury and yield. We hypothesized that a combination of 2,4-D as burndown followed by PRE herbicides including saflufenacil plus imazethapyr, S-metolachlor plus metribuzin, sulfentrazone plus cloransulam, or POST herbicides such as cloransulam, chlorimuron, fomesafen, imazethapyr, or lactofen in tank-mixtures with acetochlor can effectively control glyphosate-resistant giant ragweed.

2. Materials and Methods

Field experiments were conducted at David City, NE in 2012 and 2013 in a grower's field infested witglyphosate-resistant giant ragweed. The history of the site was a heavy reliance on glyphosate for weed control at least two times per season for the last eight years in a glyphosate-resistant corn and soybean rotation. The soil at the experimental site was silty loam with pH 5.4, 18% sand, 50% silt, 32% clay, and 2.1% organic matter. The experiment design was a randomized complete block with four replications. Glyphosate-resistant soybean (Cv. "Pioneer 93Y12") was planted on May 7 and May 24 in 2012 and 2013, respectively. The seeds were planted 3 cm deep and rows were spaced 76 cm apart. The plot size was 3 × 9 m and was comprised of four soybean rows. A total of 13 herbicide programs including burndown followed by PRE or POST herbicides were compared for control of glyphosate-resistant giant ragweed (**Table 1**). A nontreated control was included for comparison. Glyphosate treatment was included to demonstrate the presence of glyphosate-resistance in the giant ragweed population and to serve as a comparison for control for other herbicide treatments.

Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 $L\cdot ha^{-1}$ at 276 kPa equipped with a five-nozzle boom and AIXR11015 flat fan nozzles (TeeJet, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189). Herbicide treatments were applied as burndown (April 23, 2012 and May 8, 2013), PRE (May 12, 2012 and May 24, 2013), and POST (June 11, 2012 and June 28, 2013). Giant ragweed plants were 5 to 8 cm tall when burndown herbicides were applied. A blanket application of glyphosate at 1.74 $kg\cdot ae\cdot ha^{-1}$ was applied on July 11 and 30 in 2012 and 2013, respectively, for control of late-season weed species such as common waterhemp (*Amaranthus rudis* Sauer), velvetleaf (*Abutilon theophrasti* Medik.) and annual grass species. The field was rain-fed with no supplemental irrigation applied.

Visual estimations of soybean injury and giant ragweed control were recorded on a scale of 0% to 100% (0 equals no giant ragweed control or soybean injury and 100 equals complete giant ragweed control or soybean plant death) at 7, 14, 21 days after burndown treatment (DABT), at 7, and 30 days after POST treatment (DAPT), and at harvest. Giant ragweed densities were assessed by counting plants in 0.25 m^2 quadrats at the time of harvest. Giant ragweed plants that survived herbicide treatments were cut at the soil surface from two randomly selected 0.25 m^2 quadrats per plot, placed in paper bags, dried in an oven for 72 h at 60 C, and the biomass was recorded. The plots were harvested using a plot combine and soybean seed yield was recorded. The weed control efficiency (WCE) was calculated using equation:

$$WCE\% = \left[\text{Dry Weight of nontreated control} - \text{Dry Weight of herbicide treated plots}\right] \times 100 / \text{Dry weight of nontreated control}$$

Data were subjected to ANOVA using the PROC MIXED procedure in SAS version 9.3 (SAS Institute Inc., Cary, NC). Year and herbicide treatments were considered fixed effects, and replication was considered a random effect for the analysis. If the year-by-treatment interaction was non-significant, data from the 2 yr were averaged. If the year-by-treatment interaction was significant, data were analyzed separately by year. Data were

Table 1. Herbicide treatments, application timing, and rates as well as products used in a field study in Nebraska in 2012 and 2013.

Herbicide Treatment[a,b]	Herbicide Trade Name	Timing	Rate g·ae or ai·ha^{-1}	Adjuvant
Glyphosate *fb* Glyphosate	Roundup PowerMax *fb* Roundup PowerMax	Burndown POST	870 870	AMS 2% wt/wt *fb* AMS 2% wt/wt
2,4-D Amine *fb* Glyphosate	2,4-D Amine 4 *fb* Roundup PowerMax	Burndown POST	560 870	NIS 0.25% v/v + AMS 2% wt/wt
2,4-D Amine + Glyphosate *fb* Saflufenacil + Imazethapyr	2,4-D Amine 4 + Roundup PowerMax *fb* Optill	Burndown PRE	560 + 870 95	AMS 2% wt/wt MSO 1% v/v
Saflufenacil + Imazethapyr + Glyphosate	OpTill + Roundup PowerMax	Burndown	95 + 870	AMS 2% wt/wt + MSO 1% v/v
2,4-D Amine + Glyphosate *fb* S-metolachlor + Metribuzin	2,4-D Amine 4 + Roundup Power Max *fb* Boundary	Burndown PRE	560 + 870 2050	AMS 2% wt/wt
S-metolachlor + Metribuzin + Glyphosate	Boundary + Roundup PowerMax	Burndown	2050 + 870	AMS 2% wt/wt
2,4-D Amine + Glyphosate *fb* Sulfentrazone + Cloransulam	2,4-D Amine 4 + Roundup PowerMax *fb* Authority First	Burndown PRE	560 + 870 294	AMS 2% wt/wt
Sulfentrazone + Cloransulam + Glyphosate	Authority First + Roundup PowerMax	Burndown	294 + 870	AMS 2% wt/wt NIS 0.25% v/v
2,4-D Amine + Glyphosate *fb* Cloransulam + Acetochlor	2,4-D Amine 4 + Roundup PowerMax *fb* First Rate+ Warrant	Burndown POST	560 + 870 17.7 + 1600	AMS 2% wt/wt
2,4-D Amine + Glyphosate *fb* Chlorimuron + Acetochlor	2,4-D Amine 4 + Roundup PowerMax *fb* Classic + Warrant	Burndown POST	560 + 870 5.8 + 1600	AMS 2% wt/wt
2,4-D Amine + Glyphosate *fb* Imazethapyr + Acetochlor	2,4-D Amine 4 + Roundup PowerMax *fb* Pursuit + Warrant	Burndown POST	560 + 870 70 + 1600	AMS 2% wt/wt
2,4-D Amine + Glyphosate *fb* Lactofen + Acetochlor	2,4-D Amine 4 + Roundup PowerMax *fb* Cobra + Warrant	Burndown POST	560 + 870 220 + 1600	AMS 2% wt/wt *fb* COC 1% v/v
2,4-D Amine + Glyphosate *fb* Fomesafen + Acetochlor	2,4-D Amine 4 + Roundup PowerMax *fb* Flexstar + Warrant	Burndown POST	560 + 870 264 + 1600	AMS 2% wt/wt *fb* COC 1% v/v

[a]Abbreviations: AMS, ammonium sulfate; COC, crop oil concentrate; MSO, methylated seed oil; *fb*, followed by; NIS, nonionic surfactant. [b]A blanket application of glyphosate at 1.74 kg·ae·ha^{-1} + AMS 2% wt/wt was applied for control of late-season weed species.

tested for normality with the use of PROC UNIVERIATE. Visual estimations of control of giant ragweed, density, and biomass data were arcsine square-root transformed before analysis; however, non-transformed data are presented with mean separation on the basis of transformed data. Where the ANOVA indicated treatment effects were significant, means were separated at $P \leq 0.05$ using Tukey-Kramer's pairwise comparison test.

3. Results and Discussion

Year-by-treatment interaction for giant ragweed control, density, and biomass was non-significant; therefore, data from the 2 yr were averaged. Control of glyphosate-resistant giant ragweed varied among herbicide treatments (**Table 2**). Glyphosate applied alone or in tank-mixtures with S-metolachlor plus metribuzin provided the least control (≤36%) of giant ragweed at 7 days after burndown treatment (DABT). Saflufenacil plus imazethapyr had the highest giant ragweed control (93%). Burndown treatments with 2,4-D provided 63% to 66% control of giant ragweed 7 DABT; however, at 14 DABT, control was improved to 87 to 99%, and was comparable with saflufenacil plus imazethapyr (89%). This is because the epinastic injury symptoms of 2,4-D were observed at 7 DABT, but most severe symptoms were expressed at 14 DABT. Similarly, Barnett *et al.* (2013) reported 64 and 90% control of glyphosate-resistant giant ragweed, respectively, at 10 and 30 days after 2,4-D amine application. Control of giant ragweed at 21 DABT followed a similar trend to earlier observations. The burndown application of 2,4-D or saflufenacil plus imazethapyr provided 87% to 99% control at 21 DABT. Pre-

Table 2. Control of glyphosate-resistant giant ragweed at 7, 14, and 21 DABT, at 7, 30 DAPOST, and at harvest in glyphosate-resistant soybean.

Herbicide	Application timing	Rate	Giant ragweed control after burndown treatments[a,b,c]			Giant ragweed control after POST herbicide treatments[a,b,c]		
			7 DABT	14 DABT	21 DABT	7 DAPOST	30 DAPOST	At harvest
		g·ae or ai·ha^{-1}	%					
Nontreated Control[d]	-	-	0	0	0	0	0	0
Glyphosate *fb* Glyphosate	Burndown POST	870 870	36 d	54 b	56 b	43 c	46 b	10 c
2,4-D Amine *fb* Glyphosate	Burndown POST	560 870	63 b	87 a	92 a	93 a	92 a	89 ab
2,4-D Amine + Glyphosate *fb* Saflufenacil + Imazethapyr	Burndown PRE	560 + 870 95	64 b	98 a	99 a	99 a	99 a	99 a
Saflufenacil + Imazethapyr + Glyphosate	Burndown	95 + 870	93 a	94 a	89 a	85 a	68 b	63 b
2,4-D Amine + Glyphosate *fb* S-metolachlor + Metribuzin	Burndown PRE	560 + 870 2050	66 b	98 a	99 a	99 a	99 a	99 a
S-metolachlor + Metribuzin + Glyphosate	Burndown	2050 + 870	28 d	48 b	51 b	41 c	23 c	5 c
2,4-D Amine + Glyphosate *fb* Sulfentrazone + Cloransulam	Burndown PRE	560 + 870 294	64 b	94 a	99 a	99 a	97 a	96 a
Sulfentrazone + Cloransulam + Glyphosate	Burndown	294 + 870	51 c	64 b	65 b	50c	47 b	25 c
2,4-D Amine + Glyphosate *fb* Cloransulam + Acetochlor	Burndown POST	560 + 870 17.7 + 1600	64 b	86 a	87 a	85 a	89 a	87 ab
2,4-D Amine + Glyphosate *fb* Chlorimuron + Acetochlor	Burndown POST	560 + 870 5.8 + 1600	65 b	92 a	95 a	97 a	93 a	90 ab
2,4-D Amine + Glyphosate *fb* Imazethapyr + Acetochlor	Burndown POST	560 + 870 70 + 1600	65 b	94 a	96 a	96 a	95 a	95 a
2,4-D Amine + Glyphosate *fb* Lactofen + Acetochlor	Burndown POST	560 + 870 220 + 1600	65 b	94 a	93 a	97 a	90 a	89 ab
2,4-D Amine + Glyphosate *fb* Fomesafen + Acetochlor	Burndown POST	560 + 870 264 + 1600	65 b	91 a	92 a	94 a	95 a	94 a
P-value			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a]Abbreviations: DABT, days after burndown treatment; DAPOST, days after post-emergence treatment; POST, post-emergence; PRE, pre-emergence. [b]The data were arc-sine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data. [c]Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$. [d]Visual estimates of nontreated control (0%) were not included in analysis.

vious researchers reported 90% and 92% control of glyphosate-resistant giant ragweed with 2,4-D and dicamba, respectively, at 30 days after application in a bare ground study [28]. In another study, saflufenacil applied 7 or 14 days before planting no-till cotton (*Gossypium hirsutum* L.) provided >90% control of glyphosate-resistant horseweed [*Conyza canadensis* (L.) Cronq.] [22].

Burndown applications of 2,4-D followed by PRE or POST herbicide treatments were effective for control of glyphosate-resistant giant ragweed. PRE or POST herbicides prevented regrowth of the partially controlled giant ragweed plants that survived the burndown treatment. For example, saflufenacil plus imazethapyr, S-metolachlor plus metribuzin, or sulfentrazone plus cloransulam applied PRE resulted in 99% control of giant ragweed (**Table 2**). Similarly, cloransulam, chlorimuron, fomesafen, imazethapyr, or lactofen tank-mixed with acetochlor resulted in 85% to 97% control of giant ragweed at 7 days after POST treatment (DAPT) with no difference between them. Poor control of giant ragweed (≤68%) was usually observed when the burndown-only treatments were not followed by PRE or POST herbicides at 30 DAPT.

Similar results were observed for visual control ratings recorded at soybean harvest (**Table 2**). Herbicide treatments containing 2,4-D in a burndown program followed by PRE or POST herbicides provided 89% to 99% control of glyphosate-resistant giant ragweed. Similarly, 2,4-D was found most effective for control of giant ragweed and resulted in 99% control at 28 DAT [29]. This is due to the fact that giant ragweed is very sensitive to growth hormone herbicides [28] [29]. For example, a study in Ontario, Canada reported 99% control of glyphosate-resistant giant ragweed with dicamba applied in a burndown treatment before planting soybean [30]. Giant ragweed control with saflufenacil plus imazethapyr was 89% at 21 DABT; however, control was reduced to 63% at soybean harvest. The other burndown-only treatments such as S-metolachlor plus metribuzin and sulfentrazone plus cloransulam resulted in ≤25% control of giant ragweed at soybean harvest due to the fact that no PRE or POST herbicides were followed in these treatments. Although burndown-only application of 2,4-D resulted in 89% control of giant ragweed at harvest, it cannot be recommended, because it lacks diversified herbicide approach, that may result in evolution of multiple herbicide-resistant giant ragweed if applied repeatedly.

Giant ragweed densities differed among herbicide treatments (**Table 3**). The nontreated control had highest giant ragweed density (28 plants·m^{-2}); however, it was comparable with the glyphosate alone, S-metolachlor plus metribuzin, and sulfentrazone plus cloransulam treatments. The treatments with burndown application of 2,4-D generally resulted in lower giant ragweed densities (0 to 6 plants·m^{-2}). Although not significantly different with several other treatments, 2,4-D followed by PRE herbicide treatments resulted in ≤1 plant·m^{-2}. Previous research reported a giant ragweed density of 2.8 plants·m^{-2} after 30 d of 2,4-D applied alone compared to 0.3 plant·m^{-2} when 2,4-D was applied with glufosinate [28].

The results of giant ragweed control and density were reflected in biomass. The nontreated control had the highest biomass (673 g·m^{-2}), but it was usually comparable with burndown-only treatments (**Table 3**). This indicated that the burndown-only treatments were not sufficient for late-season control of giant ragweed and other weed species such as common waterhemp (data not shown). The treatments tested with 2,4-D followed by PRE or POST herbicides resulted in biomass accumulation between 0 to 113 g·m^{-2} and weed control efficiency 75 to 100%. Previous researchers reported giant ragweed biomass of 22.5 and 10.8 g·m^{-2} with 2,4-D applied at 560 and 1,120 g ae·ha^{-1}, respectively, at 30 days after application [28]. Similarly, another study reported 0.1 and 3.7 g·plant^{-1} biomass when 2,4-D was applied to 10 to 25 and 26 to 46 cm tall giant ragweed plants, respectively [29].

Year-by-treatment interaction for soybean yield was significant; therefore, data are presented separately for both years. The non-treated control and burndown-only treatments usually resulted in no yield due to extreme competition of glyphosate-resistant giant ragweed with soybeans in combination with extreme drought in 2012. This indicated that if left un-controlled by using burndown-only treatments without sequential herbicide application, giant ragweed at a density of 20 to 28 plants·m^{-2} can cause 100% yield reduction in soybean. Similar trend was observed in 2013, except burndown-only treatment of saflufenacil plus imazethapyr, and sulfentrazone plus cloransulam resulted in 1854 and 577 kg·ha^{-1} soybean yields, respectively. Burndown application of 2,4-D followed by PRE or POST herbicides resulted in higher soybean yields. No soybean injury was observed in any herbicide treatment in this study indicating all the registered herbicides were safe to apply as per the label direction.

Early-season weed control is extremely important to prevent soybean yield reduction. Giant ragweed is an early-emerging weed and if not controlled, it can compete with soybeans and significantly reduce yield. Burndown application of 2,4-D followed by PRE or POST herbicides were very effective in this study for control of glyphosate-resistant giant ragweed. Burndown-only treatments such as saflufenacil plus imazethapy provided initial control, but regrowth of giant ragweed resulted in competition later in the season that reduced soybean yield. Plant-back restriction for soybean is 15 days for 2,4-D; therefore, it is important to apply 2,4-D as burndown at least 15 days before planting soybean to avoid injury. In an earlier study, soybean was injured 11% when 2,4-D was applied 7 days before planting [24]. Soybean cultivars with traits conferring resistance to pre-plant or POST applications of 2,4-D or dicamba are being developed and may be commercialized in the near future [30] [31]. This may provide more flexibility of POST 2,4-D or dicamba application for control of glyphosate-resistant weeds, including giant ragweed [30] [32].

4. Conclusion

Results of this study indicate that soybean fields with glyphosate-resistant giant ragweed infestation require a

Table 3. Effects of herbicide treatments on glyphosate-resistant giant ragweed density, biomass, WCE, and soybean yield in 2012 and 2013.

Herbicide	Application timing	Rate	Giant ragweed[a,b,c]			Soybean Yield[a,b,c]	
			Density	Biomass	WCE	2012	2013
		g·ae or ai·ha^{-1}	No. m^{-2}	G·m^{-2}	%	Kg·ha^{-1}	
Nontreated Control[d]	-	-	28 a	673 a	-	0	0
Glyphosate *fb* Glyphosate	Burndown POST	870 870	22 ab	326 b	44 b	0	0
2,4-D Amine *fb* Glyphosate	Burndown POST	560 870	6 cd	100 cd	92 a	1227 ab	3407 a
2,4-D Amine + Glyphosate *fb* Saflufenacil + Imazethapyr	Burndown PRE	560 + 870 95	0 d	0 d	100 a	1698 a	3635 a
Saflufenacil + Imazethapyr + Glyphosate	Burndown	95 + 870	15 b	361 b	72 ab	0	1854 bc
2,4-D Amine + Glyphosate *fb* S-metolachlor + Metribuzin	Burndown PRE	560 + 870 2050	1 cd	13 cd	99 a	1379 ab	3473 a
S-metolachlor + Metribuzin + Glyphosate	Burndown	2050 + 870	26 a	496 a	41 b	0	0
2,4-D Amine + Glyphosate *fb* Sulfentrazone + Cloransulam	Burndown PRE	560 + 870 294	0 d	12 cd	97 a	1177 ab	3823 a
Sulfentrazone + Cloransulam + Glyphosate	Burndown	294 + 870	20 ab	459 a	52 b	0	577 c
2,4-D Amine + Glyphosate *fb* Cloransulam + Acetochlor	Burndown POST	560 + 870 17.7 + 1600	6 cd	113 bcd	85 ab	1211 ab	2875 ab
2,4-D Amine + Glyphosate *fb* Chlorimuron + Acetochlor	Burndown POST	560 + 870 5.8 + 1600	7 bc	202 b	84 ab	488 b	3153 ab
2,4-D Amine + Glyphosate *fb* Imazethapyr + Acetochlor	Burndown POST	560 + 870 70 + 1600	3 cd	65 cd	89 ab	1211 ab	2877 ab
2,4-D Amine + Glyphosate *fb* Lactofen + Acetochlor	Burndown POST	560 + 870 220 + 1,600	7 bc	184 bc	75 ab	1496 a	2598 ab
2,4-D Amine + Glyphosate *fb* Fomesafen + Acetochlor	Burndown POST	560 + 870 264 + 1600	4 cd	103 cd	84 ab	1261 ab	2519 ab
P-value			<0.0001	<0.0001	0.0005	0.0131	<0.0001

[a]Abbreviations: PRE, pre-emergence; POST, post-emergence; WCE; weed control efficiency. [b]Giant ragweed density and biomass data were arcsine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data. [c]Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$. [d]Treatments with zero yield values were not included in analysis.

combination of 2,4-D as burndown followed by PRE or POST herbicides for effective control. The results of this study also confirmed that giant ragweed is extremely competitive [8] [28], so growers should not allow giant ragweed to remain uncontrolled. Herbicide options are available for control of glyphosate-resistant giant ragweed in glyphosate-resistant soybean; however, the use of the same herbicide or herbicides with the same mode-of-action can result in evolution of herbicide-resistant weeds. Therefore, an integrated management approach should be adopted that may include cultural (crop rotation, planting date, and planting density) and mechanical (tillage and cultivation) strategies in addition to chemical control, which must include herbicides with different modes-of-action.

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