Weed Management in Transplanted Bell Pepper (*Capsicum annuum*) with Pretransplant Tank Mixes of Sulfentrazone, S-metolachlor, and Dimethenamid-p

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Abstract. Pepper growers currently have limited access to many effective broadleaf herbicides. Field trials were conducted over a 3-year period in Ontario to study the effect of tank mixtures of sulfentrazone (100 or 200 g·ha⁻¹ a.i.) with either s-metolachlor (1200 or 2400 g·ha⁻¹ a.i.) or dimethenamid-p (750 or 1500 g·ha⁻¹ a.i.) on transplanted bell pepper. Under weed-free conditions, there was no visual injury or reduction in plant height, fruit number, fruit size, or marketable yield of transplanted pepper with pretransplant applications of sulfentrazone applied in tank mixtures with s-metolachlor or dimethenamid-p. The tank mixture of sulfentrazone + s-metolachlor gave greater than 85% control of redroot pigweed (*Amaranthus retroflexus*) and eastern black nightshade (*Solanum ptycanthum*), but only 70% to 76% control of velvetleaf (*Abutilon theophrasti*), common ragweed (*Ambrosia artemisiifolia*), and common lambsquarters (*Chenopodium album*). The combination of sulfentrazone + dimethenamid-p provided good to excellent control of all weed species except velvetleaf. Based on this study, sulfentrazone and dimethenamid-p have potential for minor use registration in pepper.

Pepper is grown on ≈1200 ha with farm gate receipts close to \$12 million in 2005 in Ontario (Mailvaganam, 2006). Bell pepper is not a competitive crop and yield reductions can result in significant financial loss if weeds are not properly controlled (Eshel et al., 1973; Frank et al., 1992); therefore, broadleaf weed control is one of the most important weed management considerations in pepper production. Current problem weeds include velvetleaf (*Abutilon theophrasti* Medic.), redroot pigweed (*Amaranthus retroflexus* L.), common ragweed (*Ambrosia artemisiifolia* L.), common lambsquarters (*Chenopodium album* L.), and eastern black nightshade (*Solanum ptycanthum* Dun.).

Napropamide, trifluralin, chlorthal dimethyl, and s-metolachlor are the currently registered soil-applied herbicides for pepper production in Ontario [Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2006a]. Although napropamide

can provide good control of redroot pigweed and common lambsquarters early in the season, it does not provide long-term residual control of these weeds. Additionally, it is weak on common ragweed, velvetleaf, and eastern black nightshade. Trifluralin is used primarily as a grass herbicide, although it will provide early-season control of redroot pigweed and common lambsquarters. Chlorthal dimethyl will give good control of common lambsquarters and suppresses redroot pigweed, but it provides poor control of velvetleaf, common ragweed, and eastern black nightshade. S-metolachlor controls redroot pigweed and eastern black nightshade and was recently registered for use in pepper in Ontario. S-metolachlor, because of availability, grower experience, and cost, is the primary pretransplant graminicide used for weed control in pepper in Ontario. As a result, s-metolachlor was used as the tank mixture partner with sulfentrazone in these trials. Finally, dimethenamid-p was included to compare an alternate graminicide, which offers some control of common ragweed, redroot pigweed, and eastern black nightshade. Dimethenamid-p is not currently registered in pepper but could be an effective option to control troublesome weeds for pepper growers in Ontario. It would also be of significant benefit to growers in Ontario to have a tank mix to control weed species that s-metolachlor is weak on, specifically velvetleaf, common ragweed, and common lambsquarters.

The first objective of this research was to identify pretransplant herbicides with activity on velvetleaf, common ragweed, and common lambsquarters with an acceptable level of tolerance in pepper. The second objective of this research was to determine weed control and tolerance of these pretransplant herbicides applied as a tank mixture.

Materials and Methods

Field studies were conducted at the University of Guelph Ridgetown Campus, Ridgetown, Ontario, from 2003 to 2005. The soil was a Normandale fine sandy loam with 53.9% sand, 29.3% silt, 16.7% clay, 4.7% organic matter, and pH of 7.5 in 2003; a Brookston clay loam with 29.4% sand, 36.2% silt, 34.5% clay, 5.8% organic matter, and pH of 5.8 in 2004; and a Normandale very fine sandy loam with 80.6% sand, 12.3% silt, 7.2% clay, 6.1% organic matter, and pH of 7.2 in 2005. Each trial area was mouldboard plowed in the fall and cultivated twice with a field S-tine cultivator and rolling basket harrows in the spring before transplanting.

The experimental design was a randomized complete block split-plot design with four replications. The main plot treatments were s-metolachlor (1200 and 2400 g·ha⁻¹ a.i.), dimethenamid-p (750 and 1500 g·ha⁻¹ a.i.), sulfentrazone (100 and 200 g·ha⁻¹ a.i.), s-metolachlor + sulfentrazone (1200 + 100 and 2400 + 200 g·ha⁻¹ a.i.), and dimethenamid-p + sulfentrazone (750 + 100 and 1500 + 200 g·ha⁻¹ a.i.). An untreated control was included for comparison. Treatments were applied 1 d before transplanting using a CO₂-pressurized backpack sprayer calibrated to deliver 200 L·ha⁻¹ at 207 kPa using 8002 flat-fan nozzles (Spraying Systems Co., Wheaton, IL). The boom was 1.0 m long with three nozzles spaced 50 cm apart.

Plots were 1.5 m wide by 8 m long. 'Enterprise' pepper transplants, ≈6 to 8 cm tall at transplanting, were planted at a depth of 5 cm in twin rows (30 cm apart) at a rate of 29,000 transplants/ha on 29 May 2003, 7 June 2004, and 1 June 2005. There was no need for irrigation in these studies because rainfall provided adequate moisture. Plots were fertilized according to recommended Ontario crop production practices (OMAFRA, 2006b). Annual grass weeds were removed from the entire trial with an application of sethoxydim (150 g·ha⁻¹ a.i.) plus a surfactant/solvent (1 L·ha⁻¹) when the grasses reached the three to four leaf stage or pulled by hand if necessary.

The subplot factor was weed-free or weedy; one half of each plot (including the untreated control) was kept weed-free by hoeing on a weekly basis from transplanting until harvest, whereas the other half of each plot was left weedy.

Visual crop injury was rated on the weed-free half of each plot 7, 14, and 28 d after transplanting (DAT) using a scale of 0% to 100%. A rating of 0 was defined as no visible plant injury, and a rating of 100 was defined as total plant necrosis. At 56 DAT, broadleaf

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weed counts were recorded in two 0.5-m² quadrats placed in the middle of the weedy half of each plot. Weed density was taken as the average of these two readings and extrapolated to 1 m². Peppers were hand-harvested at crop maturity from the middle 3 m of the weedy and the weed-free halves of each plot at all locations and separated into marketable and nonmarketable fruit. Fruit number, fruit size, and yield were determined. Fruits were harvested on 28 Aug. and 11 Sept. 11 2003, on 20 and 31 Aug. in 2004, and on 17 and 24 Aug. in 2005.

Data were subjected to analysis of variance to determine the effect of year and year-by-treatment interactions on visual injury, broadleaf weed control, marketable fruit number, marketable fruit size, and marketable yield. Because the year-by-treatment interactions were not significant, data were combined over years and analyzed using the PROC MIXED procedure of Statistical Analysis Systems (1999). Variances were partitioned into random effects of years, blocks within years, and their interactions with fixed treatment effects. Significance of random effects was 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. Percent visual injury at 7, 14, and 28 DAT was subjected to log transformation, whereas percent weed control for each weed species at 56 DAT was subjected to arcsine transformation (Bartlett, 1947), compared on the transformed scale, and converted back to the original scale for presentation of results (Bartlett, 1947). Treatment means for visual injury, broadleaf weed control, marketable fruit number, marketable fruit size, and marketable yield were separated using Fisher's protected least significant differences ($\alpha = 0.05$).

Results and Discussion

Pepper tolerance to pretransplant herbicides. Visual injury was less than 4% in all the treatments tested, including the tank mix combinations of s-metolachlor + sulfentrazone or dimethenamid-p + sulfentrazone (Table 1). The authors are unaware of any studies that have examined pepper tolerance to dimethenamid-p. Grey et al. (2002) observed significant visual injury, including stunting, chlorosis, and necrosis as well as significant reductions in plant stand and yield in pepper with sulfentrazone at a rate of 420 g·ha⁻¹ a.i. At the rates tested in the current study, pepper exhibited excellent tolerance to sulfentrazone. In addition to a lack of visual injury, fruit number per 3 m of row, mean fruit size, and marketable yield were not less than the untreated, weed-free control in any of the treatments (Table 2). It is concluded that transplanted pepper has excellent tolerance to pretransplant applications of dimethenamid-p (750 and 1500 g·ha⁻¹ a.i.),

sulfentrazone (100 and 200 g·ha⁻¹ a.i.) as well as tank mixes of dimethenamid-p or s-metolachlor plus sulfentrazone.

Weed control in pepper with pretransplant herbicides. S-metolachlor alone (1200 g·ha⁻¹ a.i.) provided greater than 81% control of redroot pigweed, 75% control of eastern black nightshade, but less than 50% control of velvetleaf, common ragweed, and common lambsquarters (Table 3). Dimethenamid-p alone (750 g·ha⁻¹ a.i.) provided better than 80% control of redroot pigweed and eastern black nightshade; however, control of velvetleaf, common ragweed, and common lambsquarters was less than 70% (Table 3). The pretransplant application of

sulfentrazone provided 80% control of common lambsquarters, 64% and 70% control of velvetleaf and redroot pigweed, but less than 60% control of common ragweed and eastern black nightshade (Table 3). At the rates used in this study, s-metolachlor, dimethenamid-p, and sulfentrazone each applied on their own did not provide commercially acceptable control (i.e., greater than 80%) of the major broadleaf weed species typically found in pepper fields in southwestern Ontario. The poor control provided by each of these herbicides when applied alone corresponded with significant reductions in fruit number per 3 m of row, mean fruit size, and marketable yield (Table 4).

Table 1. Mean percent injury 7, 14, and 28 d after transplanting (DAT) peppers for each herbicide treatment in weed-free subplots from 2003 to 2005 at Ridgeway, Ontario².

Herbicide a.i.(s)	Herbicide rate(s) (g·ha ⁻¹ a.i.)	7 DAT (%)	14 DAT (%)	28 DAT (%)
S-metolachlor	1200	0 a	0 a	0 a
S-metolachlor	2400	0 a	1 a	1 a
Dimethenamid-p	750	1 a	0 a	0 a
Dimethenamid-p	1500	0 a	1 a	0 a
Sulfentrazone	100	0 a	0 a	0 a
Sulfentrazone	200	1 a	0 a	1 a
S-metolachlor + sulfentrazone	1200 + 100	0 a	0 a	2 a
S-metolachlor + sulfentrazone	2400 + 200	0 a	2 a	3 a
Dimethenamid-p + sulfentrazone	750 + 100	1 a	1 a	2 a
Dimethenamid-p + sulfentrazone	1500 + 200	2 a	2 a	2 a
LSD		1	2	2

²Means followed by the same letter within a column are not significantly different according to a Fisher's protected least significant difference (LSD) test ($P < 0.05$).

Table 2. Marketable fruit number per 3 m of row, fruit size, and yield of pepper for each herbicide treatment in weed-free subplots from 2003 to 2005 at Ridgeway, Ontario².

Herbicide a.i.	Herbicide rate (g·ha ⁻¹ a.i.)	Fruit number (3 m of row ⁻¹)	Fruit size (g)	Yield (t·ha ⁻¹)
Untreated weed-free control		27 a	152 a	9.1 a
S-metolachlor	1200	28 a	156 a	9.7 a
S-metolachlor	2400	28 a	151 a	9.4 a
Dimethenamid-p	750	31 a	153 a	10.5 a
Dimethenamid-p	1500	30 a	150 a	10.0 a
Sulfentrazone	100	27 a	158 a	9.5 a
Sulfentrazone	200	30 a	153 a	10.2 a
S-metolachlor + sulfentrazone	200 + 100	28 a	158 a	9.8 a
S-metolachlor + sulfentrazone	2400 + 200	28 a	159 a	9.9 a
Dimethenamid-p + sulfentrazone	750 + 100	29 a	150 a	9.7 a
Dimethenamid-p + sulfentrazone	1500 + 200	29 a	162 a	10.4 a
LSD		5	16	1.8

²Means followed by the same letter within a column are not significantly different according to a Fisher's protected least significant difference (LSD) test ($P < 0.05$).

Table 3. Percent control of *Abutilon theophrasti* (ABUTH), *Amaranthus retroflexus* (AMARE), *Ambrosia artemisiifolia* (AMBEL), *Chenopodium album* (CHEAL), and *Solanum ptycanthum* (SOLPT) at 56 d after transplanting pepper in weedy subplots from 2003 to 2005 at Ridgeway, Ontario².

Herbicide a.i.	Herbicide rate (g·ha ⁻¹ a.i.)	Weed control (%)				
		ABUTH	AMARE	AMBEL	CHEAL	SOLPT
S-metolachlor	1200	42 b	81 b	44 b	47 b	75 a
Dimethenamid-p	750	42 b	80 b	62 ab	56 ab	82 a
Sulfentrazone	100	64 a	70 c	45 b	80 a	57 b
S-metolachlor + sulfentrazone	1200 + 100	70 a	93 a	70 ab	76 ab	89 a
Dimethenamid-p + sulfentrazone	750 + 100	66 a	93 a	83 a	88 a	90 a
LSD		8	4	18	13	7

²Means followed by the same letter within a column are not significantly different according to a Fisher's protected least significant difference (LSD) test ($P < 0.05$).

Table 4. Marketable fruit number per 3 m of row, fruit size, and yield of pepper for each herbicide treatment in weedy subplots from 2003 to 2005 at Ridgetown, Ontario (comparable values in the untreated, weed-free control are also shown)².

Herbicide a.i.	Herbicide rate (g·ha ⁻¹ a.i.)	Fruit number (3 m of row ⁻¹)	Fruit size (g)	Yield (t·ha ⁻¹)
Untreated, weedy control		4 c	39 c	0.3 c
S-metolachlor	1200	14 b	109 b	3.3 b
Dimethenamid-p	750	17 b	107 b	4.0 b
Sulfentrazone	100	16 b	101 b	3.6 b
S-metolachlor + sulfentrazone	1200 + 100	25 a	157 a	8.7 a
Dimethenamid-p + sulfentrazone	750 + 100	26 a	150 a	8.7 a
Untreated, weed-free control		27 a	152 a	9.1 a
LSD		4	34	2.7

²Means followed by the same letter within a column are not significantly different according to a Fisher's protected least significant difference (LSD) test ($P < 0.05$).

The tank mix combination of s-metolachlor + sulfentrazone (1200 + 100 g·ha⁻¹ a.i.) provided greater than 80% control of common ragweed, redroot pigweed, common lambsquarters, and eastern black nightshade and 70% control of velvetleaf (Table 3). The dimethenamid-p + sulfentrazone (750 + 100 g·ha⁻¹ a.i.) treatment provided similar control of the major broadleaf weed species as the s-metolachlor + sulfentrazone treatment (Table 3). Velvetleaf control was not commercially acceptable in any of the treatments tested; however, research is currently underway to register clomazone in transplanted peppers, which would provide growers with an excellent tool to control this weed. The level of control provided by the tank mix combina-

tions of s-metolachlor + sulfentrazone and dimethenamid-p + sulfentrazone resulted in yields that were similar to the untreated, weed-free control (Table 4).

The data from this study indicate that transplanted pepper possesses acceptable levels of tolerance to dimethenamid-p applied at 750 and 1500 g·ha⁻¹ a.i. and sulfentrazone applied at 100 and 200 g·ha⁻¹ a.i. Furthermore, when s-metolachlor or dimethenamid-p was tank mixed with sulfentrazone (100 or 200 g·ha⁻¹ a.i.) and applied to the soil before transplanting pepper, there was an acceptable level of crop tolerance and control of redroot pigweed, common ragweed, common lambsquarters, and eastern black nightshade. Based on these results, sulfentrazone and dimethena-

mid-p at rates evaluated can be useful herbicide options for weed management in pepper.

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