

What Are the Most Efficacious Herbicides Applied Postemergence for Control of Multiple-Herbicide-Resistant Canada Fleabane [*Conyza canadensis* (L.) Cronq.] in Corn?

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Received: June 13, 2023

Accepted: July 9, 2023

Online Published: August 15, 2023

doi:10.5539/jas.v15n9p1

URL: <https://doi.org/10.5539/jas.v15n9p1>

Abstract

Multiple-herbicide-resistant (MHR) Canada fleabane [*Conyza canadensis* (L.) Cronq.] control has become a major concern for corn producers in Ontario. Postemergence (POST) herbicides are critical for the control of emerged MHR Canada fleabane in corn. A study that consisted of five field experiments was conducted in southwestern Ontario in fields with confirmed MHR Canada fleabane to evaluate various herbicide mixtures applied POST for the control of MHR Canada fleabane in corn. Glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST provided 63-99% control, 77-100% density reduction, and 88-100% shoot biomass reduction of MHR Canada fleabane in corn. MHR Canada fleabane interference reduced corn yield up to 58%; reduced MHR Canada fleabane interference with all herbicide treatments resulted in corn yield similar to the weed-free control. Results of this study indicate that among the herbicide mixtures evaluated glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST provided the most consistent control of MHR Canada fleabane in corn.

Keywords: corn grain yield, glyphosate-resistant, herbicide mixture, injury, postemergence herbicides, weed density, weed shoot biomass

1. Introduction

Canada fleabane is one of the most problematic weeds in corn production in many US states and in Ontario, Canada (Soltani et al., 2016, 2022; Van Wychen, 2020). Glyphosate-resistant (GR) Canada fleabane was originally confirmed from seeds collected in one county in 2010 but has now spread to 30 counties extending from the province's border with Michigan in the southwest to the eastern border with Quebec (Byker et al., 2013; Budd et al., 2017). Multiple-herbicide-resistant (MHR) Canada fleabane has been estimated to exist in 5% of all field crop hectares in Ontario and if left uncontrolled can cause a yield loss of 52% in corn or a farm-gate monetary loss of \$46.5 million (Soltani et al., 2022).

Canada fleabane is a winter or summer annual weed that is native to North America and is found in most Canadian provinces (Weaver, 2001). Canada fleabane can produce as many as a million seeds per plant that are 1 to 2 mm in length with an attached pappus which helps the seeds to be dispersed by the wind as far as 500 km away from the source (Frankton & Mulligan, 1987; Royer & Dickinson, 1999; Shields et al., 2006). Canada fleabane can emerge 11 out of 12 months of the year (Weaver, 2001); however, there are two primary emergence periods: August to October and April to May (Tozzi & Van Acker, 2014). Preplant (PP) herbicides are often used

to control Canada fleabane in corn; however, postemergence (POST) herbicides are needed for the control of emerged Canada fleabane after corn emergence (Loux et al., 2006).

MHR Canada fleabane populations in Ontario are frequently resistant to cloransulam (Group 2) and glyphosate (Group 9) and less frequently to paraquat (Group 22) (Corteva Agriscience Canada, 2022). Resistance of Canada fleabane in Ontario to multiple herbicide Groups has further complicated the management of this troublesome weed in corn production. Postemergence herbicides are critical for the control of emerged MHR Canada fleabane to minimize corn yield losses due to MHR Canada fleabane interference. Possible herbicide mixtures for postemergence control of MHR Canada fleabane in corn include glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine. However, these herbicides have not been simultaneously evaluated for the control of MHR Canada fleabane in corn under Ontario environmental conditions.

The aim of this study was to assess the efficacy of the aforementioned herbicide mixtures applied POST for the control of MHR Canada fleabane.

2. Materials and Methods

A total of five experiments were conducted over a two-year period (2021 and 2022) in fields with confirmed MHR Canada fleabane (resistance to Groups 2 and 9) at various sites (E1 to E5) in southwestern Ontario. Site description and soil characteristics for each site are listed in Table 1.

Table 1. Year, location, soil characteristics, application weather conditions, application date, seeding date, and emergence date for trials conducted in Ontario, Canada in 2021 and 2022

Year	Location	Texture	Soil Characteristics ^a						Application Weather Conditions			Application Date	Seeding Date	Emergence Date
			Sand	Silt	Clay	Organic Matter	pH	Air Temperature	Relative Humidity	Wind Speed				
			----- % -----						°C	%	km h ⁻¹			
E1	2021	Bothwell, ON	Loamy Sand	85	11	4	3.3	6.5	33	25	2	1 June	31 May	5 June
E2	2021	Zone Centre, ON	Loamy sand	85	11	4	2.5	6.8	24	56	1	16 June	31 May	5 June
E3	2021	Turin, ON	Loamy sand	82	13	6	2.2	6.1	27	86	4	8 June	31 May	5 June
E4	2022	Bothwell, ON	Sand	89	9	2	3	6.4	17	-	1	3 June	31 May	7 June
E5	2022	Kintyre, ON	Sandy loam	58	28	14	3.3	7.3	22	63	5	19 May	24 May	31 May

Note. ^a Soil cores were extracted to a depth of 15 cm and analyzed by A&L Canada Laboratories Inc. (2136 Jetstream Road, London, ON) to determine soil characteristics.

Experiments were arranged in a randomized complete block design with four replications. The experimental plots were 2.25 m wide (3 corn rows spaced 75 cm apart) by 8 m long. Glyphosate/glufosinate-resistant corn hybrids ‘DKC39-97 RIB’/‘DKC 42-04RIB’ were seeded to a depth of 4-5 cm at approximately 80,000 seeds ha⁻¹. Treatments included a weedy and a weed-free control, glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine (Table 2). Adjuvants used were based on the herbicide manufacturers’ recommendations and are listed in Tables 3 and 4.

Table 2. Active ingredients, trade names, and manufacturers^a

Active Ingredients ^b	Trade Name	Manufacturer
2,4-D amine	2,4-D Amine 600	Nufarm Agriculture Inc., Calgary AB
Atrazine	Aatrex Liquid 480	Syngenta Canada Inc., Guelph, ON
Bromoxynil	Pardner	Bayer CropScience Canada, Calgary, AB
Clopyralid	Lontrel XC	Corteva Agriscience Canada Company, Calgary, AB
Dicamba	Xtendimax	Bayer CropScience Canada, Calgary, AB
Dicamba/atrazine	Marksman	BASF Canada Inc., Mississauga, ON
Glyphosate	Roundup WeatherMAX	Bayer CropScience Canada, Calgary, AB
Glyphosate/2,4-D choline	Enlist Duo	Corteva Agriscience Canada Company, Calgary, AB
Glyphosate/dicamba	Roundup Xtend	Bayer CropScience Inc., Calgary, AB
Glyphosate/S-metolachlor/mesotrione	Halex GT	Syngenta Canada Inc., Guelph, ON
Mesotrione	Callisto 480SC	Syngenta Canada Inc., Guelph, ON
S-metolachlor/mesotrione/atrazine	Lumax EZ	Syngenta Canada Inc., Guelph, ON
S-metolachlor/mesotrione/bicyclopyrone	Acuron Flexi	Syngenta Canada Inc., Guelph, ON
S-metolachlor/mesotrione/bicyclopyrone/atrazine	Acuron	Syngenta Canada Inc., Guelph, ON
Tembotrione	Laudis	Bayer CropScience Canada, Calgary, AB
Tolpyralate	SHieldex 400SC	ISK Biosciences Corporation, Concord, OH

Note. ^a Specimen labels for each product and manufacturer contact information can be found at <https://pr-rp.hc-sc.gc.ca/lr-re/index-eng.php>.

^b Treatments containing tembotrione, tolpyralate, and mesotrione included Hasten (1.75 L ha⁻¹) (Victorian Chemical Co Pty Ltd, Coolaroo, Vic), MSO (0.5 % v/v) (Loveland Products Inc., Loveland, CO), and Agral 90 (0.2 % v/v) (Syngenta Canada Inc., Guelph, ON), respectively.

Herbicides were sprayed POST when MHR Canada fleabane was approximately 10 cm diameter/tall with a CO₂-pressurized backpack sprayer calibrated to deliver 200 L ha⁻¹ aqueous solution at 240 kPa. The boom was 1.5 m long with four Hypro ULD120-02 nozzle tips (Hypro, New Brighton, MN, USA) spaced 50 cm apart producing a spray width of 2.0 m.

Visible corn injury was evaluated 1 and 4 weeks after herbicide application (WAA) and Canada fleabane control was evaluated 4 and 8 WAA on a scale of 0-100% (0% = no corn injury/no MHR Canada fleabane control and 100% = complete death/control). Weed density was determined by counting MHR Canada fleabane plants present in 2 quadrats (0.25 m² each) within each plot at 8 WAA. Aboveground dry weight (shoot biomass) was determined by cutting MHR Canada fleabane plants at the soil level within each quadrat, placing them in a paper bag, drying them (60 °C) to constant moisture, and then weighing them. Two rows of corn in each plot were harvested at maturity with a small plot combine; weight and moisture were recorded. Yields were adjusted to 15.5% seed moisture content prior to statistical analyses.

2.1 Statistical Analysis

The GLIMMIX procedure in SAS Studio v9.4, OnDemand for Academics (SAS Institute, Cary, NC) was used for statistical analyses. Generalized linear mixed models were constructed for each parameter and consisted of the fixed effect of herbicide treatment and the random effects of environment (location-year combinations), block nested within environment, and the environment-by-treatment interaction. Data were pooled where the environment-by-treatment interaction was non-significant. Visible estimates of MHR Canada fleabane control 4 and 8 WAA were arcsine square-root transformed prior to analysis using the normal distribution. MHR Canada fleabane density and shoot biomass were analyzed using the lognormal distribution while corn yield was analyzed using a normal distribution. Model fitness and normality were assessed using the Pearson chi-square/degrees of freedom ratio and Shapiro-wilk statistic, respectively, to avoid potential overdispersion of residuals. Homogeneity of variance and the assumptions of normality (residuals are independent, homogenous, and normally distributed) were confirmed using plots of normal probability and studentized residuals. Means were separated using Tukey-Kramer multiple range test; a significance level of 0.05 was used for all analyses. All values were independently compared to zero to evaluate differences between the Canada fleabane control at 4 and 8 WAA and the weedy control. The same process was used to compare Canada fleabane density and shoot biomass to the weed-free control. The delta method was used to convert Arcsine square root transformed data

back to the data scale. The omega method (M Edwards, Ontario Agricultural College Statistician, University of Guelph, personal communication) was used to back transform data analyzed with the lognormal distribution. Data were pooled for environments where treatment-by-year-by-location interactions were non-significant.

3. Results and Discussion

3.1 Corn Injury and Yield

At 2 and 4 WAA, glyphosate/dicamba + tembotrione, glyphosate + tolpyralate + atrazine, and glyphosate + mesotrione + atrazine caused up to 5% corn injury; all other herbicide mixtures caused no corn injury (data not presented). Yield response varied based on environments. In E1 and E4, MHR Canada fleabane interference did not cause any reduction in corn yield (Table 3); however, at E2, E3, and E5, MHR Canada fleabane interference reduced corn yield 58% (nontreated control compared to weed-free control) (Tables 3 and 4). Reduced MHR Canada fleabane interference with all herbicide treatments evaluated resulted in corn yield that was comparable to the weed-free control (Tables 3 and 4).

Table 3. Multiple-herbicide-resistant Canada fleabane control 4 and 8 weeks after application (WAA), density and shoot biomass 8 WAA, and corn grain yield from herbicide mixtures applied postemergence in corn from two trials conducted in Ontario, Canada in 2021 and 2022^{a,b}

Herbicide Treatment ^c	Rate	E1 and E4				
		Visible Control		Density	Shoot Biomass	Yield
		4 WAA	8 WAA			
	g ae or ai ha ⁻¹	-----	% -----	plants m ⁻²	g m ⁻²	kg ha ⁻¹
Untreated control	-	0 b	0 b	99 b	163 c	7,910 a
Weed-free control	-	100	100	0 a	0 a	8,360 a
Glyphosate + 2,4-D amine	900 + 560	67 a	63a	21 b	16 bc	9,070 a
Glyphosate/2,4-D choline	882/838	80 a	78 a	23 b	9 bc	8,930 a
Glyphosate + clopyralid	900 + 200	81 a	79 a	16 b	5 ab	9,280 a
Glyphosate + <i>S</i> -metolachlor/mesotrione/bicyclopyrone	900 + 1268/141/35	88 a	85 a	7 ab	11 ab	8,590 a
Glyphosate + tolpyralate + atrazine	900 + 40 + 560	90 a	86 a	7 ab	13 ab	8,740 a
Glyphosate + dicamba	900 + 600	87 a	90 a	5 ab	1 ab	8,030 a
Glyphosate + dicamba/atrazine	900 + 504/996	84 a	91 a	2 ab	1 ab	7,240 a
Glyphosate + <i>S</i> -metolachlor/mesotrione/atrazine	900 + 1393/139/524	87 a	91 a	12 ab	19 ab	9,240 a
Glyphosate + mesotrione + atrazine	900 + 100 280	92 a	93 a	0 ab	0 ab	8,490 a
Glyphosate + bromoxynil + atrazine	900 + 280 + 1490	91 a	94 a	0 a	0 a	8,530 a
Glyphosate + <i>S</i> -metolachlor/mesotrione/bicyclopyrone/atrazine	900 + 1259/140/35/588	93 a	94 a	1 ab	1 ab	9,280 a
Glyphosate/ <i>S</i> -metolachlor/mesotrione + atrazine ^b	1050/1050/105 + 280	93 a	94 a	6 ab	6 ab	9,410 a
Glyphosate/dicamba + tembotrione	900/450 + 92.4	94 a	95 a	4 ab	1 ab	8,320 a
Glyphosate + tembotrione + bromoxynil	900 + 92.4 + 280	96 a	96 a	1 ab	1 ab	8,850 a
Glyphosate/dicamba + tembotrione + atrazine	900/450 + 92.4 + 576	96 a	97 a	0 ab	0 ab	8,780 a
Glyphosate + tembotrione + atrazine	900 + 92.4 + 576	97 a	97 a	0 a	0 a	9,820 a

Note. ^a Abbreviations: WAA; weeks after application.

^b Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test ($P > 0.05$).

^c Treatments containing tembotrione, tolpyralate, and mesotrione included Hasten (1.75 L ha⁻¹) (Victorian Chemical Co Pty Ltd, Coolaroo, Vic), MSO (0.5 % v/v) (Loveland Products Inc., Loveland, CO), and Agral 90 (0.2 % v/v) (Syngenta Canada Inc., Guelph, ON), respectively.

Table 4. Multiple-herbicide-resistant Canada fleabane control 4 and 8 weeks after application (WAA), density and shoot biomass 8 WAA, and corn grain yield from herbicide mixtures applied postemergence in corn from three trials conducted in Ontario, Canada in 2021 and 2022^{a,b}

Herbicide Treatment ^c	Rate	E2, E3, and E5				
		Visible Control		Density	Shoot Biomass	Yield
		4 WAA	8 WAA			
	g ae or ai ha ⁻¹	----- % -----		plants m ⁻²	g m ⁻²	kg ha ⁻¹
Untreated control	-	0 b	0 b	191 b	175 c	4,140 b
Weed-free control	-	100	100	0 a	0 a	9,950 a
Glyphosate + 2,4-D amine	900 + 560	89 a	91 a	7 a	2 ab	8,830 a
Glyphosate/2,4-D choline	882/838	95 a	96 a	1 a	0 ab	9,110 a
Glyphosate + clopyralid	900 + 200	83 a	93 a	1 a	0 ab	9,740 a
Glyphosate + S-metolachlor/mesotrione/bicyclopyrone	900 + 1268/141/35	85 a	89 a	7 a	17 b	9,480 a
Glyphosate + tolpyralate + atrazine	900 + 40 + 560	95 a	96 a	2 a	2 ab	9,410 a
Glyphosate + dicamba	900 + 600	88 a	94 a	1 a	0 ab	9,320 a
Glyphosate + dicamba/atrazine	900 + 504/996	85 a	94 a	2 a	1 ab	9,410 a
Glyphosate + S-metolachlor/mesotrione/atrazine	900 + 1393/139/524	92 a	94 a	6 a	7 b	9,390 a
Glyphosate + mesotrione + atrazine	900 + 100 280	93 a	95 a	2 a	2 ab	9,410 a
Glyphosate + bromoxynil + atrazine	900 + 280 + 1490	97 a	98 a	0 a	0 ab	9,580 a
Glyphosate + S-metolachlor/mesotrione/bicyclopyrone/atrazine	900 + 1259/140/35/588	94 a	96 a	1 a	2 ab	9,490 a
Glyphosate/S-metolachlor/mesotrione + atrazine ^b	1050/1050/105 + 280	90 a	93 a	2 a	2 ab	10,080 a
Glyphosate/dicamba + tembotrione	900/450 + 92.4	95 a	98 a	0 a	0 ab	9,320 a
Glyphosate + tembotrione + bromoxynil	900 + 92.4 + 280	97 a	97 a	0 a	0 ab	9,410 a
Glyphosate/dicamba + tembotrione + atrazine	900/450 + 92.4 + 576	97 a	99 a	0 a	0 ab	9,450 a
Glyphosate + tembotrione + atrazine	900 + 92.4 + 576	97 a	98 a	0 a	0 ab	8,770 a

Note. ^a Abbreviations: WAA; weeks after application.

^b Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test ($P > 0.05$).

^c Treatments containing tembotrione, tolpyralate, and mesotrione included Hasten (1.75 L ha⁻¹) (Victorian Chemical Co Pty Ltd, Coolaroo, Vic), MSO (0.5 % v/v) (Loveland Products Inc., Loveland, CO), and Agral 90 (0.2 % v/v) (Syngenta Canada Inc., Guelph, ON), respectively.

These results are comparable to other studies that have found minimal or no injury in corn injury from glyphosate mixtures with dicamba/atrazine, mesotrione + atrazine, S-metolachlor/atrazine, and rimsulfuron + S-metolachlor + dicamba (Brown et al., 2016). Flutterm et al. (2022) reported no injury or yield reduction in corn with mesotrione or tolpyralate applied alone or in a mixture with atrazine or bromoxynil. In other studies, no injury or yield reduction was reported in corn with glyphosate + S-metolachlor/atrazine/mesotrione/bicyclopyrone and glyphosate + S-metolachlor/mesotrione/bicyclopyrone (Jha, 2021; Lawson, 2017; Richburg et al., 2019). Another study reported up to 42% reduction in corn yield from MHR Canada fleabane interference but reduced MHR Canada fleabane interference with herbicide mixtures of glyphosate + S-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + dicamba/atrazine, and glyphosate + tolpyralate + atrazine resulted in corn yield that was similar to the weed-free control (Soltani et al., 2021). Metzger et al. (2019) reported a 47% reduction in corn yield from GR Canada fleabane interference but reduced GR Canada fleabane interference with tolpyralate + atrazine, dicamba/atrazine, and bromoxynil + atrazine applied POST resulted in corn yield that was comparable to the weed-free control.

3.2 MHR Canada Fleabane Control

The average density of MHR Canada fleabane when the herbicide treatments were applied was 42, 21, 562, 112, and 106 plants m⁻² at E1, E2, E3, E4, and E5, respectively.

In E1 and E4 environments, glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + S-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + S-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + S-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/S-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate +

tembotrione + atrazine applied POST controlled MHR Canada fleabane 67-97% at 4 WAA and 63-97% at 8 WAA; however, there was no statistical difference in MHR Canada fleabane control among the herbicide treatments evaluated at 4 or 8 WAA (Table 3).

In E2, E3, and E4 environments, glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST controlled MHR Canada fleabane 83-97% at 4 WAA and 89-99% at 8 WAA; however, there was no difference in MHR Canada fleabane control among the herbicide treatments tested at 4 or 8 WAA (Table 4).

Results of this study are similar to other research in which glyphosate + dicamba, glyphosate + dicamba/diflufenzopyr, glyphosate + dicamba/atrazine, and glyphosate + bromoxynil + atrazine applied POST provided > 90% control of GR Canada fleabane in corn (Mahoney et al., 2017). However, the same study reported only 58-76% control of GR Canada fleabane in corn with glyphosate + prosulfuron + dicamba, glyphosate + mesotrione + atrazine, and glyphosate + 2,4-D ester applied POST (Mahoney et al., 2017). Additionally, Johnson et al. (2004) reported > 90% control of GR Canada fleabane with atrazine, mesotrione + atrazine, and halosulfuron applied POST in corn. Metzger et al. (2019) reported 95% or greater control of GR Canada fleabane in corn with tolpyralate + atrazine, dicamba/atrazine, and bromoxynil + atrazine applied POST. Kruger et al. (2010) observed 90% or greater control of 0-30 cm GR Canada fleabane with dicamba or 2,4-D ester applied POST in corn. In another study, Brown et al. (2016) reported that dicamba/atrazine, mesotrione + atrazine, and saflufenacil/dimethenamid-p applied PP controlled GR Canada fleabane > 96% in corn. Similarly, Soltani et al. (2021) observed excellent control (90-100%) of GR Canada fleabane with glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + dicamba/atrazine, and glyphosate + tolpyralate + atrazine applied PP in corn. Sarangi and Jhala (2017) reported that *S*-metolachlor/atrazine/mesotrione/bicyclopyrone applied PP provided 88-91% control of GR Canada fleabane in corn.

3.3 MHR Canada Fleabane Density

In E1 and E4 environments, glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST reduced MHR Canada fleabane density 77-100% at 8 WAA however, there were no significant differences among herbicide mixtures evaluated except for glyphosate + bromoxynil + atrazine and glyphosate + tembotrione + atrazine which decreased MHR Canada fleabane density significantly greater than glyphosate + 2,4-D amine, glyphosate/2,4-D choline, and glyphosate + clopyralid (Table 3). In E2, E3 and E4 environments the herbicide mixtures evaluated applied POST reduced MHR Canada fleabane density 96-100% at 8 WAA; there were no significant differences among the herbicide treatments tested (Table 4).

Results from this research are similar to other studies in which glyphosate + dicamba, glyphosate + dicamba/diflufenzopyr, glyphosate + dicamba/atrazine, glyphosate + bromoxynil + atrazine, and glyphosate + mesotrione + atrazine applied POST reduced GR Canada fleabane density; in contrast, glyphosate + prosulfuron + dicamba, and glyphosate + 2,4-D ester applied POST reduced GR Canada fleabane density 70% and 86%, respectively (Mahoney et al., 2017). Metzger et al. (2019) reported a 99-100% reduction in the density of GR Canada fleabane in corn with tolpyralate + atrazine, dicamba/atrazine, and bromoxynil + atrazine applied POST. Brown et al. (2016) reported a 97-100% reduction in the density of GR Canada fleabane with dicamba/atrazine, mesotrione + atrazine, isoxaflutole + atrazine, saflufenacil/dimethenamid-p, *S*-metolachlor/atrazine, and rimsulfuron + *S*-metolachlor + dicamba applied PP in corn.

3.3 MHR Canada Fleabane Shoot Biomass

In E1 and E4 environments, glyphosate + 2,4-D amine, glyphosate/2,4-D choline, glyphosate + clopyralid, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + tolpyralate + atrazine, glyphosate + dicamba, glyphosate + dicamba/atrazine, glyphosate + *S*-metolachlor/mesotrione/atrazine, glyphosate +

mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST reduced MHR Canada fleabane biomass 88-100% at 8 WAA, there were no significant differences between herbicide mixtures evaluated except for glyphosate + bromoxynil + atrazine and glyphosate + tembotrione + atrazine decreased MHR Canada fleabane shoot biomass significantly greater than glyphosate + 2,4-D amine and glyphosate/2,4-D choline (Table 3). In E2, E3 and E4 environments the herbicide mixtures evaluated applied POST reduced MHR Canada fleabane shoot biomass 90-100% at 8 WAA, there was no difference between herbicide treatments tested (Table 4).

These results are similar to other research in which glyphosate + dicamba, glyphosate + dicamba/diflufenzopyr, glyphosate + dicamba/atrazine, glyphosate + bromoxynil + atrazine, glyphosate + mesotrione + atrazine, glyphosate + prosulfuron + dicamba, and glyphosate + 2,4-D ester applied POST reduced GR Canada fleabane shoot biomass 92-100% in corn (Mahoney et al., 2017). Metzger et al. (2019) reported 98-100% reduction in shoot biomass of GR Canada fleabane in corn with tolpyralate + atrazine, dicamba/atrazine, and bromoxynil + atrazine applied POST. Similarly, another study showed a 93-100% reduction in shoot biomass of GR Canada fleabane biomass with the herbicide mixtures of dicamba/atrazine, mesotrione + atrazine, isoxaflutole + atrazine, saflufenacil/dimethenamid-p, *S*-metolachlor/atrazine, and rimsulfuron + *S*-metolachlor + dicamba applied PP in corn (Brown et al., 2016).

4. Conclusions

Based on the data from this research the herbicide mixtures evaluated applied POST provided 63-99% control, 77-100% density reduction, and 88-100% shoot biomass reduction of MHR Canada fleabane; reduced weed interference resulted in corn yield that was similar to the weed-control. This study concludes that glyphosate + mesotrione + atrazine, glyphosate + bromoxynil + atrazine, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone/atrazine, glyphosate/*S*-metolachlor/mesotrione + atrazine, glyphosate/dicamba + tembotrione, glyphosate + tembotrione + bromoxynil, glyphosate/dicamba + tembotrione + atrazine, and glyphosate + tembotrione + atrazine applied POST have an adequate level of crop safety in corn and consistently controlled MHR Canada fleabane > 90%.

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Acknowledgments

Not applicable.

Authors contributions

Drs. Peter Sikkema and Nader Soltani were responsible for the study design and writing of this manuscript. Christian Willemse conducted the statistical analysis of the data collected.

Funding

This research was funded in part by Grain Farmers of Ontario (GFO), and the Ontario Agri-Food Innovation Alliance.

Competing interests

No other competing of interests has been declared.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer-reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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