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The Impact of the Addition of Urea Ammonium Nitrate to 2,4-D on the Control of Multiple-Herbicide-Resistant Canada Fleabane

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 impact of the addition of 28% urea ammonium nitrate (UAN) to 2,4-D, applied preplant (PP) to soybean, on the control of multiple-herbicide-resistant (MHR) Canada fleabane. A total of five field experiments were conducted over a two-year period (2020, 2021) in southwestern Ontario to determine if MHR Canada fleabane control with 2,4-D ester applied PP can be improved by adding UAN to the spray solution. Glyphosate + 2,4-D ester applied PP with various rates of UAN caused no soybean injury. The control of MHR Canada fleabane decreased when UAN was added to the spray solution, especially at higher rates evaluated. At 4 weeks after treatment (WAT), the predicted percent UAN concentration in the spray solution that caused a 5, 10, 20, or 50% decrease in MHR Canada fleabane control was 12, 17, 25, and 52%, respectively. At 8 WAT, the predicted percent UAN concentration that caused a 5, 10, 20, or 50% decrease in MHR Canada fleabane control was 10, 13, 18, and 33%, respectively. At 8 WAT, the predicted percent UAN concentration that caused a 5 and 10% increase in MHR Canada fleabane density was 36 and 73%, respectively. At 8 WAT, the predicted percent UAN concentration that caused a 5, 10, 20, or 50% increase in MHR Canada fleabane biomass was 2, 4, 8, and 19%, respectively. The predicted percent UAN concentration that caused a 5, 10, and 20% decrease in soybean yield was 1, 3, and 12%, respectively. This study concludes that the addition of 28% UAN, especially at the higher concentration, to 2,4-D ester reduces control and increases the density and biomass of MHR Canada fleabane.

Keywords: Canada fleabane, density, dry biomass, glyphosate-resistant, soybean yield, urea ammonium nitrate, weed control

1. Introduction

Soybean (*Glycine max* L.) production is important to agriculture in Ontario as it contributes substantially to the economy of the province. In 2022, soybean growers produced approximately 4 million tonnes of soybean from nearly 1.25 million hectares with a farm gate value of approximately $2.5 billion (Statcan, 2022). Weeds if not adequately controlled can reduce soybean yield significantly and result in substantial economic losses (Soltani et al., 2017). A meta-analysis conducted by the Weed Science Society of America (WSSA) estimated that soybean yield would be decreased by an average of 52% in North America with an estimated annual farm-gate loss of US$17 billion if weeds are not controlled (Soltani et al., 2017).

In recent years glyphosate-resistant (GR) and multiple-herbicide-resistant (MHR) weeds have spread across Ontario. Of particular concern is GR/MHR Canada fleabane (*Conyza canadensis* (L.) Cronq.), which is now confirmed in 30 Ontario counties extending from the Michigan border in southwestern Ontario to the Quebec border in the east (Budd et al., 2016; Byker et al., 2013a). It is estimated that at the present time, GR/MHR Canada fleabane is present on 5% of the field crop hectares in Ontario (Soltani et al., 2022). A recent study has estimated that soybean yield can be decreased by an average of 61% in Ontario with an economic loss of approximately $52 million if GR/MHR Canada fleabane is not controlled (Soltani et al., 2022). It was estimated that farmers can reduce their net economic loss to only $6.1 million by utilizing the best available herbicide options for the control of GR/MHR Canada fleabane in soybean (Soltani et al., 2022). It is critical to identify the best management practices for the control GR/MHR Canada fleabane in soybean.

Earlier studies have shown that herbicides such as 2,4-D ester in combination with glyphosate applied preplant (PP) can provide 95-100% control of GR Canada fleabane (Budd et al., 2017; Eubank et al., 2008; Keeling et al., 1989); however, the control was variable (Byker et al., 2013b; Budd et al., 2017; Dilliott et al., 2022). 2,4-D is a weak acid, and its herbicidal activity can be negatively affected by divalent cations when mixed in water in the spray solution through a reduction in the efficiency of absorption and translocation within the targeted weeds (Devkota et al., 2016; Mirzaei et al., 2022; Nalewaja et al., 1991; Patton et al., 2016; Roskamp et al., 2013; Schortgen & Patton, 2020, 2021).

Utilization of spray additives with 2,4-D has been shown to improve the herbicidal activity against certain weeds (Gronwald et al., 1993; Mirzaei et al., 2022). Spray additives can be special-purpose adjuvants (indirectly impact spray solution) and activator adjuvants (change chemical and physical characteristics of the herbicide) (Langdon et al., 2020; McMullan, 2000). Activator adjuvants can decrease the surface tension and contact angle of the spray droplet (angle between the leaf surface and the spray droplet), as well as influence the spreading of the herbicide on the leaf surface (Xu et al., 2010). 28% urea ammonium nitrate (UAN) is an activator adjuvant that when used in combination with some herbicides can increase herbicide absorption due to its nitrogen fertilizer ammonium ions which improve herbicide absorption and subsequent weed control efficacy (Gronwald et al., 1993; Schortgen & Patton, 2020, 2021). More research is needed to evaluate the impact of the addition of UAN to 2,4-D applied preplant to soybean on MHR Canada fleabane control (Schortgen & Patton, 2021).

Limited information exists on the impact of the addition of UAN to the carrier solution on MHR Canada fleabane with 2,4-D applied PP to soybean. Identifying the optimum UAN concentration in the carrier solution with 2,4-D applied PP for MHR Canada fleabane control may help soybean growers improve MHR Canada fleabane control and increase net returns. The hypothesis for this study was that the addition of UAN to the carrier solution would improve MHR Canada fleabane control with 2,4-D. The objective of this study was to determine if MHR Canada fleabane control with 2,4-D can be improved by adding UAN to the carrier solution.

2. Materials and Methods

A total of five experiments were conducted over a two-year period (2020, 2021) in fields with confirmed MHR Canada fleabane near Ridgetown (42.43990, -81.88767), Bothwell (42.632274, -81.872737) and Moraviantown (42.582069, -81.893135), Ontario, Canada.

The experiment was designed as a randomized complete block with four replications. Treatments included a weedy non-treated control, a weed-free control, and glyphosate (900 g ae ha^{-1}) + 2,4-D ester (528 g ae ha^{-1}) applied preplant (PP) alone and in combination with UAN at 1, 2.5, 5, 10, 25, 50 and 100% v/v. The experimental plots were 2 m wide by 8 m long. Glyphosate/dicamba-resistant soybean 'DKB 10-20'/'MK0616B2' was seeded at rate of approximately 400,000 seeds ha^{-1} in rows that were 75 cm apart at a depth of 4 cm in late May to early June of 2020 and 2021.

Herbicides were applied when MHR Canada fleabane was < 10 cm in diameter/height (1-12 days before planting) 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 soybean injury was estimated at 2 and 4 weeks after soybean emergence (WAE) and MHR Canada fleabane control was evaluated at 4 and 8 weeks after herbicide treatment (WAT) on a scale of 0 to 100% (0 = No visible injury/No control and 100 = Plant death/Total control). At 8 WAT, MHR Canada fleabane density and aboveground biomass were measured from two randomly placed 0.25 m^{-2} quadrats in each plot. Density was determined by counting all Canada fleabane plants in each quadrat. Biomass was determined by cutting all Canada fleabane plants at the soil line, placing them in a paper bag, and drying them at 60 ^{o}C in a dryer to constant moisture when the dry weight was recorded. At maturity, a small plot combine was used to harvest soybean grain from the middle two rows of each plot, and grain moisture content and weight were recorded. Soybean yield data were adjusted to 13% moisture content.

The data analysis was completed in SAS 9.4 (SAS Institute Inc., Cary, NC). Percent visible MHR Canada fleabane control, density, and dry biomass, as well as soybean yield, were regressed against the concentration of UAN in the carrier solution, expressed as a percentage (%UAN). Prior to regression analysis, scatterplots of the data were examined to determine potential models, and the final model for each variable was chosen based on the evaluation of calculated AICc values (Burnham & Anderson, 2002). Proc NLIN was utilized for regression analysis and residual plots were checked to make sure the assumptions of the analysis were met. For the chosen model, the goodness of fit was assessed using root mean square error (RMSE) and modeling efficiency (ME), as well as plots of actual vs predicted values. For percent MHR Canada fleabane control, a log-logistic model was used:

$$Y = C + (D - C)/\{1 + \exp [b (\ln \%UAN - \ln I_{50})]\} \quad (1)$$

where, C is the lower asymptote, D is the upper asymptote, b is the slope and I_{50} is the value of %UAN which gives a response halfway between C and D. For MHR Canada fleabane density and dry biomass, a linear model was used:

$$Y = A + m (\%UAN) \quad (2)$$

where, A is the y-intercept and m is the slope of the line. A log-linear model was used to regress soybean yield against %UAN:

$$Y = A + m [\ln (\%UAN + 1)] \quad (3)$$

where, A is the y-intercept and m is the slope of the line.

Predicted values of %UAN that gave a 5, 10, 20, and 50% reduction in MHR Canada fleabane control and soybean yield, or a 5, 10, 20, and 50% increase in MHR Canada fleabane density and dry biomass were calculated using the regression equations.

3. Results and Discussion

3.1 Soybean Injury

No soybean injury was observed at 2 and 4 WAE with 2,4-D ester applied PP with various concentrations of UAN in the carrier solution (Data not presented). The minimal soybean injury observed in this study is similar to Dilliott et al. (2022) who reported minimal soybean injury with glufosinate applied PP at 500 to 1000 g ai ha^{-1} and when using UAN (50 or 100%) as the carrier solution. 2,4-D ester plus glufosinate with no adjuvants was also shown to cause no injury in soybean (Dilliott et al., 2022). Thompson et al. (2017) also reported minimal soybean injury with 2,4-D applied PP. Soltani et al. (2008) reported minimal injury (0-6%) with 2,4-D ester (705 g ai ha^{-1}) applied without additives 1, 7, and 14 days preplant to soybean.

The MHR Canada fleabane density at study sites ranged from 92 to 742 plant m^{-2} on the evaluation dates. In contrast to the hypothesis for this study, at 4 WAT, the control of MHR Canada fleabane decreased when UAN was added to the carrier solution for 2,4-D ester applied PP to soybean. The predicted UAN concentrations in the carrier solution that caused a 5, 10, 20, or 50% reduction in MHR Canada fleabane control with 2,4-D ester were 12, 17, 25, and 52%, respectively (Table 1). At 8 WAT, the predicted UAN concentrations in the carrier solution that caused a 5, 10, 20, or 50% reduction in MHR Canada fleabane control were 10, 13, 18, and 33%, respectively (Table 1). Schortgen and Patton (2021) found that 2,4-D efficacy can be decreased as the rate of adjuvants such as UAN or AMS is increased above the typical rates of (2% w/w, 20 g L^{-1}), likely from salting out. Roskamp et al. (2013) suggested that 2,4-D binds to cations present in water used as herbicide carrier or from UAN added to the spray solution resulting in reduced weed control efficacy. Schortgen and Patton (2020, 2021) recommended that ammonium sulfate (AMS) used as a foliar fertilizer should be applied separately from 2,4-D DMA to prevent potential antagonism. In other studies, Dilliott et al. (2022) found no improvement of MHR Canada fleabane control with glufosinate applied PP at 500 to 1000 g ai ha^{-1} when adding 28% UAN (50 or 100%) to the carrier solution. However, in a growth room study, Cowbrough (2022) observed acceptable control of GR Canada fleabane (15 cm tall) with glufosinate (494 g ha^{-1}) plus a 1:1 ratio mixture of water and UAN (total carrier volume of 187 L ha^{-1}) and 28% UAN (187 L ha^{-1}) (Dilliott et al., 2022). In other studies, Schortgen and Patton (2021) reported greater control of dandelion (*Taraxacum officinale* F.H. Wigg.) with 2,4-D plus UAN compared to other nitrogen-based adjuvants such as potassium nitrate, ammonium sulfate, or urea. Mirzaei et al. (2022) observed reduced control of wild mustard (*Sinapis arvensis* L.) with UAN applied at 1 and 2% (w/v) with 2,4-D + MCPA compared to the control. The tankmix application of UAN at 2% (w/v) with 2,4-D + MCPA reduced efficacy for the control of wild mustard by 45% (Mirzaei et al., 2022).

Table 1. Parameter estimates and predicted values for visible percent MHR Canada fleabane control (MHRCF), MHRCF density and dry biomass, and soybean yield regressed against the percentage of UAN in the spray carrier (%UAN) for five experiments, conducted near Ridgetown, Bothwell and Moraviantown, ON in 2020 and 2021[a]

Variable	Parameter Estimates[b] (±SE)						ME	RMSE	Predicted %UAN Value[c]			
	C		*D*		*b*	I_{50}			i_5	i_{10}	i_{20}	i_{50}
MHRCF control 4 WAT (%)	13	(11)	75	(2)	2.2 (0.8)	42 (10)	0.80	16	12	17	25	52
MHRCF control 8 WAT (%)	2	(6)	62	(2)	2.4 (0.6)	32 (4)	0.86	14	10	13	18	33
	A		*m*									
MHRCF density (plants m^{-2})	160	(20)	-0.2	(0.5)			0.32	203	36	73	-	-
MHRCF dry biomass (g m^{-2})	67	(9)	1.7	(0.2)			0.55	88	2	4	8	19
Soybean yield (t ha^{-1})	1.48	(0.11)	-0.11	(0.04)			0.36	0.7	1	3	12	-

Note. [a] Every treatment included glyphosate (900 g ae ha^{-1}) and 2,4-D ester (528 g ae ha^{-1}).

Abbreviations: ME, modeling efficiency; RMSE, root mean square error, WAT, weeks after herbicide application.
[b] Log-logistic equation parameters (Equation 1): *b*, slope; *C*, lower asymptote; *D*, upper asymptote; I_{50}, EVAR value required for 50% response, linear and log-linear equation parameters (Equation 2 and 3): *A*, y-intercept; *m*, slope.

[c] i_5, i_{10}, i_{20} and i_{50} are the values of %UAN that result in a 5, 10, 20 or 50% decrease in MHRCF control or soybean yield, or a 5, 10, 20 or 50% increase in MHRCF density or MHRCF dry biomass. - indicates an estimated value outside the range of values evaluated.

At 8 WAT, the density of MHR Canada fleabane increased when UAN was added to the carrier solution wtih 2,4-D ester applied PP in soybean. The predicted UAN concentration in the carrier solution that caused a 5 and 10% increase in MHR Canada fleabane density (plants m^{-2}) with 2,4-D ester was 36 and 73%, respectively (Table 1).

At 8 WAT, the aboveground biomass of MHR Canada fleabane was increased when UAN was added to the carrier solution with 2,4-D ester applied PP in soybean. The predicted UAN concentration in the carrier solution that caused a 5, 10, 20, or 50% increase in MHR Canada fleabane aboveground biomass with 2,4-D ester was 2, 4, 8, and 19%, respectively (Table 1).

At maturity, increased MHR Canada fleabane interference when UAN was added to the carrier solution with 2,4-D ester applied PP caused a decrease in soybean grain yield. The predicted UAN concentration in the carrier solution that caused a 5, 10, and 20% decrease in soybean yield when mixed 2,4-D ester applied PP was 1, 3, and 12%, respectively (Table 1). Results are similar to Dilliott et al. (2022) who found no improvement in soybean yield with glufosinate applied PP at 500 to 1000 g ai ha^{-1} when using UAN (50 or 100%) as the carrier solution. 2,4-D ester plus glufosinate provided a comparable yield as the weed-free control (Dilliott et al., 2022). Soltani et al. (2008) observed no significant yield reduction in soybean with 2,4-D ester (705 g ai ha^{-1}) applied without additives 1, 7, and 14 days preplant.

4. Conclusions

Based on these results, we reject the hypothesis that MHR Canada fleabane control with 2,4-D applied preplant to soybean will be improved with the addition of UAN to the carrier solution. MHR Canada fleabane control decreased, and density and aboveground biomass increased when UAN was added to the carrier solution of 2,4-D ester applied PP in soybean. In addition, soybean grain yield decreased when UAN was added to the carrier solution. This study concludes that UAN should not be added to the carrier solution of 2,4-D ester applied PP for the control of MHR Canada fleabane in soybean as it can cause substantial decreases in MHR Canada fleabane control and a concomitant increase in soybean yield loss due to MHR Canada fleabane interference. Future research is needed to identify the exact reason for the antagonistic effects of UAN when added to the carrier solution with glyphosate + 2,4-D for the control of MHR Canada fleabane under Ontario environmental conditions.

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