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SHORT COMMUNICATION

Postemergence herbicides for control of glyphosate-resistant Canada fleabane in corn

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Short Title: Glyphosate-resistant Canada fleabane control in corn

Postemergence herbicides were evaluated for glyphosate-resistant Canada fleabane control in corn (*Zea mays* L.) from 2013 to 2015. By 8 wk after treatment, dicamba/atrazine (96% control), dicamba (95% control), bromoxynil + atrazine (93% control), dicamba/diflufenzopyr (90% control), and tembotrione/thiencarbaxone-methyl + dicamba (85% control) reduced population density and aboveground biomass to levels equivalent to the weed-free control.

Key words: Corn, *Zea mays* L., Canada fleabane, *Conyza canadensis* (L.) Cronq., weed control**Abbreviations:** GR, glyphosate-resistant; POST, postemergence; WAT, wk after treatment

Canada fleabane [*Conyza canadensis* (L.) Cronq.] has been a weed of increasing concern since the first glyphosate-resistant (GR) biotype was identified in 2000 in Delaware (VanGessel 2001). Over the next decade, GR Canada fleabane was reported in an additional 20 states in the U.S. before being found in Canada (Heap 2016). In 2010, GR Canada fleabane populations were

identified at eight separate locations in one southern Ontario county (Byker et al. 2013b). Since 2010, GR Canada fleabane has spread and now can be found in 28 Ontario counties, including a county adjacent to the Quebec border (Brown et al. 2016). The rapid spread of GR Canada fleabane is due to the reproduction, dispersal, and germination ecology of this species (VanGessel 2001). As a result, GR Canada fleabane must now be controlled in the major field crops of southern Ontario: corn, soybean [*Glycine max* (L.) Merr.], and winter wheat (*Triticum aestivum* L.) (Byker et al. 2013a; Ford et al. 2014; Mahoney et al. 2016).

Controlling herbicide-resistant weeds, especially those with multiple herbicide-resistant biotypes (Byker et al. 2013b) in no-till fields is challenging because there are fewer means of herbicidal control (VanGessel 2001) and other options need to be explored. Unfortunately for Ontario growers, there is limited published information on the control of GR Canada fleabane in corn (Brown et al. 2016), especially with POST herbicides. A recent study by Ford et al. (2014) examined the control of GR Canada fleabane in corn with a new glyphosate and 2,4-D premix applied POST. While this is valuable information for Ontario corn growers, the resistance technology trait used in that study is still not widely available. Therefore, the objective of this research was to evaluate the efficacy of several POST herbicides for the control of GR Canada fleabane in corn.

MATERIALS AND METHODS

From 2013 to 2015, six experiments were conducted in non-irrigated farmers' fields near Blenheim, Morpeth, Mull, and Ridgetown, Ontario with a history of GR Canada fleabane (Byker et al. 2013b). Treatments were arranged in a randomized complete block with four replications.

Glyphosate/glufosinate-resistant corn was seeded into loam soils with sufficient fertility at a rate of 80,000 seeds ha⁻¹ approximately 5 cm deep in rows spaced 75 cm apart into plots 2.25 m wide by 10 m long using a no-till planter. The herbicide treatments used in these experiments were glyphosate (900 g ha⁻¹) alone and in a tank mixture with another herbicide, a formulated premix (indicated with a “/”), or a common tank mixture (indicated with a “+”) (Table 1). Glyphosate tank mixtures included 2,4-D ester (560 g ha⁻¹), atrazine (1000 g ha⁻¹), dicamba (600 g ha⁻¹), dicamba/diflufenzopyr (200 g ha⁻¹), dicamba/atrazine (1500 g ha⁻¹), bromoxynil + atrazine (280 + 1500 g ha⁻¹), prosulfuron + dicamba (10 + 140 g ha⁻¹), mesotrione + atrazine (100 + 280 g ha⁻¹), topramezone + atrazine (12.5 + 500 g ha⁻¹), tembotrione/thiencarbaxone-methyl (45 g ha⁻¹), and glufosinate (500 g ha⁻¹). In 2014 and 2015, glyphosate tank mixtures with halosulfuron (35 or 70 g ha⁻¹) and tembotrione/thiencarbaxone-methyl + dicamba (45 + 300 g ha⁻¹) were added. Treatments were applied to rosette stage GR Canada fleabane when plants were less than 15 cm in height (corn was typically at V2 to V3 growth stage) using a CO₂ pressurized backpack sprayer calibrated to deliver 200 L ha⁻¹ of water at 207 kPa through four Hypro Ultra-low drift 120-02 nozzles (Hypro, New Brighton, MN) spaced 50 cm apart. Untreated and weed-free controls were included in each experiment. Weed-free control plots were established with a preplant application of glyphosate + saflufenacil/dimethenamid-p (900 + 735 g ha⁻¹) and maintained with hand-weeding as needed.

Crop injury and weed control were estimated visually on a scale of 0 (no injury/control) to 100% (complete plant death). Corn injury was rated 1 and 4 wk after herbicide treatment (WAT) and control of GR Canada fleabane was rated at 4 and 8 WAT. Season-long control of GR Canada fleabane was measured by collecting plant population density and aboveground dry

biomass data 8 WAT. GR Canada fleabane plants were counted within a randomly placed 1 m² quadrat each plot, cut at the soil surface, dried, and weighed.

Data were analyzed using PROC GLIMMIX (SAS Ver. 9.4, SAS Institute Inc., Cary, NC). Herbicide treatment was considered a fixed effect and random effects were environment (year-location combinations), environment $\times$ herbicide treatment interaction, and block nested within environment. Significance of the fixed effect was tested using an F-test and random effects were tested using a likelihood ratio. Residual plots were used to check that variances were randomly distributed, independent, and homogeneous using the Laplace method. Corn injury (at 1 WAT) and GR Canada fleabane control (at 4 and 8 WAT) were analyzed using a normal distribution and identity link. Corn injury (at 4 WAT) and GR Canada fleabane population density and aboveground biomass (at 8 WAT) were analyzed using a lognormal distribution and identity link. Means were separated with Fisher's protected LSD at $P < 0.05$. Data compared on the transformed scale were converted back to the original scale for presentation of results.

RESULTS AND DISCUSSION

Regardless of the herbicide used, no crop injury was observed 1 and 4 WAT in most environments, except in 2013 at a location near Ridgetown. At this location, injury 1 WAT ranged from 2 to 6% across all glyphosate tank mixtures; the exception to this was bromoxynil + atrazine with 13% injury (data not shown). However, injury was transient as all treatments were similar to the untreated control by 4 WAT (data not shown). Soltani et al. (2010) similarly reported that herbicide injury in corn can be temporary. For weed control, population density,

and aboveground biomass, no significant environment $\times$ herbicide treatment interactions were detected and the data were combined across environments.

All glyphosate tank mixtures controlled GR Canada fleabane better than glyphosate alone (13% control) at 4 and 8 WAT (Table 1). Across all glyphosate tank mixtures, bromoxynil + atrazine was the best option as control at 4 and 8 WAT, population density, and aboveground biomass were similar to the weed-free control. This result was consistent with a recent study in winter wheat where a POST tank mixture containing bromoxynil controlled GR Canada fleabane (Mahoney et al. 2016).

The next best options included dicamba (i.e., a glyphosate tank mixture with dicamba, dicamba/diflufenzopyr, dicamba/atrazine, or tembotrione/thiencarbaxone-methyl + dicamba). With these glyphosate tank mixtures, GR Canada fleabane control 8 WAT, population density, and aboveground biomass were equivalent to the weed-free control (Table 1). Observations of acceptable levels of GR Canada fleabane control with dicamba treatments were consistent with OMAFRA (2013) guidelines and other studies (Johnson et al. 2004; Byker et al. 2013a).

For the remaining glyphosate tank mixtures, 2,4-D ester, mesotrione + atrazine, and topramezone + atrazine suppressed GR Canada fleabane (control ranged from 65 to 71% at 4 WAT and 71 to 76% at 8 WAT), while control from atrazine, tembotrione/thiencarbaxone-methyl, glufosinate, and halosulfuron tank mixtures (control ranged from 39 to 57% at 4 WAT and 36 to 42% 8 WAT) was unacceptable (Table 1). GR Canada fleabane population density and aboveground biomass for all of these glyphosate tank mixtures were greater than the weed-free control. These results are consistent with a report of decreased sensitivity of GR Canada fleabane to 2,4-D (Ford et al. 2014) and with a study by Johnson et al. (2004) indicating poor control of GR Canada fleabane with glufosinate. However, contrary to the results of the current study,

Johnson et al. (2004) found that atrazine, mesotrione + atrazine, and halosulfuron each provided greater than 90% control of GR Canada fleabane.

The results of this research demonstrated that the most effective POST glyphosate tank mixtures for controlling GR Canada fleabane were bromoxynil + atrazine followed by dicamba, dicamba/diflufenzopyr, dicamba/atrazine, or tembotrione/thiencarbaxone-methyl + dicamba. This information will be important for Ontario corn growers that need to manage GR Canada fleabane with POST herbicides.

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Table 1. Visual estimates of GR^a Canada fleabane control 4 and 8 WAT with glyphosate or glyphosate plus POST herbicides and GR Canada fleabane population density and aboveground biomass 8 WAT in corn from 2013 to 2015 in Ontario.

Treatment ^b	Rate --- (g ha ⁻¹) ---	Control		Density (plants m ⁻²)	Biomass --- (g m ⁻²) ---
		4 WAT	8 WAT		
		----- (%) -----			
Untreated control	---	---	---	100 <i>g</i>	231.9 <i>h</i>
Weed-free control	---	100 <i>a</i>	100 <i>a</i>	0 <i>a</i>	0 <i>a</i>
Glyphosate	900	13 <i>g</i>	13 <i>e</i>	77 <i>fg</i>	100.7 <i>g</i>
2,4-D ester	560	65 <i>cd</i>	71 <i>bc</i>	11 <i>cd</i>	5.3 <i>cd</i>
Atrazine	1000	42 <i>ef</i>	37 <i>d</i>	25 <i>de</i>	27.5 <i>e</i>
Dicamba	600	76 <i>b</i>	95 <i>a</i>	1 <i>a</i>	0.2 <i>a</i>
Dicamba/diflufenzopyr ^c	200	73 <i>bcd</i>	90 <i>a</i>	2 <i>ab</i>	0.9 <i>ab</i>
Dicamba/atrazine	1500	75 <i>bc</i>	96 <i>a</i>	1 <i>a</i>	0.6 <i>a</i>
Bromoxynil + atrazine ^d	280 + 1500	87 <i>ab</i>	93 <i>a</i>	1 <i>a</i>	0.5 <i>a</i>
Prosulfuron + dicamba ^d	10 + 140	58 <i>de</i>	71 <i>bc</i>	23 <i>de</i>	8.0 <i>d</i>
Mesotrione + atrazine ^d	100 + 280	71 <i>bcd</i>	76 <i>bc</i>	4 <i>bc</i>	2.9 <i>bc</i>
Topramezone + atrazine ^e	12.5 + 500	67 <i>cd</i>	67 <i>c</i>	8 <i>c</i>	6.1 <i>cd</i>
Tembotrione/thienencarbaxone-methyl	45	41 <i>ef</i>	42 <i>d</i>	63 <i>fg</i>	35.1 <i>ef</i>
Glufosinate	500	57 <i>de</i>	42 <i>d</i>	34 <i>ef</i>	26.4 <i>e</i>
Halosulfuron ^{fg}	35	39 <i>f</i>	37 <i>d</i>	52 <i>efg</i>	62.2 <i>efg</i>
Halosulfuron ^{fg}	70	39 <i>f</i>	36 <i>d</i>	55 <i>efg</i>	69.9 <i>fg</i>
Tembotrione/thienencarbaxone-methyl + dicamba ^g	45 + 300	73 <i>bcd</i>	85 <i>ab</i>	2 <i>ab</i>	1.0 <i>ab</i>

Note: Values with lowercased letters within a column are not significantly different according to Fisher's protected LSD at $P < 0.05$.

^a Abbreviations: GR, glyphosate-resistant; POST, postemergence; WAT, wk after herbicide application.

^b All treatments listed after glyphosate included glyphosate in a tank mixture at 900 g ha⁻¹, “/” indicates a premix, and “+” indicates a tank mixture.

^c Included non-ionic surfactant at 0.25% v/v plus 28% UAN at 1.25% v/v.

^d Included non-ionic surfactant at 0.2% v/v.

^e Included mineral oil + surfactant blend at 1.25% v/v.

^f Included non-ionic surfactant at 0.25% v/v.

^g Treatments were added in 2014 and 2015.