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Responses of winter wheat (*Triticum aestivum* L.) to autumn applied post-emergence herbicides

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Abstract

The adoption of new production practices such as no-till and the use of non-residual herbicides such as glyphosate in the preceding crop has resulted in an increase of winter annual, biennial, and perennial weeds in winter wheat in Ontario. Few post-emergence (POST) autumn applied herbicide options are available to control these weeds. Five field trials were conducted in Ontario to evaluate the POST application of dicamba at 140 and 280 g ai/ha, 2,4-D amine, MCPA amine, dichlorprop plus 2,4-D ester, bromoxynil plus MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl. The autumn POST application of dicamba, MCPA amine, bromoxynil plus MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl did not cause any visual injury and there was no decrease in winter wheat height or yield. The POST application of 2,4-D amine and dichlorprop plus 2,4-D ester caused minor visual injury at 24–31 weeks after treatment (WAT). Winter wheat height was reduced as much as 8% with the POST application of dichlorprop plus 2,4-D ester. Yield was reduced up to 9% and 14% with the POST application of 2,4-D amine and dichlorprop plus 2,4-D ester, respectively. Based on these results, the POST application of 2,4-D amine and dichlorprop plus 2,4-D ester premix in the autumn results in unacceptable injury in winter wheat. However, dicamba, MCPA amine, bromoxynil, MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl have an adequate margin of crop safety for use in weed management in winter wheat in Ontario.

Keywords: Crop injury; Bromoxynil; Dicamba; Dichlorprop; MCPA amine; Thifensulfuron-methyl; Tribenuron-methyl; 2,4-D amine

1. Introduction

Winter cereals have become more popular among growers in Ontario in recent years as new varieties and improved prices have caused a shift away from other field crops such as maize and soybeans to winter cereals (Swanton, 2004). Winter wheat (*Triticum aestivum* L.) is the most popular winter cereal crop grown in Ontario. Winter wheat crop management has changed in the last 10–15 years in response to new production systems (no-till), economic pressures, and demands by the end users. The adoption of reduced-till and no-till production practices and the use of non-residual herbicides such as glyphosate in the preceding crop has resulted in a resurgence of winter annual, biennial, and perennial weeds such as *Stellaria media* (common chickweed), *Capsella bursa-pastoris* (shepherd's purse), *Thlaspi arvense* (stinkweed), *Daucus carota* (wild carrot), *Lactuca scariola* (prickly lettuce), and *Taraxacum officinale* (dandelion). The rapid adoption of glyphosate-tolerant soybean in maize/soybean/winter wheat crop rotations has resulted in an increase in winter annual and biennial weeds in the autumn since residual herbicides which control some of the seedlings of these species are not generally used with glyphosate-tolerant soybeans.

Dicamba is a benzoic acid herbicide, and 2,4-D amine, MCPA amine, and dichlorprop plus 2,4-D ester (premix formulated) are phenoxy herbicides that are

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very effective for the control of a wide spectrum of annual, biennial, and perennial species including *Stellaria media*, *Capsella bursa-pastoris*, *Thlaspi arvense*, *Lactuca scariola,* and *Taraxacum officinale* (OMAF, 2004). These herbicides are growth-regulator-type herbicides that in sensitive weeds cause uncontrolled cell division and growth, which results in vascular tissue destruction (Vencill, 2002).

Bromoxynil plus MCPA (premix formulated) is a benzonitrile plus phenoxy herbicide that inhibits photosynthesis and causes uncontrolled cell division and growth in sensitive weeds (Vencill, 2002). Bromoxynil plus MCPA can provide control of annual broadleaved weeds such as *Polygonum convovulus* (wild buckwheat), *Xanthium strumarium* (cocklebur), *Polygonum persicaria* (lady's thumb), *Chenopodium album* (common lambsquarters), *Sinapis arvensis* (wild mustard), *Solanum* Spp. (nightshades), *Amaranthus retroflexus* (redroot pigweed), *Ambrosia artemisiifolia* (common ragweed), *Capsella bursa-pastoris*, *Thlaspi arvense*, *Abutilon theophrasti* (velvetleaf) and suppression of perennial broadleaf weeds such as *Convolvulus arvensis* (field bindweed), *Sonchus arvensis* (perennial sow-thistle), and *Cirsium arvense* (Canada thistle) (OMAF, 2004).

Thifensulfuron-methyl plus tribenuron-methyl (premix formulated) is a sulfonylurea herbicide that inhibits the activity of acetolactate synthase (ALS), an important enzyme necessary for the biosynthesis of branched chain amino acids, isoleucine, leucine, and valine (Vencill, 2002). Thifensulfuron-methyl plus tribenuron-methyl is applied at low rates, has low mammalian toxicity, and controls several broadleaved weeds that occur in Ontario such as *Polygonum convovulus*, *Stellaria media*, *Spergula arvensis* (corn spurry), *Galeopsis tetrahit* (hempnettle), *Polygonum persicaria*, *Chenopodium album*, *Sinapis arvensis*, *Amaranthus retroflexus*, *Capsella bursa-pastoris*, *Thlaspi arvense*, *Sonchus arvensis*, and *Cirsium arvense* (OMAF, 2004).

There are currently few autumn applied post-emergence (POST) herbicide options available to manage winter annual, biennial, and perennial weeds in Ontario. More research is needed to identify new weed management options for autumn application in winter wheat. The objective of this study was to evaluate the tolerance of winter wheat to an autumn POST application of dicamba, 2,4-D amine, MCPA amine, dichlorprop plus 2,4-D ester, bromoxynil plus MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl under Ontario growing conditions.

2. Materials and methods

Field experiments were initiated in the autumn of 1998 (two locations), 2002, and 2003 at the Huron Research Station, Exeter, Ontario. One additional trial was initiated in the autumn of 2001 at the Ridgetown College Research Farm, Ridgetown, Ontario. The soil type at Exeter was a Orthic Humic Gleysol Brookston clay loam with 32% sand, 38% silt, 30% clay, 3.8% organic matter and a pH of 8.1 in 1998, 32% sand, 41% silt, 27% clay, 4.0% organic matter and a pH of 7.9 in 2002, and 39% sand, 37% silt, 24% clay, 5.3% organic matter and a pH of 7.9 in 2003. The soil type at Ridgetown was a grey–brown Podzolic Watford/Brady sandy–clay loam with 51% sand, 23% silt, 26% clay, 5.4% organic matter and a pH of 6.8. Seedbed preparation consisted of moldboard plowing followed by two passes with a field cultivator.

The experimental design was a randomized complete block design with four replicates. Treatments consisted of a non-treated control and POST applications of dicamba at 140 and 280 g ai/ha, 2,4-D amine at 550 and 1100 g ai/ha, MCPA amine at 850 and 1700 g ai/ha, dichlorprop plus 2,4-D ester (premix formulated) at 1017 and 2034 g ai/ha, bromoxynil plus MCPA ester (premix formulated) at 560 and 1120 g ai/ha, and thifensulfuron-methyl plus tribenuron-methyl (premix formulated) at 15 and 30 g ai/ha (plus Agral 90® at 0.2% v/v). The doses used represent single and double the manufacturer's recommended dose for each herbicide when applied in the spring. Plots were 2 m wide and 10 m long at Exeter and 2 m wide and 8 m long at Ridgetown. Pioneer '25R47', one of the commonly grown winter wheat cultivars in Ontario, was seeded in rows spaced 18 cm apart. Winter wheat was seeded on October 15, 1998 (both locations), September 26, 2002, and October 14, 2003 in Exeter and October 20, 2001 in Ridgetown at a rate of 150 kg/ha.

Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 200 L/ha of spray solution at a pressure of 241 kPa. The boom was 1.5 m long with four 8002 flat-fan nozzles (Teejet 8002 flat-fan nozzle tip; Spraying Systems Co., Wheaton, IL) spaced 0.5 m apart. Herbicide applications were made 14 and 34 days after planting (DAP) in 1998, 36 DAP in 2001, 32 DAP in 2002, and 36 DAP in 2003.

Visual crop injury was rated 24, 26, 28, and 31 weeks after treatment (WAT) (ie. the following spring) on a scale of 0–100%. A rating of 0 was defined as no visible injury and a rating of 100 was defined as total necrosis. At 32 WAT, heights of 10 randomly selected plants were measured in each plot from the soil surface to the highest growing point. Yield was measured at crop maturity by harvesting the middle 1.5 m of each plot with a plot combine. Winter wheat was harvested at Exeter on July 21, 1999 (both locations), July 25, 2003, and July 26, 2004, and at Ridgetown on August 1, 2002. Yields were adjusted to 13% moisture.

All data were subjected to analysis of variance (ANOVA) and were combined over experiments and years and analysed using the Proc Mixed procedure of SAS (Ver. 8, SAS Inst., Cary NC). Variances of percent visual injury at 24, 26, 28, and 31 WAT, plant height, and yield (all experiments) were partitioned into the fixed effects of herbicide treatment and into the random effects of environment and block (environment). Significance of random effects were tested using a Z-test of the variance estimate and fixed effects were tested using F-tests. Error assumptions of the variance analyses (random, homogeneous, normal distribution of error) were confirmed using residual plots and the Shapiro–Wilk normality test. To meet assumptions of the variance analysis, visual injury ratings were subjected to square root transformation (Bartlett, 1947). Treatment means were separated using Fisher's Protected LSD at $P = 0.05$. Means of injury ratings were compared on the transformed scale and were converted back to the original scale for presentation of results. The Type I error was set at 0.05 for all statistical comparisons.

3. Results and discussions

The random effects of experiments, years, years by location, and their interactions with herbicide treatments were not significant for any of the variables analysed. Thus, it was possible to pool the means for each variable analysed. Visual crop injury symptoms included a decrease in height and severe growth distortion of the heads of the winter wheat.

3.1. Dicamba

The POST application of dicamba in the autumn at 140 and 280 g/ha did not cause any visual injury at 24, 26, 28, and 31 WAT, and there was no decrease in the height or yield of winter wheat compared to the non-treated control (Table 1). Edwards and Miller (1978) found nine cultivars of spring wheat were tolerant to dicamba and one cultivar was sensitive. Schroeder and Banks (1989) reported that some winter wheat cultivars were sensitive to dicamba when applied in the spring. Robinson and Fenster (1973) reported that only one winter wheat cultivar of five cultivars evaluated was sensitive to dicamba. Rinella et al. (2001) reported that 38–90% of 'Wakefield' winter wheat seeds were underdeveloped when dicamba was applied at 140 g/ha in the spring.

3.2. 2,4-D amine

The POST application of 2,4-D amine in the autumn at 550 and 1100 g/ha resulted in minimal visual crop injury of up to 0.6%, 1.5%, 1.4%, and 2.9% at 24, 26, 28, and 31 WAT, respectively (Table 1). Plant height was not affected but yield was reduced by 8% at 550 g/ha and 9% at 1100 g/ha. Crop injury generally increased as the dose of 2,4-D amine was increased although differences were not always statistically significant (Table 1). Robinson and Fenster (1973) reported that winter wheat yield was reduced 14% and 24% when 2,4-D amine was applied in the autumn at 560 and 840 g/ha, respectively.

Table 1
Visual injury 24, 26, 28, and 31 weeks after treatment (WAT), plant height, and yield of winter wheat treated with autumn applied post-emergence herbicides at five Ontario locations in 1999–2004[1]

		Visual injury					
Treatments[2]	Dose (g ai/ha)	24 WAT (%)	26 WAT (%)	28 WAT (%)	31 WAT (%)	Height (cm)	Yield (t/ha)
Dicamba	140	0.1 a	0 a	0 a	0 a	85 ab	5.59 bcde
Dicamba	280	0.5 ab	0.4 ab	0.1 a	0 a	84 abc	5.51 cde
2,4-D amine	550	0.5 ab	0.7 b	1.3 b	2.0 b	83 abc	5.29 de
2,4-D amine	1100	0.6 b	1.5 c	1.4 bc	2.9 b	81 bcd	5.24 ef
MCPA amine	850	0.1 a	0.3 ab	0 a	0 a	88 a	5.90 ab
MCPA amine	1700	0.2 ab	0.2 ab	0.3 a	0 a	83 abc	5.63 abcd
Dichlorprop/2,4-D	1017	0.6 ab	2.4 cd	2.0 bc	2.7 b	78 d	5.26 ef
Dichlorprop/2,4-D	2034	1.4 c	2.8 d	2.5 c	3.5 b	80 cd	4.93 f
Bromoxynil/MCPA	560	0.2 ab	0.1 a	0.1 a	0 a	87 a	5.99 a
Bromoxynil/MCPA	1120	0 a	0 a	0 a	0 a	87 a	5.90 ab
Thifensulfuron-methyl/tribenuron-methyl	15	0 a	0 a	0.1 a	0 a	87 a	5.89 ab
Thifensulfuron-methyl/tribenuron-methyl	30	0 a	0.1 a	0 a	0 a	86 a	5.87 ab
Non-treated	0	0 a	0 a	0 a	0 a	85 ab	5.73 abc
SE (±)		0.2	0.2	0.3	1.0	2	0.08

[1] Data have been pooled for all locations and years; means for percent injury have been transformed back to original scale. Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD test ($P < 0.05$).

[2] Thifensulfuron-methyl/tribenuron-methyl treatments included non-ionic surfactant Agral 90® at 0.02% v/v.

3.3. *MCPA amine*

The POST application of MCPA amine in the autumn at 850 and 1700 g/ha did not cause any visual injury at 24, 26, 28, and 31 WAT, and there was no decrease in plant height or yield (Table 1). Tottman (1977) reported some crop injury to wheat when MCPA was applied in the spring. However, others have reported little injury with MCPA in winter wheat (Wicks et al., 1999).

3.4. *Dichlorprop plus 2,4-D ester*

The POST application of dichloroprop plus 2,4-D ester in the autumn at 1017 and 2034 g/ha resulted in as much as 1.4%, 2.8%, 2.5%, and 3.5% visual injury at 24, 26, 28, and 31 WAT, respectively (Table 1). Winter wheat height was reduced 8% and 6% and yield was reduced 8% and 14% at the dose of 1017 and 2034 g/ha, respectively. Crop injury generally increased as the dose of dichloroprop plus 2,4-D ester was increased although differences were not always statistically significant (Table 1). Similar winter wheat crop injury has been reported with 2,4-D amine alone and in combination with other herbicides (Robinson and Fenster, 1973; Wicks et al., 1999).

3.5. *Bromoxynil plus MCPA ester*

The POST application of bromoxynil plus MCPA ester in the autumn at 560 and 1120 g/ha did not result in any visual injury, plant height reduction, or yield reduction in winter wheat (Table 1). The level of winter wheat injury seen in this study is similar to that of other studies where injury was minimal and transitory with no effect on the yield (Robinson and Fenster, 1973).

3.6. *Thifensulfuron-methyl plus tribenuron-methyl*

The POST application of thifensulfuron-methyl plus tribenuron-methyl in the autumn at 15 and 30 g/ha did not cause any visual injury at 24, 26, 28, and 31 WAT, and there was no decrease in plant height or yield (Table 1). These results are similar to those reported by Wicks et al. (1999) in winter wheat. Bailey et al. (2004) reported no wheat injury in ten cultivars evaluated with the POST application of thifensulfuron-methyl plus tribenuron-methyl at 47 g/ha in Virginia.

4. Conclusions

The POST application of dicamba, MCPA amine, bromoxynil plus MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl when applied in the autumn did not cause any visual injury at 24, 26, 28, and 31 WAT. In addition, there was no decrease in plant height or yield. The POST application of 2,4-D amine and dichlorprop plus 2,4-D ester in the autumn caused significant visual injury at 24, 26, 28, and 31 WAT compared to the non-treated control. Winter wheat height and yield were reduced with the POST application of dichlorprop plus 2,4-D ester. Crop injury generally increased as the dose of 2,4-D amine or dichlorprop plus 2,4-D ester was increased. Based on these results, the POST application 2,4-D amine and dichlorprop plus 2,4-D ester in the autumn results in unacceptable crop injury in winter wheat. However, dicamba, MCPA amine, bromoxynil plus MCPA ester, and thifensulfuron-methyl plus tribenuron-methyl at the manufacturer's recommended dose applied POST in the autumn have an adequate margin of crop safety for autumn weed management in winter wheat under Ontario growing conditions.

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