Tolerance of Eight Sweet Corn (*Zea mays* L.) Hybrids to Pyroxasulfone

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Abstract. Pyroxasulfone is an experimental herbicide for use in field corn (*Zea mays* L.) and soybean that may have potential for weed management in sweet corn. Tolerance of eight sweet corn hybrids to pyroxasulfone applied preemergence (PRE) at rates of 0, 209, and 418 g·ha⁻¹ a.i. were studied at two Ontario locations in 2005 and 2006. Pyroxasulfone applied PRE at 209 and 418 g·ha⁻¹ caused minimal (less than 3%) injury in Harvest Gold, GH2041, GH9589, GSS9299, GG214, GG446, GG763, and GG447 sweet corn hybrids at 7, 14, and 28 days after emergence. Pyroxasulfone applied PRE did not reduce plant height, cob size, or yield of any of the sweet corn hybrids tested in this study. Based on these results, pyroxasulfone applied PRE at the rates evaluated can be safely used for weed management in Harvest Gold, GH2041, GH9589, GSS9299, GG214, GG446, GG763, and GG447 sweet corn.

Pyroxasulfone (KIH-485) is an experimental herbicide developed by Kumiai Chemical Industry Company (White Plains, NY) that has potential for weed management in corn, soybean, cereals, and cotton (Anonymous, 2006). The herbicide has been reported to have activity on a broad spectrum of weeds, including *Digitaria* species, *Panicum* species, *Setaria* species, barnyard grass (*Echinochloa crus-galli*), velvetleaf (*Abutilon theophrasti*), *Amaranthus* species, common ragweed (*Ambrosia artemisiifolia*), common lambsquarters (*Chenopodium album*), jimsonweed (*Datura stramonium*), and *Polygonum* species (Anonymous, 2006).

Sweet corn is an important vegetable crop in Ontario, valued at nearly \$23 million (Mailvaganam, 2006). Currently, there are only three registered soil-applied herbicides for annual grass control: dimethenamid, EPTC and S-metolachlor (Ontario Ministry of Agriculture, Food, and Rural Affairs, 2006). The registration of pyroxasulfone would provide Ontario sweet corn producers with a new, broad-spectrum herbicide that controls selected annual grass and broadleaf weed species. Furthermore, if used in a diversified, integrated weed management program, it would reduce the selection intensity for herbicide-resistant weeds. Although

the mode of action of pyroxasulfone is not completely understood, it is thought to be a seedling growth inhibitor that interferes with fatty acid biosynthesis. The spectrum of weeds controlled with pyroxasulfone is similar to the acetanilide herbicides such as S-metolachlor, acetochlor, and alachlor. However, pyroxasulfone provides superior control of certain important broadleaf weeds such as common ragweed and velvetleaf when compared with other acetanilide herbicides (Dyer et al., 2004; Geier and Stahlman, 2004). Pyroxasulfone may also provide superior control of some annual grasses such as wild proso millet (*Panicum miliaceum*), fall panicum (*Panicum dichotomiflorum*), and crabgrass (*Digitaria* spp.) (Anonymous, 2006). Pyroxasulfone has a relatively long soil half-life at 35 to 45 d (Anonymous, 2006).

Sensitivity of sweet corn to herbicides is dependent on the application rate, hybrid, and environmental conditions. Sweet corn hybrid sensitivity has been documented for foramsulfuron (Diebold et al., 2003), bentazon (Diebold et al., 2004), prosulfuron (O'Sullivan and Sikkema, 2001), mesotrione (O'Sullivan et al., 2002), nicosulfuron (Corbett et al., 2005; O'Sullivan et al., 2000; Robinson et al., 1993; Stall and Bewick, 1992), primisulfuron (O'Sullivan and Sikkema, 2002), isoxaflutole (O'Sullivan et al., 2001), and thifensulfuron-methyl (Soltani et al., 2005b). Before pyroxasulfone can be registered for use in sweet corn, hybrid sensitivity must be determined.

There is no published information on the sensitivity of sweet corn hybrids to the pre-emergence (PRE) application of pyroxasulfone. Therefore, the objective of this study was to determine the sensitivity of Harvest Gold, GH2041, GH9589, GSS9299, GG214, GG446, GG763, and GG447 to pyroxasulfone applied PRE.

Field experiments were conducted at the University of Guelph, Ridgetown Campus, Ridgetown, Ontario, and the Huron Research Station, Exeter, Ontario, in 2005 and 2006. The soil at the Ridgetown location was a Watford/Brady loam composed of 49% sand, 34% silt, 17% clay, and 9.2% organic matter with a pH of 7.2 in 2005 and 51% sand, 32% silt, 16% clay, and 5.5% organic matter with a pH of 7.2 in 2006. The soil at the Exeter location was a Brookston clay loam composed of 31% sand, 38% silt, 31% clay, and 4.6% organic matter with a pH of 8 in 2005 and 21% sand, 42% silt, 37% clay, and 3.7% organic matter with a pH of 7.4 in 2006. Seedbed preparation consisted of moldboard plowing in the fall and cultivation in the spring. Fertilizer was broadcast and incorporated before seeding based on soil tests and local recommendations.

The experiments were arranged in a split-plot design with four replications. The main plots were pyroxasulfone rate, and the subplots were sweet corn hybrids. Selection of herbicide rates was based on the manufacturer-recommended use rates for the soil type. Treatments consisted of a nontreated control and two rates of pyroxasulfone (0, 209, and 418 g·a.i./ha⁻¹) representing the untreated control and 1× and 2× of the proposed label rate. Eight of the most commonly grown processing sweet corn hybrids in southwestern Ontario encompassing a range of endosperm genotypes were selected: Harvest Gold (*Su*), GH2041 (*Su*), GH9589 (*Su*), GSS9299 (*Sh₂*), GG214 (*Su*), GG446 (*Su*), GG763 (*Sh₂*), and GG447 (*Su*). Each of the main plots was 6 m wide × 8 m long at Ridgetown and 6 m wide × 10 m long at Exeter. The subplots each consisted of a single row of each sweet corn hybrid with rows planted 75 cm apart. The sweet corn was thinned to 50,000 plants/ha shortly after emergence.

To maintain the trial weed-free, a pre-plant-incorporated application of a preformulated mixture of S-metolachlor plus atrazine (1:0.8) was applied before planting at 2.16 and 2.88 kg·ha⁻¹ a.i. at Exeter and Ridgetown, respectively. In 2006, at Ridgetown, an additional herbicide application of 280 g·ha⁻¹ a.i. of bromoxynil and 1.12 kg·ha⁻¹ a.i. of atrazine was applied postemergence (POST) for broadleaf weed control. The plots were then kept weed-free using interrow cultivation and hand-hoeing as required.

Pyroxasulfone was applied PRE 4 to 8 d after planting. Herbicide applications were made using a CO₂-pressurized backpack sprayer at both the Ridgetown and Exeter locations. At Ridgetown, ULD120–02 (ULD120–02 Tip; Spraying Systems Co., Wheaton, IL) air induction nozzles were used at 207 kPa, and the sprayer was calibrated to deliver 200 L·ha⁻¹. At Exeter, XR8002VS (XR 8002VS Tip; Spraying Systems Co.) flat fan nozzles were used at 241 kPa, and the sprayer was again calibrated to deliver 200 L·ha⁻¹.

Crop injury, including stand reduction, was rated visually between the nontreated

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hybrids compared with the respective treated hybrids on a scale of 0% to 100% at 7, 14, and 28 d after emergence (DAE). A rating of 0% was defined as no visible effect of the herbicide and 100% was defined as plant death. Average corn height (based on 10 random plants per subplot) was measured for each subplot 21 DAE. The height of the plant was defined as the maximum height from the soil surface with the leaves fully extended. At maturity, each subplot was harvested by hand and cob size; marketable (a cob greater than 5 cm in diameter) and total yields were recorded. Because the statistical analysis for total and marketable yields were similar, only marketable yields are reported.

All data were subjected to analysis of variance. Tests were combined over locations and years and analyzed using the PROC MIXED procedure of SAS (Statistical Analysis Systems, 1999). Variances of percent crop injury at 7, 14, and 28 DAE; plant height; cob size; and yield were partitioned into the fixed effects of herbicide treatment, hybrid, and herbicide-hybrid interaction and into the random effects of site-year, block (site-yr), site year-treatment, site year-hybrid, and site year-hybrid-treatment. 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. To meet the assumptions of the variance analysis, visual injury at 7, 14, and 28 DAE were subjected to an arcsine square root transformation and cob size data were log-transformed (Bartlett, 1947). Treatment means were separated using Fisher's protected least significant difference test. Means of percent injury and cob size were compared on the transformed scale and were converted back to the original scale for presentation of results. Type I error was set at 0.05 for all statistical comparisons.

Results and Discussion

Statistical analysis of the data on visible injury, plant height, cob size, and yield showed that the random effects of location, year, year by location, and interactions with treatments were not significant. Therefore, data were pooled and averaged over years and locations (Tables 1–4).

Visible injury. Visible injury symptoms observed were leaf and stem distortion. No visible injury occurred in GH2041, GH9589, GG214, and GG446 hybrids when pyroxasulfone was applied at 209 and 418 g·ha⁻¹ a.i. (Table 1). Minor visible injury (less than 3%) occurred in Harvest Gold, GSS9299, GG763, and GG447 sweet corn hybrids. Injury to Harvest Gold and GSS9299 was transient and only observed 7 DAE with no injury observed 14 and 28 DAE. The injury to GG763 and GG447, although slight, was still observed 28 DAE. However, none of the injury caused lasting damage and was not statistically significant. Visible injury did not increase

Table 1. Sweet corn hybrid visible injury (%) 7, 14, and 28 d after emergence (DAE) when treated with pyroxasulfone applied preemergence at Exeter and Ridgetown, ON, Canada, in 2005 and 2006.^z

Sweet corn hybrid	Pyroxasulfone rate (g·ha ⁻¹ a.i.)							
	209		418		209		418	
	7 DAE		14 DAE		28 DAE			
	(%)							
Harvest Gold	1 a	1 a	0 a	0 a	0 a	0 a	0 a	
GH2041	0 a	0 a	0 a	0 a	0 a	0 a	0 a	
GH9589	0 a	0 a	0 a	0 a	0 a	0 a	0 a	
GSS9299	1 a	1 a	0 a	0 a	0 a	0 a	0 a	
GG214	0 a	0 a	0 a	0 a	0 a	0 a	0 a	
GG446	0 a	0 a	0 a	0 a	0 a	0 a	0 a	
GG763	2 a	2 a	2 a	2 a	2 a	2 a	2 a	
GG447	0 a	1 a	0 a	0 a	0 a	1 a	1 a	
SE	1	1	1	1	1	1	1	

^zResults are averaged for both locations and years; means followed by the same letter within a column are not significantly different according to Fisher's protected least significant difference test ($P < 0.05$) on the arcsine (square root) transformed scale; means presented are backtransformed from the arcsine (square root) scale.

Table 2. Sweet corn hybrid plant height (cm) 21 d after emergence when treated with pyroxasulfone applied preemergence at Exeter and Ridgetown, ON, Canada, in 2005 and 2006.^z

Sweet corn hybrid	Pyroxasulfone rate (g·ha ⁻¹ a.i.)			
	0 (cm)	209 (cm)	418 (cm)	SE
Harvest Gold	48 a	48 a	47 a	7
GH2041	47 a	49 a	46 a	7
GH9589	49 a	50 a	51 a	7
GSS9299	43 a	44 a	44 a	6
GG214	46 a	47 a	47 a	7
GG446	44 a	46 a	45 a	6
GG763	43 a	44 a	43 a	5
GG447	40 a	39 a	40 a	4

^zResults are averaged for both locations and years; means followed by the same letter within a row are not significantly different according to Fisher's protected least significant difference test ($P < 0.05$).

significantly as herbicide rate increased and is consistent with previous studies on clopyralid (Soltani et al., 2005a) and topramezone (Soltani et al., 2007). This observation is in contrast to that observed when sensitive sweet corn hybrids were treated with bentazon (Diebold et al., 2004), isoxaflutole (O'Sullivan et al., 2001), mesotrione applied POST (O'Sullivan et al., 2002), nicosulfuron (Morton and Harvey, 1992; O'Sullivan et al., 2000), nicosulfuron plus rimsulfuron (O'Sullivan et al., 1995; O'Sullivan and Bouw, 1998), primisulfuron (O'Sullivan and Sikkema, 2002), prosulfuron (O'Sullivan and Sikkema, 2001), or thifensulfuron-methyl (Soltani et al., 2005b) in which injury increased with increasing herbicide rate. In fact, when mesotrione was applied POST, visual injury increased by 15% to 25% when the application rate was doubled (O'Sullivan et al., 2002).

Plant height. No reduction in plant height was observed in any of the eight sweet corn hybrids treated with pyroxasulfone (Table 2). Plant heights were similarly unaffected by increasing herbicide rate. These findings are similar to those found with applications of clopyralid (Soltani et al., 2005a) and topramezone (Soltani et al., 2007), but differ

Table 3. Sweet corn hybrid cob size (g) treated with pyroxasulfone applied pre-emergence at Exeter and Ridgetown, ON, Canada, in 2005 and 2006.^z

Sweet corn hybrid	Pyroxasulfone rate (g·ha ⁻¹ a.i.)			
	0 (g)	209 (g)	418 (g)	SE
Harvest Gold	331 a	330 a	329 a	22
GH2041	292 a	291 a	290 a	11
GH9589	340 a	328 a	340 a	13
GSS9299	290 a	296 a	288 a	11
GG214	310 a	303 a	305 a	11
GG446	346 a	344 a	334 a	15
GG763	323 a	317 a	311 a	15
GG447	318 a	317 a	323 a	11

^zResults are averaged for both locations and years; means followed by the same letter within a row are not significantly different according to Fisher's protected least significant difference test ($P < 0.05$) on the log-transformed scale; means presented are backtransformed.

Table 4. Sweet corn hybrid yield (t·ha⁻¹) treated with pyroxasulfone applied pre-emergence at Exeter and Ridgetown, ON, Canada, in 2005 and 2006.^z

Sweet corn hybrid	Pyroxasulfone rate (g·ha ⁻¹ a.i.)			SE
	0	209	418	
	(t·ha ⁻¹)			
Harvest Gold	16.2 a	16.1 a	16.1 a	0.9
GH2041	12.8 a	12.6 a	11.7 a	1.0
GH9589	19.2 a	18.9 a	18.4 a	0.9
GSS9299	12.4 a	13.2 a	13.1 a	0.9
GG214	15.3 a	15.4 a	16.0 a	1.1
GG446	17.9 a	18.4 a	17.5 a	0.9
GG763	15.0 a	15.0 a	14.8 a	1.0
GG447	14.5 a	14.1 a	14.5 a	0.9

^zResults are averaged for both locations and years; means followed by the same letter within a row are not significantly different according to Fisher's protected least significant difference test ($P < 0.05$).

from other studies in which selected sweet corn hybrids were negatively affected by increasing herbicide application rates. As herbicide rate increased, plant heights of susceptible hybrids were increasingly reduced when bentazon (Diebold et al., 2004), nicosulfuron (O'Sullivan et al., 2000; Robinson et al., 1993), nicosulfuron plus rimsulfuron (O'Sullivan et al., 1995;

O'Sullivan and Bouw, 1998), foramsulfuron (Diebold et al., 2003), isoxaflutole (O'Sullivan et al., 2001), mesotrione (O'Sullivan et al., 2002), prosulfuron (O'Sullivan and Sikkema, 2001), or thifensulfuron-methyl (Soltani et al., 2005b) was applied. Although pyroxasulfone did not reduce sweet corn height, herbicides such as bentazon (Diebold et al., 2004), nicosulfuron (O'Sullivan et al., 2000), or prosulfuron (O'Sullivan and Sikkema, 2001) have the potential to reduce sweet corn height as much as 100%.

Cob size. Pyroxasulfone did not have any detrimental effect on cob size, regardless of sweet corn hybrid or herbicide application rate (Table 3). Other studies have shown that cob size of susceptible varieties can be reduced by up to 67% (Soltani et al., 2005b).

Yield. Yield of Harvest Gold, GH2041, GH9589, GSS9299, GG214, GG446, GG763, and GG447 sweet corn hybrids were unaffected by the application of pyroxasulfone at 209 or 418 g·ha⁻¹ a.i. (Table 4). Other herbicides such as clopyralid (Soltani et al., 2005a) and topramezone (Soltani et al., 2007) also caused no reduction to yield when the herbicide was applied at the label rate. These results are in contrast to other studies that have shown that susceptible varieties can be negatively affected by certain herbicides. For example, Diebold et al. (2004), showed that bentazon can reduce the yield of Delmonte 2038 by up to 94%. Foramsulfuron has been shown to cause a 92% or greater reduction in yield of Delmonte 2038 when the herbicide is applied at the registered rate (Diebold et al., 2003). Soltani et al. (2005b) demonstrated that the yield of the highly sensitive hybrid Delmonte 2038 could be reduced by 98% by thifensulfuron-methyl, and the yield of four moderately sensitive hybrids (Empire, GH1861, GH2298, and GH2684) can be reduced by 51% to 77%. When mesotrione (O'Sullivan et al., 2002), nicosulfuron (O'Sullivan et al., 2000), or nicosulfuron plus rimsulfuron (O'Sullivan et al., 1995; O'Sullivan and Bouw, 1998) was applied to sensi-

tive hybrids, yield decreased as application rate increased.

Conclusions

In this study, the sweet corn hybrids GH2041, GSS9299, GG214, GG446, GG447, GG763, Harvest Gold, and GH9589 were shown to be tolerant to pyroxasulfone. Pyroxasulfone applied PRE to eight sweet corn hybrids had no negative effect on sweet corn injury, height, cob size, or yield. As the rate of pyroxasulfone was increased from 1× to 2× of the label rate, there was no negative effect on any sweet corn hybrid. This study shows that pyroxasulfone can be safely applied to these eight sweet corn hybrids at the proposed label rate.

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