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SHORT COMMUNICATION

Control of glyphosate-resistant common ragweed in corn with preemergence herbicides

Nader Soltani, Lynette Brown and Peter H. Sikkema

Abstract: Four field experiments were conducted during 2016 and 2017 to evaluate the efficacy of preemergence herbicides to control of glyphosate-resistant common ragweed in corn.

Dicamba, dicamba/atrazine, mesotrione+atrazine, isoxaflutole+atrazine, saflufenacil/dimethenamid-P and S-metolachlor/mesotrione/bicyclopyrone/atrazine were the most efficacious herbicides, providing 94-100% control of GR common ragweed and reducing density and biomass 98-100%.

Keywords: Aboveground biomass, density, preemergence herbicides, shoot dry weight

Introduction

The continuous use of glyphosate in glyphosate-resistant (GR) corn and soybean has resulted in the evolution of GR weeds which are increasingly limiting grower's use of glyphosate in North America and other parts of the world (Heap 2017). In Canada, there are currently five

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Abbreviations: GR, glyphosate-resistant; GS, glyphosate-susceptible; WAT, weeks after herbicide treatment; PP, preplant; PRE, preemergence; POST, postemergence

known weed species that are resistant to glyphosate (Heap 2017). Four of these GR weed species, giant ragweed (*Ambrosia trifida* L.), Canada fleabane [*Conyza canadensis* (L.) Cronquist], common waterhemp (*Amaranthus tuberculatus* var. *rudis*) and common ragweed (*Ambrosia artemisiifolia* L.) have been documented in Ontario (Heap 2017).

Glyphosate-resistant common ragweed was first confirmed resistant to glyphosate in Ontario from seed collected in 2011 (Heap 2017). Common ragweed has evolved resistance to four herbicide modes-of-action including chlorimuron-ethyl, cloransulam-ethyl, and imazethapyr (Group 2), atrazine (Group 5), linuron (Group 7) and glyphosate (Group 9) (Heap 2017). Most of the GR common ragweed biotypes in Ontario are also resistant to acetolactate synthase (ALS) inhibiting herbicides (Heap 2017).

Common ragweed is a weed in the *Asteraceae* family which is native to North America and was first found in 1838 in Michigan, USA (Wagner and Beals 1958). In eastern Canada, the earliest documentation of common ragweed was in Prescott, Ontario; while other collections suggest that common ragweed is native to the Canadian Prairies (Bassett and Terasmae 1962). Common ragweed is one of the top five most commonly occurring weeds in southern Ontario, occurring in nearly 35% of agricultural fields in this region (Frick and Thomas 1992). Common ragweed is a major cause of hay fever in humans and thus has been designated as a noxious weed under the “Weeds Control Act” in Ontario which requires property owners to eradicate this weed or weed seeds from their land (Cowbrough 2006).

Common ragweed has prolonged pattern of emergence and typically flowers during the latter part of the summer to early autumn with each plant producing nearly one billion pollen grains which can be carried over 200 km with the wind (Mitich 1996). Common ragweed due to its early and prolonged germination pattern is very competitive in corn and soybean and has

potential to reduce yield significantly in these crops if not adequately controlled early in the season. Weaver (2001) found that common ragweed at the density of >32 plants per square meter can reduce corn yield as much as 38% under Ontario environmental conditions. Soybean yield losses have ranged from 70% (Weaver 2001) to 73% (Van Wely et al. 2014) due to common ragweed interference in Ontario.

Common ragweed is controlled best with tillage or soil-applied herbicides early in the season (Jordan et al. 2013). Limited information exists on the control of GR common ragweed in corn with soil-applied herbicides under Ontario environmental conditions. More research is needed to ascertain if preemergence (PRE) herbicides registered for broadleaf weed control in corn can adequately control GR common ragweed in corn. The resistance of GR common ragweed biotypes in Ontario to acetolactate synthase (ALS) inhibiting herbicides (Heap 2017) reduces the number of herbicide options for corn producers. It is imperative to determine the efficacy of herbicides with different modes of action for the control of GR common ragweed in corn. Currently, the registered broadleaf herbicides applied PRE, in corn with potential for the control of common ragweed include atrazine, dicamba, *S*-metolachlor, dimethenamid-P, pyroxasulfone, mesotrione + atrazine, pethoxamid, dicamba/atrazine, isoxaflutole + atrazine, *S*-metolachlor/atrazine, flumetsulam, *S*-metolachlor/mesotrione/ atrazine, *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, mesotrione + rimsulfuron and saflufenacil/dimethenamid-P. The efficacy of these herbicides to control GR common ragweed in GR corn is not known under Ontario environmental conditions. Ineffective herbicides applied by growers will result in reduced control, lower corn yields and unnecessary loading of pesticides in the environment.

This research intends to evaluate various broadleaf herbicides, applied PRE, at the manufacturer's highest label rate in eastern Canada to control GR common ragweed in GR corn.

Materials and Methods

A study consisting of four field trials (two in 2016 and two in 2017) was conducted in a farmer's field near Tecumseh, Ontario which had a heavy infestation of GR common ragweed. The two experiments in each calendar year were separated in time (two weeks apart). Treatments for each experimental trials are listed in Table 1. Trials were arranged in a randomized complete block design and were replicated four times. The herbicide rates selected are the highest registered label rate in eastern Canada. Weed-free control plots were maintained weed-free with saflufenacil/dimethenamid-P (735 g a.i. ha⁻¹) applied PRE followed by hand hoeing as needed. Plots consisted of 4 rows of corn, spaced 0.75 m apart, that were 8 m long. Glyphosate-resistant corn was seeded 5 cm deep at the rate of approximately 75,000 seeds ha⁻¹ in early May to early June of each year.

A CO₂-pressurized back-pack sprayer calibrated to deliver 200 L ha⁻¹ of water at 200 kPa was used to apply the herbicide treatments. The boom was 1.5 m long with four nozzles (Hypro ULD120-02 nozzle tips, Hypro, New Brighton, MN) spaced 0.5 m apart resulting in a 2.0 m spray width. Treatments were applied 1 to 2 d after seeding corn.

Corn injury (2 and 4 weeks after crop emergence, WAE) and GR common ragweed control (4 and 8 weeks after application, WAA) were visually evaluated on a scale of 0 (no injury/no control) to 100% (complete plant death/complete control). In addition, at 4 WAA, GR common ragweed density and aboveground dry weight (biomass) were determined from randomly selected one square meter of each plot. GR common ragweed plants were counted and then cut at

the soil surface, put in a paper bag and were dried in an oven (60°C) for at least 48 hours before weighting. Since the field site was approximately 100 km from campus it was not practical to move machinery for harvest at this site, therefore, corn was hand harvested only from the middle 2 rows of the weedy and weed-free control plots.

The GLIMMIX procedure in SAS (Ver. 9.4, SAS Institute Inc., Cary, NC) was used to carry out data analysis. Herbicide treatments were considered as fixed effects and the environment (year and application timing) and replications within environment were considered as the random effect. The random effects were assigned to facilitate broad-sense inference, that is, to be able to apply the conclusions of the treatment effects to new environments. Different models and distributions were assessed using the AICC as well as a residual analysis, the latter consisting of reviewing residual plots and the Shapiro-Wilk statistic. Once a final model was confirmed, least square means (LSMEANS) were calculated and Tukey's adjustment was applied to pairwise comparisons to separate variations among means ($p < 0.05$). Percent GR common ragweed control was analyzed using a normal distribution; density and dry weight data was best described using a lognormal distribution. Treatment means calculated using the lognormal distribution were back-transformed for presentation due to the fact that there is no link function to display values on the mean scale.

Results and Discussion

There was minimal corn injury with herbicides evaluated at 2 and 4 WAE (data not shown). Corn yield averaged 3.98 t ha⁻¹ for the untreated weedy plots and 10.7 t ha⁻¹ for the weed-free plots which indicates a 63% yield reduction in the weedy plots compared to the weed-free plots (data not shown). Among PRE herbicides evaluated, *S*-metolachlor at 1600 g a.i. ha⁻¹,

dimethenamid-P at 693 g a.i. ha⁻¹, pyroxasulfone at 150 g a.i. ha⁻¹, pethoxamid at 1200 g a.i. ha⁻¹ and flumetsulam at 50 g a.i. ha⁻¹ controlled GR common ragweed minimally ranging from 8 to 27% at 4 WAA and 7 to 28% at 8 WAA (Table 1). Results are similar to Van Wely et al. (2014) that found inconsistent control of GR common ragweed in soybean. Flumetsulam (70 g a.i. ha⁻¹), applied preplant (PP), controlled GR common ragweed 33-58% at 4 WAA and 20-57% at 8 WAA, respectively (Van Wely et al. 2014). Taziar et al. (2016) found only 9-39% control of common ragweed with dimethenamid-P (544 g a.i. ha⁻¹), *S*-metolachlor (2022 g a.i. ha⁻¹) and pyroxasufone (544 g a.i. ha⁻¹) applied PRE in dry bean. Similarly, Li et al. (2016) reported only 3-4% control of common ragweed with dimethenamid-P (544 g a.i. ha⁻¹) or *S*-metolachlor (1050 g a.i. ha⁻¹) applied PRE in dry bean.

Atrazine at 1500 g a.i. ha⁻¹, *S*-metolachlor/atrazine at 2880 g a.i. ha⁻¹, mesotrione + rimsulfuron at 144+15 g a.i. ha⁻¹ and *S*-metolachlor/mesotrione/atrazine at 2056 g a.i. ha⁻¹ controlled GR common ragweed 63 to 87% at 4 WAA and 62 to 87% at 8 WAA.

The best herbicide treatments, dicamba at 600 g a.i. ha⁻¹, dicamba/atrazine at 1800 g a.i. ha⁻¹, mesotrione + atrazine at 140+1500 g a.i. ha⁻¹, isoxaflutole + atrazine at 105+1063 g a.i. ha⁻¹, saflufenacil/dimethenamid-P at 735 g a.i. ha⁻¹, and *S*-metolachlor/mesotrione/bicyclopyrone/atrazine at 2022 g a.i. ha⁻¹ controlled GR common ragweed 94 to 100% at 4 and 8 WAA (Table 1). In other studies, the tankmix of mesotrione (105 g a.i. ha⁻¹) + atrazine (2240 g a.i. ha⁻¹) was shown to control glyphosate-susceptible GS and GR common ragweed 91 to 99% in Nebraska (Ganie and Jhala 2017). Whaley et al. (2006) found that GS common ragweed control was increased from 37 and 49% to >83% and 95% when atrazine at 280 and 560 g a.i. ha⁻¹ was tankmixed with mesotrione, respectively. Armel et al. (2003) reported that mesotrione, applied PRE, did not adequately control GS common ragweed, but when combined with acetochlor

>80% control was achieved in corn. In other studies, PRE application of atrazine alone (1000 g a.i. ha⁻¹) and *S*-metolachlor/atrazine (1000 g a.i. ha⁻¹) provided inconsistent control (51 to 65%) of GS common ragweed in corn in 2008 (Soltani et al. 2012). However, PRE application of isoxaflutole + atrazine (40 + 400 g a.i. ha⁻¹) and dicamba/atrazine (1000 g a.i. ha⁻¹) controlled GS common ragweed 63-100% and 98-100%, respectively (Soltani et al. 2012).

S-metolachlor, dimethenamid-P, pyroxasulfone, pethoxamid and flumetsulam, applied PRE, did not cause any significant reduction in GR common ragweed density (Table 1). Atrazine, *S*-metolachlor/atrazine, mesotrione + rimsulfuron and *S*-metolachlor/mesotrione/atrazine, applied PRE, reduced GR common ragweed density 76 to 95% compared to the weedy control. Dicamba, dicamba/atrazine, mesotrione + atrazine, isoxaflutole + atrazine, saflufenacil/dimethenamid-P and *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, applied PRE, reduced GR common ragweed density 99 to 100% (Table 1). In other studies, Taziar et al. (2016) found that *S*-metolachlor (1050 g a.i. ha⁻¹), pyroxasufone (100 g a.i. ha⁻¹) and dimethenamid-P (544 g a.i. ha⁻¹), applied PRE, did not significantly reduce GS common ragweed density. In contrast, Li et al. (2016) reported that *S*-metolachlor (1050 g a.i. ha⁻¹) and dimethenamid-P (544 g a.i. ha⁻¹), applied PRE, reduced GS common ragweed density 60% and 76%, respectively.

Glyphosate-resistant common ragweed aboveground biomass reduction relative to the weedy control followed a similar pattern as control and density evaluations (Table 1). *S*-metolachlor, dimethenamid-P, pyroxasulfone, pethoxamid and flumetsulam, applied PRE, caused no significant reduction in the biomass of GR common ragweed (Table 1). Atrazine, *S*-metolachlor/atrazine, mesotrione + rimsulfuron and *S*-metolachlor/mesotrione/atrazine decreased GR common ragweed biomass 84, 88, 81 and 93% compared to the weedy control, respectively

(Table 1). Dicamba, dicamba/atrazine, mesotrione + atrazine, isoxaflutole + atrazine, saflufenacil/dimethenamid-P and *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, applied PRE, decreased biomass of GR common ragweed 98 to 100% compared to the untreated weedy control treatment (Table 1). In other studies, Van Wely et al. (2014) found inconsistent biomass reduction in GR common ragweed in soybean. Flumetsulam (70 g a.i. ha⁻¹), and saflufenacil/dimethenamid-P (245 g a.i. ha⁻¹) caused 21-65 and 84-95% biomass reduction in GR soybean, respectively (Van Wely et al. 2014). Taziar et al. (2016) reported that *S*-metolachlor (1050 g a.i. ha⁻¹), pyroxasufone (100 g a.i. ha⁻¹) and dimethenamid-P (544 g a.i. ha⁻¹), applied PRE, did not provide any reduction in GS common ragweed biomass. However, in contrast Li et al. (2016) reported that *S*-metolachlor (1050 g a.i. ha⁻¹) and dimethenamid-P (544 g a.i. ha⁻¹) applied PRE, reduced GS common ragweed biomass 68% and 42%, respectively.

This study concludes that dicamba, dicamba/atrazine, mesotrione + atrazine, isoxaflutole + atrazine, saflufenacil/dimethenamid-P, and *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, applied PRE, can adequately control GR common ragweed in corn. In addition, there is potential for *S*-metolachlor/mesotrione/atrazine, applied PRE, to control GR common ragweed in corn. However, the other registered herbicides evaluated including *S*-metolachlor, dimethenamid-P, pyroxasulfone, pethoxamid, flumetsulam, atrazine, *S*-metolachlor/atrazine and mesotrione + rimsulfuron, applied PRE, do not provide an adequate control of GR common ragweed in glyphosate-resistant corn in Ontario.

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Table 1. Percent control 4 and 8 WAA, density and dry weight 4 WAA for glyphosate-resistant common ragweed in glyphosate-resistant corn with PRE herbicides in 2016 and 2017. Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test at $P<0.05$.^a

GR common ragweed					
Treatment ^b	Rate (g a.i. ha ⁻¹)	Visible control (%)		Density (# m ⁻²)	Aboveground biomass (g m ⁻²)
		4 WAT	8 WAT		
Weedy control		0 f	0 e	179.4 h	25.7 d
Weed-free control		100 a	100 a	0.0 a	0.0 a
S-metolachlor	1600	8 ef	7 de	124.7 h	31.1 d
Dimethenamid-P	693	14 e	15 d	107.2 gh	22.2 d
Pyroxasulfone	150	27 e	28 d	69.2 fgh	14.8 d
Pethoxamid	1200	18 e	17 d	82.0 fgh	19.2 d
Atrazine	1500	63 d	67 bc	22.7 def	4.0 c
Dicamba	600	100 a	98 a	0.1 ab	0.0 ab
Dicamba/atrazine	1800	100 a	100 a	0.0 a	0.0 a
Mesotrione + atrazine	140+1500	94 ab	94 a	2.0 bcd	0.4 abc
Flumetsulam	50	22 e	24 d	98.8 fgh	17.6 d
Isoxaflutole + atrazine	105+1063	97 a	98 a	2.1 abcd	0.1 ab
Saflufenacil/dimethenamid-P	735	100 a	99 a	0.4 ab	0.1 ab
S-metolachlor/atrazine	2880	73 bcd	69 bc	22.2 cdef	3.2 bc
S-metolachlor/mesotrione/atrazine	2056	87 abc	87 ab	9.8 bcde	1.7 bc
S-metolachlor/mesotrione/bicyclopyrone/atrazine	2022	98 a	97 a	2.3 abc	0.1 ab
Mesotrione + rimsulfuron	144+15	70 cd	62 c	42.4 efg	4.9 c

^a Abbreviations: PRE, preemergence; WAA, weeks after herbicide application.

^b All herbicide treatments included glyphosate (450 g a.e. ha⁻¹).