Canadian Journal of Plant Science
Revue canadienne de phytotechnie

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Journal:	<i>Canadian Journal of Plant Science</i>
Manuscript ID	CJPS-2016-0343.R2
Manuscript Type:	Short Communication
Date Submitted by the Author:	14-Feb-2017
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Keywords:	Canada fleabane, glyphosate resistance, weeds, herbicides

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SHORT COMMUNICATION

Biologically effective rate of metribuzin for glyphosate-resistant Canada fleabane control in soybean

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Abstract: Eight field experiments were conducted during 2013-2015 to determine the dose response of glyphosate-resistant Canada fleabane to metribuzin PP in tank-mixture with glyphosate in soybean. At 4 WAE, the predicted metribuzin rates required to cause 5, 10 and 20% soybean injury were 1599, 2074 and $>2240 \text{ g ai ha}^{-1}$, respectively.

Key words: Canada fleabane, glyphosate resistance, preplant herbicides, soybean

Soybean [*Glycine max* (L.) Merr.] is the most important grain crop in Ontario. It is grown on approximately 1.2 million hectares annually with the production of nearly 3.6 million tonnes that contributes farm gate value of \$2 billion (Statistics Canada 2015). One of the greatest challenges facing Ontario soybean growers is the control of glyphosate resistant (GR) Canada fleabane

Received 28 October 2016, accepted XX XX 2017.

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Abbreviations: BER, biological effective rate; GR, glyphosate resistant; PP, preplant; WAA, weeks after application

(*Conyza canadensis*). GR Canada fleabane was first reported in Ontario in 2010 and has now been confirmed in 30 counties (from Essex county in the southwest to Glengarry county adjacent to the Quebec border) (Byker et al. 2013c).

Canada fleabane is a prolific winter or summer annual weed that is capable of producing over 200,000 seeds per plant (Weaver 2001). The seeds of Canada fleabane are small, 1 to 2 mm long, and have a pappus that aids dispersal of this weed through wind (Weaver 2001). Ninety percent of Canada fleabane seeds fall within 100 m of the mother plant (Dauer et al. 2007). However, Canada fleabane seed is found in the planetary (atmospheric) boundary layer allowing for dispersal as far as 500 km (Shields et al. 2005). Canada fleabane is an extremely competitive weed and lack of control in soybean can lead to significant yield losses. Byker et al. (2013b) found that in absence of any weed management tactics, GR Canada fleabane interference can cause as much as 93% reduction in soybean seed yield.

Canada fleabane emerges in the fall as well as in the spring; therefore, it has to be controlled in the fall or early spring before planting crops (Loux et al. 2006). Byker et al. (2013a) reported that saflufenacil can provide effective control of GR Canada fleabane. However, control has been inconsistent (Ikley 2012; Budd et al. 2016). Recent studies have shown that metribuzin tank-mixed with glyphosate can provide consistent control of GR Canada fleabane in Ontario. Byker et al. (2013a) found that glyphosate (900 g ae ha⁻¹) plus metribuzin applied at 1120 g ai ha⁻¹ provided greater than 97% control of GR Canada fleabane at 8 WAA. However, high rates of metribuzin have been reported to cause soybean injury depending on environmental conditions (Byker et al. 2013a).

The biologically effective rate (BER) of metribuzin for the control of GR Canada fleabane has not been determined. BER is critical in determining the minimum effective dose of herbicides

needed to control weeds (Byker et al. 2013a). The objective of this study was to determine the dose response of GR Canada fleabane to metribuzin applied preplant in tank-mixture with glyphosate (900 g ae ha⁻¹) in soybean. It was hypothesized that an increased rate of metribuzin (>1120 g ai ha⁻¹) can be identified that can provide an effective control of GR Canada fleabane and has an acceptable margin of crop safety in soybean.

Eight field trials were conducted over a three-year period (2013, 2014 and 2015) in commercial soybean production fields in southwestern Ontario and southeast Nebraska with confirmed and uniform GR Canada fleabane populations. Field trials were established as a randomized complete block design with four replications as four blocks. Soybean was seeded to a depth of approximately 5 cm at a rate of approximately 400,000 seeds ha⁻¹. Each plot was 2.25 m wide (3 rows spaced 75 cm apart) and 8.0 m long.

All herbicide treatments were applied preplant (PP) when the Canada fleabane was up to 10 cm in diameter/height. Herbicide treatments in the metribuzin BER trials consisted of glyphosate (900 g ae ha⁻¹) in all treatments and metribuzin at 0, 35, 70, 140, 280, 560, 1120, and 2240 g ai ha⁻¹. A weedy and weed-free control was included in each replicate. The weed-free control was established with glyphosate (900 g ae ha⁻¹) plus imazethapyr/saflufenacil (100 g a.i. ha⁻¹) applied PP, followed by hand hoeing/hand weeding as required throughout the growing season. Herbicide treatments were applied with a CO₂-pressurized back-pack sprayer equipped with Hypro ULD120-02 nozzle tips (Hypro, New Brighton, MN) calibrated to deliver 200 L ha⁻¹ of water at 200 kPa. Herbicide applications were made with a 1.5 m boom with four nozzles spaced 50 cm apart.

Soybean injury was visually estimated on a scale of 0 (no injury) to 100% (complete plant death) at 2 and 4 weeks after soybean emergence (WAE). Control of GR Canada fleabane was

visually estimated on a scale of 0 (no control) to 100% (complete control) at 4 and 8 weeks after treatment application (WAA). GR Canada fleabane density was determined at 4 WAA by counting the number of plants in two 0.5 m² quadrats placed randomly between the center two soybean rows in each plot. Canada fleabane biomass was determined by cutting plants at the soil surface from a randomly selected 1 m² quadrat per plot which were then oven-dried at 60 C until they reached a constant weight.

Data were analyzed using non-linear regression (PROC NLIN) in SAS 9.4 (Statistical Analysis Systems, Cary, NC, USA). Herbicide treatment was considered a fixed effect, while environment (year-location combinations), the interaction between environment and herbicide treatment, and replicate nested within environment were considered random effects. Significance of the fixed effect was tested using a F-test and random effects were tested using a Z-test of the variance estimate. The UNIVARIATE procedure was used to test data for normality and homogeneity of variance. The untreated control (for control ratings) and the weed-free control (for density and biomass) were excluded from the analysis. However, all values were compared independently to zero to evaluate treatment differences with the untreated control. Because glyphosate was applied with all metribuzin treatments, the glyphosate alone treatment was equivalent to a metribuzin rate of zero.

All parameters were regressed against metribuzin rate, designated as RATE in the equations. Visual percent soybean injury at 2 and 4 WAE was related to metribuzin rate using a nonlinear, exponential equation (Eq. 1).

$$Y = f * (\exp [g * \text{RATE}]) \quad (\text{Eq. 1})$$

where Y is percent soybean injury, f is a magnitude constant and g is a rate constant.

A four parameter log-logistic model equation (Eq. 2) was used to determine the dose response for percent visual GR Canada fleabane control.

$$Y = C + (D - C) / (1 + \exp [-b (\ln \text{RATE} - \ln I_{50})]) \quad (\text{Eq. 2})$$

where Y is percent visual GR Canada fleabane control, C is the lower asymptote, D is the upper asymptote, b is the slope and I_{50} is the rate which gives a response halfway between C and D .

An inverse exponential equation (Eq. 3) was used to determine the dose response for reduction in GR Canada fleabane density or biomass (dry weight).

$$Y = h + j * (\exp [-k * \text{RATE}]) \quad (\text{Eq. 3})$$

where Y is GR Canada fleabane density or biomass, h is the lower asymptote, j is the magnitude of the response and k is the slope of the response.

There were no significant interactions ($p < 0.05$) between year by location, herbicide by location and herbicide by location by year; therefore data for all environments were combined and averaged. Regression equations were used to calculate predicted metribuzin rates (g ai ha^{-1}) required to cause 5, 10, and 20% crop injury (R_5 , R_{10} and R_{20}), or 80, 90 and 95% control of GR Canada fleabane or 80, 90 and 95% reduction in GR Canada fleabane density or dry weight (R_{80} , R_{90} and R_{95}). If any rate was predicted to be higher than $2240 \text{ g ai ha}^{-1}$, it was simply expressed as “>2240” since it would be improper to extrapolate outside the range of maximum rate evaluated in this study.

Based on regression analysis, the predicted metribuzin rates required to cause 5, 10 and 20% soybean injury were 2062, >2240, and >2240 g ai ha^{-1} at 2 WAE and 1599, 2074, and >2240 g ai ha^{-1} at 4 WAE, respectively (Table 1). Crop injury consisted of leaf burn of the lower leaves for treatments with high metribuzin rates (1120 and 2240 g ai ha^{-1}). Results are similar to studies by Ikley (2012) which found no soybean injury with the addition of metribuzin (572 g ai ha^{-1}) to

glyphosate. Eubank et al. (2008) also found no soybean injury with metribuzin (420 g ai ha⁻¹) to glyphosate (860 g ae ha⁻¹) in soybean.

The predicted metribuzin rates required to achieve 80, 90, and 95% visual control of GR Canada fleabane were 659, 1093, and 1730 g ai ha⁻¹ at 4 WAA and 783, 1355, and 2237 g ai ha⁻¹ at 8 WAA, respectively (Table 1). In other studies Tardif and Smith (2003) reported metribuzin (1120 g ai ha⁻¹) provided 73% control of non-glyphosate resistant Canada fleabane at 4 WAA in Ontario. Similarly, Eubank et al. (2008) also reported that metribuzin (420 g ai ha⁻¹) plus glyphosate (860 g ai ha⁻¹) provided 66-73 and 53-60% control of GR Canada fleabane at 2 and 4 WAA under Mississippi environmental conditions, respectively. Ikley (2012) found as much as 98% control of GR Canada fleabane with the addition of metribuzin (572 g ai ha⁻¹) to glyphosate under Maryland environmental conditions.

The predicted metribuzin rates required to achieve 80, 90, and 95% reduction in density of GR Canada fleabane were 410, 588, and 768 g ai ha⁻¹, respectively, similar to 497, 711, and 925 g ai ha⁻¹ required to reduce GR Canada fleabane above ground biomass 80, 90, and 95%, respectively (Table 1). The highest current registered rate for metribuzin of 1120 g ai ha⁻¹ is sufficient to provide >85% reduction in Canada fleabane density and biomass. Results are in agreement with Byker et al. (2013a) which found 100% reduction in GR Canada fleabane aboveground biomass with glyphosate (900 g ai ha⁻¹) plus metribuzin (1120 g ai ha⁻¹) at 8 WAA under Ontario environmental conditions. Eubank et al. (2008) also found as much as 86% reduction in GR Canada fleabane density with metribuzin (420 g ai ha⁻¹) plus glyphosate (860 g ai ha⁻¹) under Mississippi environmental conditions.

This study concludes that the current highest label rate of metribuzin (1120 g ai ha⁻¹) tank-mixed with glyphosate (900 g ai ha⁻¹) does not always provide acceptable control of GR Canada

fleabane. Since higher rates of metribuzin can also result in unacceptable soybean injury under some conditions, further studies are needed to explore three-way tank-mixes of metribuzin for the control of GR Canada fleabane. For example, saflufenacil has shown relatively good efficacy for control of GR Canada fleabane; therefore, a biological effective rate should be determined for a tank-mixture of metribuzin, glyphosate, and saflufenacil.

Acknowledgements

Funding for this project was provided in part by the Grain Farmers of Ontario and through the Growing Forward (GF 2) program administered by the Agricultural Adaptation Council.

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Table 1. Regression parameter estimates and predicted metribuzin rates from exponential model of visual crop injury 2 and 4 WAA, dose-response model of visual Canada fleabane control 4 and 8 WAA, and inverse exponential model of Canada fleabane density and dry weight 4 WAA.^a

Variable	Parameter estimates ^b (±SE)				Predicted metribuzin rate (g ai ha ⁻¹) ^c		
<i>Exponential</i>	<i>f</i>	<i>g</i>			<i>R</i> ₅	<i>R</i> ₁₀	<i>R</i> ₂₀
Injury 2 WAA	0.38 (0.31)	0.0013 (0.0004)			2062	>2240	>2240
Injury 4 WAA	0.48 (0.26)	0.0015 (0.0003)			1599	2074	>2240
<i>Dose-response</i>	<i>C</i>	<i>D</i>	<i>b</i>	<i>I</i> ₅₀	<i>R</i> ₈₀	<i>R</i> ₉₀	<i>R</i> ₉₅
Control 4 WAA	14 (3)	100 (0)	1.6 (0.2)	319 (26)	659	1093	1730
Control 8 WAA	8 (3)	100 (0)	1.5 (0.2)	334 (33)	783	1355	2237
<i>Inverse exponential</i>	<i>h</i>	<i>j</i>	<i>k</i>				
Density	1.3 (68)	767 (93)	0.0039 (0.0014)		410	588	768
Dry weight	0 (0)	179 (26)	0.0032 (0.0013)		497	711	925

^a Abbreviations: WAE, weeks after soybean emergence; WAA, weeks after herbicide application

^b Exponential parameters (Eq. 1): *f*, magnitude constant; *g*, rate constant.

Dose response parameters (Eq. 2): *b*, slope; *C*, lower asymptote; *D*, upper asymptote; *I*₅₀, rate required for 50% response.

Inverse exponential (Eq. 3): *h*, lower asymptote; *j*, magnitude of response; *k*, slope of response.

^c *R*₅, *R*₁₀ and *R*₂₀ are the rates required to give 5, 10 and 20% soybean injury; *R*₈₀, *R*₉₀ and *R*₉₅ are the rates required to give 80, 90 and 95% control of Canada fleabane or an 80, 90 and 95% reduction in Canada fleabane density or dry weight.