Journal of Agricultural Science; Vol. 16, No. 3; 2024
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

What Are the Most Efficacious Herbicides Applied Preplant for Control of Multiple-Herbicide-Resistant Canada Fleabane in Corn?

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Received: December 21, 2023 Accepted: February 2, 2024 Online Published: February 15, 2024
doi:10.5539/jas.v16n3p39 URL: https://doi.org/10.5539/jas.v16n3p39

Abstract

New weed management strategies are needed to effectively control multiple-herbicide-resistant (MHR) Canada fleabane in corn. Five experiments were established in growers' corn fields with confirmed MHR Canada fleabane to determine the efficacy of various herbicides applied preplant (PP). In 2021 environments, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provided excellent control (90-100%) of MHR Canada fleabane but glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone and glyphosate + *S*-metolachlor/atrazine/mesotrione controlled MHR Canada fleabane 77-84% and 87-96%, respectively at 4, 8, and 12 weeks after application (WAA). Herbicide tankmixes evaluated reduced MHR Canada fleabane density and biomass 91-100%. In 2022 environments, all glyphosate tankmixes evaluated provided 97-100% control, 99-100% density reduction, and 100% biomass reduction of MHR Canada fleabane in corn. In 2021 and 2022 environments MHR Canada fleabane interference reduced corn yield 41 and 32%, respectively; reduced MHR Canada fleabane interference with all herbicide treatments resulted in corn yield similar with the weed-free control. Results of this study indicate that glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provide excellent and consistent control of MHR Canada fleabane. However, glyphosate + *S*-metolachlor/atrazine/mesotrione and glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone do not provide consistent control of MHR Canada fleabane in corn.

Keywords: glyphosate-resistant, corn injury, weed density, weed biomass, herbicide tankmix, corn yield

1. Introduction

Corn is an important grain crop grown in Ontario. Corn growers in Ontario seeded approximately 920,000 hectares and produced nearly 14 million tonnes of corn with a farm-gate value of over $2.8 billion in 2022 (OMAFRA, 2022). Approximately 60% of the grain corn produced in Ontario is used for feed purposes while the remaining 40% is used for various industrial uses (OMAFRA, 2022). Corn yield loss from weed interference is one of the most important factors preventing growers from obtaining optimum yield (Soltani et al., 2016).

Multiple-herbicide-resistant (MHR) weeds and glyphosate-resistant (GR) weeds have become a major issue in corn production in Ontario (Soltani et al., 2022). Currently, one of the most problematic MHR weeds for crop producers in Ontario is Canada fleabane. Canada fleabane is a winter or summer annual weed from the Asteraceae family that can produce as many as a million seeds per plant (Frankton and Mulligan, 1987; Weaver, 2001). Canada fleabane seeds are 1 to 2 mm long and have an attached pappus that aids in wind dispersal; seeds can travel as far as 550 km from the parent plant (Frankton & Mulligan, 1987; Royer & Dickinson, 1999; Shields et al., 2006). Canada fleabane has a long emergence pattern throughout the cropping season (spring, summer, or fall) and therefore is best controlled with a preplant (PP) herbicide application that has residual activity (Loux et al., 2006; Weaver, 2001).

The first confirmation of GR Canada fleabane in Canada was from seeds collected in Essex County, ON in 2010 (Byker et al., 2013). GR Canada fleabane has now been confirmed in 30 counties across southern Ontario (Budd et al., 2017; Soltani et al., 2022). The herbicide-resistant Canada fleabane populations in Ontario have been reported to be mostly resistant to glyphosate (Group 9) and cloransulam (Group 2), and less frequently to paraquat (Group 22) (Corteva Agriscience Canada, 2022).

It has been estimated that MHR Canada fleabane is present in 5% of field crop hectares in Ontario (Soltani et al., 2022). Additionally, it has been estimated that MHR Canada fleabane interference causes an average 52% corn yield loss with a monetary loss of $46.5 million if MHR Canada fleabane is left uncontrolled (Soltani et al., 2022). Herbicide options that effectively control MHR Canada fleabane are needed to minimize corn yield loss from MHR Canada fleabane interference and maximize net returns to Ontario corn producers.

Preplant corn herbicide mixtures with residual activity that have the potential to control Canada fleabane include glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/atrazine/mesotrione, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p. Limited information exists on the efficacy of these herbicides to control MHR Canada fleabane in corn under Ontario environmental conditions.

The objective of this study was to evaluate the efficacy of the aforementioned herbicide mixtures 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 five 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}			
2021	Bothwell, ON (E1)	Loamy Sand	85	11	4	3.3	6.5	15	63	3.8	27 May	31 May	5 June
2021	Zone Centre, ON (E2)	Loamy sand	85	11	4	2.5	6.8	22	34	2.1	1 June	31 May	5 June
2021	Turin, ON (E3)	Loamy sand	82	13	6	2.2	6.1	27	88	3.3	8 June	31 May	5 June
2022	Zone Centre, ON (E4)	Sand	89	9	2	3.0	6.4	22	68	1.4	31 May	31 May	7 June
2022	Kintyre, ON (E5)	Sandy loam	58	28	14	3.3	7.3	22	63	5.1	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 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} in rows that were 0.75 m apart (3 rows in each plot).

Treatments included a weedy and a weed-free control, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/atrazine/mesotrione, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p (Table 2). Adjuvants used were based on the herbicide manufacturers' recommendations and are listed in Tables 3 and 4.

Table 2. Herbicide tankmixture, trade name, rate, and manufacturer for preplant field trials in Ontario, Canada in 2021 and 2022

Herbicide tank-mixture	Trade name	Rate (g ai/ae ha^{-1})	Manufacturer
Glyphosate+*S*-metolachlor/ mesotrione/bicyclopyrone	Roundup WeatherMax+ Acuron Flexi XR	900+1268/141/35	Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON
Glyphosate+*S*-metolachlor/ atrazine/mesotrione	Roundup WeatherMax+Lumax EZ	900+1393/524/139	Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON
Glyphosate+isoxaflutole+atrazine	Roundup WeatherMax+ Converge Flexx Herbicide+ Aatrex Liquid 480	900+105+1060	Bayer CropScience Inc. Calgary, AB, Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON
Glyphosate+isoxaflutole/diflufenican+atrazine	Roundup WeatherMax+ Not Available+Aatrex Liquid 480	900+255+1060	Bayer CropScience Inc. Calgary, AB, Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON
Glyphosate+*S*-metolachlor/atrazine/ mesotrione/bicyclopyrone	Roundup WeatherMax+Acuron XR	900+1259/588/140/35	Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON
Glyphosate+mesotrione+atrazine[c]	Roundup WeatherMax+ Callisto 480SC+Aatrex Liquid 480	900+140+1490	Bayer CropScience Inc. Calgary, AB, Syngenta Canada Inc., Guelph, ON, Syngenta Canada Inc., Guelph, ON
Glyphosate/dicamba+isoxaflutole/diflufenican	Roundup Xtend+Not Available	900/450+255	Bayer CropScience Inc. Calgary, AB, Bayer CropScience Inc. Calgary, AB
Glyphosate/dicamba+isoxaflutole/ diflufenican+atrazine	Roundup Xtend+Not Available+ Aatrex Liquid 480	900/450+255+1060	Bayer CropScience Inc. Calgary, AB, Bayer CropScience Inc. Calgary, AB, Bayer CropScience Inc. Calgary, AB
Glyphosate+saflufenacil/dimethenamid-p	Roundup WeatherMax+Integrity	900+75/660	Bayer CropScience Inc. Calgary, AB, BASF Canada, Mississauga, ON

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

Herbicides were sprayed PP when MHR Canada fleabane was approximately 10 cm diameter/tall with a CO_2-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 corn emergence (WAE) and Canada fleabane control was evaluated 4, 8, and 12 weeks after application (WAA) on a scale of 0-100% (0% = no corn injury/no weed control and 100% = complete death/control). Weed density was determined by counting Canada fleabane plants present in 2 quadrats (0.25 m^2 each) within each plot at 8 WAA. Aboveground dry weight (biomass) was determined by cutting 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 combined at harvest 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 to analyze each parameter at an alpha level of 0.05. Data were pooled where environment-by-treatment interactions were non-significant. Visible estimates of GR Canada fleabane control at 4, 8, and 12 WAA were analyzed using a Gaussian distribution with identity link, and where required, data were arcsine square-root transformed prior to analysis. A lognormal distribution with identity link was used to analyze MHR Canada fleabane density and biomass while a normal distribution with identity link was used to analyze corn yield. The variance was partitioned into 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. Model fitness and potential overdispersion were evaluated using the Pearson chi-square/degrees of freedom ratio and Shapiro-wilk statistic. Assumptions of normality and homogeneity of variance were confirmed by visually examining plots of normal probability and studentized residuals, respectively. The difference between MHR Canada fleabane control at 4, 8, and 12 WAA and the nontreated control were evaluated by independently comparing all values to zero. The same method was used to compare MHR Canada fleabane density and biomass to the weed-free control. Arcsine square root transformed data were back-transformed post-analysis. Data analyzed using a lognormal distribution were back-transformed using the omega method (M Edwards, Ontario Agricultural College Statistician, University of Guelph, personal communication). Data were pooled where treatment-by-year-by-location interactions were non-significant. Least-square means were separated using Tukey-Kramer multiple range test.

3. Results and Discussion

3.1 Corn Injury and Yield

At 2 and 4 WAE, treatments containing isoxaflutole/diflufenican resulted in corn injury that was ≤ 5%; other herbicide treatments caused no corn injury (data not presented). Yield responses varied based on environments. In 2021 environments (E1, E2, and E3) and 2022 environments (E4 and E5) MHR Canada fleabane interference reduced corn yield 41 and 32%, respectively (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 similar to the weed-free control (Tables 3 and 4). These results are similar to other studies that have shown minimal or no corn injury with herbicide mixtures of dicamba/atrazine (1800 g ai ha^{-1}), mesotrione + atrazine (140 + 1500 g ai ha^{-1}), isoxaflutole + atrazine (105 + 1063 g ai ha^{-1}), saflufenacil/dimethenamid-p (735 g ai ha^{-1}), *S*-metolachlor/atrazine (2880 g ai ha^{-1}), and rimsulfuron + *S*-metolachlor + dicamba (15 + 684 + 360 g ai ha^{-1}) applied PP in corn (Brown et al., 2016). In other studies, MHR Canada fleabane interference reduced corn yield as much as 42%, but reduced MHR Canada fleabane interference with glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + dicamba/atrazine, and glyphosate + tolpyralate + atrazine applied PP in corn resulted in corn yield that was similar to the weed-free control (Soltani et al., 2021). Other studies have also reported no corn injury or grain yield reduction with glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone and glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone applied PP in corn (Jha, 2021; Lawson, 2017; Richburg et al., 2019).

Table 3. Glyphosate-resistant Canada fleabane control 4, 8, and 12 weeks after application (WAA), density and biomass 8 WAA, and corn yield from herbicide tankmixtures applied preplant in corn from three field trials conducted in southwestern Ontario, Canada in 2021

Herbicide treatment	Rate	2021 environments (E1, E2, and E3)					
		Visible control[c]			Density	Biomass	Yield
		4 WAA[d]	8 WAA	12 WAA			
	g ae or ai ha^{-1}	--------------- % ---------------			plants m^{-2}	g m^{-2}	kg ha^{-1}
Nontreated control[a]	-	0 d	0 c	0 b	122 c	244 c	6,200 b
Weed-free control	-	100	100	100	0 a	0 a	10,450 a
Glyphosate+*S*-metolachlor/mesotrione/bicyclopyrone	900+1268/141/35	77 c	84 b	81 a	8 b	21 b	10,140 a
Glyphosate+*S*-metolachlor/atrazine/mesotrione	900+1393/524/139	87 bc	89 ab	96 a	11 b	20 b	10,750 a
Glyphosate+isoxaflutole+atrazine	900+105+1060	90 abc	93 ab	94 a	2 ab	4 ab	10,920 a
Glyphosate+isoxaflutole/diflufenican+atrazine	900+255+1060	95 abc	98 ab	97 a	1 ab	1 ab	11,240 a
Glyphosate+*S*-metolachlor/atrazine/mesotrione/bicyclopyrone	900+1259/588/140/35	96 abc	98 ab	98 a	0 ab	1 ab	10,850 a
Glyphosate+mesotrione+atrazine[b]	900+140+1490	99 ab	100 a	99 a	1 ab	1 ab	10,520 a
Glyphosate/dicamba+isoxaflutole/diflufenican	900/450+255	92 abc	99 a	99 a	0 a	0 a	11,030 a
Glyphosate/dicamba+isoxaflutole/diflufenican+atrazine	900/450+255+1060	99 ab	100 a	100 a	0 a	0 a	10,680 a
Glyphosate+saflufenacil/dimethenamid-p	900+75/660	100 a	100 a	100 a	0 a	0 a	11,180 a

Note. [a] The nontreated control was excluded from visible control analyses; herbicide tankmixtures were compared to the nontreated control using p-values from the Least Square Means table.

[b] Treatment included Agral 90 (Syngenta Canada Inc., Guelph, ON) (0.2% v/v).

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

[d] Abbreviations: WAA; weeks after application.

Table 4. Glyphosate-resistant Canada fleabane control 4, 8, and 12 weeks after application (WAA), density and biomass 8 WAA, and corn yield from herbicide tankmixtures applied preplant in corn from two field trials conducted in southwestern Ontario, Canada in 2022

Herbicide treatment	Rate	2022 environments (E4 and E5),					
		Visible control[c]			Density	Biomass	Yield
		4 WAA[d]	8 WAA	12 WAA			
	g ae or ai ha^{-1}	--------------- % ---------------			plants m^{-2}	g m^{-2}	kg ha^{-1}
Nontreated control[a]	-	0 b	0 b	0 b	161 b	102 a	5,400 b
Weed-free control	-	100	100	100	0 a	0 a	7,930 ab
Glyphosate+*S*-metolachlor/mesotrione/bicyclopyrone	900+1268/141/35	100 a	99 a	99 a	0 a	0 a	8,270 a
Glyphosate+*S*-metolachlor/atrazine/mesotrione	900+1393/524/139	100 a	99 a	98 a	0 a	0 a	7,780 ab
Glyphosate+isoxaflutole+atrazine	900+105+1060	99 a	99 a	99 a	0 a	0 a	7,790 ab
Glyphosate+isoxaflutole/diflufenican+atrazine	900+255+1060	99 a	99 a	98 a	0 a	0 a	7,590 ab
Glyphosate+*S*-metolachlor/atrazine/mesotrione/bicyclopyrone	900+1259/588/140/35	100 a	99 a	99 a	0 a	0 a	7,910 ab
Glyphosate+mesotrione+atrazine[b]	900+140+1490	100 a	99 a	99 a	0 a	0 a	8,620 a
Glyphosate/dicamba+isoxaflutole/diflufenican	900/450+255	99 a	99 a	97 a	2 a	0 a	7,780 ab
Glyphosate/dicamba+isoxaflutole/diflufenican+atrazine	900/450+255+1060	100 a	99 a	99 a	0 a	0 a	8,180 ab
Glyphosate+saflufenacil/dimethenamid-p	900+75/660	100 a	99 a	99 a	0 a	0 a	8,440 a

Note. [a] The nontreated control was excluded from visible control analyses; herbicide tankmixtures were compared to the nontreated control using p-values from the Least Square Means table.

[b] Treatment included Agral 90 (Syngenta Canada Inc., Guelph, ON) (0.2% v/v).

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

[d] Abbreviations: WAA; weeks after application.

3.2 MHR Canada Fleabane Control

The average MHR Canada fleabane density at the PP herbicide application timing was 62, 60, 378, 167, and 140 plants m^{-2} at E1, E2, E3, E4, and E5, respectively.

In 2021 environments at 4 WAA, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provided excellent MHR Canada fleabane control (90-100%) but glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone and glyphosate + *S*-metolachlor/atrazine/mesotrione provided 77% and 87% control of MHR Canada fleabane, respectively (Table 3). At 8 WAA, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p controlled MHR Canada fleabane 99-100% which was greater than glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone (84%); the remaining herbicide treatments provide similar MHR Canada fleabane control to all other herbicide treatments evaluated (Table 3). At 12 WAA, all herbicide mixtures provided similar MHR Canada fleabane control (Table 3).

In 2022 environments glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/atrazine/mesotrione, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provided 99-100%, 99%, and 97-99% control of MHR Canada fleabane at 4, 8, and 12 WAA, respectively (Table 4). These results are similar to those reported by Brown et al. (2016) who reported 99, 97, and 97% control of GR Canada fleabane with dicamba/atrazine, mesotrione + atrazine, and saflufenacil/dimethenamid-p, applied PP to corn, respectively. In another study, GR Canada fleabane control was 99-100, 90-97, 97-98, and 98-99% with glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + dicamba/atrazine, and glyphosate + tolpyralate + atrazine applied PP in corn (Soltani et al., 2021). Sarangi and Jhala (2017) observed 88-91% control of GR Canada fleabane with *S*-metolachlor/atrazine/mesotrione/bicyclopyrone applied PP in corn.

3.3 MHR Canada Fleabane Density

In 2021 environments, at 8 WAA, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/atrazine/mesotrione, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p reduced Canada fleabane density in corn 93, 91, 98, 99, 100, 99, 100, 100, and 100%, respectively (Table 3); in the 2022 environments at 8 WAA the aforementioned herbicide mixtures reduced Canada fleabane density 99-100% in corn (Table 4). In other studies, herbicide mixtures of dicamba/atrazine (1800 g ai ha^{-1}), mesotrione + atrazine (140 + 1500 g ai ha^{-1}), isoxaflutole + atrazine (105 + 1063 g ai ha^{-1}), saflufenacil/dimethenamid-p (735 g ai ha^{-1}), *S*-metolachlor/atrazine (2880 g ai ha^{-1}), and rimsulfuron + *S*-metolachlor + dicamba (15 + 684 + 360 g ai ha^{-1}) reduced GR Canada fleabane density 100, 100, 99, 100, 97, and 98% in corn, respectively (Brown et al., 2016).

3.4 MHR Canada Fleabane Biomass

In 2021 environments, at 8 WAA, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone, glyphosate + *S*-metolachlor/atrazine/mesotrione, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p reduced Canada fleabane biomass 91, 92, 98, 100, 100, 100, 100, 100, and 100%, respectively (Table 3); in the 2022 environments at 8 WAA the aforementioned herbicide mixtures reduced Canada fleabane biomass 100% in corn (Table 4). In other studies, herbicide mixtures of dicamba/atrazine (1800 g ai ha^{-1}), mesotrione + atrazine (140 + 1500 g ai ha^{-1}), isoxaflutole + atrazine (105 + 1063 g ai ha^{-1}), saflufenacil/dimethenamid-p (735 g ai ha^{-1}), *S*-metolachlor/atrazine (2880 g ai ha^{-1}), and rimsulfuron + *S*-metolachlor + dicamba (15 + 684 + 360 g ai ha^{-1}) reduced GR Canada fleabane biomass 100, 99, 98, 100, 93, and 99% in corn, respectively (Brown et al., 2016).

4. Conclusions

Results of this study indicate that glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provided excellent control of MHR Canada fleabane under Ontario environmental conditions. However, glyphosate + *S*-metolachlor/mesotrione/bicyclopyrone and glyphosate + *S*-metolachlor/atrazine/mesotrione do not always provide excellent and consistent control of MHR Canada fleabane under some Ontario environmental conditions. Among the tankmixes evaluated, glyphosate + isoxaflutole + atrazine, glyphosate + isoxaflutole/diflufenican + atrazine, glyphosate + *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, glyphosate + mesotrione + atrazine, glyphosate/dicamba + isoxaflutole/diflufenican, glyphosate/dicamba + isoxaflutole/diflufenican + atrazine, and glyphosate + saflufenacil/dimethenamid-p provided the most consistent control MHR Canada fleabane in corn under the environments evaluated.

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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 A. Willemse conducted the statistical analysis of the data collected.

Funding

Funding for this research was provided in part by The Grain Farmers of Ontario (GFO) and the Alliance Funding program of the Ontario Ministry of Agriculture, Food and Rural Affairs.

Competing Interests

No other competing interests have 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.