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# Control of Multiple-Herbicide-Resistant Canada Fleabane With Fall, Spring, and Sequential Herbicide Applications in Winter Wheat

Nader Soltani[1], Christy Shropshire[1] & Peter H. Sikkema[1]

[1] University of Guelph Ridgetown Campus, Ridgetown, ON, Canada

Correspondence: Nader Soltani, University of Guelph Ridgetown Campus, 120 Main St. East, Ridgetown, ON, N0P 2C0, Canada. E-mail: soltanin@uoguelph.ca

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**Abstract**

Limited information exists on the efficacy of pyrasulfotole/bromoxynil, fluroxypyr/halauxifen-methyl + MCPA EHE, and clopyralid applied in the fall, spring, or sequentially [fall followed by (fb) spring] for the control of multiple-herbicide-resistant (MHR) Canada fleabane in winter wheat under Ontario environmental conditions. Three field experiments were initiated in the autumn of 2020 and 2021 for a total of 6 site-years to evaluate fall- and spring-applied herbicides and their sequential applications for the control of MHR Canada fleabane in winter wheat in Ontario. Pyrasulfotole/bromoxynil applied in the fall, spring, or sequentially controlled MHR Canada fleabane 83, 99, and 100%, respectively at 8 weeks after the spring application (WAB); the spring and sequential applications provided better control than the fall application. Fluroxypyr/halauxifen + MCPA and clopyralid applied in the fall, spring, or sequentially controlled MHR Canada fleabane 97 to 100% and 99 to 100%, respectively at 8 WAB. Based on orthogonal contrasts the spring and sequential herbicide applications provided greater control than the fall application (8 WAB). MHR Canada fleabane interference reduced winter wheat yield up to 27% in this study. Based on orthogonal contrasts reduced MHR Canada fleabane interference with the fall application resulted in 17% higher winter wheat yield than when herbicide application was delayed to the spring. Although MHR Canada fleabane was controlled very effectively with clopyralid winter wheat yield was lower, presumably due to crop injury; this observation will have to be explored further in future research. Results from this study indicate that pyrasulfotole/bromoxynil and fluroxypyr/halauxifen + MCPA applied in the fall can be used to effectively control MHR Canada fleabane and minimize winter wheat yield loss due to weed interference.

**Keywords:** glyphosate-resistant, winter wheat injury, sequential herbicide application, weed control, orthogonal contrasts, yield

## 1. Introduction

Winter wheat (*Triticum aestivum* L.) is one of the most important crops grown globally. In Ontario, winter wheat is commonly grown in rotation with soybean, corn, and dry bean. In 2021, nearly 2.7 million tonnes of winter wheat valued at approximately $980 million was grown on approximately 440,000 hectares in Ontario (OMAFRA 2022). One of the major impediments to maximizing winter wheat production is yield loss from weed interference (Klein, 2019). A meta-analysis published by the Weed Science Society of America (WSSA) estimated that winter wheat yield would be reduced by an average of 23% in North America if weeds are not controlled and the monetary loss was estimated to be US$2.19 billion (Flessner et al., 2021).

The spread of glyphosate-resistant (GR) and multiple-herbicide-resistant (MHR) weeds in recent years in Ontario fields has further complicated weed control in winter wheat. MHR Canada fleabane (*Conyza canadensis* (L.) Cronq.) has become a troublesome weed in winter wheat in recent years. MHR Canada fleabane was first confirmed in Canada from seed collected in 2010 in Essex County, Ontario (Byker et al., 2013). Since then, MHR Canada fleabane has been confirmed across southern Ontario and is estimated to be present on 5% of the field crop hectares in Ontario (Budd et al., 2017; Soltani et al., 2022). The MHR Canada fleabane found in Ontario carries resistance to both glyphosate (Group 9) and cloransulam (Group 2), while resistance to paraquat (Group 22) is slightly less frequent (Corteva Agriscience Canada, 2022). Potential yield loss in winter wheat from MHR Canada fleabane has been estimated to be 8% with an economic loss of approximately $1.7 million (Soltani et al., 2022). There are limited herbicide options to control MHR Canada fleabane in winter wheat in

Ontario. More research is needed to find efficacious herbicides/tank mixtures with adequate crop safety for the control of MHR Canada fleabane in winter wheat.

Pyrasulfotole (Group 27)/bromoxynil (Group 6) is a postemergence (POST) broadleaf herbicide from the benzoylpyrazole and hydroxybenzonitrile chemical families that control a wide range of problematic weeds including Canada fleabane, sowthistle, chickweed, cleavers, common ragweed, flixweed, hemp-nettle, kochia, lambsquarters, pale smartweed, redroot pigweed, Russian thistle, shepherd's purse, stinkweed, volunteer canola, volunteer soybean, wild buckwheat, and wild mustard (OMAFRA, 2023; Shaner, 2014). Pyrasulfotole/ bromoxynil having fast-acting contact and systemic activity and multiple modes of action can be also an effective tool for weed resistance management in winter wheat (OMAFRA, 2023; Shaner, 2014).

Fluroxypyr/halauxifen-methyl + MCPA EHE, is a Group 4 POST herbicide from the pyridine carboxylic acids, arylpicolinate, and phenoxy carboxylic acid chemical families that can control a wide range of annual broadleaf weeds such as Canada fleabane, cleavers, shepherd's-purse, pigweeds, sowthistle, Canada thistle, henbit, purple deadnettle, wild buckwheat, common ragweed, and common lambsquarters, including herbicide-resistant biotypes (Corteva Agriscience, 2023).

Clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) is a Group 4 selective POST herbicide from the pyridine carboxylic acid chemical family that can control a wide spectrum of broadleaf weeds, including Canada fleabane, Canada thistle, clovers, tufted vetch, dandelion, wild buckwheat, and common ragweed (OMAFRA, 2023; Shaner, 2014). Clopyralid is absorbed rapidly by foliage and is translocated within the plant by both the xylem and phloem (OMAFRA, 2023; Shaner, 2014).

Limited information exists on the efficacy and crop safety of pyrasulfotole/bromoxynil, fluroxypyr/ halauxifen-methyl + MCPA EHE, and clopyralid applied in the fall or spring or sequentially (fall fb spring) for the control of MHR Canada fleabane in winter wheat. The objective of this study was to assess fall or spring-applied pyrasulfotole/bromoxynil, fluroxypyr/halauxifen-methyl + MCPA EHE, and clopyralid, and their sequential applications for the control of MHR Canada fleabane in winter wheat in Ontario.

## 2. Materials and Methods

A total of six experiments were initiated over a two-year period (2020, 2021) in fields with confirmed MHR Canada fleabane (resistance to Groups 2 and 9) near Ridgetown, Zone Centre, and Clachan, ON. Experiments were arranged in a randomized complete block design with four replications. Treatments included a weedy non-treated control, pyrasulfotole/bromoxynil (205 g ai ha$^{-1}$), fluroxypyr/halauxifen-methyl + MCPA EHE (82 + 372 g ai ha$^{-1}$), and clopyralid (200 g ai ha$^{-1}$) applied in the fall, spring, and sequentially. Adjuvants used were based on the herbicide manufacturers' recommendations and are listed in Table 1.

The experimental plots were 2 m wide by 8 m long. Winter wheat '25R40' (Corteva Agriscience, Suite 2450, 215-2nd Street SW, Calgary, AB, T2P 1M4) was seeded with a double-disc drill at approximately 150 kg ha$^{-1}$ in rows spaced 19 cm apart at a depth of 3 cm in Oct./Nov. of 2020 and 2021.

The fall herbicides were applied POST when MHR Canada fleabane was < 10 cm in diameter/height 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. Spring herbicide applications were made in late April/early May.

Visible winter wheat injury was measured at 1 and 4 weeks after fall herbicide application (WAA) and 1 and 4 weeks after spring herbicide application (WAB) and MHR Canada fleabane control was evaluated at 4 WAA and 4 and 8 WAB on a scale of 0 to 100% (0 = no visible injury/no control and 100 = plant death/total control). At maturity, a small plot combine was used to harvest winter wheat, and grain moisture content and weight were recorded. Yield data were adjusted to 14% moisture content.

### *2.1 Statistical Analysis*

Data were analyzed using the GLIMMIX procedure (SAS Ver. 9.4, SAS Institute Inc., Cary, NC), with $P < 0.05$ as the chosen level of significance. The generalized linear mixed model consisted of herbicide treatment as the fixed effect and environment, environment by treatment interaction, and replicate within the environment as the random effects. MHR Canada fleabane visible percent control following the fall herbicide application and winter wheat yield was analyzed using the Gaussian distribution. Visible percent control of MHR Canada fleabane following the spring herbicide application was arcsine square root transformed prior to being analyzed using the Gaussian distribution. The least-square means were back-transformed as needed for the presentation. The chosen distributions were the ones that best met the analysis assumptions. The non-treated control for MHR Canada fleabane visible percent control was excluded from the analysis due to having assigned values resulting in zero variance. However, a comparison with the value zero was still possible using the P-value associated with each mean in the LSMEANS output table.

## 3. Results and Discussion

### *3.1 Winter Wheat Injury*

At 1 and 4 WAA and 1 and 4 WAB there was no visible winter wheat injury from any of the herbicide treatments evaluated (data not presented). These results are similar to other studies that have shown minimal injury in winter wheat with herbicide applications that included pyrasulfotole, bromoxynil, fluroxypyr, halauxifen, and MCPA (Mahoney et al., 2016; McNaughton et al., 2014; Reddy et al., 2012; Robinson et al., 2015; Soltani et al., 2006, 2020; Quinn et al., 2020).

### *3.2 MHR Canada Fleabane Control*

At 4 WAA, MHR Canada fleabane was controlled 31-34% with pyrasulfotole/bromoxynil, 46-48% with fluroxypyr/halauxifen + MCPA, and 29-32% with clopyralid (Table 1). At 4 WAB, MHR Canada fleabane was controlled 82% with pyrasulfotole/bromoxynil, 95% with fluroxypyr/halauxifen + MCPA, and 99% with clopyralid applied in the fall (Table 1). MHR Canada fleabane was controlled 97% with pyrasulfotole/ bromoxynil, 87% with fluroxypyr/halauxifen + MCPA, and 87% with clopyralid, applied in the spring (Table 1). The sequential applications (fall fb spring applications of the same herbicide) of pyrasulfotole/bromoxynil, fluroxypyr/halauxifen + MCPA, and clopyralid controlled MHR Canada fleabane 99, 100, and 100%, respectively (Table 1). At 4 WAB, orthogonal contrasts indicated that sequential applications of herbicide treatments evaluated improved MHR Canada fleabane control 7% compared to fall applications alone. Similarly, sequential applications of the herbicide treatments evaluated improved MHR Canada fleabane control 9% compared to spring applications alone (Table 1). There was no difference between fall and spring applications or clopyralid versus other herbicide treatments (Table 1).

Table 1. Multiple-herbicide-resistant (MHR) Canada fleabane control following a fall and/or spring herbicide application and winter wheat yield at sites near Ridgetown, Zone Centre, and Clachan, ON in 2021 and 2022 (n = 6). Means followed by a different letter within a column are significantly different according to a Tukey-Kramer multiple range test at $P < 0.05$ [a]

| Treatment | Herbicide Rate | Application Timing | MHR Canada Fleabane Control [a] | | | Winter Wheat Yield |
|---|---|---|---|---|---|---|
| | | | 4 WAA | 4 WAB | 8 WAB | |
| | g ai ha$^{-1}$ | | --- | % | --- | t ha$^{-1}$ |
| Non-treated weedy control | | | 0 c | 0 e | 0 d | 3.06 cd |
| Pyrasulfotole/bromoxynil[b] | 205 | Fall | 31 b | 82 d | 83 c | 3.98 ab |
| Pyrasulfotole/bromoxynil | 205 | Spring | - | 97 ab | 99 ab | 3.60 abc |
| Pyrasulfotole/bromoxynil | 205 | Fall + Spring | 34 b | 99 a | 100 a | 4.12 ab |
| Fluoroxypyr/halauxifen + MCPA EHE | 82 + 372 | Fall | 46 a | 95 abc | 97 b | 4.18 a |
| Fluoroxypyr/halauxifen + MCPA EHE | 82 + 372 | Spring | - | 87 bcd | 100 a | 3.56 abc |
| Fluoroxypyr/halauxifen + MCPA EHE | 82 + 372 | Fall + Spring | 48 a | 100 a | 100 a | 3.90 ab |
| Clopyralid | 200 | Fall | 29 b | 99 a | 99 ab | 3.35 bcd |
| Clopyralid | 200 | Spring | - | 87 cd | 100 a | 2.69 d |
| Clopyralid | 200 | Fall + Spring | 32 b | 100 a | 100 a | 2.92 cd |
| *Contrasts* | | | | | | |
| Fall vs spring application | | | | 93 vs 91 | 95 vs 100** | 3.83 vs 3.28** |
| Fall vs sequential application | | | | 93 vs 100** | 95 vs 100** | 3.83 vs 3.65 |
| Spring vs sequential application | | | | 91 vs 100** | 100 vs 100 | 3.28 vs 3.65* |
| Clopyralid vs other treatments | | | | 97 vs 95 | 100 vs 98* | 2.98 vs 3.89** |

*Note.* * and ** denote significance at $P < 0.05$ and $P < 0.001$, respectively.

[a] Abbreviations: WAA, weeks after fall herbicide application; WAB, weeks after spring herbicide application.

[b] Included 1 L ha$^{-1}$ of ammonium sulfate (AMS).

At 8 WAB, MHR Canada fleabane was controlled 83% with pyrasulfotole/bromoxynil, 97% with fluroxypyr/halauxifen + MCPA, and 99% with clopyralid, applied in the fall (Table 1). MHR Canada fleabane was controlled 99% with pyrasulfotole/bromoxynil, 100% with fluroxypyr/halauxifen + MCPA, and 100% with clopyralid, applied in the spring (Table 1). The sequential applications of pyrasulfotole/bromoxynil fluroxypyr/halauxifen + MCPA, and clopyralid provided excellent (100%) control of MHR Canada fleabane (Table 1). At 8 WAB, orthogonal contrasts indicated that the spring application of the herbicide treatments evaluated provided 5% greater control of MHR Canada fleabane than the fall applications (Table 1). The sequential applications of herbicide treatments evaluated improved MHR Canada fleabane control 5% compared to fall applications alone. The sequential applications of the herbicide treatments evaluated provided comparable MHR Canada fleabane control as the spring applications (Table 1). Clopyralid controlled MHR Canada fleabane 2% greater than the other herbicide treatments evaluated (Table 1).

The results of this study are similar to other studies in which pyrasulfotole/bromoxynil, halauxifen, fluroxypyr/halauxifen + MCPA, pyrasulfotole/bromoxynil/fluroxypyr, pyrasulfotole/bromoxynil/thiencarbazone, pyrasulfotole/bromoxynil/thiencarbazone + MCPA, and fluroxypyr/halauxifen + pyroxsulam + MCPA controlled GR Canada fleabane 94-100% in winter wheat (Soltani et al., 2020). Quinn et al. (2020) reported that GR Canada fleabane was controlled 91-98% with pyrasulfotole/bromoxynil, 83-97% with fluroxypyr/halauxifen + MCPA, and 86-97% with clopyralid applied in the spring. In another study, GR Canada fleabane was controlled 54-60% with bromoxynil + MCPA, 82-87% with fluroxypyr + MCPA, 95-97% with pyrasulfotole/bromoxynil, and 86-96% with clopyralid in winter wheat (Mahoney et al., 2016). Other studies showed that in winter wheat GR Canada fleabane was controlled 97-98% with pyrasulfotole/bromoxynil, 82-100% with bromoxynil + fluroxypyr, 91-97% with bromoxynil + MCPA, 83-88% with fluroxypyr, 85-93% with halauxifen + florasulam, and 90-98% with 2,4-D + fluroxypyr + clopyralid (Kumar et al., 2017). Zimmer et al. (2018) also observed 90% control and 75% density reduction of GR Canada fleabane with halauxifen. However, McCauley et al. (2017) found only 65-80% control of GR Canada fleabane with halauxifen alone in non-cropped fields.

### *3.2 Winter Wheat Yield*

MHR Canada fleabane interference reduced winter wheat yield up to 27% (highest yielding treatment compared to the non-treated/weedy control). There was a higher winter wheat yield with pyrasulfotole/bromoxynil and fluroxypyr/halauxifen + MCPA compared to clopyralid. Pyrasulfotole/bromoxynil applied in the fall and sequentially increased winter wheat yield 30 and 35%, respectively compared to the non-treated control (Table 1). Fluroxypyr/halauxifen + MCPA applied in the fall and sequentially increased winter wheat yield 37 and 27% compared to the non-treated control, respectively (Table 1). Winter wheat yield with all other herbicide treatments evaluated was similar to the non-treated weedy control (Table 1). Orthogonal contrasts indicated that winter wheat yield was 0.55 t $ha^{-1}$ greater with the fall compared to the spring application of the herbicide treatments evaluated (Table 1). There was no significant difference in winter wheat yield with the sequential applications compared to the fall applications alone (Table 1). However, winter wheat yield was 0.37 t $ha^{-1}$ greater with the sequential applications compared to spring applications alone. Clopyralid reduced winter yield by 0.91 t $ha^{-1}$ compared to all other herbicide treatments evaluated (Table 1). Derksen et al. (1989) reported a significant yield reduction in winter wheat with clopyralid applied POST in the spring and no yield reduction when clopyralid was applied in the fall. However, Quinn et al. (2020) observed no yield reduction with the POST application of clopyralid applied in the spring for the control of GR Canada fleabane in winter wheat. Similarly, other studies observed no yield reduction in winter wheat with herbicide applications that included pyrasulfotole, bromoxynil, fluroxypyr, halauxifen, and MCPA applied in the spring for the control of GR Canada fleabane (McNaughton et al., 2014; Robinson et al., 2015; Soltani et al., 2020).

## 4. Conclusions

Results of this study show that pyrasulfotole/bromoxynil applied in the sequentially can provide excellent control of MHR Canada fleabane with no reduction in winter wheat yield. Fluroxypyr/halauxifen + MCPA applied in the fall or spring provides excellent control of MHR Canada fleabane with no reduction in winter wheat yield. Clopyralid applied in the fall, spring, or sequentially provides excellent control of MHR Canada fleabane but may cause a significant reduction in winter wheat yield. Results indicate that early MHR Canada fleabane control in the fall is crucial to minimize winter wheat yield loss from MHR Canada fleabane interference. In conclusion, pyrasulfotole/bromoxynil and fluroxypyr/halauxifen + MCPA applied in the fall and sequentially can be used effectively to control MHR Canada fleabane and maintain optimum winter wheat yield in winter wheat.

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