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Sweet Corn Hybrid Responses to Thifensulfuron-methyl

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Abstract. **Limited information exists on sweet corn (*Zea mays*) tolerance to postemergence (POST) applications of thifensulfuron-methyl under Ontario growing conditions. Eight sweet corn hybrids were evaluated for tolerance to thifensulfuron-methyl in four field experiments conducted in 2003 and 2004. Thifensulfuron-methyl was applied POST at 6 and 12 g·ha^{-1} a.i., the registered and twice the registered rate for use in soybean in Ontario. Sweet corn hybrid responses to thifensulfuron-methyl varied. Delmonte 2038 was the most sensitive to thifensulfuron-methyl and had as much as 92% visual injury, 76% height reduction, and 98% yield reduction compared to the nontreated control. Empire, GH1861, GH2298, and GH2684 hybrids showed visual injury of 53%, 55%, 53%, and 61%, height reduction of 34%, 31%, 32%, and 26% and yield reduction of 77%, 68%, 68%, and 51%, respectively. GG214, GH2547, and GSS9299 sweet corn hybrids were not as sensitive to thifensulfuron-methyl. The initial sensitivity observed in these hybrids was minimal and transient with no effect on yield. Although thifensulfuron-methyl is safe for use on some sweet corn hybrids, it has the potential to cause severe crop injury and yield reduction in other hybrids and therefore it should not be recommended for weed management in sweet corn production in Ontario.**

Sweet corn (*Zea mays*) production is important to the economy of Ontario where nearly 200,000 t of sweet corn is produced on 17,000 ha. Sweet corn has a farm-gate value of $22 million, and ranks as the second largest vegetable crop in Ontario in terms of farm-gate value (Mailvaganam, 2004; Ontario Ministry of Agriculture and Food, 2002). Effective weed control is important for the production of sweet corn. The only herbicides registered for postemergence (POST) broadleaf weed control in sweet corn in Ontario are atrazine, bentazon, and bromoxynil [Ontario Ministry of Agriculture and Food (OMAF), 2004]. More research is needed to identify POST herbicides that can more effectively control emerged problem broadleaf weeds in sweet corn production.

Thifensulfuron-methyl is a sulfonylurea herbicide developed for use in soybean (*Glycine max*) production that inhibits the activity of acetolactate synthase (ALS), an important enzyme necessary for the biosynthesis of branched-chain amino acids isoleucine, leucine, and valine in plants (Vencill, 2002). Thifensulfuron-methyl is applied at very low doses, has low mammalian toxicity, has low potential for groundwater contamination, and controls several broadleaf weeds that occur in Ontario such as common lambsquarters (*Chenopdium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), velvetleaf (*Abutilon theophrasti* Medic.), ladysthumb (*Polygonum persicaria* L.), and wild mustard (*Sinapis arvensis* L.), including triazine-resistant biotypes (OMAF, 2004; Sarmah and Sabadie, 2002). There is minimal residual carryover with thifensulfuron-methyl and the rotation restriction to crops planted subsequently in the rotation is only 60 d (Schroeder, 1998).

The currently registered POST broadleaf herbicides in sweet corn do not effectively control late emerging velvetleaf and triazine-resistant redroot pigweed, whereas thifensulfuron-methyl effectively controls both of these weeds (OMAF, 2004). Consequently, having thifensulfuron-methyl registered for use in sweet corn would be of benefit to growers who must manage these troublesome weeds. Sensitivity of sweet corn to herbicides is dependent on the application rate, hybrid, and environmental conditions. Some of the commonly grown sweet corn hybrids in Ontario such as Calico Belle, Delmonte 2038, and GH2684 have shown sensitivity to other herbicides such as AE F130360, bentazon, CGA152005, mesotrione, nicosulfuron, primisulfuron, and RPA201772 (Diebold et al., 2003, 2004; O'Sullivan and Sikkema, 2001, 2002; O'Sullivan et al., 1999, 2000, 2002; Robinson et al., 1993). Hybrid sensitivity is an important factor for registration of herbicides in sweet corn. Little published information exists on the sensitivity of sweet corn hybrids to the POST application of thifensulfuron-methyl.

The objective of this study was to determine the tolerance of eight commonly grown processing sweet corn hybrids to POST applications of thifensulfuron-methyl for possible Canadian registration of this herbicide for use in sweet corn production in Ontario.

Materials and Methods

Field studies were conducted at the Huron Research Station, Exeter, Ont., and Ridgetown College, Ridgetown, Ont., in 2003 and 2004. The soil at Exeter was a Brookston clay loam with 23% sand, 47% silt, 30% clay, 4.0% organic matter and pH of 7.7 in 2003, and 34% sand, 33% silt, 33% clay, 3.8% organic matter, and pH of 8.0 in 2004. The soil at Ridgetown was a Watford/Brady loam with 50% sand, 29% silt, 21% clay, 8.2% organic matter and pH of 6.8 in 2003, and 51% sand, 32% silt, 17% clay, 5.5% organic matter, and pH of 7.2 in 2004. Seedbed preparation at both locations consisted of fall moldboard plowing followed by two passes with a field cultivator in the spring.

The experiments were arranged in a split-plot design with four replications. The main plots were herbicide rates and subplots were eight sweet corn hybrids. Selection of herbicide rates and spray additives was based on the current maximum use rate in soybean in Ontario. The treatments consisted of a nontreated check and two rates of thifensulfuron-methyl (6 and 12 g·ha^{-1}), the maximum registered use rate and twice the maximum registered use rate in soybean. Thifensulfuron-methyl treatments included 0.1% and 0.2% v/v nonionic surfactant at 6 and 12 g·ha^{-1}, respectively (OMAF, 2004). The main plots were 6 m wide (eight rows) by 10 m long at Exeter and 6 × 8 m at Ridgetown. Each of the eight rows in a plot was planted with a different hybrid.

Sweet corn was planted on 3 June 2003 and 5 June 2004 at Exeter, and 5 June 2003 and 28 May 2004 at Ridgetown. The row spacing was 75 cm and plants were thinned to a final plant population of 50,000 plants/ha. Eight of the most commonly grown processing sweet corn hybrids in southwestern Ontario were selected. Hybrids included Delmonte 2038, Empire, GG214, GH1861, GH2298, GH2547, GH2684, and GSS9299. Hybrids chosen encompassed a range of endosperm genotypes. A preemergence application of a preformulated mixture of *S*-metolachlor plus atrazine (1:0.8) was applied immediately after planting at 2.16 kg·ha^{-1} a.i. in all trials, and plots were maintained weed-free by inter-row cultivation and hand hoeing as required.

Thifensulfuron-methyl was applied to four- to five-leaf stage, 21 d after planting (DAP) in 2003 and 23 DAP in 2004 at Exeter, and 19 DAP in 2003 and 18 DAP in 2004 at Ridgetown. Treatments were applied with a CO_2-pressurized backpack sprayer, calibrated to deliver 200 L·ha^{-1} with XR8002VS (Teejet XR8002VS Tip, Spraying Systems Co., Wheaton, Ill.) flat-fan nozzles at 241 and 207 kPa pressure at Exeter and Ridgetown, respectively.

Visual crop injury was rated on a scale of 0% to 100% at 7, 14, and 28 d after treatment (DAT). A rating of 0% was defined as no visible effect of the herbicide and 100% was defined as plant death. Visual injury included leaf color changes from green to yellow with a copper tint, leaf distortion and crinkling, growth reduction, and in some sweet corn hybrids total plant necrosis. Height of five randomly selected plants was determined 21 DAT by measuring from the soil surface to the highest point of the corn plant with the leaves extended. The entire

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Table 1. Mean visual injury (%) of eight sweet corn hybrids 7, 14, and 28 d after treatment (DAT) with thifensulfuron-methyl postemergence[z] at 6 and 12 g·ha^{-1} a.i. at Exeter and Ridgetown, Ont., in 2003 and 2004.

Sweet corn hybrid	Mean visual injury (%)					
	Thifensulfuron-methyl rate (g·ha^{-1} a.i.)					
	6	12	6	12	6	12
	7 DAT		14 DAT		28 DAT	
Delmonte 2038	33 a[y]	43 a	69 a	81 a	83 a	92 a
Empire	24 a	29 b	25 bc	53 b	16 b	36 bc
GG214	4 b	14 c	3 d	7 c	2 c	3 d
GH1861	28 a	39 ab	23 c	55 b	10 bc	37 bc
GH2298	26 a	26 b	35 b	53 b	16 b	34 c
GH2547	2 b	9 c	2 d	5 c	1 c	1 d
GH2684	27 a	33 ab	35 b	61 b	21 b	49 b
GSS9299	5 b	15 c	3 d	8 c	1 c	4 d
SE	5	5	7	6	3	3

[z]Thifensulfuron-methyl treatments included 0.1% and 0.2% v/v nonionic surfactant at 6 and 12 g·ha^{-1}, respectively.

[y]Results are averaged for both locations and years; means within a column followed by the same letter are not significantly different according to a Fisher's Protected LSD test ($P \leq 0.05$) on the arcsine (square root) transformed scale; means presented are back-transformed from the arcsine (square root) scale.

row of sweet corn in each plot was harvested by hand at maturity and cob size, marketable (cobs >5 cm in diameter) and total yield were determind. As the statistical analyses for total and marketable yields were similar, only total yields are reported.

All data were subjected to analysis of variance (ANOVA). Tests were combined over locations and years and analyzed using the PROC MIXED procedure of SAS (SAS 1999). Variances of percent injury at 7, 14, and 28 DAT, plant height, cob size, and yield were partitioned into the fixed effects of herbicide treatment, hybrids, and herbicide-by-hybrids interaction and into the random effects of test and block (test). 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 DAT, and cob size data were subjected to an arcsine square root transformation (Bartlett, 1947). Treatment means were separated using Fisher's protected LSD. Means of percent injury 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

Visual injury. At 7, 14, and 28 DAT, thifensulfuron-methyl applied POST at 6 and 12 g·ha^{-1} caused more injury in Delmonte 2038, Empire, GH1861, GH2298 and GH2684 than in GG214, GH2547, and GSS9299 sweet corn hybrids (Table 1). Visual injury increased with increasing rates of thifensulfuron-methyl.

Visual injury in GG214, GH2547, and GSS9299 was most severe at 7 DAT. However, the injury was transient as indicated by the rating completed 14 and 28 DAT. Visual injury was most severe at 14 DAT in Empire, GH1861, GH2298, and GH2648 hybrids, while Delmonte 2038 showed the highest injury at 28 DAT. Thifensulfuron-methyl POST injuries observed in this study with Delmonte 2038 are consistent with other findings that have shown it to be one of the most sensitive hybrids in Ontario exhibiting as much as 94% injury when treated with sulfonylurea herbicides (Diebold et al., 2003; O'Sullivan et al., 1998, 2000; O'Sullivan and Sikkema, 2001, 2002). Visual injury generally increased as thifensulfuron-methyl rate was increased from 6 to 12 g·ha^{-1}. Grey et al. (2000) and O'Sullivan and Sikkema (2001) found similar differential hybrid injury and rate responses with other sulfonylurea herbicides in sweet corn.

Plant height. Sweet corn height data are reported for each hybrid and rate individually, and contrasts were performed comparing height between rates within hybrids (Table 2). The visual injury observed in this study was reflected in the plant height. Thifensulfuron-methyl applied POST at 6 g·ha^{-1} reduced plant height by 72, 20, 15, 22, and 16% in Delmonte 2038, Empire, GH1861, GH2298, and GH2684 hybrids, respectively (Table 2). Thifensulfuron-methyl applied POST at 12 g·ha^{-1} reduced sweet corn height by 76%, 34%, 9%, 31%, 32%, 8%, 26%, and 11% in Delmonte 2038, Empire, GG214, GH1861, GH2298, GH2547, GH2684, and GSS9299 hybrids, respectively (Table 2). Plant heights were generally reduced as the herbicide rate was increased although these results were not always statistically significant. Robinson et al. (1994) observed that POST applications of nicosulfuron significantly decreased plant height in the Zenith sweet corn. Grey et al. (2000) reported significant decreases in height of four out of ten sweet corn hybrids evaluated with nicosulfuron application. O'Sullivan et al. (2000) observed that plant height decreased with increased nicosulfuron application in the eleven hybrids evaluated. In two other experiments, plant height was reduced in five and three out of eight hybrids evaluated (O'Sullivan et al., 2000).

Cob size. Sweet corn cob size data are reported for each hybrid and rate individually, and contrasts were performed comparing cob size or yield between rates within hybrids (Table 3). Thifensulfuron-methyl applied POST at 6 g·ha^{-1} reduced cob size 9% to 54% and at 12 g·ha^{-1} reduced cob size 25% to 67% among the hybrids tested (Table 3). There was no significant effect on cob size of GG214, GH2547, and GSS9299 sweet corn hybrids.

Yield. Sweet corn yield data are reported for each hybrid and rate individually, and contrasts were performed comparing cob size or yield between rates within hybrids (Table 4). Thifensulfuron-methyl applied POST reduced yield 21% to 98% at the 6 g·ha^{-1} rate and 51% to 98% at 12 g·ha^{-1} in Delmonte 2038, Empire, GH1861, GH2298, and GH2684 sweet corn hybrids (Table 4). There was no significant effect on yield of the other sweet corn hybrids. O'Sullivan et al. (2000) observed significant variability in yield loss among a range of sweet corn hybrids treated with nicosulfuron, another sulfonylurea herbicide. Grey et al. (2000) found that only one of eleven sweet corn hybrids had a decreased yield with nicosulfuron. Robinson et al. (1994) observed that POST applications of nicosulfuron resulted in complete crop loss in one hybrid (Merit), a 50% reduction in yield in another, but no reduction in yield in Zenith. Stall and Bewick (1992) determined that 4 of 12 hybrids demonstrated a response to nicosulfuron rate and marketable yield was significantly lower at higher rates. Similar sweet corn yield responses were also reported with other sulfonylurea herbicides such as AE F130360, CGA 152005, primisulfuron, and rimsulfuron (Diebold et al., 2003; O'Sullivan et al., 1998; O'Sullivan and Sikkema, 2001, 2002; Van Wychen et al., 1997).

Table 2. Height (cm) of eight sweet corn hybrids 21 d after treatment with thifensulfuron-methyl postemergence[z] at 0, 6, and 12 g·ha^{-1} a.i. at Exeter and Ridgetown, Ont., in 2003 and 2004.

Sweet corn hybrid	Ht (cm)			
	Thifensulfuron-methyl rate (g·ha^{-1} a.i.)			
	0	6	12	SE
Delmonte 2038	100 a[y]	28 b	24 b	5
Empire	92 a	74 b	58 c	3
GG214	93 a	90 ab	85 b	2
GH1861	93 a	79 b	64 c	3
GH2298	92 a	72 b	63 c	3
GH2547	93 a	89 ab	86 b	2
GH2684	98 a	82 b	73 c	2
GSS9299	87 a	82 ab	77 b	2

[z]Thifensulfuron-methyl treatments included 0.1% and 0.2% v/v nonionic surfactant at 6 and 12 g·ha^{-1}, respectively.

[y]Results are averaged for both locations and years; letters represent the statistical comparison using contrasts of the means among thifensulfuron-methyl rates within a variety; means within a row followed by the same letter indicate no significant difference according to a Fisher's protected LSD test ($P \leq 0.05$).

Table 3. Cob size (g) of eight sweet corn hybrids treated with thifensulfuron-methyl postemergence[z] at 0, 6 and 12 g·ha^{-1} a.i. at Exeter and Ridgetown, Ont., in 2003 and 2004.

	Cob size (g) Thifensulfuron-methyl rate (g·ha^{-1} a.i.)			
Sweet corn hybrid	0	6	12	SE
Delmonte 2038	243 a[y]	111 b	80 c	14
Empire	209 a	172 b	124 c	7
GG214	236 a	225 a	217 a	4
GH1861	213 a	164 b	131 c	8
GH2298	214 a	168 b	146 c	6
GH2547	232 a	245 a	238 a	5
GH2684	229 a	208 b	171 c	7
GSS9299	206 a	206 a	199 a	3

[z]Thifensulfuron-methyl treatments included 0.1% and 0.2% v/v nonionic surfactant at 6 and 12 g·ha^{-1}, respectively.
[y]Results are averaged for both locations and years; means have been back transformed to the original scale; letters represent the statistical comparison using contrasts of the means among thifensulfuron-methyl rates within a variety; Means within a row followed by the same letter indicate no significant difference according to a Fisher's protected LSD test ($P \leq 0.05$).

Table 4. Yield (t ha^{-1}) of eight sweet corn hybrids treated with thifensulfuron-methyl postemergence[z] at 0, 6 and 12 g·ha^{-1} a.i. at Exeter and Ridgetown, Ont., in 2003 and 2004.

	Yield (t·ha^{-1}) Thifensulfuron-methyl rate (g·ha^{-1} a.i.)			
Sweet corn hybrid	0	6	12	SE
Delmonte 2038	17.0 a[y]	0.3 b	0.3 b	1.3
Empire	14.9 a	8.1 b	3.5 c	1.0
GG214	16.5 a	17.4 a	16.4 a	0.3
GH1861	16.1 a	11.0 b	5.1 c	0.9
GH2298	16.5 a	8.1 b	5.2 c	1.1
GH2547	20.4 a	20.4 a	21.9 a	0.9
GH2684	17.0 a	13.4 b	8.3 c	1.0
GSS9299	12.6 a	13.7 a	13.4 a	0.4

[z]Thifensulfuron-methyl treatments included 0.1% and 0.2% v/v nonionic surfactant at 6 and 12 g·ha^{-1}, respectively.
[y]Results are averaged for both locations and years; letters represent the statistical comparison using contrasts of the means among thifensulfuron-methyl rates within a variety; means within a row followed by the same letter indicate no significant difference according to a Fisher's protected LSD test ($P \leq 0.05$).

Conclusions

Differential sensitivity of sweet corn hybrids to other sulfonylurea herbicides has been reported in other studies conducted in Ontario (Diebold et al., 2003, 2004; O'Sullivan and Sikkema, 2001, 2002; O'Sullivan et al., 1999, 2000, 2002). In this study, differential sensitivity to postemergence application of thifensulfuron-methyl was observed in sweet corn hybrids. Delmonte 2038 was most sensitive to thifensulfuron-methyl, followed by Empire, GH1861, GH2298, and GH2684. Injury to these hybrids was persistent and resulted in significant yield losses. Generally, crop injury increased as thifensulfuron-methyl rate increased from 6 to 12 g·ha^{-1}. GG214, GH2547, and GSS9299 were not as sensitive to thifensulfuron-methyl at either rate of application. The initial injury observed in these hybrids was minimal and transient with no detrimental effect on cob size or yield.

This research concludes that thifensulfuron-methyl, although safe for use on some sweet corn hybrids, has the potential to cause severe crop injury and yield reduction in other hybrids. Therefore, thifensulfuron-methyl should not be recommended for weed management in sweet corn in Ontario.

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